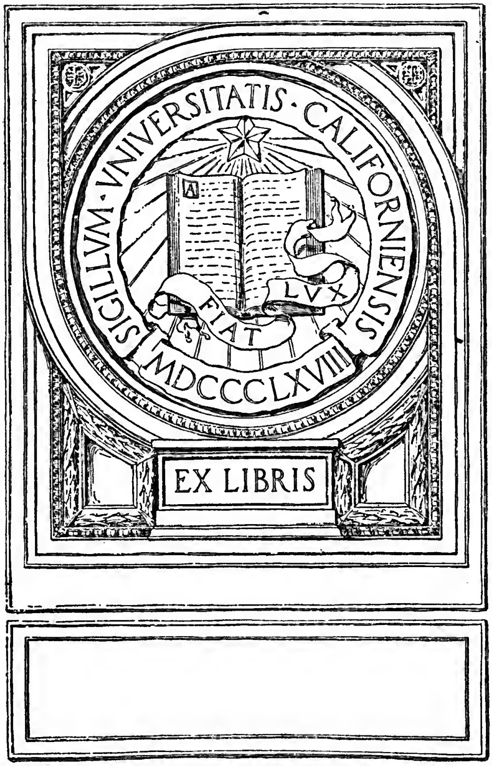
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EXCAVATION

MACHINERY, METHODS AND COSTS

EXCAVATION

MACHINERY
METHODS AND COSTS

INCLUDING A REVISION OF
"EXCAVATING MACHINERY"

BY
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PREFACE

A noteworthy development in the field of excavating machinery has taken place since the publication of the book, "Excavating Machinery" in 1913. The author has received so many requests for information concerning the more recent types of excavators and the newer uses of older types, that it has seemed desirable to present this work.

The new book embodies some of the material of the former work, but is entirely re-cast and largely re-written. The new text has two general divisions; the first comprising a description of the construction, method and typical cost of operation of each type of excavator, and the second embodying a comparative study of the efficient and economic use of the different types of machines in the various fields of construction work. The author has endeavored to describe the makes and types of excavators commonly used in all classes of work. He has not attempted to describe or even mention every make of excavator, but every type has been treated in sufficient detail to give a clear idea of its construction and field of work.

The cost data are not intended to be an arbitrary guide for the use of any type of excavator in any stated class of work. The conditions and circumstances attending work of this character are so variable, and there are usually so many unforeseen factors which affect the progress of a job, that information of this kind can only be *suggestive*. The illustrative "costs of operation" given in the first division, are merely typical outlines. The quantities should be modified to suit local conditions and combined with ruling prices to secure usable cost data for any definite case. In the second division the cost data have been selected to offer a variety of conditions on recent examples of earthwork. No attempt has been made to standardize these data or to formulate the results for any series of operations for any type of machine. The author has derived many equations from his experience, but hesitates to publish them on account of their possible misuse. Several formulæ prepared by well-known authorities are given, but the reader is cautioned against rule-of-thumb application of these, as well as of the general cost information.

The bibliography at the end of each chapter has been revised and brought up-to-date. Although not complete, the references given are sufficiently varied and comprehensive to give a general survey of the subject.

This work is, of necessity, a compilation of information from various sources, and the author has tried to give due acknowledgment. He expresses his appreciation of the information received from the many references and the assistance given by the various societies, companies and individuals.

A. B. McD.

Washington, D. C.,
March, 1919.

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DIVISION I

A discussion of the Construction, Methods and Cost of Operation of Various Types of Excavators.

EXCAVATION MACHINERY, METHODS AND COSTS

CHAPTER I

TOOLS FOR LOOSENING AND HAND EXCAVATION

1. Tools for Loosening.—The lighter soils of alluvial and glacial drift origin; loam, sand and soft clay, can be excavated with the smaller types of excavators without preliminary loosening. However, very dense and hard soils must be first be loosened unless the larger power excavators are to be used.

The tools and methods used in loosening soils largely depend on the nature and magnitude of the work, the kind of soil, the amount of material to be handled, the depth of cut, etc. The hand tools ordinarily used are the mattock, the pick, the shovel and the plow.

2. Mattock.—The mattock is a long-handled tool, shaped like a pick-axe, but having blades instead of points; the blades being set at right angles to each other. This tool is used for grubbing, cleaving and trimming the surface preparatory to the loosening.

3. Pick.—The pick is the universally used tool for the loosening of dense, hard material, especially in restricted places as narrow trenches, pits and corners where the plow or power excavators cannot be utilized. This tool is provided with either two points or a point and a chisel-shaped end. The amount of material which can be loosened in a 10-hr. day by one laborer depends on the kind of soil, the efficiency of the man, the supervision, the working conditions as to space, climate, etc.; a fair average will be 10 cu. yd. of indurated gravel or clay and 20 cu. yd. of dense clay.

4. Plow.—The plow is the most serviceable tool for the loosening of dense soils where there is unrestricted space for its use. There are several types of plow, each style being adapted for a particular class of work. The ordinary mold-board type, used for agricultural purposes, is suitable for ordinary soils but for very dense, hard soils a plow with a heavy, wedge-shaped share, known as a "railroad" or "pavement" plow is necessary. The former type of plow is shown in Fig. 1 and the latter type in Fig. 2. A two-horse plow with a driver and man to hold the plow will loosen about 400 cu. yd. of average soil per 10-hr. day. If the material is dense, tough clay, the output per 10-hr day with a four-horse team and three men will be about 200 cubic yards. The following table gives the cost of plowing per 10-hr. working day, under average conditions.

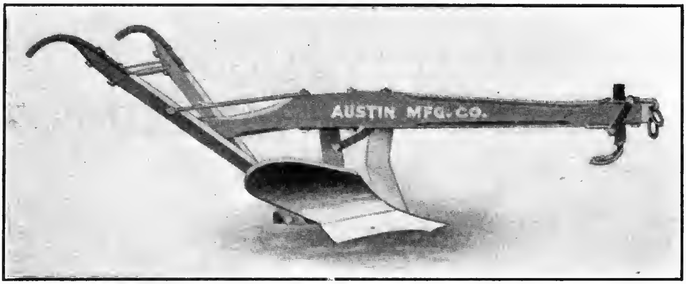

Fig. 1.—Ordinary mold-board plow. (*Courtesy of Austin Mfg. Co.*)

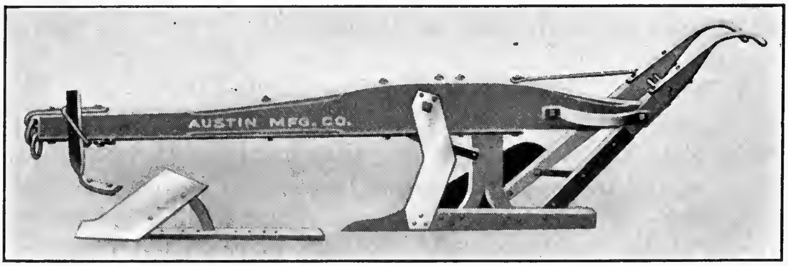

Fig. 2.—Typical railroad plow. (*Courtesy of Austin Mfg. Co.*)

Labor:

Team, plow, and driver	$4.00		
Plow holder	1.75		
Total, labor cost		$5.75	
Repairs, depreciation, etc		1.25	
Total cost			$7.00

Total amount of material loosened........ 400 cu. yd.

Cost of loosening material, $7.00 ÷ 400 = 1.75 cents per cu. yd.

abor:

Team, plow and driver	$4.00	
Plow holder	1.75	
Beam rider	1.75	
Total labor cost		$7.50
Repairs, depreciation, etc.		1.50
Total cost		$9.00

Total amount of material loosened..... 200 cu. yd.

Cost of loosening material, $9.00 ÷ 200 = $0.045 per cu. yd.

5. Shovel.—Shovels are made with either long or short handles and round, square or pointed blades. The round-ended blade is more efficient in the removal of stiff, dense soils and should be used with a short D-handle. The long-handled, round-ended shovel is the best type for ordinary soils and for the greater lifting conditions. The amount of material which can be shoveled per 10-hr. day depends on the condition and nature of the soil, the method of disposal, the type of shovel used, the efficiency of the man, etc. A laborer can shovel loose material and elevate it upon a platform or into a wagon at the rate of from 15 cu. yd. to 10 cu. yd. per 10-hr. day for lifts of from 3 ft. to 5 ft., respectively. These quantities should be reduced to from 8 cu.yd. to 5 cu. yd. for a dense, tough clay or a hard gravel.

6. Résumé.—The following data[1] gives the cost of loosening and shoveling for various kinds of soil conditions.

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[1] From Earth Excavation by Gillette, Mining Engineers' Handbook, Peele.

COST OF PLOWING

(Wages $1.50 and horse-keep $1.00 per 10-hr. day)

Soil	Labor	Cu. yd. per hour	Labor cost, per cu. yd., cents
Loam	1 driver, 1 holder, 2 horses	50	1.0
Gravel and loam	1 driver, 1 holder, 2 horses	35	1.4
Fairly tough clay	1 driver, 1 holder, 2 horses	25	2.0
Very hard soil	1 driver, 1 holder, 4–6 horses, and 2 men on plow beam of rooter plow	15–20	5–8
Ordinary soil	1 driver, 6 horses, on gang plow	40	1.9

COST OF LOADING BY SHOVELING

Method	Cu. yd. per man-hour	Cost per cu. yd. (Wages, 15 cents per hour) Cents	Authority
Mud into wheelbarrows	0.8	19.0	M. Ancelin
Gravel into wheelbarrows	1.7–2.7	7.0	M. Ancelin
Earth into wheelbarrows	1.6–4.8	5.0	M. Ancelin
Earth into wheelbarrows, aver.	2.2	7.0	M. Ancelin
Earth (all kinds) into wagons	2.1	7.5	Cole (*a*)
Earth into wheelbarrows, aver.	2.8	5.25	Gillepsie
Earth (all kinds) into wagons	2.0	7.5	D. K. Clark
Sand into cars from high face	1.8	8.25	Gillette (*b*)
Plowed gravelly soil into wagons	1.3	11.3	Gillette (*c*)
Iowa soil	1.5–2.0	8.5	J. M. Brown
Iowa soil	2.8	(*d*)	J. M. Brown
Clay and gravel into carts	1.0	15.0	E. Morris
Loam into carts	1.2	12.5	E. Morris
Sandy earth into carts	1.4	10.75	E. Morris
Loose sand into carts	2.0	7.5	G. A. Parker
Clay, tenacious, Chicago	1.25	(*e*)	G. A. Parker
Hardpan into low dump cars	1.5	10.0	Gillette
Average earth	1.75	8.6	Gillette

(*a*) 10 miles, Erie Canal. (*b*) 10,000 cu. yd. bank measurement. (*c*) 20,000 cu. yd. in embankment. (*d*) A rush job. (*e*) Spaded out and handled with forks.

7. Bibliography.—The reader should consult the following for further information:

Books

1. "American Civil Engineers' Pocket Book," edited by MANSFIELD MERRIMAN, 3d edition, published in 1916 by John Wiley & Sons, New York. 1496 pages, 1047 figures, 4¼ in. × 7 in. Cost, $5.00.
2. "Earthwork and Its Cost," by H. P. GILLETTE, 2d edition, published in 1912 by McGraw-Hill Book Company, New York. 60 figures, 5 in. × 8 in. Cost, $2.00.
3. "Handbook of Cost Data," by H. P. GILLETTE, published by McGraw-Hill Book Company, New York. 1900 pages, 4½ in. × 7 in. Cost, $5.00.

Magazine Articles

1. Comments on the Use of the Mattock. *Engineering-Contracting,* January 15, 1908. 1800 words.
2. Earth Excavation. *Zeitschrift des Vereines Deutscher Ingenieure,* September 3, 1910. Illustrated, 7200 words. Serial.

CHAPTER II

DRAG AND WHEEL SCRAPERS

8. General Description.—The scraper consists of a steel pan with a cutting edge and rests directly on the surface or is suspended from a frame mounted on either two or four wheels. The scraper is usually hauled by two horses, and a snatch team of horses or a traction engine are used to load in dense, hard soils.

The following types of scrapers are in common use and will be described; the drag or slip scraper, the Fresno scraper, the two-wheel scraper and the four-wheel scraper.

9. Drag Scraper.—The drag scraper consists of a steel scoop with a rounded back and curved bottom. The latter is either provided with runners or reinforced with a sheet of hard steel, known as a "double bottom." Wooden handles are attached to the sides near the rear of the scoop and are used by the driver in its operation. A heavy bail provides for the attachment of a team of horses. The following table gives the description and cost of the various sizes of the ordinary drag scraper:

No.	Description	Capacity, cu. ft.	Weight, lb.	Cost, f.o.b. factory
1	With runners	7	95	$11.50
2	With runners	5	85	11.00
3	With runners	3½	75	9.75
1	With double bottom	7	100	13.00
2	With double bottom	5	90	12.50

Drag scrapers are generally used in gangs of from 3 to 10, the driver usually loading and dumping the scoop. In the construction of an embankment, when a laborer is employed to spread out the material at the dump, he assists in the emptying of the scrapers. The material can be excavated directly when the soil is a loam, soft clay or sand. For harder soils the material must first be loosened with a plow. The scrapers will not excavate and carry to the spoil bank an amount equal to the capacities given in the above table. Rarely does a scraper go out of the excavation filled and the material is generally in a loose condition. At least 25 per cent. should be allowed for the shrinkage of the loose material when compacted in an embankment.

The author recommends the following rule for the cost of moving earth with drag scrapers.

For 50 ft. hauls or less the cost of moving 1 cu. yd. of earth will be 10 cents. For each additional 50 ft. of haul add 2 cents. When the soil is hard, add 3 cents to the figures derived from the above rule, which applies only to average soils.

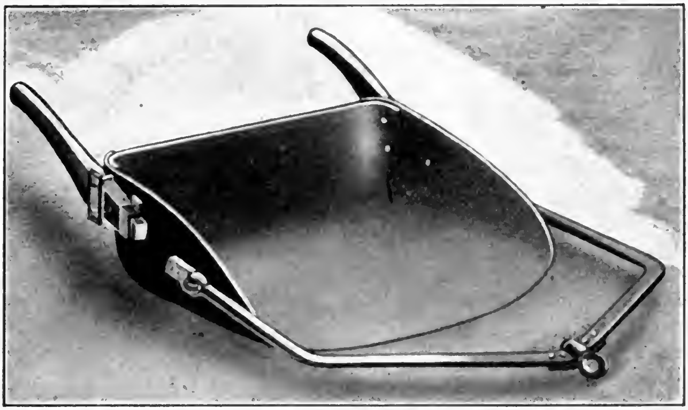

Fig. 3.—Front view of drag scraper. *(Courtesy of Western Wheeled Scraper Co.)*

Drag scrapers are very efficient up to hauls of 100 ft. and can be satisfactorily used up to 200-ft. hauls. A two-horse team and scraper can move in a 10-hr. working day, the following average amount of loose material:

For a haul of 25 ft.	70 cu. yd.
For a haul of 50 ft.	60 cu. yd.
For a haul of 100 ft.	50 cu. yd.
For a haul of 150 ft.	40 cu. yd.
For a haul of 200 ft.	35 cu. yd.

Drag scrapers are especially adapted to borrowing from the side of an embankment or wasting from shallow cuts or ditches. The cost of maintenance of a drag scraper is small and its useful life is limited largely by the physical condition of the scoop.

Figures 3, 4 and 5 show the front view and rear views of a well-known make of drag scraper.

10. Field of Use.—The drag scraper has been generally used in this country during the past 40 years in the construction of railroads, highways and waterways. In recent years its field of operation has been extended to include irrigation and drainage canals, large, shallow excavations for reservoirs, cellars, etc. This type of scraper is not economical in the moving of earth over 200 ft. and for jobs whose magnitude is greater than about 50,000 cu. yd.

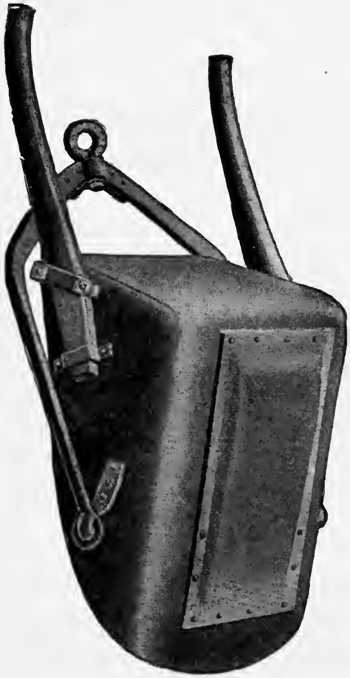

Fig. 4.—Rear view of drag scraper with double bottom. (*Courtesy of Austin Mfg. Co.*)

Fig. 5.—Rear view of drag scraper with runners. (*Courtesy of Austin Mfg. Co.*)

11. Fresno Scraper.—The Fresno scraper has a long, narrow pan which rests directly on the surface in loading but, in dumping and returning from the dump, is carried on adjustable runners. Figures 6 and 7 illustrate the Fresno scraper in loading and dumping positions and the following table gives the various sizes, capacities, weights and costs of a typical make:

No.	Description	Capacity, cu. ft.	Weight, lb.	Cost, f.o.b. factory
1	5 ft. cutting edge	18	300	$37.00
2	4 ft. cutting edge	14	270	30.00
3	3½ ft. cutting edge	12	245	28.00

The Fresno scraper is generally operated in groups of from 2 to 10, depending upon the character and magnitude of the work. Each scraper is operated by a driver and, on heavy work, a laborer assists in both loading and dumping while in light work the driver loads his own scraper.

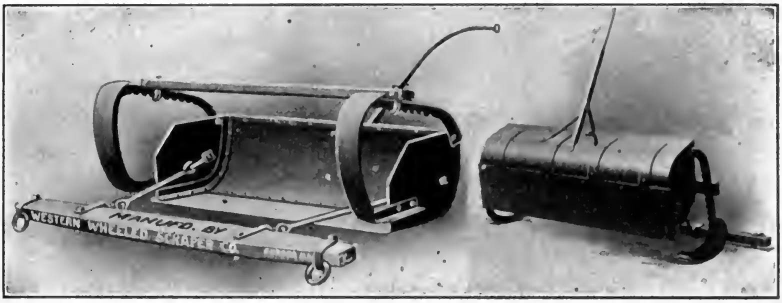

FIG. 6. FIG. 7.

FIG. 6.—Buck scraper, ready to load. (*Courtesy of Western Wheeled Scraper Co.*)
FIG. 7.—Buck scraper, dumped.

The economical haul of a Fresno is about 300 ft. It requires less time to load and unload this type of scraper than it does a two-horse wheeler, but the expense of the two extra horses on a four-horse Fresno balances these items when the haul exceeds 300 ft.

12. Field of Use.—The Fresno scraper is generally more efficient than the drag scraper since it is easier to load and moves more earth. For side-hill work this scraper is especially efficient, as it will often push ahead of itself a large mass of loose material.

In the arid West the Fresno has had a wide field of usefulness in the excavation of large, shallow canals. Under average working conditions, the amount of sandy-clay soil moved by a scraper will vary from 60 to 125 cu. yd. with a haul of from 75 to150 ft., during a 10-hr. day, at a cost of from 7 to 10 cents per cu. yd.

13. Two-wheel Scraper.—The two-wheel scraper consists of a steel box mounted on a single pair of wheels and equipped with levers so that the box may be raised, lowered and dumped, while the scraper is in motion. An automatic end-gate is sometimes attached to the front of the pan to prevent the loss of material, especially on steep slopes.

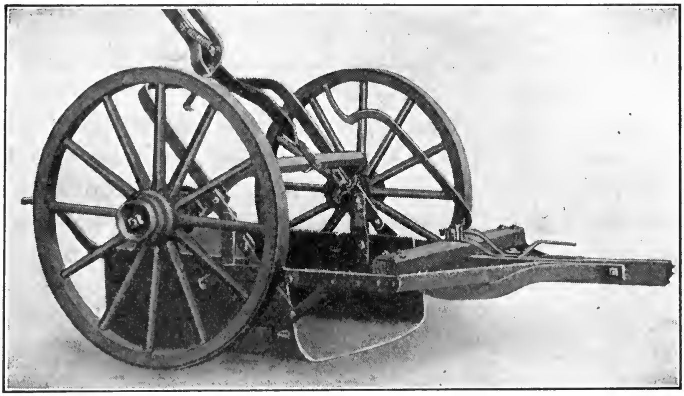

Fig. 8.—Wheel scraper, ready to load. (*Courtesy of Western Wheeled Scraper Co.*)

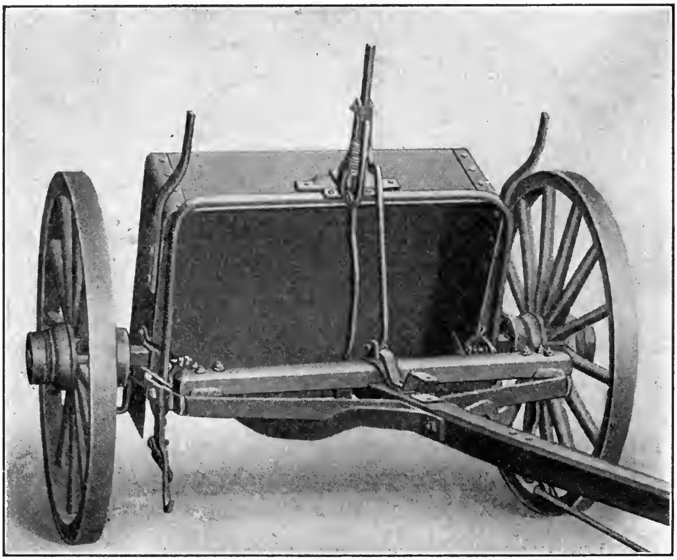

Fig. 9.—Wheel scraper, returning to pit. (*Courtesy of Western Wheeled Scraper Co.*)

Figures 8 and 9 show two positions of the scraper and the following table gives the various sizes, capacities, weights and costs of a well-known make:

No.	Capacity, cu. ft.	Weight, lb.	Cost, f.o.b. factory
1	9	500	$50.00
2	12	650	60.00
2½	14	700	63.00
3	16	800	65.00

The wheel scraper is an excellent earth mover up to hauls of 800 ft. and is more efficient than the drag scraper for hauls over 200 ft. The No. 3 wheeler requires the use of a snatch-team in ordinary material and a No. 2 in hard material, and for long hauls this size of scraper is the most economical. For average soil and hauls not greater than 400 ft., the No. 2 wheeler is the most efficient. The average load (place measurement) carried by the wheeler is as follows: No. 1, ⅕ cu. yd.; No. 2, ¼ cu. yd.; No. 3, ⅓ cu. yd.

As in the case of drag scrapers, the wheeler never leaves the excavation filled to its rated capacity. For long hauls and where the material is tough and hard to handle, it is economical to use shovelers to heap up the bowls of the scraper, before the teams start.

The author recommends the following rule for the cost of moving earth with two-wheel scrapers.

For 100-ft. hauls or less the cost of moving 1 cu. yd. of earth will be 10 cents. For each additional 100 ft. of haul add 2 cents. When the soil is hard add 3 cents to the figures given by the above rule, which applies only to average soils.

A two-horse team and scraper can move in a 10-hr. working day, the following average amounts of loose material:

For a haul of 100 ft.	50 cu. yd.
For a haul of 200 ft.	50 cu. yd.
For a haul of 300 ft.	40 cu. yd.
For a haul of 400 ft.	30 cu. yd.

Two-wheel scrapers should work in groups of from 4 to 6 for hauls up to 400 ft. and in gangs of from 8 to 12 for longer hauls. One man is necessary to load and dump the scraper and in hard or tough soils two men are required to load the larger size machines.

14. Field of Use.—The two-wheel scraper has about the same scope of efficient operation as the drag scraper; the construction of levees and enbankments, the making of shallow excavations, and the borrowing of material for relatively short hauls. The economical operation of the wheeler is limited to hauls of from 200 ft. to 800 ft. and for jobs not exceeding 50,000 cu. yd. in magnitude.

The two-wheel scraper is especially serviceable in the construction of small railroad and reservoir embankments and levees where the continual movement of the teams over the dump is an important factor in the compacting of the material.

15. Four-wheel Scraper.—The four-wheel scraper consists of a pan, having a capacity of either ½ cu. yd. or 1 cu. yd., and hung by chains on a frame, which is carried by two trucks. The pan is hung so that the front or cutting edge, in the loading position, touches the surface. The front wheels are small and underhung so that short and sharp turns may be made. The pan is operated by four levers, which are all within easy reach of the driver and operator, who is seated just behind and on the right-hand side of the rear truck. The motive power is a team of horses. A snatch-team or a traction engine is used in loading.

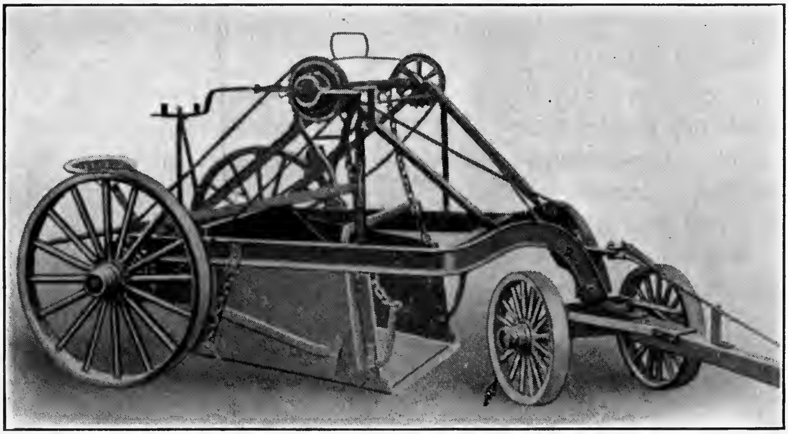

Fig. 10.—Maney four-wheel scraper. (*Courtesy of Baker Mfg. Co.*)

The pan when filled is elevated automatically by a sprocket chain. The scraper is then moved to the dump where the pan is elevated to the proper height, when an automatic trip throws the clutch on the axle out of gear, stopping the winding and thus preventing the machine from becoming spool bound. The load is dumped through a lever-operated gate in the rear of the pan while the scraper moves over the dump.

The Maney four-wheel scraper, with pan in loading position is shown in Fig. 10, and the following table gives the sizes, capacities, weights, and costs of this type of excavator:

No.	Capacity, cu. ft.	Weight, lb.	Cost
1	13.5	1350	$240.00
2	27.0	2350	$375.00

The four-wheel scraper is about 100 per cent. more efficient than the two-wheel scraper for 200-ft. hauls, and the efficiency increases with the length of haul. This scraper can be economically used for hauls up to 2000 ft.

Table I.—Cost Per Cubic Yard of Scraper Work

I. Drag Scraper

Character of the soil	Length of haul			
	50 ft.	100 ft.	150 ft.	200 ft.
Average soil	$0.10	$0.12	$0.14	$0.16
Hard soil	0.13	0.15	0.17	0.19

II. Two-wheel Scraper

Character of soil	Length of haul			
	100 ft.	200 ft.	300 ft.	400 ft.
Average soil	$0.10	$0.12	$0.14	$0.16
Hard soil	0.13	0.15	0.17	0.19

Character of soil	Length of haul			
	500 ft.	600 ft.	700 ft.	800 ft.
Average soil	$0.18	$0.20	$0.22	$0.24
Hard soil	0.21	0.23	0.25	0.27

Note.—The rules on pages 7 and 11, and the above table are based on the following costs:

Team and driver	$5.00 per 10 hr. day.
Snap man	2.50 per 10 hr. day.
Foreman	5.00 per 10 hr. day.
Laborer for dumping	2.50 per 10 hr. day.

III. Four-

Cost of moving dirt with Baker-

Length of haul		2000′	1500′	1400′	1300′	1200′	1100′
No. of machs.	Daily cost						
20	$119.50	528 c. y. 22.6¢					
15	94.50	396 c. y. 23.6¢	528 c. y. 17.9¢				
14	89.50	370 c. y. 24.2¢	493 c. y. 18.2¢	528 c. y. 16.9¢			
13	84.50	343 c. y. 24.6¢	458 c. y. 18.4¢	490 c. y. 17.2¢	528 c. y. 16.0¢		
12	79.50	317 c. y. 25.1¢	422 c. y. 18.8¢	453 c. y. 17.5¢	487 c. y. 16.3¢	528 c. y. 15.1¢	
11	74.50		387 c. y. 19.3¢	415 c. y. 17.9¢	447 c. y. 16.7¢	484 c. y. 15.4¢	528 c.y. 14.1¢
10	69.50		352 c. y. 19.7¢	378 c. y. 18.4¢	406 c. y. 17.1¢	440 c. y. 15.8¢	480 c. y. 14.5¢
9	64.50		317 c. y. 20.3¢	340 c. y. 18.9¢	365 c. y. 17.7¢	396 c. y. 16.2¢	432 c. y. 14.9¢
8	59.50		282 c. y. 21.1¢	300 c. y. 19.8¢	325 c. y. 18.3¢	352 c. y. 16.9¢	384 c. y. 15.5¢
7	54.50		246 c. y. 22.1¢	264 c. y. 20.6¢	284 c. y. 19.2¢	308 c.y. 17.7¢	336 c. y. 16.2¢
6	49.50		211 c. y. 23.5¢	226 c. y. 21.9¢	244 c. y. 20.3¢	264 c. y. 18.7¢	288 c. y. 17.2¢
5	44.50		176 c. y. 25.3¢	189 c. y. 23.6¢	203 c. y. 21.9¢	220 c. y. 20.2¢	240 c. y. 18.5¢
4	39.50						
3	34.50						
2	29.50						

NOTE.—Above yardage figured on basis of Teams traveling 20 miles per 10-hr. day.

Cost Based on Following Data.

Team and Driver	@$ 5.00	Per 10 hr. day.
Rented Tractor & Operator	@$12.00	Per 10 hr. day.
Snap Man	@$ 2.50	Per 10 hr. day
Foreman	@$ 5.00	Per 10 hr. day

wheel Scraper

Maney four-wheel 1-yd. scraper

1000′	900′	800′	700′	600′	500′	400′	300′	200′
NOTE—Figures in upper part of each square represent number of cubic yards moved per day Lower figures represent the cost per cubic yard.								
528 c. y. 13.2¢								
475 c. y. 13.8¢	528 c. y. 12.2¢							
422 c. y. 14.1¢	469 c. y. 12.7¢	528 c. y. 11.3¢						
370 c. y. 14.7¢	411 c. y. 13.3¢	462 c. y. 11.8¢	528 c. y. 10.3¢					
317 c. y. 15.6¢	352 c. y. 14.1¢	396 c. y. 12.2¢	452 c. y. 10.9¢	528 c. y. 9.4¢				
264 c. y. 16.8¢	292 c. y. 15.2¢	330 c. y. 13.5¢	377 c. y. 11.8¢	528 c. y. 10.1¢	528 c. y. 8.4¢			
211 c. y. 18.7¢	235 c. y. 16.8¢	264 c. y. 14.9¢	301 c. y. 13.1¢	352 c. y. 11.2¢	472 c. y. 9.4¢	528 c. y. 7.5¢		
			226 c. y. 15.3¢	264 c. y. 13.0¢	317 c. y. 10.9¢	396 c. y. 8.7¢	528 c. y. 6.5¢	
				176 c. y. 16.8¢	211 c. y. 14.1¢	264 c. y. 11.2¢	352 c. y. 8.4¢	528 c. y. 5.6¢

EXAMPLE.—6 Baker-Maney's on a 600 Foot Haul.

To find cost per cubic yard consult column headed 600 *feet*, run down this column until it intersects column marked "6" on the extreme left. This is shown as 9.4 cents, the cost per cubic yard. No. Cubic Yards = 528.

No plowing is necessary when using tractor for loading on ordinary jobs.

16. Field of Use.—The four-wheel scraper is the most efficient form of scraper for shallow excavation, where the total amount of material to be moved is less than 50,000 cu. yd, and the soil conditions do not require the use of a power excavator.

In the construction of roads, railroad cuts and canals where the cut varies from 1 ft. to 4 ft., and the haul is from 500 to 1000 ft., 7 to 10 scrapers, loaded by a traction engine, can excavate and move from 500 to 800 cu. yd. of clay and loam, per 10-hr. day, at a cost of from 10 to 15 cents per cu. yd.

17. Résumé.—The field of usefulness of the scraper is large and varied. In the construction of railroad embankments, levees for river protection and shallow cuts, the scraper has been in successful use for about 40 years. For the excavation of broad, shallow ditches for drainage and irrigation works, the scraper has come into a limited use during the past decade. It is a familiar tool in the grading of streets, the digging of cellars for buildings and the excavation of large shallow areas for reservoirs and the foundations of various structures. The scraper is an efficient and economical type of excavator where the yardage is small, roughly speaking, less than 50,000 cu. yd. and within the scope of the type employed. Considering the first part of the above statement, a dry-land excavator can generally be used for the construction of levees, when the job is greater than 50,000 cu. yd., at a cost of about 50 per cent. less than with a scraper. In a similar manner, a steam shovel supersedes the scraper in the excavation of large foundations, street and railroad cuts, etc. In the excavation of small ditches, the wheel excavator is a much more efficient machine and for large ditches, the dipper dredge supplants the scraper.

The Fresno scraper has been used with considerable success in the arid West on canal and embankment construction. This is especially true of side-hill work, when the ditch lies partly in cut and partly in fill. The scraper works downhill, pushing a large amount of earth ahead of itself into the embankment, which is consolidated by the tramping of the teams. For ditches from 8 to 20 ft. wide on the bottom, side slopes of 1½ to 1, and less, and for depths of from 3 to 8 ft., the Fresno scraper will, under average working conditions, remove about 100 cu. yd. during a 10-hr. day and at an operating cost of about 8 cents per cubic yard.

The drag scraper can operate economically up to a haul of 200 ft., the two-wheel scraper up to a haul of 800 ft., and the four-wheel scraper up to a haul of 2000 feet.

The cost of excavation is rather difficult to formulate and one upon which authorities differ. Table I is based upon the rules given on pages 7 and 11, and will be found to be approximately correct, under average working conditions.

18. Bibliography.—For additional information, see the following:

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2. "The Chicago Main Drainage Channel," by C. S. HILL. published in 1896 by Engineering News Publishing Company, New York. 129 pages, 105 figures, 8 in. × 11 in.
3. "Construction of Roads and Pavements," by T. R. AGG, published in 1916 by McGraw-Hill Book Company, New York. 432 pages, 116 figures, 6 in. × 9 in. $3.00.
4. "Earthwork and Its Cost," by H. P. GILLETTE, 2d edition, published in 1912 by McGraw-Hill Book Company, New York. 60 figures, 5 in. × 8 in. Cost, $2.00.
5. "Economics of Road Construction," by H. P. GILLETTE, published in 1906 by Engineering News Publishing Company, New York. 41 pages, 9 figures.
6. "Elements of Highway Engineering," by A. H. BLANCHARD, published in 1915 by John Wiley & Sons, New York. 497 pages, 202 figures, 6 in. × 9 in. Cost, $3.00.
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8. "Roads and Pavements," by IRA O. BAKER, published in 1914 by John Wiley & Sons, New York. 698 pages, 171 figures, 6 in. × 9 in. Cost, $4.50.
9. "Text-Book on Highway Engineering," by BLANCHARD-DROWNE, published in 1911 by John Wiley & Sons, New York. 761 pages, 234 figures, 6 in. × 9 in. Cost, $4.50.

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1. Bowford's and Evershed's Patent Excavator. *The Engineer*, London, February 11, 1898. Illustrated, 1200 words.
2. A Cable-power Scraper for Earth Excavation, C. G. NEWTON. *Engineering News*, October 20, 1904. Illustrated, 500 words.
3. Cost of Wheel-scraper Work. *Engineering-Contracting*, August 28, 1907 and July 22, 1908.

4. The Economic Handling of Earth by Wheel and Fresno Scrapers. *Engineering & Contracting*, June 3, 1914. Illustrated, 7000 words.

5. Excavating with Large Scrapers. *Engineering News*, December 25, 1913. Illustrated, 1000 words.

6. Excavation with Fresno Scrapers. *Engineering-Contracting*, July 15, 1908, November 3, 1909 and November 24, 1909.

7. Examples of High and Low Cost of Wheel-scraper Work, with Comments on the Efficiency of the Work Done. *Engineering-Contracting*, July 22, 1908. 1300 words.

8. A Four-wheel Scraper of Large Capacity for Excavation and Grading. *Engineering News*, May 19, 1910. 1000 words.

9. Hints on Handling Wheel Scrapers. *Engineering-Contracting*, August 28, 1907. 1500 words.

10. Low Cost of Excavation with Fresno Scrapers by WALTER N. FRICKTAD. *Engineering-Contracting*, November 3, 1909. Illustrated, 2000 words.

11. Methods and Cost of Moving Earth with Fresno Scrapers in Arizona, and the Cost of Trimming Slopes. *Engineering-Contracting*, October 2, 1907. 1500 words.

12. Methods and Costs of Loading Dump Wagons with Scrapers and the Design of a Loading Platform. *Engineering-Contracting*, January 23, 1907. 1200 words.

13. Methods of Excavation for Buildings. *Engineering Record*, January 16, 1915. Illustrated, 4000 words.

14. Operation Analysis of New Machines Which Cheapen the Moving of Earth on Road Work. *Engineering Record*, July 31, 1915. Illustrated, 3000 words.

15. Scraper Excavators. *Engineering News*, March 21, 1907. Illustrated, 2000 words.

CHAPTER III

BLADE OR ROAD GRADERS

19. General Description.—The blade or road grader consists of a scraper blade suspended from a frame mounted on either two or four wheels. The blade is so hung that it may be placed at various angles, horizontally or vertically, and reversed with the back of the blade facing the front of the machine. The blade is operated by a set of levers or wheels which are under the control of the driver or a special operator. The grader is hauled by 4 to 6 horses, although for the larger size graders or for stiff soils, a traction engine is often used and furnishes a steadier and more efficient power.

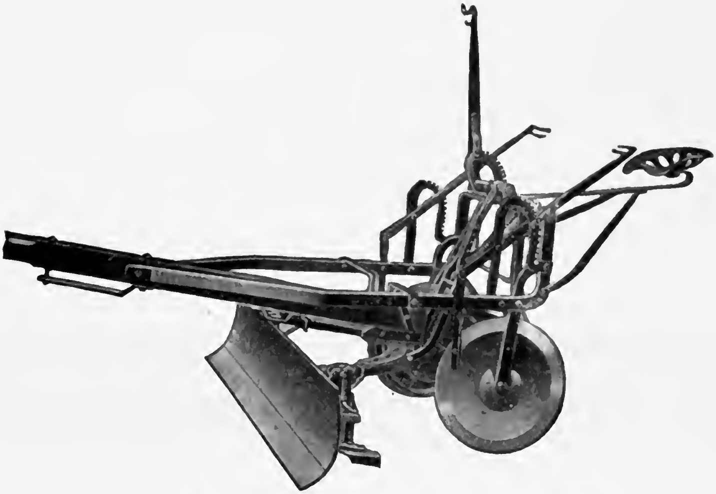

FIG. 11.—Two-wheel grader. (*Courtesy of Baker Mfg. Co.*)

The scraping or blade grader is used primarily for the making of successive shallow cuts and the gradual movement of the material from a lower to a higher elevation.

20. Two-wheel Grader.—The simplest form of a scraping or blade grader is the two-wheel grader, which consists of a two-wheel truck carrying an adjustable blade. The blade can be raised or lowered and adjusted vertically and horizontally. The wheels are flanged to prevent the lateral sliding of the machine on a slope. The machine is hauled by two or four horses and is controlled by one man, who is seated at the rear and acts as driver and operator.

A well-known make of two-wheel grader is shown in Fig. 11. This machine weighs 700 lb. and costs $115.00 f.o.b. factory.

21. Field of Use.—The two-wheel grader can be economically used in the grading, leveling and crowning of earth roads, the excavation of ditches, the grubbing and leveling of land and the cleaning of gutters and pavements. The machine is especially adapted to the excavation of small road, drainage and irrigation ditches. In a sandy-clay or loam, the average capacity of a grader operated by a two-horse team and driver will be about ½ mile of a V-shaped ditch, 24 in. deep, in a 10-hr. day.

22. Four-wheel Blade Grader.—The four-wheel grader consists of an adjustable scraper blade carried by a frame which is supported on two-wheel trucks. The front wheels are arranged to cut under the frame so that short turns may be made. The blade is suspended by a pivoted frame which is operated by levers at the rear of the machine. By means of a simple operating mechanism, the blade may be set at any angle with the direction of the draft, raised or lowered to any height or angle and tilted to the front or rear. The rear axle is generally made telescoping, so that the frame of the machine may be shifted to either side. In road construction, this provides for the bearing of a rear wheel against the side of the ditch, to resist the side draft.

The tractive power may be horses or a traction engine; the latter being more efficient in dense hard soils.

The following table gives the sizes, weights and costs of a typical make of four-wheel grader.

Description	Blade	Weight	Cost, f.o.b. factory
Light	15 in. × 6 ft.	1400 lb.	$175.00
Standard	18 in. × 7 ft.	2700 lb.	250.00
Large	18 in. × 8 ft.	4000 lb.	325.00
Very large	16 in. × 12 ft.	6100 lb.	750.00

Light, standard and very large road graders are shown in Figs. 12, 13, and 14, respectively.

FIG. 12.—Light four-wheel grader. (*Courtesy of Western Wheeled Scraper Co.*)

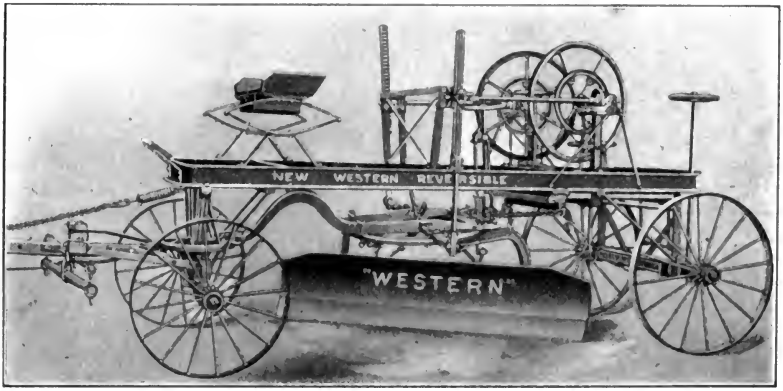

FIG. 13.—Standard road grader. (*Courtesy of Western Wheeled Scraper Co.*)

FIG. 14.—Very large road grader. (*Courtesy of Austin Mfg. Co.*)

23. Reclamation Grader.—In moving the earth from a lower to a higher elevation, the lateral thrust of the material, especially in stiff soils, tends to displace the machine. To counteract this side-draft, a grader with pivoted axles is often used. This machine, by keeping its wheels always in a vertical position, utilizes its weight to counteract the side pressure of the earth on the mold board. This type of grader, known as the Reclamation grader, has proved very efficient in the excavation of irrigation ditches. The blade is hung so as to provide a much greater latitude in the vertical adjustment of the blade than is obtained with the ordinary blade grader. The grader is hauled by 12 horses or a traction engine, weighs 3000 lb. and costs $1000.00. Figure 15 shows this ditcher in operation during the construction of a large ditch near Broomfield, Colorado.

Fig. 15.—Reclamation grader excavating irrigation ditch.

24. Method of Operation.—The blade grader is operated so as to excavate a thin slice of earth from one side of cut and move it laterally by the side thrust of the oblique blade. Considerable lateral movement of excavated material may be secured in this

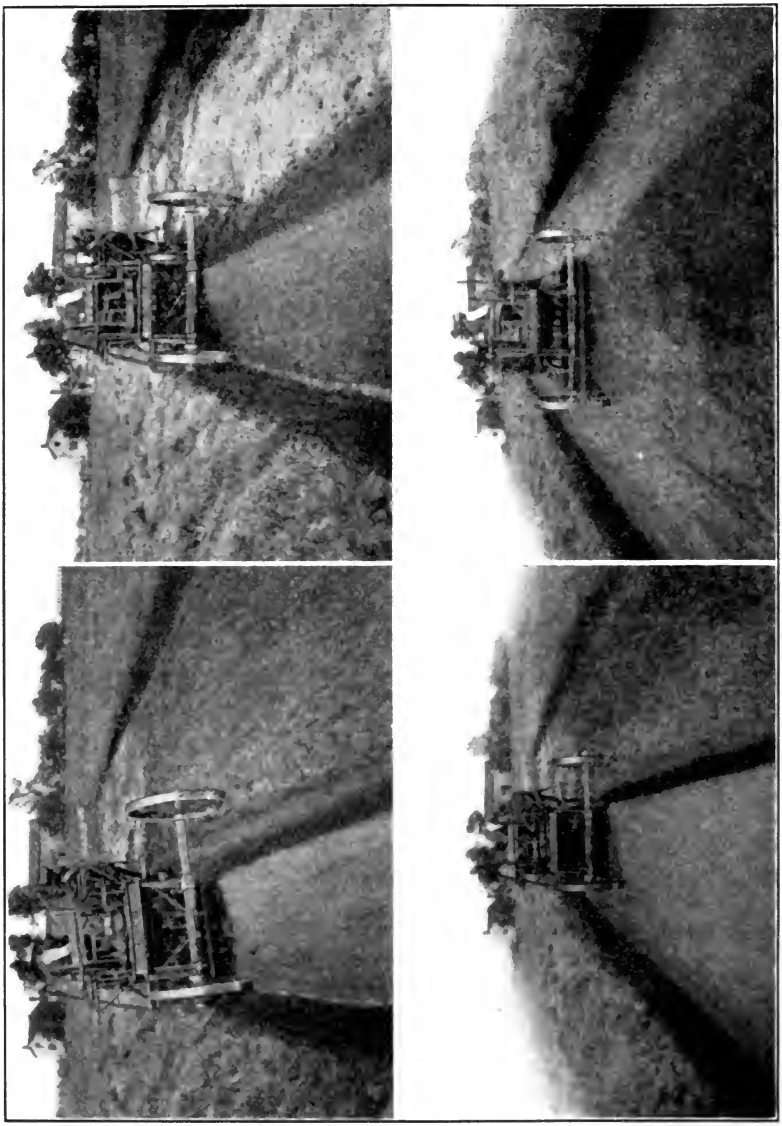

Fig. 16.—Diagram showing four stages of road construction.

way by making several trips or rounds of the grader. The various steps in the construction of a road are shown in Fig. 16. The grader commences excavation at the side of the road with the blade tilted and turned so as to act as a plow. The second trip is made with the blade lowered to a slight vertical angle and with the front and rear wheels in line, the machine follows along the line of the first furrow. The third round consists in the moving of the earth from the berm toward the center of the road, and is made with the rear wheels near the center of the road. The final round is made with the blade set square across the road the so set as to smooth down and even off the loose earth brought to the center of the road.

25. Field of Use.—The road grader is used principally in the construction and maintenance of roads. This type of excavator is especially serviceable when used in coördination with the wheeled scraper or elevating grader to finish the surface of the excavation. In the regrading of old roads where the side ditches are narrow and deep, the blade grader is the only machine that can be efficiently used.

The blade grader has been adapted in recent years; to the leveling of the surface preparatory to the excavation of ditches, the cutting down of banks, the excavation of lateral irrigation ditches, and the cleaning of snow from the streets in cities.

26. Cost of Operation.—The two-wheel grader will excavate V-shaped ditches up to a depth of 24 in., at an average cost of 3 cents per rod. Two horses and one man at an operating cost of about $4.00 per day will be able to construct about ½ mile of ditch per 10-hr. day, under average working conditions.

The standard size of four-wheel graders will average about 1000 cu. yd. or 18,000 sq. yds. of road surface, in road construction or maintenance per 10-hr. day. The cost of road construction will vary from 1½ cents to 2½ cents per cu. yd., depending on soil, width of road, size of scraper depth of cut, etc. The services of five horses and two men, at an operating cost of about $12.00 per day, will be required.

27. Résumé.—The road grader can be efficiently used in the construction and maintenance of roads and small ditches. The limitations of this machine depend to a great extent upon its size and construction. The two-wheel grader is adapted to the grading up of roads, the leveling of the surface, and the excavation of small ditches where the soil is dry and not too hard.

The four-wheel grader is especially serviceable in the grading up of roads and the excavation of the upper sections of large ditches. The Reclamation grader is useful in side-hill work and the construction of the small ditches in dry, loose soils. A grader of any type cannot operate successfully in very loose and wet soils nor in very dense, hard soils.

Where a large amount of road construction is included in one contract it is advisable to use a traction engine for motive power. A saving of from ½ to 1 cent per cu. yd. of material moved may often be affected by the substitution of a traction engine for horses.

The leveling of the surface preparatory to irrigation or further excavation can be efficiently accomplished by the use of the Shuart grader. This machine consists of a scraping steel blade attached to a frame carried on four low wheels. At each side of the frame is a guard which enables the blade to push along ahead of itself a large amount of the excavated material. The blade can be raised and lowered by means of levers.

28. Bibliography.—See Art. 33, page 29.

CHAPTER IV

ELEVATING GRADERS

29. General Description.—The elevating grader consists of a frame supported on two two-wheel trucks. From the frame is suspended a plow and a transverse inclined frame, which carries a wide traveling endless belt. The moving belt frame or elevator is so constructed and supported, that the extension of the belt beyond the center of the machine may be varied and the inclination of the belt changed. The form of plow used may be either of the disc or the ordinary mold-board type. The plow is suspended from an independent beam, which is so hung from the main frame that the plow may be adjusted in four ways; longitudinal, transverse, vertical, and tilting. The plow loosens the soil and raises it upon the lower end of the inclined belt, which carries to the outer and upper end of the elevator, where it falls on to the spoil bank or into wagons. An elevating grader with a mold-board plow is shown in Fig. 17 and one equipped with a disc plow in Fig. 18. The elevator side of a grader is shown in Fig. 19.

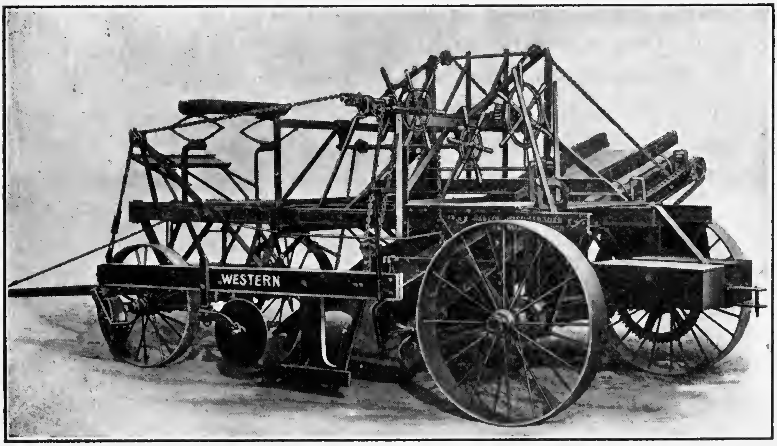

Fig. 17.—Plow side of elevating grader. (*Courtesy of Western Wheeled Scraper Co.*)

The elevating grader is generally made in three sizes; each of which is especially adapted for a special field of work. The following table gives a statement of the size, weight and cost of the various sizes of a well-known make:

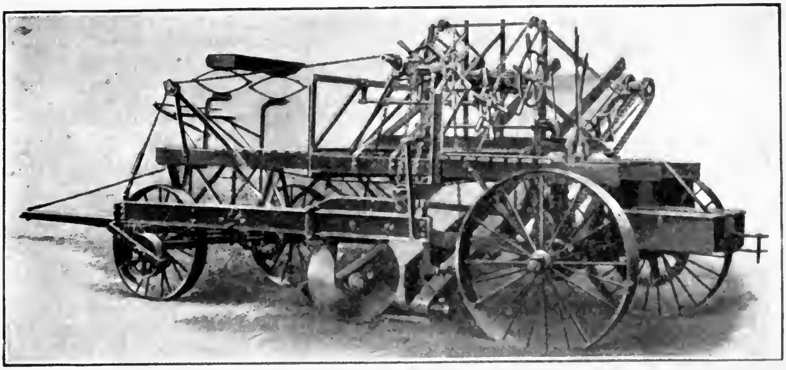

FIG. 18.—Plow side of elevating grader. (*Courtesy of Western Wheeled Scraper Co.*)

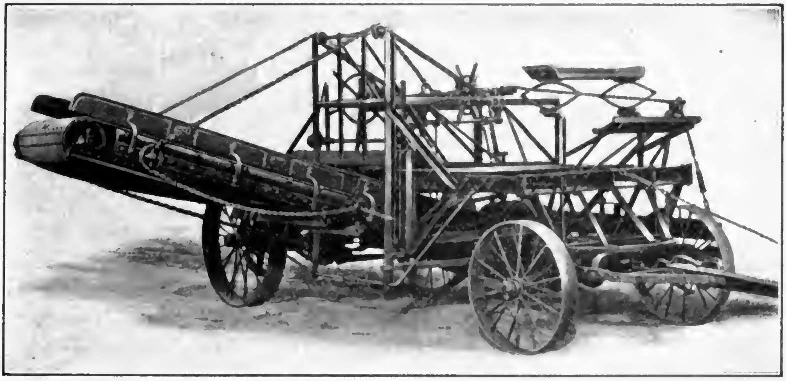

FIG. 19.—Elevator side of elevating grader. (*Courtesy of Western Wheeled Scraper Co.*)

Size	Conveying radius, ft.	Weight, lb.	Cost, f.o.b. factory
Small	10 to 18	8,600	$1000.00
Standard	14 to 24	9,400	$1050.00
Large	12 to 30	12,000	$1700.00

30. Field of Use.—The small size or Junior grader is especially adapted for loading wagons, working in narrow cuts or for other use where a narrow machine and short elevator are required. For narrow ditch excavation, elevators as short as 10 ft. and made in one piece, can be utilized.

The standard or ordinary size of grader equipped with an elevator from 15 to 24 ft. long is of general use for loading wagons, road and street excavation, the construction of earth embankments and levees, etc.

The large size or Giant grader is especially adapted for use in the construction of heavy materials and equipped with an elevator which will dump material from 12 to 30 ft. from the machine. This grader is adapted to work of great magnitude, the excavation of stiff heavy soils, and severe working conditions. It will excavate a ditch having a top width of about 50 ft. and an average depth of about 6 feet.

The traction engine is the most economical form of motive power, especially for the larger sizes of grader and in the excavation of dense, hard soils. The elevating belt is, in the larger machines, sometimes propelled by a 5- to 7- h.p. gasoline engine, mounted on the rear of the frame.

31. Cost of Operation.—The standard size of elevating grader will excavate from 800 to 1000 cu. yd. of ordinary soil, during a 10-hr. working day. From 12 to 16 horses, or a 20-h.p. traction engine, two drivers and an operator, will be required for its efficient operation. For a haul of about 300 ft., five 1½-yd. dump wagons will be needed to keep one grader busy. The cost of operation will vary from 8 to 15 cents per cubic yard, depending on soil and labor conditions, the kind of motive power used, the method of disposal of the excavated material, etc.

32. Résumé.—The elevating grader is an efficient machine for a wide range of shallow excavation where the soil conditions are favorable. Very loose and light soils of a sandy or silty nature cannot be raised by the plow, and wet, sticky soils, such as gumbo, work with great difficulty. The presence of roots, stumps, boulders and other obstructions in the soil make the operation of the grader difficult and unsatisfactory.

The elevating grader has been universally used on road construction in this country during the last 30 years. It is a more economical machine than the blade grader, since the excavated material can be moved up to a distance of 30 ft. by the former machine while several trips would be required of the latter. The blade grader should follow the elevating grader to smooth up and finish the surface.

In recent years, the elevating grader has been used successfully in the West in the excavation of large ditches and canals, where the bottom width exceeds 10 feet.

On railroad construction, the use of the grader is not practicable unless the width of cut is more than 35 ft.; the space necessary for the wagons to pass the machine for direct loading without rehandling of the excavated material.

The grader has recently been adapted to the construction of earthen dams, embankments, levees, fire protection walls, etc. In this class of work, the machine borrows the material which is generally transported in dump wagons to the site of the embankment.

The use of the gasoline engine to operate the belt conveyor has not been found economical except for the largest size of machine. The traction engine should always be used for motive power where soil conditions are favorable. It has been found in the use of the grader in irrigation work in isolated dry and hot sections of the west that horses and mules are difficult to secure and keep. Light and loose sandy soils will not stand up under the heavy weight of a traction engine, while some dense clayey soils pack so hard under the engine wheels as to render their excavation difficult.

33. Bibliography.—For additional information, consult the following references:

Books

1. "American Civil Engineers Pocket Book," edited by MANSFIELD MERRIMAN, 3d edition, published in 1916 by John Wiley & Sons, New York. 1496 pages, 1047 figures, 4¼ in. × 7 in. Cost, $5.00.

2. "The Chicago Main Drainage Channel," by C. S. HILL, published in 1896 by Engineering News Publishing Company, New York. 129 pages, 105 figures, 8 in. × 11 in.

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2. Earth Handled Cheaply in Grading Utah Roads. *Engineering News,* July 6, 1916. Illustrated, 1000 words.

3. Gasoline Tractors for Southern Road Work. *Engineering News,* August 27, 1914. Illustrated, 1300 words.

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5. Operation Analysis of New Machines Which Cheapen the Moving of Earth on Road Work. *Engineering Record,* July 31, 1915. Illustrated, 3000 words.

6. Steam Excavating and Grading Machine. *Engineering News,* August 15, 1901. Illustrated, 1100 words.

CHAPTER V

CAPSTAN PLOWS

34. General Description.—About 40 years ago, a ditching plow was devised in western Indiana for the excavation of small drainage ditches. This form of excavator known as the capstan plow consists of a large double mold-board plow, which is hung from a framework mounted on two trucks for transportation from place to place. See Fig. 20.

Fig. 20.—Capstan plow.

The complete plow outfit consists of the plow and the means of propulsion; two capstans or a specially devised traction engine. A ditching company operating one of these outfits, usually travels from place to place and lives in two cabins mounted on wheels; one cabin for a dining room and the other for sleeping quarters. Six to eight men and from 10 to 20 horses are used to operate an outfit.

35. Method of Operation.—Originally, the plow was pulled through the soil by from 30 to 40 team of oxen, making the ditch at one cut. As oxen went out of use as draft animals, wooden capstans were utilized to operate the plow by manilla rope cables. Later the capstans were improved by constructing them of steel and wood, and wire cables replaced the rope cables.

The capstans are set ahead of the plow, one on either side of the ditch line and attached to the beam of the plow by steel cables. A long horizontal pole projects from the capstan, and to the outer end of this sweep is attached several teams of horses. See Fig. 21. The latter are driven in a circular path around the capstan the drum of which revolves and winds up the rope or cable, drawing the plow through the soil. By operating either one or both capstans together, the plow may be moved to one side or straight ahead.

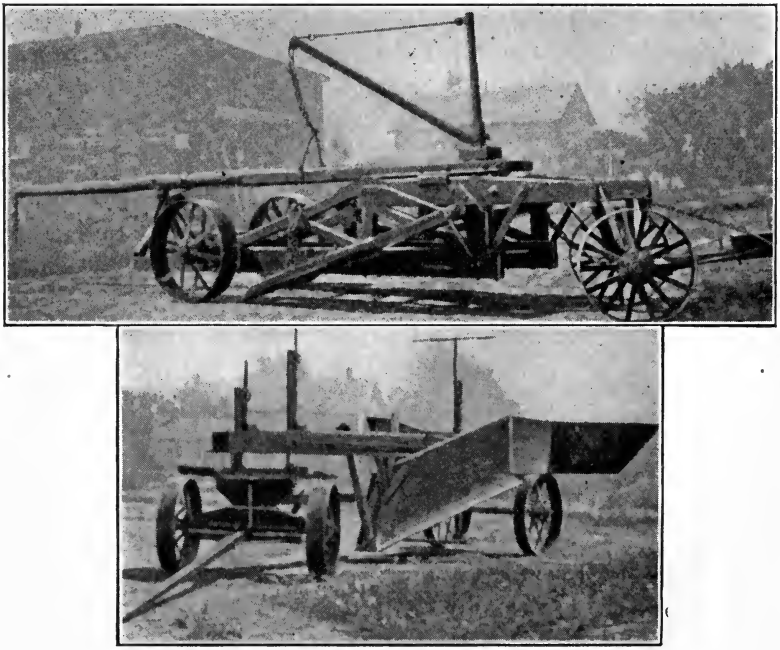


Fig. 21.—Capstan and plow outfit.

Recently in Minnesota, a gasoline tractor has been devised and successfully utilized as the source of motive power. This machine is supported on two long caterpillar tractors, 30 in.

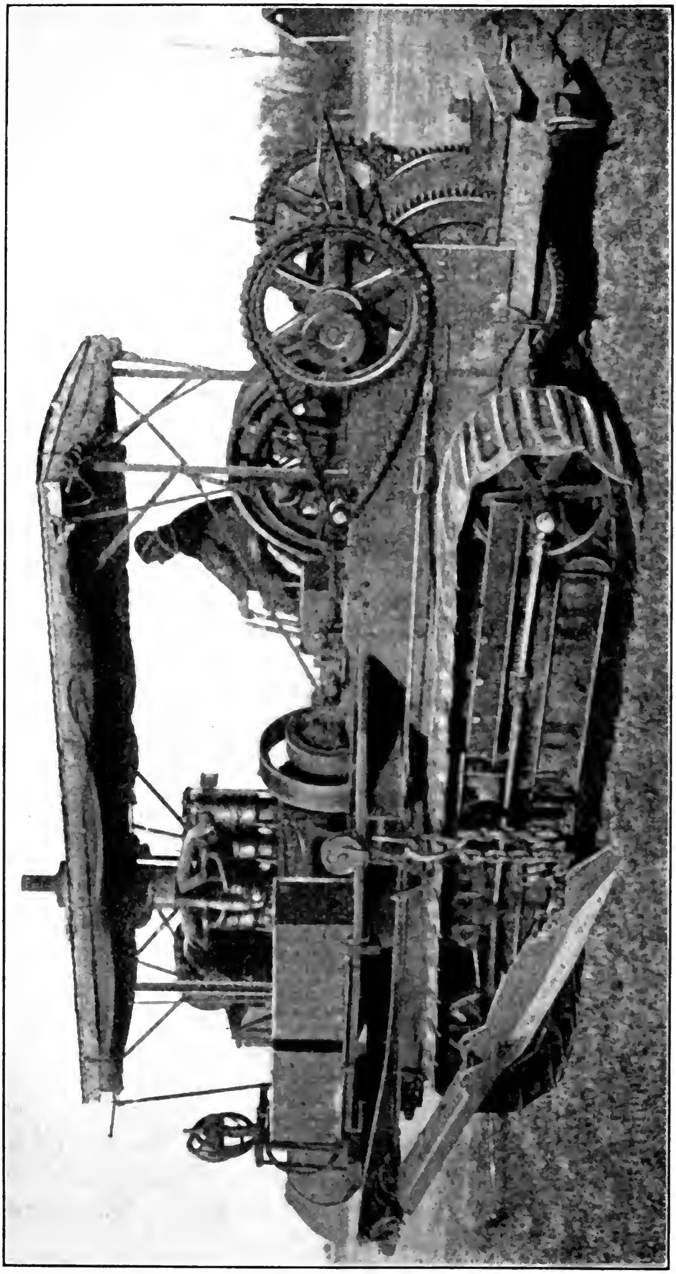


FIG. 22.—Caterpillar tractor operating a ditching plow.

wide and carries a cable drum, 16 in. in diameter and 24 in. long. The drum is driven from the main driving shaft of the 60-h.p. engine and is geared so that the cable is wound in at a rate of from 14 to 18 ft. per minute, depending upon the amount of cable on the drum. Ordinarily about 1000 ft. of wire cable is used. The caterpillar tractor is shown in Fig. 22. The method of operation is as follows. The plow, removed from its four-wheel carriage is left at the beginning of the ditch, the cable attached to its beam. The tractor moves down along the ditch line, paying out the cable as it advances. When the proper point is reached the traction gear is thrown out and the drum gear thrown into mesh. The strain of the cable is counteracted by two anchor flukes, one on each side of the front end of the machine. When the plow reaches the end of the cut, the drum gear is released, the traction gear is thrown in and the machine moves ahead to a new position.

The tractor is operated by one man and a helper; one man rides the plow. A team and driver are used for hauling fuel and supplies, while a foreman directs the operations of the outfit.

36. Cost of Operation.—The standard horse-driven plow cuts a ditch about 8 ft. wide on top, 18 in. wide on the bottom and about 3 ft. in depth. About 6 men and 20 horses are required to operate the outfit. From 50 to 100 rods of ditch at a contract price of from $1.00 to $2.00 per rod are cut during a 10-hr. day, depending on soil conditions.

The power ditching outfits, operated by the gasoline tractors use steel plows which cut a ditch section having a 2 ft. bottom width and an average depth of 3½ feet.

37. Résumé.—The capstan plow has been generally used in the Middle West in the construction of small drainage ditches. The recent adaptation of the caterpillar tractor as a source of motive power, will extend its use to the drainage of swamp and marsh lands, which have previously been inaccessible for teams.

The capstan plow, in soils free from obstructions and not too dense, works easily and rapidly and constructs a ditch of uniform cross-section. Where the surface of the ground has a uniform slope, this machine will make an efficient ditch, but for undulating or uneven land it is useless, unless the surface has been previously graded off.

As a general thing capstan plow ditches are too small and where the slope is light, they soon fill up and become useless.

The author has seen many such ditches which after several years service, were nearly filled up with débris, silt, weeds, Russian thistle, tumble weed, etc.

The capstan plow can only be used efficiently and satisfactorily for the excavation of small lateral ditches for irrigation and drainage systems, where the slope of the ground surface is uniform and sufficiently large to give a flushing velocity with the ditch running half full.

38. Bibliography.—The following articles are given for reference:

Magazine Articles

1. Ditching with Capstan Plows. *Engineering News*, February 3, 1916. Illustrated, 1200 words.
2. Gasoline Tractor Developed in Power Ditching. *Engineering Record*, July 29, 1916. Illustrated, 900 words.

CHAPTER VI

POWER SHOVELS

39. General Description.—Power shovels may be classified as to the kind of power used for their operation. Until recently all shovels were operated by steam power, but with the universal adaptation of electricity to the operation of machinery, the electric motor has in some cases replaced the steam engine as a prime mover for their operation. The steam shovel is still the most generally used type for economic reasons.

Power shovels may also be classified as to their construction and method of operation:

First, those where the machinery is mounted on a fixed platform, and the sphere of operation is limited to an arc of about 200 degrees about the head of the machine.

Second, those where the machinery is mounted on a revolving platform, and the sphere of operation is within a circle the center of which is the middle of the machine.

The first class may be divided into three types, depending on the manner of supporting the platform.

(*a*) Machines mounted on trucks of standard gage, used largely in railroad construction.

(*b*) Machines mounted on trucks with wheels other than standard gage and used in various classes of excavation.

(*c*) Machines mounted on trucks with small broad-tired wheels and used in railroad, highway, basement and other kinds of construction.

The second class is made only in the smaller sizes and the truck is mounted on small, wide, flat-tired wheels for transit over ordinary roads. These light revolving shovels are especially adapted for the excavation of small, scattered railroad cuts, street grading, trench and ditch construction.

The machines of type (*a*) are generally preferred for railroad construction. A wooden or steel car-body is supported on two four-wheel trucks of standard gage. The crane, which is generally made of structural steel, is so arranged that it can be lowered to pass overhead bridges and through tunnels.

The shovels of type (*b*) were first built and are still used on general construction work. They are mounted on a wide wooden steel frame or car-body, which is supported on four small wheels of 7 to 8 ft. gage. Great stability is thus given to the machine by placing it near the ground with a wide base. For transportation, when near a railroad, the machine is placed on a flat car and the boom is removed and placed on a separate car. Away from a railroad line, the machine can be readily dismantled and shipped in sections by wagons, trucks or boat. This type of shovel, on account of its portableness and quick adaptability to all kinds of work in any locality, makes it desirable for general use.

The three types differ principally in their method of support, but otherwise are similar in their details of construction and operation.

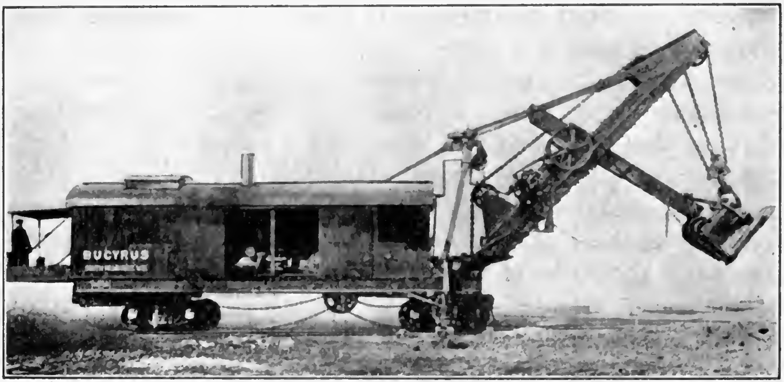


Fig. 23.—Bucyrus seventy C steam shovel. (*Courtesy of Bucyrus Co.*)

FIRST CLASS—FIXED PLATFORM SHOVELS

40. Construction.—The general arrangement is the same in all makes of steam shovel. On the platform of the car-body is placed the operating machinery and power equipment, the boiler at the rear end, the engines near the center and the A-frame and boom at the front end of the car. Figure 23 shows a Seventy C Bucyrus Steam Shovel.

CAR-BODY

The trucks, whether of standard railroad type or special construction, are generally placed near the ends of the car, nearly under the boiler on the rear end and under the A-frame on the front end. For type (*a*) of this class, the trucks are generally the extra heavy M. C. B. standard with all steel diamond frames. The inside axles of both trucks are chain connected to sprocket wheels operated by the engine, thus furnishing the propelling power for moving the shovel in either direction along the track.

The frame, supported by and pivoted to the trucks, is made up of steel I-beams and channels well braced longitudinally and transversely and strongly riveted and bolted together. The frame is sometimes floored with heavy planking, usually 3 in. oak or yellow pine, upon which rests the power equipment. The size of the car-body varies with the capacity of the shovel, an average size such as a 75-ton shovel, has a length of 40 ft. and a width of 10 feet. The ends of the frame are generally equipped with automatic couplers of an approved type, so that the machine may be coupled into a train.

As the car-body is subjected to severe and rapidly repeated strains, it is necessary that it shall be very rigidly constructed at the front end, under the A-frame supports, and the turntable. Some manufacturers use oak timbers between the steel members, claiming that the wood acts as a cushion to resist the continual twisting and wrenching strains. Doubtless the wood does add a certain amount of elasticity to the frame and tends to reduce the tendency to shear off bolts and rivets and to crystallize the steel. The wood should be of the most durable variety, such as white oak.

The car-body supports a framework of timber or steel upon which is applied a sheathing of wood or corrugated steel to form the sides and roof of a car. This is necessary to protect the machinery from climatic conditions. In the later types of shovels, sliding doors are provided, so that light and ventilation may be had in pleasant weather.

BOILER

The boiler may be either of the vertical type with submerged flues or of the horizontal locomotive type. The former is more economical of floor space, but the latter is more economical in the use of fuel, and for this reason is generally used in the larger machines. The boiler should be of ample capacity, as it is often worked to the limit with the throttle wide open. Steam pressure is generally maintained at about 100 lb. with a blow-off at from 125 to 150 pounds.

Water should always be supplied to the boiler through an injector or by means of a feed-pump. Water is stored in a sheet-iron tank located in a rear corner of the platform. The tank usually has a capacity of about 1000 gal. or enough for one-half day's operation of the machine. At the rear end of the platform is placed a bin, tank or open box to hold the fuel for the boiler or engine. Coal and wood are generally used for steam boilers, while gasoline or kerosene is used when a gas engine supplies the power. The water may be supplied to the storage tank by siphoning or pumping it out of the tender of a locomotive, a tank car, or a tank wagon.

ENGINES

The engines are either of the vertical type with a single steam cylinder or of the horizontal type with double steam cylinders. The engines control the three principa operations of the shovel; hoisting, swinging, and thrusting. In some of the older types of shovels, all three operations are controlled by one engine. This type has three drums mounted on one shaft, the hoisting drum in the center and the swinging drums on each side. The latter are reversed and operated by the same lever. The drums are actuated and controlled either by positive gearing or friction clutches. The former is slow in operation and subjects the machinery to great jarring and severe shocks in digging hard material. The latter is quick and smooth in operation, and gives a minimum of shocks in hard material, but is liable to bind through overheating of the friction surfaces. To alleviate this source of trouble, the diameter of the friction drums should be at least twice that of the cable drums. The positive gearing generally has a longer life and requires fewer repairs than the friction clutch, but the latter is the more popular at the present time on account of its rapidity and smoothness of action. The single shaft with its three drums, rotates continuously in one direction under the action of a large steel gear driven by a steel pinion on the engine shaft. The hoisting chain passes over a sprocket, at the top of the mast or the foot of the boom, and this revolves an axle to which another sprocket wheel is fastened. The latter operates an endless chain which revolves a drum placed on the upper side of the boom near the dipper handle. This drum is controlled by a friction clutch and operated by the cranesman. In the older types of machine a chain is attached to the end of the dipper handle, and wound around the drum. The rotation of the drum raises and lowers the dipper handle. In later types, a rack on the bottom of the dipper handle moves a pinion on a shaft which is operated as described above.

The recent types of steam shovel use a small independent engine to thrust the dipper into the bank, placed on the upper side of the boom, and is of the double-cylinder, horizontal type. It operates a set of gears, which revolve a shaft on which is set a steel pinion feeding into a steel-toothed rack on the bottom side of the dipper handle. The engine may be either reversible or controlled by a friction clutch. With the use of the former type, the dipper handle is always actuated and controlled by the engine, while with the latter type, the release of the friction allows the dipper and handle to lower by gravity.

Instead of having the swinging of the boom actuated from the main engine, some makes of steam shovel use an independent swinging engine. This is usually a double-cylinder, horizontal, reversible engine, of less power than the main or hoisting engine. A chain or cable passes around the swinging circle and is wound around the drum of the engine, starting from the two ends of the drum in opposite directions.

The size of the engines vary with the type used and the capacity of the shovel. They should be made of ample power for use in the hardest and toughest material. The power of an engine depends on the size of its cylinders, varying from 6 by 8 in. to 13 by 16 inches. These engines are subjected to almost continuous shocks and vibratory strains and should be made of the very best and strongest materials. The more important parts such as the shafts and gears should be of the best tool and cast steel, respectively.

BOOM

The boom is a simple beam made in two sections, separated far enough to allow for the free passage of the dipper handle. It may be constructed of wood reinforced with steel plates or entirely of steel. It is made narrow at the ends and wide near the center where the dipper handle rests. The greatest strain is at this point. It is made of such length as to reach 14 to 20 ft. above the track or ground surface, and to swing with a radius of from 15 to 20 ft., through an angle of from 180 to 240 degrees. The lower end of the boom rests on the swinging circle which is pivoted to the front end of the platform. The boom revolves with the swinging circle. Its upper and outer end is connected to the top of the A-frame with steel rods or bars.

The hoisting chain or cable passes from the hoisting drum to the fair lead or sheaves just below the turntable, then up over the sheave near the foot of the boom and thence along the boom to the sheave at the outer end of the boom, and thence to the shovel at the outer end of its handle. The revolution of the hoisting drum lets out or draws in the chain or cable and thus lowers or raises the shovel.

A-FRAME

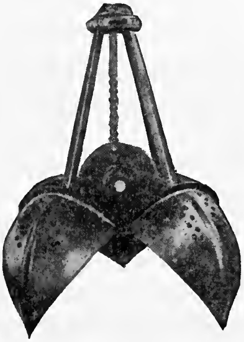
This is a frame made up of heavy steel bars with timber reinforcement or entirely of structural steel posts. The feet of the posts are supported on each side of the platform just back of the turntable. The top of the frame carries a pivoted cast-steel head block to which is fastened the rods or bars from the outer end of the boom. The A-frame is given a slight inclination toward the boom and is made several feet shorter. The height of the boom when it is lowered, must be less than the overhead clearance, where a shovel has to pass through tunnels or under bridges, or in railroad and street work.

DIPPER HANDLE

The handle to the lower end of which is attached the dipper or shovel, is generally made of a single timber of white oak. Upon its lower side is fastened the toothed rack which moves over the pinion on the upper side of the boom. The operation of this pinion was described in the section entitled "Engines." The upper edges of the handle are reinforced with steel angles or bent plates.

DIPPER

The shovel or dipper is made in the form of a scoop with closed side, open top and a hinged door for the rear or bottom. It is made of heavy steel plates strongly reinforced at top and bottom with steel bars. The top or front edge of the dipper is provided with a cutting edge of flange steel for soft material, or of heavy forged steel teeth for hard material. These teeth can be readily unbolted for sharpening or repairs. The bottom of the bucket is of heavy steel hinged to the rear side of the dipper, and closed by a spring-latch on the front side. A small line leads from the door to the side of the boom where the cranesman stands. When the filled dipper is over the car or wagon, a jerk on the line by the cranesman opens the latch and causes the bottom to drop, releasing the contained material.

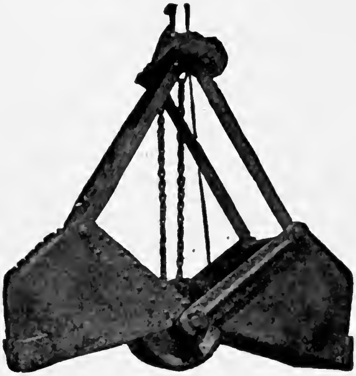


CAPACITY		HEIGHT		DIAMETER		WEIGHT
Cu. Yd.	Cu. Ft.	Closed	Open	Closed	Open	
½	13½	5'-10"	6'- 6"	4'-6"	5'-7"	1750 lbs.
¾	20¼	7'- 4"	7'-10"	5'-6"	7'-0"	3450 lbs.
1	27	8'- 0"	8'-10½"	6'-0"	7'-1"	4250 lbs.
1¼	33¾	8'-3½"	9'- 2½"	6'-3"	7'-3"	4775 lbs.
1½	40½	9'- 5"	10'- 0½"	6'-6"	8'-6"	6800 lbs.
2	52	10'- 0"	11'- 2"	7'-0"	8'-9"	8400 lbs.

Fig. 24.—Browning orange-peel buckets. (*Courtesy of Browning Mfg. Co.*)

Dippers vary in size from ½ cu. yd. to 6 cu. yd. and require corresponding machines weighing from 10 to 130 tons.

The shape of the dipper and the character of the cutting edge should depend on the character of the material to be excavated. Teeth should be used as a cutting edge for hard material, while they cause considerable trouble in dumping in removing sticky clay. For sand, gravel and the average clay and loam, a wide smooth cutting edge should be used. A large, wide dipper should be used when the material is filled with large stone or boulders. For soft, loose material such as sand, loose gravel and dry earth, the shovel should be deep with a cross-section nearly square. A wide, shallow-mouthed dipper is the best shape for the excavation of cemented gravel, hard dry materials or wet clay. The bottom of the dipper should be slightly larger than the top, to facilitate the dumping of sticky material. A great deal of time is often lost in cleaning the dipper when it is excavating sticky soils such as gumbo. A sprinkling hose is very useful for removing this sort of material from the sides of the dipper, and to prevent its adhering.



Capacity		Height		Length		Width	Weight	Weight
Cu. Yd.	Cu. Ft.	Closed	Open	Closed	Open		No Shoes	With Shoes
½	13½	5′-8″	6′-9″	5′-0″	6′-0″	2′-5″	2100 lbs.	2300 lbs.
¾	20¼	6′-1″	7′-2″	5′-4″	6′-7″	3′-1″	2500 lbs.	2750 lbs.
1	27	6′-5″	7′-7½″	5′-8″	7′-2″	3′-1″	2600 lbs.	2850 lbs.
1½	40½	7′-2″	8′-5¾″	6′-4″	8′-0″	3′-7″	4500 lbs.	4900 lbs.
2	54	7′-8″	8′-11½″	6′-8″	8′-7″	4′-1″	4800 lbs.	5875 lbs.
3	81	7′-9″	8′-7″	6′-8″	9′-8″	5′-1″		8450 lbs.

Fig. 25.—Browning clam-shell buckets. (*Courtesy of Browning Mfg. Co.*)

The dipper is fastened to the handle by means of heavy forged arms and braces. A hinged bail connects the top of the dipper with the hoisting line. In some makes of shovel this line is fastened directly to the top of the bail and is carried up and fastened to the boom near its outer end.

TYPES OF BUCKETS

Several kinds of dippers or buckets are used with the steam shovel. The dipper described previously is the type generally used in ordinary excavation work. The ordinary type of dipper is shown in Fig. 26. When loose sand and gravel are to be excavated, the clam-shell or orange-peel buckets are efficient. Figure 25 gives the details and dimensions of a standard make of clam-shell bucket, while Fig. 24 gives the same information for the orange-peel bucket.

JACK BRACES

The swinging of the boom, dipper and handle from side to side tends to tip the front end of the car. To prevent this, jack braces are placed on the sides of the car-body at the feet of the A-frame. These braces are of heavy cast steel and are attached to the platform at their upper ends by means of cast-steel hinges or sockets. The lower ends carry screw jacks which can be easily raised and lowered to get a bearing on the ground surface. The lower ends of the braces are connected to the under side of the car-body by heavy bars or rods. These are also hinged so that the whole brace may be swung back against the car-body, when not in use.

In one well-known type of shovel the engines are mounted directly on the swinging circle and revolve with the crane. This arrangement allows more room on the platform for the boiler and affords direct transmission of power in hoisting. A sectional, detailed view of this type of shovel is shown in Fig. 26.

Table II gives the dimensions, weights, and capacities of a standard make of steam shovel.

The cost of a steam shovel varies from $250.00 to $400.00 per ton; and the more the total weight, the greater the weight per cubic yard of bucket.

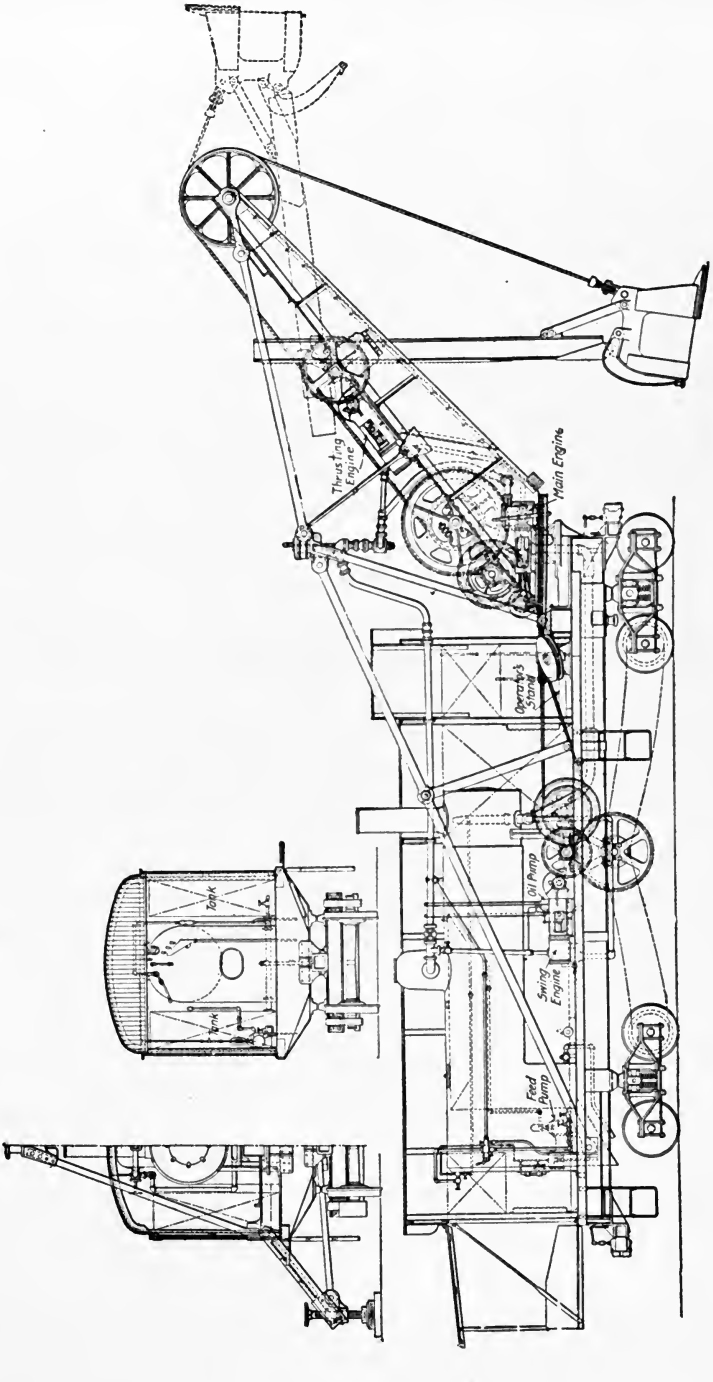


FIG. 26.—Detail views of Atlantic steam shovel. (Courtesy of Bucyrus Co.)

TABLE II.—SIZE OF A STANDARD STEAM SHOVEL.

Type	Chain						Wire rope	
Class	110 C	100 C	85 C	70 C	60 C	40 R or C	80	45
Effective pull on dipper (lb.)	98,000	91,000	70,000	64,000	56,000	33,000	80,000	45,000
Capacity of dipper (cu. yd.)	3½ to 6	3½ to 5	3 to 4	2½ to 3	2½	1½	3 to 5	2½
Size of engines (double cylinder) main swing thrust	13″×16″ 9″×9″ 9″×9″	12½″×16″ 8″×8″ 8″×8″	12″×15″ 8″× 8″ 8″× 8″	10″×14″ 7½″×7″ 7½″×7″	10″×12″ 7½″×7″ 7½″×7″	8″×8″ 5½×6″ 5½×6″	12″×12″ 9″×9″ 9″×9″	10″×10″ 7″×8″ 7″×8″
Car-body length width	44′ 9¾″ 10′	44′ 2″ 10′	41′ 4″ 10′	36′ 4½″ 10′	35′ 9′ 3″	26′ 5⅜″ 7′	42′ 10′	36′ 10′
Wheel base traction truck	35′ 6″	35′ 10½″	33′ 5″	30′ 3½″	28′ 9″	16′ 2″ 21′ 1½″	36′	31′
Width over traction wheels	....	....	....	....	....	15′		
Height of A-frame extreme lowered	20′ 7¾″ 14′ 6″	19′ 3″ 14′ 6½″	19′ 14′ 6″	19′ 14′ 6″	18′ 10″ 14′ 6″	14′ 1½″	21′ 8″ 15′	19′ 6″ 15′
Boiler type dimensions	Loco. 58″ × 18′ 3″	Loco. 54″ × 18′	Loco. 50″×18′	Loco. 44″×18′	Loco. 44″×17′	Loco. 42″×13′ 6″	Loco. 52″×21′ 4″	Loco. 46″×20′
Water tanks—total capacity (gal.)	1,800	1,600	1,600	1,500	1,500	700	2,000	1,950
Weight in working order (tons)	130	113	101	87	77	48	101	73
Shipping weight domestic (tons) export, boxed, approximate (gross tons)	116 121	101 104	89 91¾	75 77¾	65 67	42 43	88¾ 96	64½ 71½

41. Method of Operation.—A steam shovel of the first class is generally operated by a crew of 7 men; an engineer, a cranesman, a fireman, and 4 laborers. The engineer and cranesman directly control the movements of the machine. The fireman keeps the boiler supplied with fuel and water and sees that the machinery is in good running order. The laborers are generally under the direct control of the cranesman and their duties consist in the breaking down of high banks, assisting in the loading of the dipper, leveling the surface in front of the machine, laying the new track, operating the jack braces, and for general service about the shovel. In rock excavation, from 2 to 6 extra laborers are required for breaking up the rock, mud-capping, etc.

The engineer stands at the set of levers and brakes which are located in front of the machinery. The cranesman stands on a small platform on the right side and near the lower end of the crane. The former controls and directs the raising and lowering of the dipper, the swinging of the crane, and the traction of the whole machine. The cranesman controls the operation of the dipper, and of the dipper handle, regulating the depth of cut, releasing the dipper from the bank and emptying it into the car, wagon, or spoil bank.

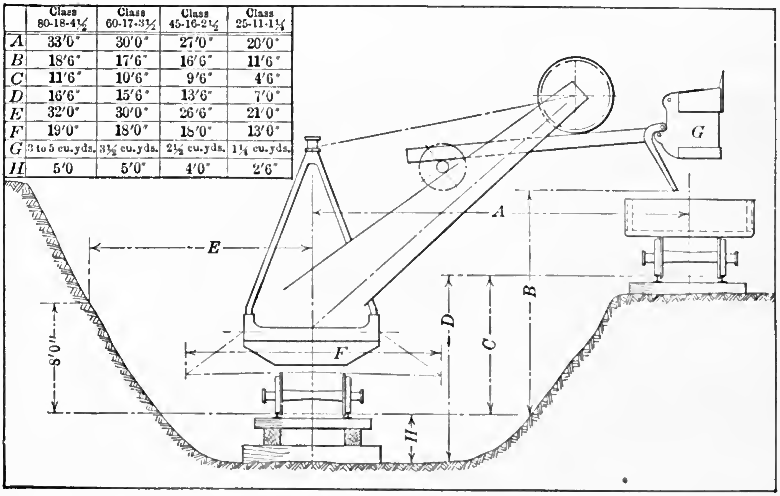
The process of excavation commences with the dipper handle nearly vertical and the dipper resting on the floor of the pit with the cutting edge directed toward the bank. The engineer then moves a lever throwing the hoisting drum into gear and starting the engine. The revolution of the hoisting drum winds up the hoisting lines and pulls the dipper upward. Simultaneously, the cranesman starts the thrusting engine and moves the dipper handle forward as the dipper rises. These two motions must be made smoothly and coördinately or the hoisting engine will be stalled and the whole machine tipped suddenly forward. When the shovel has reached the top of the cut or its highest practicable position, the engineer throws the hoisting drum out of gear and sets the friction clutch with a foot brake,thus bringing the dipper to a stop. Immediately, the cranesman releases his brake and slightly reverses the thrusting engine which thus draws back the dipper handle and withdraws the dipper from the face of the excavation.

When the dipper digs clear of the excavation it is unnecessary to release it as described for the last motion. The engineer then starts the swinging engine into operation and moves the crane to the side until the dipper is over the dumping place. With a foot brake he sets the friction clutch controlling the swinging drums and stops the sidewise motion of the crane. The cranesman then pulls the latch rope, which opens the latch and allows the door at the bottom of the dipper to drop and to release the contents. The engineer releases the friction clutch by the foot brakes and reverses the swinging engine, pulling the crane and dipper back to position for the next cut. As the boom is swung around, the engineer gradually releases the friction clutch of the hoisting drum and allows the dipper to slowly drop toward the bottom of the cut. When near the point of commencing the new cut and as the dipper handle approaches a vertical position, the cranesman releases the friction clutch on the hoisting engine with his foot brake. Thus, as the last part of the drop is made by the dipper, it is also brought into proper position and the length of the dipper arm regulated for the commencement of the new cut. As the dipper drops into place, the bottom door closes and latches by its own weight. The time required to make a complete swing depends upon the character of the material and the skill of the operator, but under ordinary conditions this should average between 20 and 40 seconds.

After the entire face of the cut has been removed within reach of the dipper, the shovel is moved ahead. When the shovel moves on a track, a new section of track is laid ahead of the section on which the machine rests. The laborers release the jack screws of the braces, and the engineer throws the propelling gear into place, starts the engine, and the shovel moves ahead 3 to 5 feet. The jack braces are then set into position, the wheels are blocked, and the shovel is ready for another cut. The maximum width of cut depends upon the size of shovel, length of crane, height of face, etc., and varies from 15 to 30 feet. The shovel may cut on a level or slightly descending grade and by working back and forth on different levels may excavate a cut of almost any depth and width.

The steam shovel of the fixed-platform class will excavate any material except solid rock, which must first be blasted down and broken up into pieces small enough for the dipper to handle. The excavated material may be dumped into and carried away by: (1) dump wagons, hauled by teams or by traction engines; (2) dump cars holding from 1½ to 6 cu. yd., drawn by horses or dinkey locomotives over narrow-gage track; and (3) dump cars of large size, from 4 to 12 cu. yd., or gondola or flat cars hauled by large-sized locomotives over standard-gage track.

The dimensions and working limitations of a well-known make of steam shovel of this class are shown in Fig. 27 and Table III.



	Class 80-18-4½	Class 60-17-3½	Class 45-16-2½	Class 25-11-1¼
A	33′0″	30′0″	27′0″	20′0″
B	18′6″	17′6″	16′6″	11′6″
C	11′6″	10′6″	9′6″	4′6″
D	16′6″	15′6″	13′6″	7′0″
E	32′0″	30′0″	26′6″	21′0″
F	19′0″	18′0″	18′0″	13′0″
G	3 to 5 cu.yds.	3½ cu.yds.	2½ cu.yds.	1¼ cu.yds.
H	5′0	5′0″	4′0″	2′6″

Fig. 27.—Diagram of limitations of the Atlantic steam shovel. (*Courtesy of Bucyrus Co.*)

TABLE III.—WORKING LIMITS OF A FIXED-PLATFORM SHOVEL

Type	Chain						Wire-rope	
Class	110 C	100 C	85 C	70 C	60 C	40 C or R	80	45
Dumping radius, A.......	32′	29′	29′	27′	25′	21′ 6″	33′	27′
Height of dump, B.......	17′	17′	16′ 6″	16′ 6″	16′	12′	18′ 6″	16′ 6″
Depth of cut, shovel track to loading track, C.....	10′	10′	9′ 6″	9′ 6″	9′	5′	11′ 6″	9′ 6″
Maximum depth of through cut, D................	16′	15′ 6″	15′	14′	13′	7′ 9″	16′ 6″	13′ 6″
Digging radius—8-ft. Elevation, E.............	33′	33′	33′	30′	27′	23′	32′	26′
Spread of jack screws, F....	22′	20′	20′	18′ 4″	18′	15′	19′	18′
Height of boom, G........	33′	28′ 9″	29′ 1″	27′ 0½″	26′ 9″	21′ 3½″	33′	27′ 7″
Depth of cut below rail, H	6′	5′ 6″	5′ 6″	4′ 6″	4′	2′ 9″	5′	4′

The values for "Digging Radius at 8-ft. Elevation," given in Table III, are theoretical figures which are generally not realized in practice. It would be conservative to use values of from 60 per cent. to 80 per cent. of those given in the table for actual working conditions.

The output of a steam shovel depends on its size, the character of the material to be excavated, the efficiency of the crew, climatic conditions, location of material with relation to the shovel, relation of shovel to point of dumping, efficiency of wagon or car service, etc. When working under favorable conditions, the maximum working capacity of a shovel will average about one-half of its theoretical capacity as rated by the manufacturers. A shovel is generally in actual operation about 40 per cent. of the working time, and delays for repairs, coaling, watering, oiling,

Table IV.—Steam Shovel Service

Division	Shovel size (tons)	45	55	65	70	75	90	95	Summary
Iron ore................	Observations	....	....	....	7	....	1	1	9
	Maximum	....	....	....	1512	....	2728	1350	2728
	Minimum	....	....	....	892	....	2728	1350	1305
	Average	....	....	....	1095	....	2728	1350	892
Sand and gravel.........	Observations	2	....	....	3	....	....	....	5
	Maximum	373	....	....	3300	....	....	....	3300
	Minimum	360	....	....	1602	....	....	....	360
	Average	366	....	....	2365	....	....	....	1566
Earth and glacial drift....	Observations	....	....	1	3	....	....	1	5
		....	....	1065	1426	....	....	1073	1426
		....	....	1065	569	....	....	1073	569
		....	....	1065	893	....	....	1073	963
Rock....................	Observations	....	....	5	16	....	....	5	26
	Maximum	....	....	896	1542	....	....	1200	1542
	Minimum	....	....	264	168	....	....	154	154
	Average	....	....	601	682	....	....	873	704
Clay....................	Observations	....	1	2	5	1	....	1	10
	Maximum	....	320	780	1415	820	....	990	1450
	Minimum	....	320	474	498	820	....	990	320
	Average	....	320	627	1064	820	....	990	870
General summary........	Observations	2	1	8	34	1	1	8	55
	Maximum	373	320	1065	3300	820	2728	1350	3300
	Minimum	360	320	264	168	820	2728	154	168
	Average	366	320	665	991	820	2728	972	934

Note.—Figures give daily output in cu. yd.

etc. The log of efficient shovel operation under favorable working conditions would be about as follows:

Operation	Time (per cent.)
Moving shovel	10
Breaking up rock, mucking, etc	10
Waiting for cars or wagons	15
Repairs	5
Actual loading	60
Total	100

Table IV gives the actual output of about 50 shovels, which were in actual operation for several weeks. These records were collected by Mr. R. T. Dana, of the Construction Service Company of New York.

42. Field of Use.—The steam shovel of the fixed platform type may be called the universal American excavator for dry-land excavation. It can excavate any kind of soil except solid rock and can operate satisfactorily wherever the soil is firm enough to support its weight and the magnitude of the work is sufficient to warrant its use.

The steam shovel was first devised for railroad construction, but during the past quarter of a century its scope has been gradually extended to include the excavation of gravel and clay pits, stone quarries, ore beds, and tunnels, the construction of canals, embankments, levees, reservoirs, etc.

43. Cost of Operation.—The cost of operating a steam shovel depends upon the class of work, the kind of material to be excavated, the size and efficiency of the machine, the peculiar conditions affecting each job, the facilities for removing the material, etc.

The cost of operation of a 2½-cu. yd. steam shovel for a 10-hr. day, in the excavation of earth and gravel, under average conditions, would be approximately as follows:

Labor:

1 engineer	$ 5.00
1 cranesman	4.00
1 fireman	3.00
½ watchman @ $50 per month	1.00
4 pitmen @ $1.75	7.00
1 team and driver (hauling coal, water, etc.)	3.50
Total labor cost	$23.50

Fuel and Supplies:

3 tons of coal @ $4.00	$12.00
Oil and waste	1.50
Water	0.50
Total fuel and supplies	$14.00

General:

Repairs	$ 5.00
Incidental expenses	2.40
Depreciation (5 per cent. of $12,000)	3.00
Interest (6 per cent. of $12,000)	3.60
Total general cost	$14.00
Total cost of operation per 10-hr. day	$51.50
Average excavation	1700 cu. yd.
Average cost of operating shovel, $51.50 ÷ 1700 =	3.0¢. per cu. yd.

The same steam shovel used in the excavation of a stiff clay or shale would probably require the service of two extra laborers at $1.75 a day each. The average daily excavation would vary from 800 to 1200 cu. yd., or with a mean of 1000 cu. yd., the cost of operating the shovel would be about 5 cents per cubic yard.

For the excavation of rock which requires blasting, the crew for earth excavation would be increased as follows:

4 pitmen @ $1.75	$7.00	
2 laborers @ $1.50	3.00	
		$10.00
The amount of coal used would be increased by 1 ton, making an added fuel expense of		4.00
The following item, would be added for blasting: dynamite, powder, caps, fuse, etc.		1.50
Total cost of operating shovel per 10-hr. day		$66.50
Average excavation		800 cu. yd.
Cost of operating shovel		8.3¢. per cu. yd.

The above statements do not include the cost of transporting the shovel to and from the work, the cost of living and camp expenses, office and other incidental expenses.

The cost of the disposal of the excavated material varies from nothing when the material is directly dumped upon the sides of the excavation, to 15 or 20 cents per cubic yard, when the material must be hauled a long distance and spread. The disposal generally consists of two operations—the hauling and the dumping. The cost of hauling varies with the conveyance used, dump wagon or car, and the length of the haul. On railroad work the cost may sometimes be increased by delays of the trains of dump cars. The cost varies from 3 to 12 cents per cubic yard. The cost of dumping varies from ½ cent per cubic yard for wagons to 1½ cents per cubic yard for cars.

SECOND CLASS—REVOLVING SHOVELS

44. Construction.—The revolving shovel is designed for light, rapid work and easy transportation over roads. The essential features of this type of shovel are a lower or truck platform on which are located the operating and excavating equipment.

PLATFORMS

The lower or truck platform is made up of a rectangular frame of steel I-beams and channels, strongly braced and riveted together. This platform rests on two steel axles, the front one pivoted and the rear one fixed in position. The propulsion of the machine under its own power is affected by chain or gear drive actuated from the main shaft of the engine. By turning the front axle the direction of the machine's movement may be governed. The wheels are small in diameter, of wide-tired wood or steel, or flanged railroad wheels when the shovel is to operate on a track. Upon the top of the steel frame is fastened a large, heavy steel casting which comprises a circular gear, the roller track and the central journal or gudgeon, which supports the revolving frame.

The upper frame carries the machinery and the boom, and corresponds to the car-body of the First Class shovel. This platform is a rigid framework of structural-steel members which are strongly braced and riveted. A heavy cast-steel socket is located on the under side of the frame and rests on the journal of the lower frame. The whole operating machanism of the shovel can rotate in a complete circle about the lower truck frame. A well-known make of revolving shovel is shown in Fig. 28.

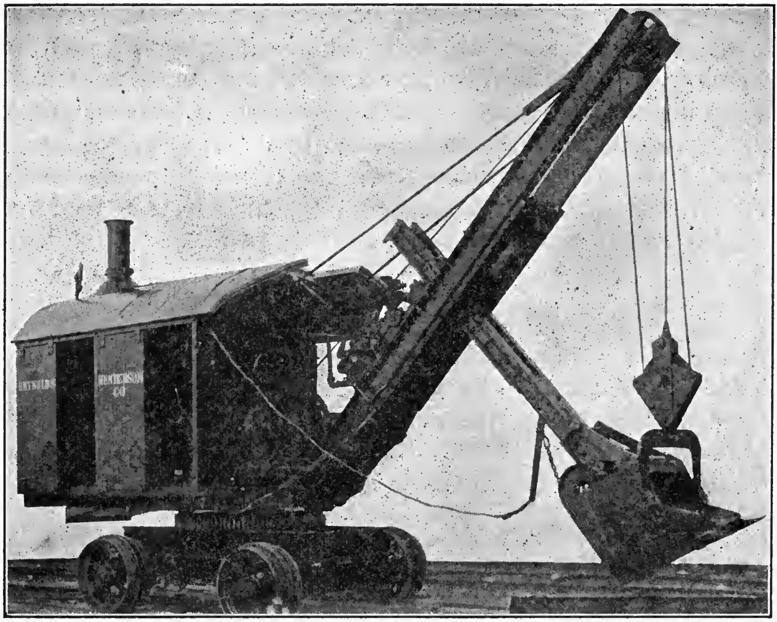


FIG. 28.—Bucyrus revolving steam shovel. (*Courtesy of Bucyrus Co.*)

POWER EQUIPMENT

The power equipment of a revolving steam shovel consists of a vertical boiler and the engines for hoisting, swinging, and thrusting.

The boiler is of the vertical, submerged, multi-tubular type, and made to operate under a working pressure of from 100 lb. to 125 pounds. The boiler feed consists of an injector and a pump, which can supply water to the boiler while the shovel is in operation. The boiler is located on the rear end of the upper platform.

The engines are all double-cylinder, horizontal, and reversible. The swinging and hoisting engines are located in front of the boiler near the front end of the upper platform. The thrusting engine is located on the upper side of the crane or boom. The hoisting drum is controlled by a friction band which is operated

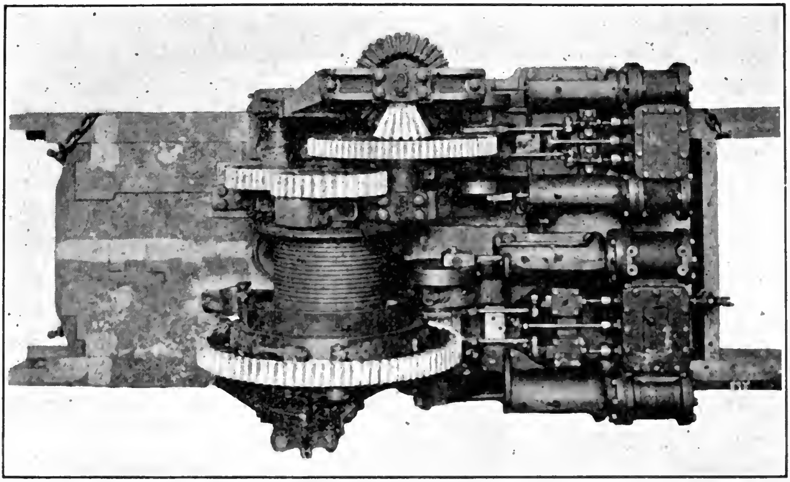


Fig. 29.—Operating machinery of a revolving shovel. (*Courtesy of Thew Automatic Shovel Co.*)

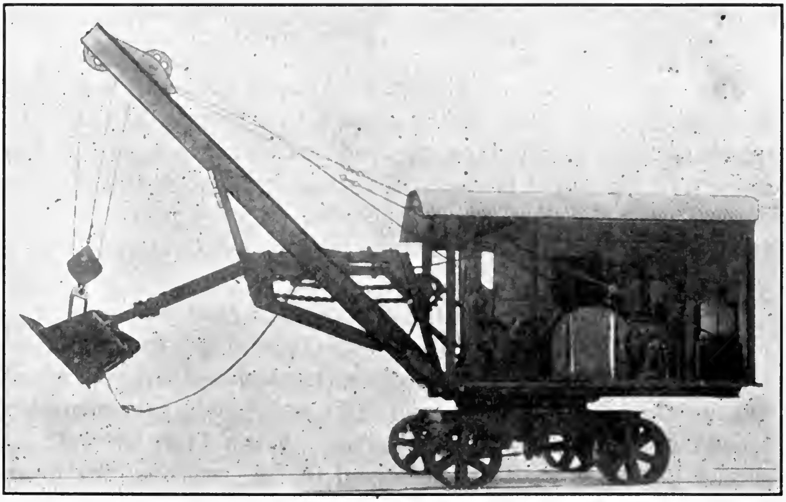


Fig. 30.—Revolving shovel operated by gasoline power. (*Courtesy of Thew Automatic Shovel Co.*)

by a foot lever. Figure 29 shows the swinging and hoisting engines of a well-known make of revolving shovel. The thrusting engine in several makes is of the double, horizontal, reversible type which is used on shovels of the fixed-platform class. One make, the Thew Automatic Shovel, uses a very unique and efficient method of thrusting or crowding the dipper. A carriage or trolley to which is hinged the upper end of the dipper arm, moves horizontally along a track. As the carriage moves forward, the center of rotation of the dipper is changed and produces a prying action. The crowding motion is always in a horizontal direction. The movement of the carriage is controlled by the cranesman, who operates the throttle lever of the crowding engine. The throttle is also connected to a "trip," which automatically shuts off the steam when the carriage reaches either end of the trackway, Fig. 30.

Gasoline power can be used to great economic advantage when coal is high in price and inaccessible. The prime mover is then a gasoline engine which is mounted on the rear of the platform and belt-connected to the operating units. See Fig. 30.

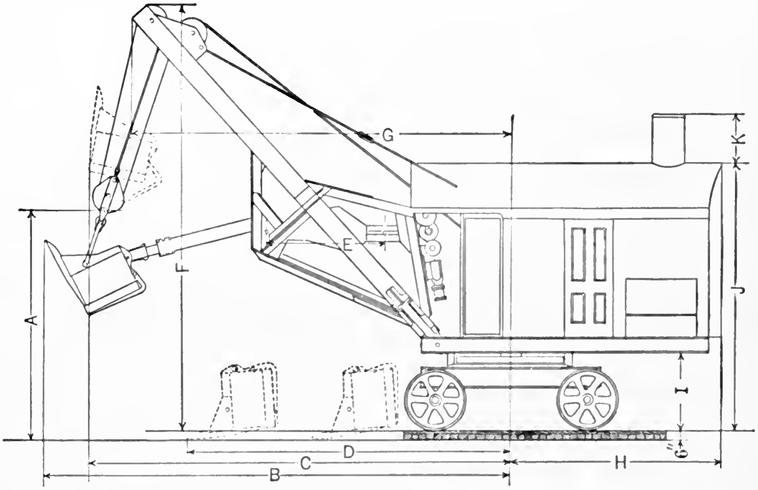
The upper platform is provided with a housing of wood or corrugated steel for the enclosure and protection of the machinery.

EXCAVATING EQUIPMENT

The crane or boom is a structural frame of steel, or of steel and wood. The lower end is hinged to the turntable and the upper end is supported by guy rods which extend to the rear corners of the upper frame. The boom is made in two sections and so arranged that the dipper handle may move between them. Upon the upper side of the boom is located the thrusting mechanism.

The dipper handle is of steel, or hardwood reinforced with steel plates. The lower end of the handle is attached to the dipper. Upon the under side of the handle is the steel-toothed rack which engages the pinion of the shipper shaft, which is the gear-operating mechanism of the thrusting engine. In the Thew shovel, the dipper handle is made of steel and in two sections; the lower member telescopes into the upper section, and the two may be clamped in any position.

The dipper is usually constructed of steel plates and forgings. The cutting edge is usually made of manganese steel and for hard soils is provided with tool-steel teeth which can be removed and replaced when worn out or broken.



Type No.	A Dumping Height	B Max. Digging Radius	C Dumping Radius	D Digging Radius at Floor	E Length of Crowd	F Height of Boom	G Swing of Boom	H Rear End Clearance	I Turntable Clearance	J Height of House	K Height of Stack	Width of House
A-O	10′0″	21′0″	19′0″	13′6″	5′0″	19′0″	18′6″	9′4″	3′3″	12′3″	2′8″	7′0″
O	10′0″	22′0″	19′9″	15′6″	5′6″	19′0″	19′0″	9′9″	3′6″	12′6″	2′8″	8′0″
O High Lift	12′0″	22′9″	20′9″	15′6″	5′0″	22′0″	18′0″	9′9″	3′6″	12′6″	2′8″	8′0″
O Fertilizer	10′0″	18′0″	16′0″	12′0″	6′9″	15′0″	10′2″	5′8″	2′11″	12′0″	.....	7′0″
O Elec. Ry.	10′0″	22′0″	20′0″	15′6″	5′0″	*15′6″	19′0″	7′6″	3′0″	12′0″	.....	7′0″
A-I	10′6″	24′0″	21′6″	18′0″	6′0″	21′0″	19′6″	9′11″	3′10″	13′6″	4′0″	8′10″
A-I High Lift	13′6″	27′0″	24′6″	19′6″	6′0″	24′0″	21′6″	10′6″	3′10″	13′6″	4′0″	8′10″
I	10′6″	24′6″	22′0″	18′6″	7′0″	21′0″	21′0″	11′6″	4′2″	14′0″	3′10″	9′2″
I High Lift	16′0″	28′0″	24′6″	19′0″	7′0″	26′6″	18′0″	11′6″	4′2″	14′0″	3′10″	9′2″
3	11′0″	28′6″	25′9″	20′6″	8′6″	23′6″	24′0″	12′0″	4′3″	14′6″	3′10″	9′9″

* This dimension 18′ 6″ when boom is extended.

FIG. 31.—Diagram of limitations of revolving shovel. (*Courtesy of Thew Automatic Shovel Co.*)

45. Method of Operation.—A revolving steam shovel is generally operated by a crew of three to five men; an engineer, a fireman, and one to three laborers. The engineer controls the operation of the machine. The fireman feeds the boiler with fuel and water and keeps the machinery oiled and greased. The laborers haul coal, assist in the loading of the shovel in hard material, break down the bank, plank the floor of the excavation for the support of the shovel, etc. The engineer stands at the set of levers and brakes which are located near the front end of the upper platform. The method of operation of this type of shovel is similar to that of the fixed-platform class, and the reader is referred to the detailed description given under that section. Note, however, that in the case of the revolving shovel, there is no cranesman, and the engineer directly controls the three operating motions of hoisting, swinging, and thrusting.

The revolving shovel will excavate any class of material, except solid rock, which must first be blasted down and broken into pieces of a size which can be handled by the dipper. The excavated material may be dumped into spoil banks along the side of the excavation, or into wagons hauled by horses or traction engines, or into dump cars hauled by dinkey locomotives over a narrow-gage track.

The dimensions and working limitations of an efficient make of revolving steam shovel of the revolving-platform class are given in Fig. 31. In column 1 of the table the class numbers correspond to dipper capacities of 5/8, 7/8, 1 1/8 or 1 3/8, 3/4 or 1 (for shale excavation), and 1 3/4 cu. yd., respectively.

The actual working capacities of revolving shovels depend upon the nature of the material, depth of cut, efficiency of hauling equipment, efficiency of engineer, size, capacity, and efficiency of shovel, etc. In ordinary clay, under average working conditions, with a cut of from 5 ft. to 10 ft., the output for a 10-hr. day should average from about 500 cu. yd., for a 5/8-cu. yd. machine, to 1000 cu. yd. for a 1 3/4-cu. yd. machine.

46. Field of Use.—The revolving shovel is a very efficient and serviceable machine for the excavation of dry soils when the required output does not exceed about 1000 cu. yd per 10-hr. working day. When the excavation is light and widely distributed over a wide area or within narrow limits for long distances, this type of shovel is much more economical than its larger and heavier protypes of the fixed-platform class. Hence, in recent years, the revolving shovel has been successfully adapted to allotment grading, highway and street grading, railroad construction, cellar and reservoir excavation, sewer trench construction, stripping of quarries, the operation of gravel pits, brick yards, etc., etc.

The revolving shovel has a wide scope of usefulness on account of its light weight, portability, full circle swing, hill climbing power and thrusting device for dipper operation.

47. Cost of Operation.—The cost of operation of a revolving shovel depends upon the class of work, the character of the soil, the size of the machine, the facilities for removing the material, the peculiar conditions affecting each job, etc.

The cost of operation of a ¾-yd. revolving steam shovel for a 10-hr. day, in the operation of clay or gravel, under average conditions would be approximately as follows:

Labor:		
1 engineer	$5.00	
1 fireman	3.00	
1 laborer	2.00	
Total labor cost		$10.00
Fuel and Supplies:		
½ ton coal @ $4.00	$2.00	
⅙ gal. cylinder oil @ 50¢	0.08	
1⅒ gal. engine oil @ 40¢	0.04	
Waste, packing, etc.	0.18	
Total cost of fuel and supplies		$ 2.30
General and Overhead Charges:		
Depreciation (based on 20-year life)	$0.75	
Interest @ 6%	0.85	
Repairs, incidentals, etc.	1.40	
Total fixed charges		$ 3.00
Total cost for 10-hr. day		$15.30
Average daily output		300 cu. yd.
Average cost of operating shovel, $15.30 ÷ 300 =		$0.051 per cu. yd.

The above statement does not include the cost of transporting the shovel to and from the work, the cost of living and camp expenses, office and other incidental expenses. It is assumed that the magnitude of the job warrants the use of dump wagons or other suitable transportation equipment for the removal of the excavated material.

48. Electrically Operated Shovels.—When electric power is available at low cost and in a sufficient and uninterrupted supply, as in a large city or along the lines of large power plants, recent experience has shown the economy of the operation of power shovels by this form of power.

Advantages of Electric Power.—When electric power costs 3 cents per kilowatt hour and coal costs $5.00 per ton, the cost of operation of an electric shovel is about one-half that of a steam shovel. Under favorable conditions, the use of electric power is desirable and economical for the following reasons:

1. Less labor required for operation; does away with the fireman and shovel becomes a one-man machine.
2. Eliminates the expense and handling of coal and water.
3. Economy of power; as power is only used when shovel is operating. Steam must be kept up continuously in case of steam shovel.
4. Operation is smoother, steadier and quieter than that of steam shovel.
5. Eliminates trouble of freezing pipes in cold weather and boiler temperature in hot weather.
6. Eliminates labor of banking fires at night and delay in getting up steam at commencement of work.

Electric Equipment.—The prime mover is the electric motor which may be operated by either direct- or alternating-current service. The wound-rotor type of motor is used on all of the motions, when alternating current is available. When direct current is used, compound-wound motors are used with the exception of a series motor which is sometimes used on the hoisting motion. The various sizes of motors for the various capacities of shovels are given in Table V.

TABLE V.—SIZES OF MOTORS

Weight of shovel (tons)	Size of dipper (cu. yd.)	Power of motors		
		Hoist (h.p.)	Swing (h.p.)	Thrust, (h.p.)
30	1	50	30	30
35	1¼	50	30	30
35	1¼	60	30	30
35	1¼	75	35	35
42	1½	75	30	30
65	2	100	35	35
95	3⅓	150	50	50
100	4	200	80	80

Shovel service is unusually severe on electric equipment, especially on the hoist and thrust motors. On the hoist motor, the work is generally at high torque and low speed and the motor is frequently stalled when the shovel strikes an obstruction or is digging in hard rock. The sudden starting or stopping of the boom likewise tends to stall the motor and burn it out. The motors must be controlled by automatic magnetic controllers and so designed that the torque and radiating capacity will be proportioned to the work to be done. The controller for any motor must be supplied with proper resistance to allow maximum work to be secured without burning out the motor. Quick acceleration and instant braking of the motor must be provided for. The thrust motor is subjected to the severest service as maximum torque or power must be exerted when the motor is practically at a standstill. Such a motor is frequently stalled and at these times the torque must remain nearly constant. A preventing resistance must be provided for the motor which is generally connected through a friction clutch which will hold up to a point corresponding to a value slightly less than the maximum torque of the motor but which will still permit the motor to revolve slowly when a greater torque is required.

The whole equipment must be of the rugged type to withstand the severe vibration of shovel operation. All electric shovels use motors of 600 volt capacity or lower. On revolving shovels, a single motor drive has been found to be the more satisfactory on account of the economy in initial cost and the simplicity and flexibility of operation. On the smaller shovels using motors not over 50 h.p. capacity, drum reversing controllers are generally used, while on the larger shovels, magnetic switch controllers operated from master switches, are used.

The current is taken from trolley wires, or a transformer, on a high power line, and is received through the truck by wire cables. In the case of revolving shovels, the current is transmitted to the motor above through copper rings on the truck frame and carbon brushes suspended from the rotating turntable.

49. Field of Usefulness.—The electric-power shovel is especially adapted to the construction of city and interurban electric lines. The electrically operated revolving shovel is the most efficient excavator for track trenching which requires the shallow excavation of dense, hard material to a uniform grade.

In recent years, this type of shovel has been successfully

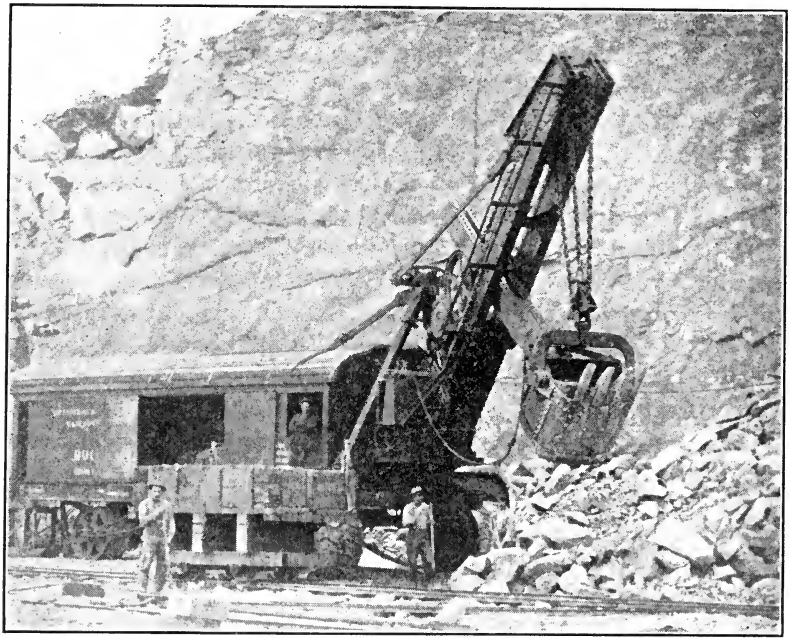


FIG. 32.—Electrically operated shovel on quarry work. *(Courtesy of Westinghouse Elec. & Mfg. Co.*

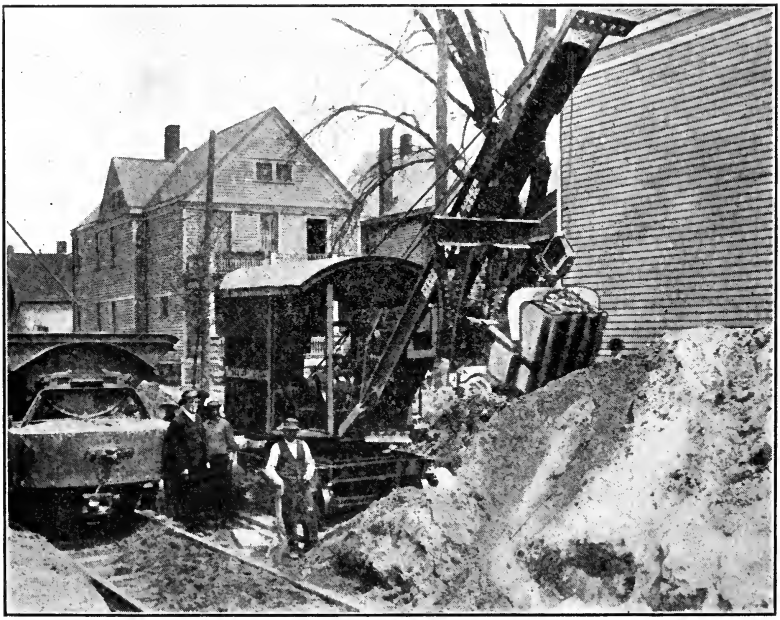


FIG. 33.—An electrically operated revolving shovel. *(Courtesy of Thew Automatic Shovel Co.)*

adapted to the excavation of mines and tunnels, for plant service in handling ores, fuel, fertilizer, etc., and for use in brickyards, gravel pits, etc.

Figure 32 shows an electrically operated shovel in the quarry work of a cement plant and Fig. 33 a revolving shovel on interurban railway construction.

50. Résumé.—The steam shovel is one of the most efficient and universally useful of modern excavators. When the soil is sufficiently firm to support it and the work is of sufficient magnitúde to warrant its use, it can be used economically for all classes of work, such as railroad cuts, the excavation of streets, trenches, ditches, cellars, the stripping of ore beds, gravel pits and clay beds, etc., etc. It can be used for the excavation of all kinds of material from loam and clay to hard-pan and rock. Rock in formation must be loosened by blasting before the shovel can handle it.

The output of a steam shovel depends on its size, the character of the material to be excavated, the efficiency of the crew, the climatic conditions, location of material with relation to the shovel, relation of shovel to point of dumping, efficiency of wagon or car service, etc. When working under favorable conditions, the maximum working capacity of a shovel will average about one-half of its theoretical efficiency. It is almost imposible to keep a shovel continuously suppplied with wagons or cars and even so, this would mean perfect operation without delays for repairs, breaks, coaling, watering, oiling, etc.

The cost of operation and capacity of a steam shovel, as stated in the previous paragraph, depend on a great many factors, and it is difficult to arrive at any stated values. Recent results from the use of steam shovels, on the Panama Canal indicate the following:

A 70-ton shovel, equipped with a 2½-cu. yd. dipper will average 1200 cu. yd. of earth excavation during an 8-hr. working day.

A 95-ton shovel, equipped with a 5-cu. yd. dipper will average 2500 cu. yd. of earth and rock excavation and 2000 cu. yd. of rock, during an 8-hr. working day.

For the making of estimates, the author would suggest adding the following to the estimated cost of operation:

Ten per cent. on initial cost of plant for depreciation,
Six per cent. on initial cost of plant for interest on investment,
Five per cent. on initial cost of plant for repairs.

The small, revolving type of shovel has demonstrated its efficiency for ordinary jobs such as small railroad cuts, street grading, cellar excavation and for use in the clay pits of brickyards and cement works. The electrically operated shovel is the most economical for electric traction work and in large cities where the current is accessible at a low unit cost.

Hand shoveling has been almost entirely superseded by power-machine shoveling, on work where the amount of work will justify the cost of installation of the plant. The relative economy of the two methods may be determined approximately by estimating the cost per cubic yard by hand labor and the same cost by power machine, including in the total cost by the latter method the items of plant installation, depreciation, interest, and repairs. A comparison can be made for the excavation of ordinary soil of loam, clay, and sand, under average working conditions, between power shovel and hand labor. This discussion cannot be exact as there are many indeterminate and variable conditions of soil, labor, efficiency, etc., which will affect the results for the peculiar conditions of each case. However, the reader is urged to study the method of analysis, as it can easily be applied to the investigation of other methods and of other types of machinery.

Illustrative Example.—Let us assume a loam and clay soil with few boulders or obstructions; the hauling to be done by 2-yard dump wagons of sufficient number to keep the hand shovelers or power shovel busy; the cut to average 8 ft., and runways to be arranged for the incoming and outgoing teams; the material first to be loosened in the case of hand shoveling.

Cost of Shoveling by Hand

Loosening:

1 plow team, with driver and plow holder;	
Team, plow and driver	$4.00
Plow holder	1.75
Total labor cost, per day	$5.75
Repairs, depreciation, etc	1.25
Total cost of loosening	$7.00
Total amount of loosened material (cu. yd.)	400
Unit cost of loosening material, per cu. yd., $7.00 ÷ 400 =	$0.0175

Shoveling and Loading:

One man can shovel and load about 20 cu. yd. per 10-hr. day. Hence, the plow should loosen enough material to keep 20 men busy. Loading dump wagons, these men can work efficiently in 4 groups of 5 men each. Each group of 5 men can load on an average 6 wagons per hour or 50 wagons per 10-hr. day, allowing for delays.

1 foreman	$3.50
20 laborers @ $1.75 each	35.00
Total labor cost, per day	$38.50
Repairs, incidentals, etc.	1.50
Total cost of shoveling and loading	$40.00
Total amount of earth handled (cu. yd.)	400
Unit cost of shoveling and loading, per cu. yd. $40.00 ÷ 400 =	00.10
Total cost of hand shoveling 400 cu. yd.	47.00
Unit cost of hand shoveling, per cu. yd., $47.00 ÷ 400 =	$0.1175

Assume also a revolving steam shovel equipped with a ¾-yard dipper and operated by an engineer, fireman, and two pitmen. With good wagon service, the average output will be 500 cu. yd. per 10-hr. day. The shovel will load on an average 30 wagons per hour.

COST OF POWER SHOVELING

Labor:			
1 engineer	$5.00		
1 fireman	3.00		
2 pitmen, @ $1.75 each	3.50		
Total labor cost, per day		$11.50	
Fuel and Supplies:			
¾ ton coal @ $4.00	$3.00		
Oil and supplies	1.00		
Total fuel and supplies		$4.00	
General and Overhead Charges:			
Depreciation[1]	$1.00		
Interest[2]	1.20		
Repairs and incidentals	1.80		
Total fixed charge		$4.00	
Total cost of operation per 10-hr. day			$19.50
Average daily output (cu. yd.)			500
Unit cost of power shovel operation, per cu. yd., $19.50 ÷ 500 =			$0.039

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[1] Based on 5 per cent. and 20-year life.

[2] Based on 6 per cent. and 20-year life.

The above data show that the output is increased by 25 per cent. at a reduction in cost of 65 per cent. by the use of the steam shovel. The average loading time by hand shoveling was assumed as 10 min. and for the steam shovel as 2 minutes. This means a saving of about 4 min. per cubic yard by the use of the steam shovel.

If the teams are paid at the rate of 50 cents per hour for a 10-hr. day, the economy in the value of the team time saved, for different shovel outputs, will be as follows:

ECONOMY IN TEAM COST

300 cu. yd. per 10-hr. day, at 3 min.[1]	900 min. or 15 hr. @ 50¢.	$7.50
400 cu. yd. per 10-hr. day, at 3 min.[1]	1200 min. or 20 hr. @ 50¢.	10.00
500 cu. yd. per 10-hr. day, at 3 min.[1]	1500 min. or 25 hr. @ 50¢.	12.50
600 cu. yd. per 10-hr. day, at 3 min.[1]	1800 min. or 30 hr. @ 50¢.	15.00

Thus, it will be noted that the saving in team time per 10-hr. day, on the basis of an efficient shovel operation of 600 cu. yd., is nearly enough to pay for the operating cost of the shovel. Hence, it is likewise true that the economy resulting from the efficient use of a power shovel is often equal to the entire cost of shoveling and loading by hand methods. If the job comprised the removal of 45,000 cu. yd. and hand shoveling cost 10 cents per cubic yard, the use of a steam revolving shovel would effect a saving sufficient to pay for the cost of the machine.

51. Bibliography.—For additional information, the reader is referred to the following:

Books

1. "American Civil Engineers' Pocket Book," edited by Mansfield Merriman, 3d edition, published in 1916 by John Wiley & Sons, New York. 1496 pages, 1047 figures, 4¼ in. × 7 in., Cost, $5.00.

2. "The Chicago Main Drainage Channel," by C. S. Hill, published in 1896 by Engineering News Publishing Company, New York. 129 pages, 105 figures, 8 in. × 11 in.

3. "Earth and Rock Excavation," by Charles Prelini, published in 1905 by D. Van Nostrand, New York. 421 pages, 167 figures, 6 in. × 9 in. Cost, $3.00.

4. "Earthwork and Its Cost," by H. P. Gillette, published in 1910 by Engineering News Publishing Company, New York. 254 pages, 54 figures, 5½ in. × 7 in. Cost, $2.00.

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[1] Value of 3 min. is used as being conservative.

6. "Handbook of Steam-shovel Work," prepared for the Bucyrus Company of Milwaukee, Wis., by The Construction Service Company of New York. Published in 1911. 374 pages, 85 figures, 4 in. × 6½ in. Cost, $1.50.

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PART II

DREDGES

Introductory.—The power shovel is not well adapted to earthwork operations in wet or soft soils on account of the concentration of the heavy weight of the machine and loaded dipper over a long, narrow area. The crane of the power shovel is short and of heavy construction, and exerts a great pressure over a small area of base. Hence, with the demand for an excavator with a long boom for the removal of the excavated material to spoil banks adjacent to the excavation, and also for a wide base over which to distribute the load as a small unit pressure over the soft soil, the dredge or dredging machine was devised.

Dredges may be divided into two general classes; dry-land excavators and floating excavators. The various types of dry-land excavators will be discussed in Chapters VII to XI inclusive and the floating excavators in Chapters XII to XV, inclusive.

CHAPTER VII

SCRAPER EXCAVATORS

52. Classification.—Dry-land excavators are those types which move over and operate from the surface of the land. They may be classified as to their construction, method of operation and use as follows: scraper excavators, templet excavators, trench excavators, and cableways. Scraper excavators will be discussed in this chapter and the other three classes in succeeding chapters.

53. General Description.—Scraper excavators may be subdivided into two classes, as to their method of operation; the stationary machine with pivoted boom, and the revolving dredge.

A—STATIONARY SCRAPER EXCAVATOR

54. Varieties.—The stationary scraper excavator has developed during the last 30 years through a series of types; the drag boat dredge, the excavator with two booms, the light scraper bucket excavator and the walking scoop dredge. The drag boat excavator is the application of a narrow and deep hull, which may be drawn along the excavated ditch by means of cables anchored ahead of the boat. As this type of machine is very limited in its scope, rarely used at the present time and properly, a dipper dredge, no further description will be given of it here.

55. Traction Excavator with Two Booms.—An early type of scraper dredge comprised a framework which carried the boiler, engines, coal bunkers, A-frame, booms, dipper or scraper, etc. This machine moves along ahead of the excavation on rollers. A machine of this type, mounted on caterpillar tractors, has recently been used in the Middle West for the excavation of drainage ditches. See Fig. 34.

The principal feature of this excavator is the use of two booms, set a distance apart, depending on the width of the ditch to be excavated. The booms swing from the center of the ditch to each side. The buckets are fastened to arms which slide along the booms. Each bucket is filled by lowering the point of the boom and moving the bucket through the earth toward the machine. The bucket is emptied by raising the point of the boom and swinging to the side of the ditch. One bucket is filled while the other is dumped. This feature adds greatly to the capacity of the machine. Equipped with 42-ft. booms, a two-boom excavator has averaged 100 cu. yd. per hour in the construction of a channel with a 25-ft. bottom, a 48-ft. top and an average depth of 12 feet. This type of machine makes a uniform cross-section with smooth side slopes and a fairly true grade. On account of the excessive weight and cost of transportation of this type of excavator, the lighter and more portable types have come into more general use at the present time (1918).

Fig. 34.—Traction excavator with two booms.

56. Small Traction Ditcher.—About 8 years ago (1910), a small, portable, dry-land machine was devised for the excavation of small ditches. This machine is shown in Fig. 35.

As will be seen from the illustration, the machine consists of a platform, which moves on two sets of caterpillar tractors and carries the machinery, A-frame, boom and dipper. The whole framework is constructed of steel. The engines of the regular, horizontal, friction-drum type are operated by a 25- h.p. gasoline engine, which consumes about 2 gal. of gasoline per hour. The boom is made in two sections; the main section and the movable section, which is hinged to the main section near the lower end. The scraper bucket is fastened to a steel frame which is hinged to the movable section of the boom. In loading, the bucket is drawn down and toward the machine and when filled the movable and lower section of the boom is raised and hooked to the upper section. Then the whole boom is swung to one side and the dipper inverted and dumped. This machine operates a ¾-yd. dipper on a 20-ft. boom. One man is required to operate the machine. Its weight is about 12 tons, but on account of the distribution of the load over a large area of the surface by the caterpillar tractors, the machine may be used on soft soil.

FIG. 35.—Gopher dry-land traction ditcher. (*Courtesy of Dix Machine Co.*)

57. Small Scraper-bucket Excavator.—Recently, the demand for a machine that can economically construct the smaller sized channels of drainage and irrigation systems of the Middle West and South has led to the production of several light, portable and inexpensive machines. A well-known type is shown in Fig. 36 and will be described in the following section.

The machine consists of a steel framework, supported on two trucks, each of which consists of a heavy steel axle and two steel wheels, 5 ft. in diameter and 2 ft. wide. The frame supports a platform which carries the operating equipment.

Near the front end of the platform are placed the operating drums and gears which are belt connected to an internal combustion engine mounted near the rear end. The hoisting and dragline drums are controlled by friction clutches operated by levers. The internal combustion engine is generally used on these small, portable machines on account of their compactness, cleanliness and ease and economy of operation. A machine equipped with a ¾-yd. bucket and a 50-ft. boom will require a 40-h.p. 4-cycle

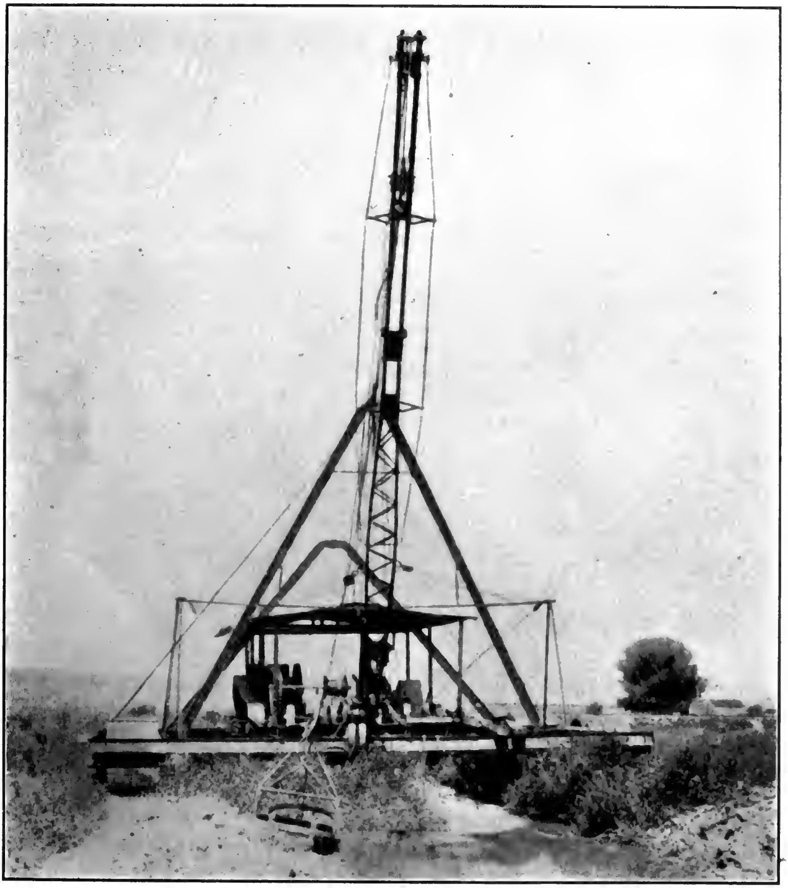

Fig. 36.—Light scraper excavator. (*Courtesy of Economy Excavator Co.*)

gasoline engine which will run on a consumption of from 20 to 25 gal. of gasoline per 10-hr. day. The engine should be provided with forced-oil feeder, gear-driven magneto, carbureter, throttle, governor, large oil tank, etc.

The excavating equipment consists of the boom and bucket or scoop. The boom is generally made adjustable or extensible and is formed of steel channels, latticed and braced with truss rods. The lower end of the boom rests in a universal joint at the front end of the platform while the upper end is supported from the A-frame by cables and carries the sheave over which the hoisting cable passes. The bucket is a steel scoop provided with manganese or tool-steel teeth.

One man is required to operate the machine and one man to handle the track in soft soil. The operator controls the operation of the excavator by a set of levers. The bucket is lowered to the surface by releasing the hoisting line. Then the drag line is pulled in and this draws the bucket toward the machine, scooping up a thin slice of earth on its way. When the bucket is near the machine and filled, the boom is swung to one side until the bucket is over the spoil bank, when it is inverted and dumped.

The machine can be moved ahead without interrupting its operations by means of a cable attached to a "dead man." The excavator weighs about 12 tons and costs about $5000.

58. Walking Scoop Dredge.—The walking dredge is rather a novelty in the field of excavating machinery and derives its name from its ability to move over the ground under its own power and to turn short angles or curves without sliding or skidding. The walking scoop dredge was first used about 1905 and is similar in general construction and operation to the floating dipper dredge. Another type, placed on the market in 1914, is an adaptation of the walking principle to the drag-line excavator and will be discussed under *Revolving Excavator*.

The walking dredge consists of a wooden hull, constructed of heavy timbers, and braced along the sides by large, overhead, wooden trusses. The hull is made of sufficient width to straddle the ditch as it is being excavated. On the front of the hull is placed the A-frame, which generally is composed of two heavy timbers bolted to the sides of the hull at their lower ends with their upper ends meeting in a "head" casting. The A-frame is set in a vertical plane and braced by wire cables, which extend from the top of the frame to the rear of the hull. Figure 37 gives a side view of a dredge showing truss and A-frame in detail.

On the floor of the hull is placed the boiler and machinery. When steam power is used the equipment is very similar to that used on a floating-dipper dredge; the boiler being placed on the rear end and in front are placed the hoisting and swinging engines. On account of the expense of getting coal, where the work is a long distance from a railroad, it has been found more economical to use a gasoline engine to furnish the power. Engines from 16 to 50 h.p. are used, depending on the capacity of the machine, the size of the ditch and the character of the soil. A machine with a 40-ft. boom and a 1¾-yd. dipper has been satisfactorily worked with a 50-h.p. gasoline engine.

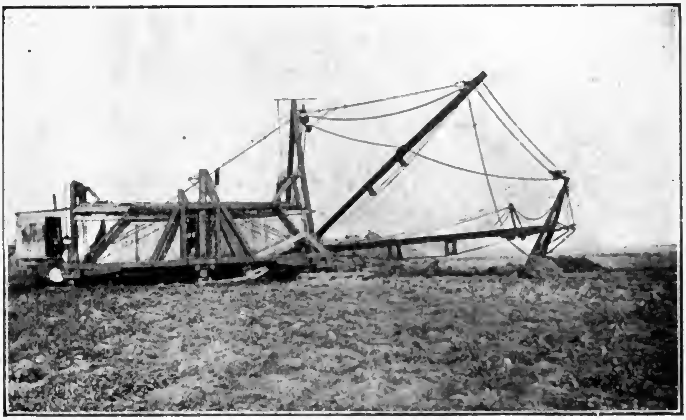

Fig. 37.—Side view of walking dredge.

The excavator is supported at each of its corners by a timber platform constructed like a stone boat and called a foot. Each foot is 6 ft. wide, 8 ft. long and 4 in. thick and an iron bar fastened to the bottom near the front edge prevents slipping. Each pair of feet is joined transversely by a light timber, so that both will move conjointly and in the same direction. Each foot is pivoted to the hull and connected to a drum by a chain, so that by revolving the drum, the direction of the feet may be changed by the operator. In the center of each side or midway between the corner feet, is a center foot, similar in construction to the corner feet but having a length of 14 ft. and a width of 6 feet. On the under side of each center foot, a 6 × 6-in. timber is fastened transversely to prevent slipping. A large timber extends from the top of each center foot, between each pair of trusses, where it is pivoted. A chain, one end of which is fastened to the side timbers of the hull, passes over the two pulleys attached to the frame on which the foot support is pivoted, and then passes along the hull to the rear corner and across the back end to a drum near the center of the hull. To move the machine the drum is revolved and the winding up of the chain pulls the foot support gradually to a vertical position. This raises the dredge from the corner feet and it moves ahead about 6 feet. The rear chain is then released and the weight is taken off of the center foot, which is pulled ahead by a chain attached to a drum, located near the center of the front part of the hull. Figure 38 shows a detail view of a corner foot.

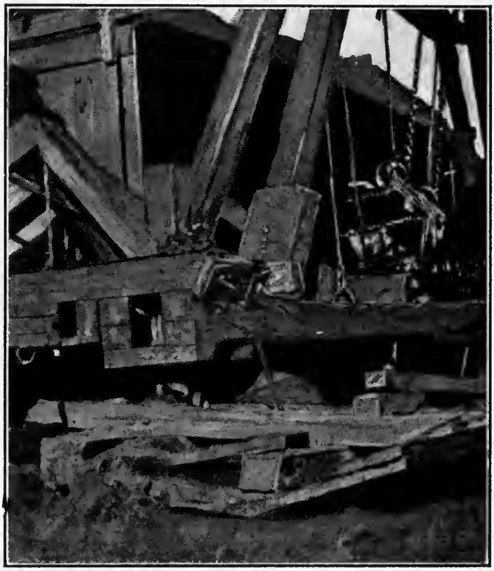

FIG. 38.—Corner foot of walking dredge.

The boom is made up of two parts, the upper part is supported at its lower end on a turntable similar to those used on a floating-dipper dredge. The upper end is supported by a cable from the peak of the A-frame. The lower part of the boom is pivoted at one end to the lower end of the upper section and on its outer end is pivoted an iron-trussed framework shaped like a walking beam. A chain or wire cable passes from the upper end of this frame to a drum on the hull. By the winding up of this chain or cable, the top of the frame may be pulled back. To the lower end of the frame is fastened the dipper which is shaped like the pan of a slip scraper. A chain or cable is also fastened to the frame at the back of the scoop. This line passes over pulleys in the outer ends of the booms and then to a drum on the hull. By the winding up of this line the scoop is pulled back and tilted to a vertical position. Figure 39 will clearly show the details of the boom and scoop. To excavate, the lower section of the boom is lowered until the tip of the scoop is at the required level; the line attached to the upper end of the walking beam is then wound up and the scoop is thus forced forward into the earth. After the scoop is filled the lower section of the boom is raised and at the same time swung to one side until the scoop is over the spoil bank, where the upper line is released and the lower line is pulled in until the scoop is drawn back to the boom and the contents of the scoop are dumped.

FIG. 39.—Dipper and dipper arm of walking dredge.

The machine can move ahead, across country at the rate of 1 mile in about 10 hours. It can make a quarter turn in about 50 feet. On very soft swampy land the machine can be operated by placing a large pontoon under the hull to float the machine and support the larger part of its weight. It may be operated as a rear or head-on excavator. In the first case, the machine starts at the outlet and backs up away from the excavation like a drag-line excavator, while in the latter case, the machine starts at the upper end of the ditch and straddles it as it excavates.

B—REVOLVING EXCAVATOR

59. Drag-line Excavator.—The best known and most generally used type of dry-land machine, is the revolving type of scraper-bucket excavator. This class of machine may be mounted in one of three different ways as follows:

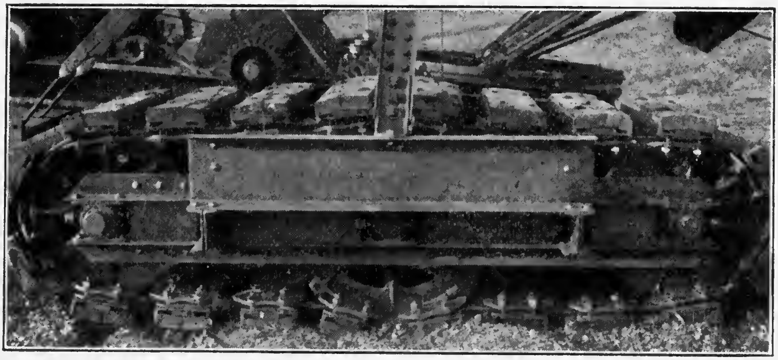

Fig. 40.—Caterpillar tractor of gopher ditcher.

1. On skids and rollers, when the machine travels over the planks laid on the surface. The machine moves ahead by pulling up to its bucket, which acts as an anchor.

2. On trucks, when the machine is mounted on small steel, four-wheel trucks. The machine moves ahead as in the case of skids and rollers.

3. On caterpillar tractors, when the machine is supported on four moving plarforms which are especially adapted for soft soil condition and allow the machine to move ahead without the use of planking, tracks, etc. See Fig. 40.

The essential parts of a scraper-bucket excavator are the substructure, which consists of the upper and lower platforms and turntable, the power equipment, the hoisting engines, the swing-

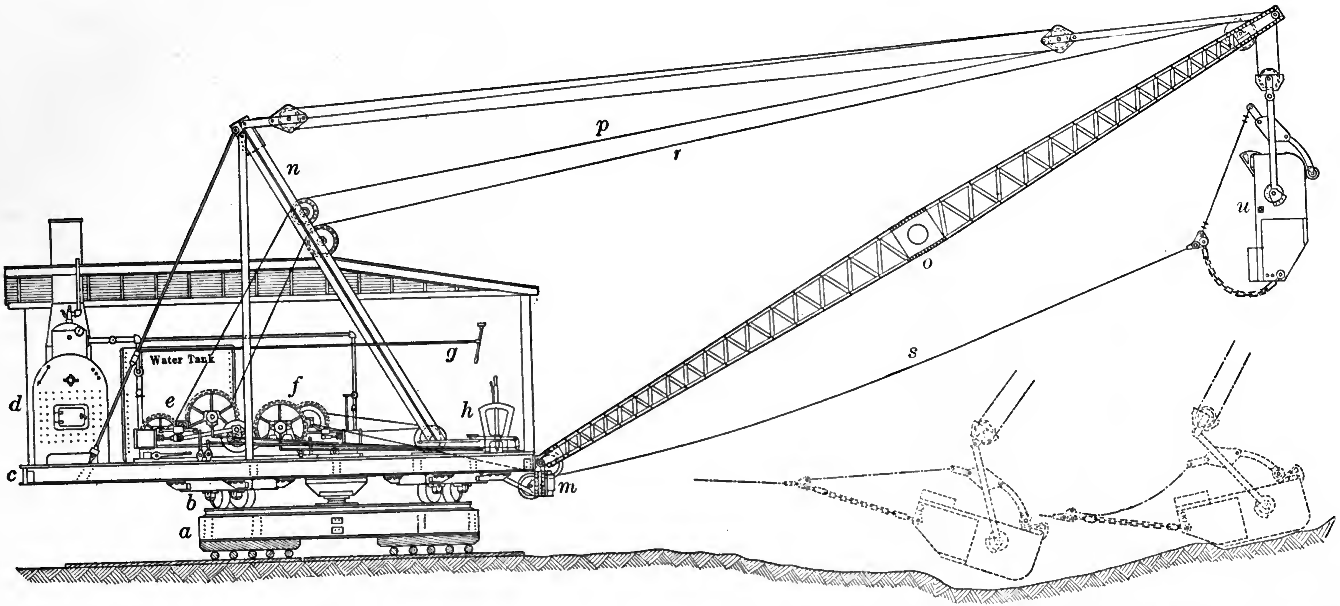

FIG. 41.—Detail view of drag-line excavator. *a*, Lower frame; *b*, turntable; *c*, upper frame; *d*, boiler; *e*, hoisting engine; *f*, swinging engine; *g* and *h*, operating levers; *m*, fair lead; *n*, A-frame; *o*, boom; *p*, boom fall line; *r*, hoisting line; *s*, drag line; *u*, bucket. (*Courtesy of Lidgerwood Mfg. Co.*)

ing engines, A-frame, boom and bucket. The essential parts and their system of coördination and method of operation are practically the same in all the various makes of the scraper-bucket or drag-line excavator. The only differences are in the details of construction, such as will be noted hereafter in the machinery and buckets. The principal parts of a drag-line excavator are shown in Fig. 41.

The sub-structure consists of a lower platform, an intermediate turntable and an upper platform. The lower frame consists of a rectangular-shaped open box, whose members are steel channels or I-beams. The frame is mounted either on wooden rollers, double-flanged truck wheels or four-wheeled compensating trucks. Figure 42 shows a typical make of lower frame mounted on the four-wheeled trucks.

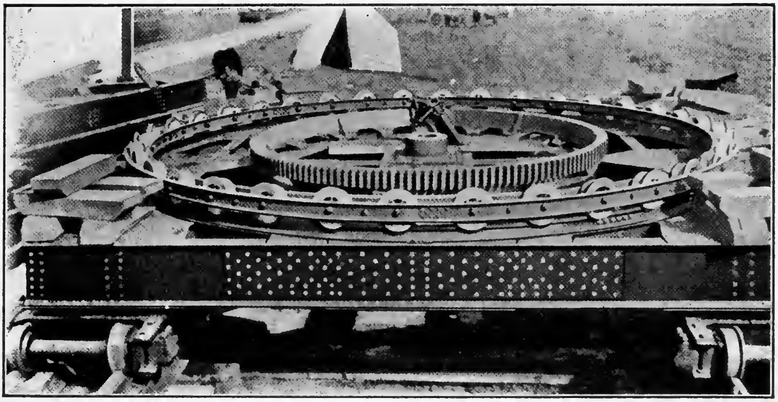

Fig. 42.—Lower frame of drag-line excavator. (*Courtesy of Lidgerwood Mfg. Co.*)

Upon the upper suface of the lower platform is fastened the track upon which runs the swinging circle. In the center of the upper surface of the lower frame is fastened the female section of the central pivot.

The turntable consists of a swinging circle, which is a steel frame supporting several flanged wheels. See Fig. 42. In one make of excavator the swinging circle consists of several independent trucks fastened to the bottom surface of the upper frame, while in other makes the circle is composed of a larger number of smaller wheels revolving between two tracks.

The upper framework or platform is built of steel channels and I-beams of lighter section than those in the lower frame. The various members are made in sections, which can be easily transported and readily assembled. Upon the lower surface of this frame is fastened the male section of the central pivot.

The power equipment may be made up upon the basis of using steam, gasoline or electricity as the source of power.

BOILER

The steam equipment is the one generally used and will be described first. It consists of a boiler, steam pump, injector, water tank and piping. The style of boiler used depends on the power required. A vertical tube or brick-set boiler cannot be used. The gross horse power required for the operation of the excavator should be estimated and 25 per cent. added to this amount to determine the rated horse power of the boiler, which should be used.

It is often necessary where an excavator is at work in regions where the water supply is highly impregnated with salts, to purify the water before it is used in the boiler. This is best accomplished by running the water from the supply tank into a Feed Water Heater, where escape steam from the boiler is used to heat the water to the boiling point and this water after being freed of its salts and other impurities held in solution, is pumped into the boiler. This purification of the feed water prevents the incrustation of the boiler and thus greatly increases its efficiency. The writer has found that the use of "Boiler Compounds" or "Purgers" is at best an unsatisfactory and troublesome method of removing scale from boiler tubes. The only safe and reliable method is to remove the cause of incrustation before the water is admitted into the boiler. This will save time and expense in cleaning the boiler and also save coal. With a 100-h.p. boiler a Feed Water Heater having a height of 6 ft. 5 in. and a diameter of 24 in. would be of ample capacity. These dimensions will vary, however, with the type of heater used.

This surplus power is often needed under exceptional conditions such as excavation of very stiff or heavy soil, foaming of water in boiler tubes, excavation of frozen soil, use of poor-grade fuel, adverse atmospheric conditions, etc. On account of the high cost of fuel and the poor quality of water generally obtainable on drainage contracts, that type of boiler should be used that will give the greatest efficiency with the smallest fuel consumption.

On the smaller size machines, a vertical boiler is generally used. Figure 43 shows the boiler and hoisting engine used on a well-known make of excavator. On the larger size machines, a return-tube fire box or locomotive type of boiler is generally used, as shown in Fig. 44.

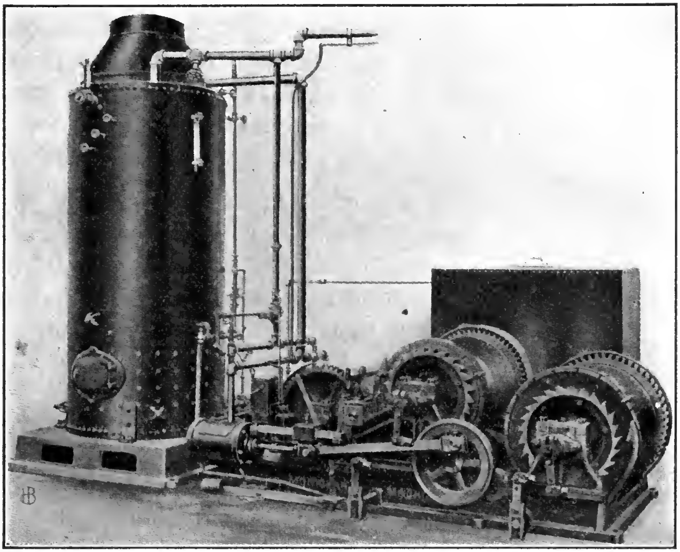

FIG. 43.—Boiler and hoisting engine of drag-line excavator. (*Courtesy of Monighan Machine Co.*)

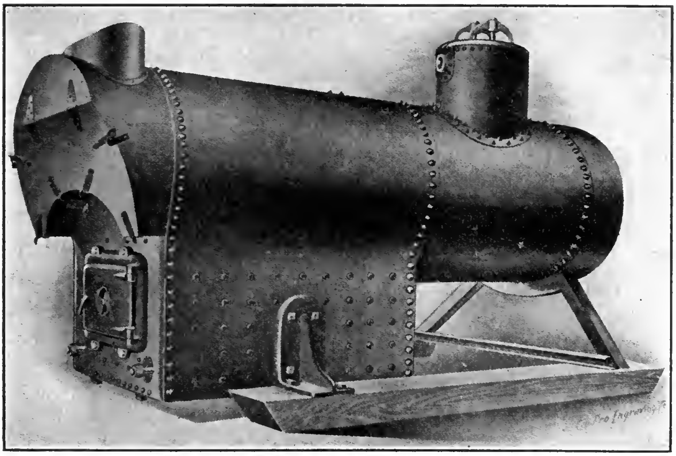

FIG. 44.—Locomotive type of boiler. (*Courtesy of Monighan Machine Co.*)

A steam pump of the standard duplex type is generally connected to the boiler direct or to a water tank, which supplies the boiler by an injector.

MAIN ENGINE

The hoisting engines, which are generally termed the main engines of an excavator, are generally horizontal, double-cylinder, friction drum type and self-contained on a single cast-iron or steel bed plate. The engine is always set directly in front of the boiler, with a narrow passageway between. There is probably no severer test to which machinery can be put than that of dredging. The continued application for long periods of time of the shocks of throwing on and off the varying load is a very trying test of an engine's strength and durability. It is especially necessary that all gears be of steel, the shafts very heavy, the shaft and wrist pins large, and the front drum of extra thickness and well braced inside. The writer has known of cases where the continual breaking of the various parts of an engine has caused serious delays and great loss of time and money to the contractor. The engine of some makes of excavator has three drums; the rear drum is used for handling the boom fall line, the center drum is for the hoisting line and the front drum for the drag line. See Fig. 43. In other makes of excavator, the engine has simply the hoisting and drag-line drums; the outer end of the boom being raised and lowered by a small winch, which is operated independently of the main engine. See Fig. 48. Some makes of engine provide double-band outside friction clutches actuated by auxiliary steam rams, which give a good control over the operation of the drums. This is necessary in the case of the drag-line and hoisting drums.

SWINGING ENGINE

The mechanism for swinging the upper platform, machinery and boom, and for propelling the excavator over the ground surface is sometimes contained in the main engine. Some manufacturers, however, provide a separate swinging engine, self-contained on its own base plate. This engine is of the steam reverse type and drives through a chain of gears, a pinion which operates the large circular rack on the lower frame. The swinging engine used on a well-known make of drag-line excavator is shown in Fig. 45. The swinging engine should be provided with some device for keeping the swinging lines tight. To insure smoothness of operation, an auxiliary steam cylinder should be connected to the tumbling shaft. The cylinder and throttle are generally operated by a single lever.

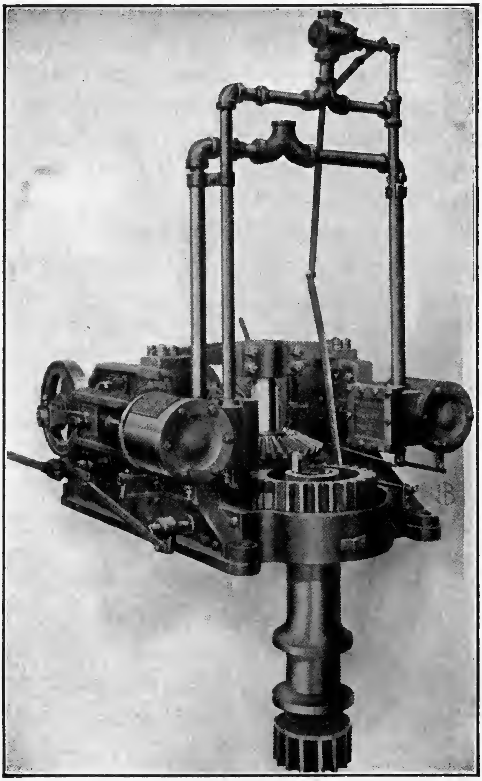

Fig. 45.—Swinging engine of drag-line excavator. (*Courtesy of Monighan Machine Co.*)

In Minnesota and South Dakota in recent years (1907–18), gasoline and kerosene engines have been used for the driving of the machinery of drag-line excavators. The engine is mounted on a base just in the rear of the engine to which it is belt connected. The drums of the engine are provided with outside band friction clutches, which are controlled by pneumatic thrust cylinders. The swinging mechanism is mounted on the same base and to one side of the hoisting and drag-line drums. Double-cone friction clutches are used to operate the swinging drums.

The gasoline engine should have a capacity of 40 to 50 h.p. for an excavator with a 1¾-cu. yd. to a 2½-cu. yd. bucket. As is well known, the internal combustion engine should be mounted on a stable and rigid base for efficient and uniform operation. On the upper platform of a drag-line excavator, the engine is subjected to severe shocks and vibration and such parts as the crank, crank pin, main shaft, governor, etc., must be made of extra heavy section and weight to resist the unusually severe strains. The writer has seen the Otto and Stickney engines used on 2¼- and 2½-yd. bucket excavators, and even with these heavily built engines, the breaks have been numerous. It is especially necessary that a liberal excess of power be used and experience has proven the wisdom of using not less than 50 per cent. horse power in excess of that estimated.

A small air compressor actuated by a belt connection with the engine, furnishes compressed air to a receiving tank. The air is then supplied to the thrust cylinders, which control the band friction clutches on the drums. A water tank for supplying water to cool the cylinder of the engine and a gasoline supply tank are also placed on the upper platform near the engine. The gasoline engine is much more economical to operate than a steam equipment in localities where coal is expensive and requires long and costly hauling and also where water is scarce and poor in quality.

Where electric power is available and reasonable in cost, it is advisable to use electric motors, in place of the steam-boiler equipment. Either alternating or direct current may be used. The motors may be gear or belt connected to the shafts of the hoisting and swinging engines. The drums of these engines are controlled by outside band friction clutches, which are actuated by pneumatic thrust cylinders. A small belt-connected air compressor with receiving tank supplies the compressed air for the rams. On a 120-ton machine equipped with a 2½-yd. dipper, a 115-h.p., 60-cycle, 3-phase motor for the swinging engine are suitable for the power equipment. The cost of current will vary from ¼ to 1 cent per cubic yard of excavated material depending on the market price.

The reliability, cleanliness, and economy of this form of power are strong factors in favor of its use. It has been used to a considerable extent in recent years in reclamation work in the arid regions of the West, where coal and water are scarce and expensive, and electric power is available from local transmission lines of water-power plants.

The hoisting, dragging and swinging mechanism to be used in connection with gasoline and electric power is shown in Fig. 46.

The assembled machinery on a drag-line excavator in operation is shown in Fig. 48, which is a view of the interior of the engine house.

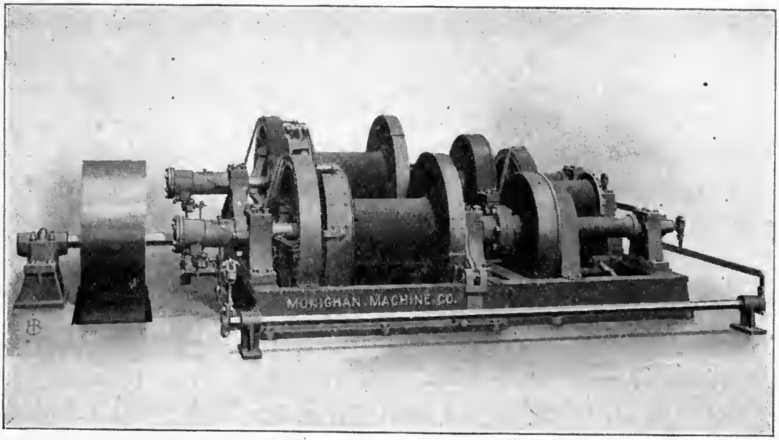

Fig. 46.—Mechanism for drag-line excavator operated by gasoline or electric power. (*Courtesy of Monighan Machine Co.*)

BOOM

The boom or crane is composed of a structural steel framework, generally two channels braced together for the smaller excavators and two latticed girders braced together for the larger excavators. See Fig. 47. The lower ends of the main members, channels, or latticed girders, are spread apart at the lower end and hinged to the outer corners of the front side of the upper platform. The upper ends of the main members are joined together so as to form a boxing wherein one or more sheaves are placed. The main members are cross-braced with small lateral trusses so designed as to resist the severe lateral strains occasioned by the sudden starting and stopping of the swinging of the boom.

A-FRAME

The top of the boom is connected by cables with the top of a vertical frame called an "A"-frame. This frame is located near the front end of the main engine and the lower ends are bolted to the sides of the upper platform, while the upper ends are framed together to form a boxing for a sheave. The top of the "A"-frame is guyed back to the two rear corners of the upper platform. The top of the boom may be raised or lowered by means of a wire cable, which passes from the end of the boom over the sheave at the top of the "A"-frame and thence down to a winch on the floor of the house. See Figs. 41 and 48.

FIG. 47.—Drag-line excavator with steel framed boom.

BUCKET

The bucket may be one of three types; the scraper bucket, the clam-shell bucket and the orange-peel bucket. The last two types are only used for special work such as rock excavation (rock previously loosened by blasting), narrow trench or ditch excavation, the removal of sand and silt from channels, etc. The dimensions, weights and cost of these two types are given in Figs. 24 and 25.

The scraper bucket is the type in general use with a drag-line excavator, and as the name of the machine implies, the bucket is filled by being dragged toward the machine by a line or cable. There are several makes or styles of these scraper buckets, which

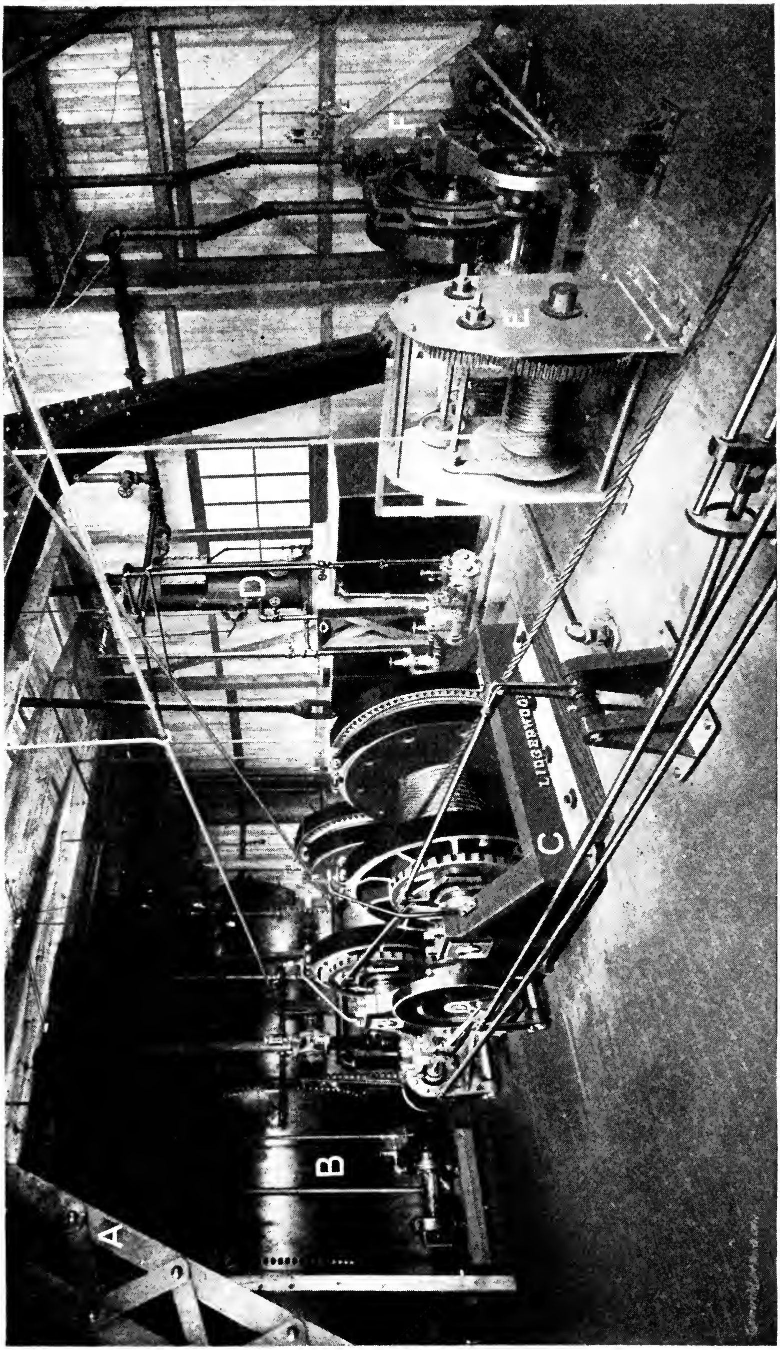

Fig. 48.—Interior view of engine house of drag-line excavator. A, "A" Frame; B, boiler; C, hoisting engine; D, feed water heater; E, deck winch; F, swinging engine. (*Courtesy of Lidgerwood Mfg. Co.*)

differ only in their details of construction. A few of these types are described in the following paragraphs.

The Page bucket is shown in Fig. 49 and is operated as follows: the digging or drag line attached to the bail of the bucket is drawn toward the machine by operation of the front drum. The initial pull on the drag line gives the bucket the correct digging position, and the chisel edge lip enters the earth at the proper angle. By a slight manipulation of the tension on the hoisting line, the proper angle is maintained for either a thin cut, as in hard digging, or for a heavy cut to fill the bucket quickly, as in soft digging. When the bucket is filled, the foot-brake of the front drum is applied, the pneumatic control reversed, and the bucket hoisted by the application of the friction of the rear drum of the main engine, the operator meanwhile paying out the drag line. The front end of the bucket is held up by means of tension on the dumping line, which is a branch of the drag line. The power is then applied to the swinging engine, the machine is swung to the dumping place, the tension is released and the bucket automatically dumps by gravity. The tension being applied or released by pressure on the drag-line brake lever, the operation of dumping is always under complete control.

Fig. 49.—"Page" scraper bucket. (*Courtesy of Lidgerwood Mfg. Co.*)

The Brownhoist Shnable Drag-line Bucket is a back dumping bucket and consists of a shell, a pulling bail and a combination hoisting bail and back-gate. See Fig. 54. The pulling bail is connected to the shell (in its digging position) at points above the center of gravity and also is connected to the hoisting bail and back-gate by links in such a manner that tension on the drag line forces the gate to close. The bucket is operated by two single-part lines, the drag line and the hoist line. The bucket may be made to dig at any desired slope by carrying the tension on the hoist line while it is being paid out.

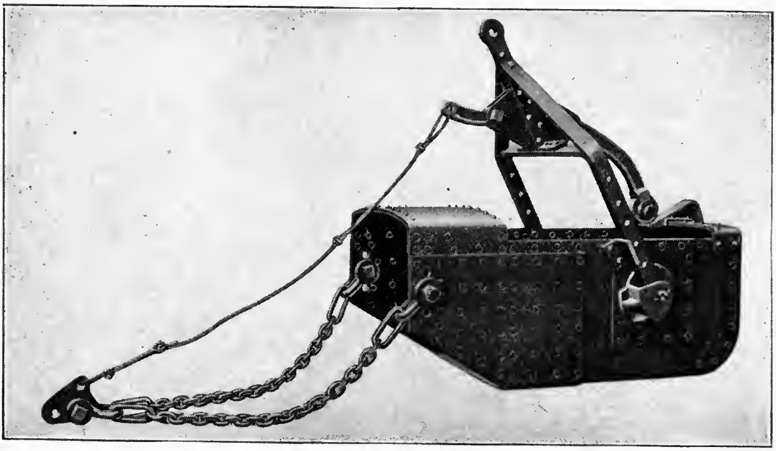

Fig. 50.—"Monighan" two-line drag bucket. (*Courtesy of Monighan Machine Co.*)

The Martinson bucket or generally known as the Monighan scraper bucket is very similar to the Page bucket and like it is a two-line appliance. The operation of the machinery for digging, swinging and dumping is the same as described above for the Page bucket. The drag line, in the case of the Page bucket, is fastened to the top of the front end of the bucket, thence passes up over a small sheave in the upper part of the bail and thence out to a connection with the two side chains and from here to the front drum. A reference to Fig. 50 will show that in the use of the Monighan bucket, the bucket is held horizontally by the lever mechanism which is connected to the drag line by a cable. When the bucket is dropped and the drag line released, the bucket assumes a vertical position and dumps by gravity.

The Browning scraper bucket has two hoisting lines besides the drag line; one attached to the end of the bail and the other fastened to the rear of the bucket. The drag is fastened to a bail, which projects in front of the bucket and which may be set at different angles to the bottom of the bucket. The dimensions, weights and costs of the various sizes are given in Fig. 51.

Capacity Cu. Yd.	Extreme Length	Extreme Height	Extreme Width	Hoist Rope	Dump Rope	Drag Rope	Weight
¾	7-6	6-1	4-4	⅝	⅝	¾	1500 lbs.
1	8-3	7-0	4-9	¾	¾	¾	2000 lbs.
1½	10-3	8-5	5-0	¾	¾	⅞	2850 lbs.
2	11-2	9-8	5-3	⅞	¾	1	3800 lbs.
2½	11-6	10-9	5-9	⅞	⅞	1⅛	4750 lbs.
3	12-0	12-0	6-3	⅞	⅞	1¼	5900 lbs.
3½							

FIG. 51.—Browning scraper buckets. *(Courtesy of Browning Mfg. Co.)*

The Austin scraper bucket is a two-line excavator similar to the Page bucket. The distinctive feature of this bucket is a latch, which hooks over a pin on the front end and maintains it in a horizontal position. The bucket may be dumped at any position by releasing the latch and allowing the bucket to assume a vertical position and dump the contents.

The Bucyrus scraper bucket is very similar to the Browning bucket shown in Fig. 51. The distinctive features are a rigid bail connection for the drag line and a rounded back. By varying the angle, which the drag-line bail makes with the bottom of the bucket, a downward force may be exerted and assist in the excavation of stiff material. The rounded back is of advantage in the excavation of sticky or gumbo soil, as the material will not stick to the bucket and the material as it is excavated is rolled up and decreases the resistance to the loading up of the bucket.

Fig. 52.—"Iverson" bucket.

A novel bucket has recently been devised and put on the market by M. S. Iverson of New York. The improvements claimed for this bucket by the inventor to give it superiority in construction and operation over all other types of drag-line buckets are as follows:

The elimination of the tension between the drag line and the hoist line, while the bucket is being hoisted to the dumping place. This is affected by the use of a latching device which automatically hooks over the bail of the bucket, when the latter is pulled forward by the drag line. Thus the bucket may be hoisted from any position in relation to its distance from the end of the boom. Figure 52 shows the bucket being hoisted over the spoil bank by the hoist line alone; the drag line being slack.

The reduction of repairs on the bucket, due to the design and improved methods of construction.

The reduction of weight on the bucket on account of the elimination of the drag-line strain.

The resulting increase in size of the bucket on account of the reduction of work which the machine is subjected to, by the use of the tension feature.

The following quotation from a letter of a contractor, who used the Iverson bucket in excavation work connected with the construction of the Fourth Avenue Subway, Brooklyn, N. Y., will give the results of several months actual test of this bucket.

> "The bucket possesses two features which will figure to a great advantage against any other drag-line bucket, the most important feature that of doing away with the tension between the drag line and the lift line (since the bucket is a locked one) and the second feature that of preventing the compression on the front of the bucket, thereby doing away with a lot of useless reinforcement, has proven to be of such a great advantage to the machine operating the bucket that our own Browning crane can do a good day's work with 65 lb. of steam with this new bucket whereas other buckets would stall in the bank with 85 lb. and would require 100 lb. of steam to do the same work."

The bucket is made in ½, ¾, 1, 1½, 2, 2½ and 3 cu. yd. capacities and equipped with either forged- or manganese-steel teeth.

A bucket which has been in successful operation for several years on the Pacific Coast is the Weeks bucket. The principles involved in its construction and operation can be understood by a reference to the line drawings in Fig. 53.

Like all other buckets of this type, it is operated by two lines, a drag or haul line, which pulls the bucket forward and a return line to draw it back. The body of the shovel or bucket consists of a pan, open at the top and front, a sloping back to facilitate the return of the shovel after dumping and lugs attached to the vertical sides for use in dumping the load forward. To the front part of the sides of the pan is attached a rigid upright yoke or mast, which contains two sheaves, over which pass the chains, which, when properly operated, cause the shovel to dig and release. A bail, which consists of two short chains, holds a sheave, around which passes the digging chain, one end of which is fastened to the casing of the sheave. The other end of this chain is attached to a lug at the back of the shovel and the rehaul or return line fastens to the digging chain at a suitable point near the boom. The bail by which the shovel is drawn forward may be flexible as described above or it may be rigid. The latter is preferred in excavating soft material. The cutting edge is generally curved upward to assist in releasing the shovel from its cut.

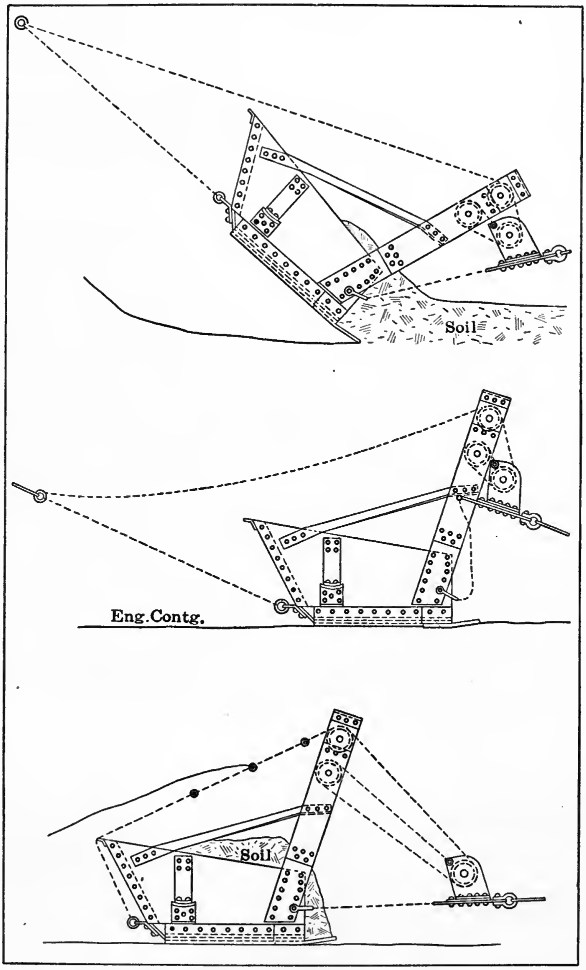

Fig. 53.—"Weeks" drag-line bucket. (*Courtesy of Engineering-Contracting.*)

The shovel is operated from the boom of a drag-line excavator or a simple boom of a derrick or tower by drawing the bucket back and forth across the area to be excavated by the haul line and return line. To excavate with the shovel the haul line is made taut, the return line is tightened slightly, which action, by aid of the sheaves, draws the mast and haul line together (see Fig. 53), which thus tips the shovel forward on its cutting edge, and in this position it is drawn forward until filled. The return line is then slackened, causing the mast and haul lines to draw apart, after which the drawing in of the haul line releases the shovel (now filled) and owing to the slightly upturned cutting edge the shovel rises out of the material. In this loaded condition, the shovel is drawn forward to the point where it is to be dumped. The latter action is caused by the slacking of the tail line, which causes the shovel to take a vertical position, allowing its contents to fall out of the front end. When the shovel is operated from a swinging boom, the shovel is raised and swung to the side for dumping.

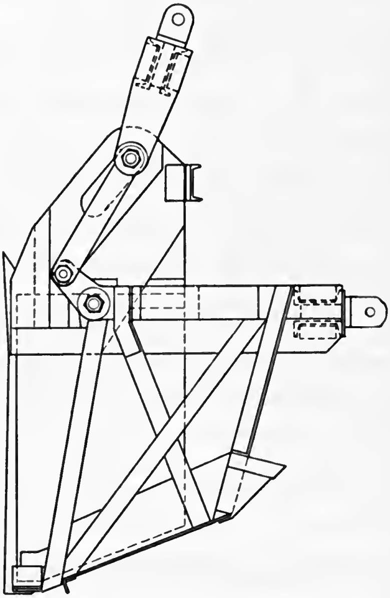

Fig. 54.—Shnable drag-line bucket. (*Courtesy of Brown Hoisting Machinery Co.*)

The shovel is constructed of heavy steel plate and equipped with a manganese steel cutting edge, and cast steel back.

The shovels are constructed in the following sizes and weights:

Size	Weight
15 cu. ft.	1520 lb.
22 cu. ft.	2120 lb.
34 cu. ft.	3050 lb.
42 cu. ft.	4100 lb.

The 34 cu. ft. is the size generally used and is usually operated by means of an 8¼ × 10-in. double drum hoisting engine, requiring from 35 to 60 h.p. depending on the kind of material to be excavated.

The capacity of the shovel varies from 350 to 500 cu. yd. per 10-hr. day. Three men are generally required in an ordinary crew, one to operate the shovel, one to operate the boiler, and a general laborer.

CABLES

The experience of most contractors (including some noted above), in the use of drag-line excavators, is that the principal source of expense for repairs is in the wearing out of cables. The drag-line cable especially is subject to great wear in passing over the guide sheaves on the front of the upper platform. These guide sheaves are called the "fair lead" and in the latest form, consist of two horizontal sheaves mounted on a casting on which is pivoted a swinging frame, carrying two vertical sheaves. This frame, in revolving, will take the direction of the drag line and thus maintain a straight lead at all times.

The drag-line and hoisting cables are continually subjected to vibratory stress and shocks and should be made of the very best plow steel. There are several, well-known brands or makes, generally designated by a colored strand woven into the cable and thus deriving the names, "red strand," "yellow strand," etc.

60. Method of Operation.—A steam-operated machine requires the services of four men; an engineer, a fireman and two laborers. The engineer stands at the front end of the platform and by means of the brakes and levers controls the entire operation. The fireman keeps the boiler fed with fuel and water and has general supervision of the machinery. The laborers act as pitmen and are of general service about the machine. The fireman is unnecessary when the excavators are operated by electric motors or internal-combustion engines.

The operation of excavation commences with the bucket in the first position shown in Fig. 41. The engineer releases the hoisting-line and drag-line drums and allows the bucket to drop to the surface, where it will be in the second position shown in Fig. 41. The further manipulation of the bucket depends on the type of bucket used and has been described in the previous section entitled "*Bucket.*"

61. Cost of Operation.—The cost of operation of a scraper-bucket excavator depends on the class of work, the kind of material to be handled, the efficiency of the engineer, the character and cost of the power used, etc.

The type of machine in general use is a steam-power excavator, equipped with a 2½-yd. bucket. Such a machine, on ditch or railroad construction should excavate about 1000 cu. yd. of loam and clay during a 10-hr. day. The following is a typical case of the cost of operation, under such conditions, for a 10-hr. day:

Operating Cost of Steam-power Scraper-bucket Excavator

Labor:			
1 engineer	$5.00		
1 fireman	3.00		
2 laborers, @ $1.75 each	3.50		
1 team and driver (hauling coal, etc.)	3.50		
Total labor cost, per day		$15.00	
Fuel and Supplies:			
2 tons of coal, @ 4.00	$8.00		
Oil and waste	1.65		
Water	0.35		
Total fuel and supplies		$10.00	
General and Overhead Expenses:			
Repairs	$4.00		
Incidental expenses	2.00		
Depreciation (10 per cent. of $10,000)[1]	5.00		
Interest (6 per cent. of $10,000)[1]	3.00		
Total general and overhead expense		$14.00	
Total cost of operation for 10-hr. day			$39.00
Average daily excavation (cu. yd.)			1000
Unit cost of scraper-bucket excavation, cu. yd.,			$39.00 ÷ 1000 = $0.039.

62. Field of Usefulness.—The field of work of the drag-line excavator has become a wide one since 1910. Its early use was largely in reclamation work, the construction of ditches and dikes

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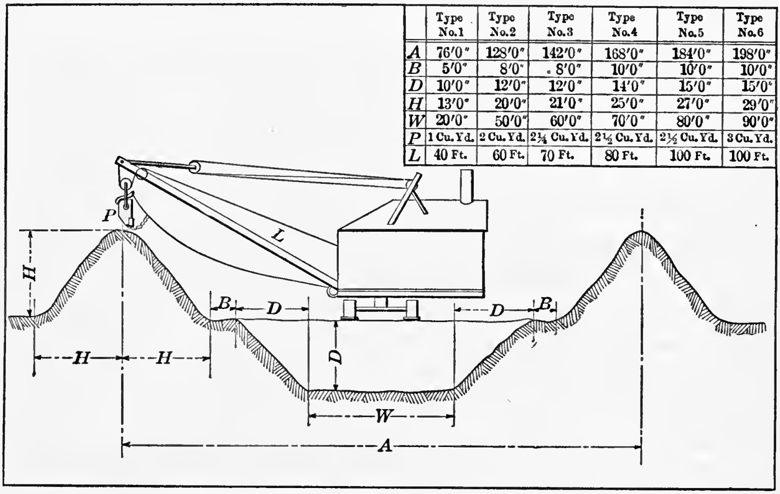
[1] Based on a life of 10 years and 200 working days per year.

on irrigation and drainage projects. Its great length of boom gives this excavator a wide radius of operation and permits of the deposition of material in spoil banks at a sufficient distance from the sides of the cut to prevent caving of the banks. The drag-line principle permits the excavation of material at a considerable depth below the surface and its elevation to a correspondingly high elevation above the surface. The limitations of the drag-line excavator are shown in Fig. 55.

The use of the caterpillar tractor allows a heavy machine to move over soft, wet soils on drainage work. The machine starts at the lower end of the canal and excavates as it moves upstream, thus allowing the surplus soil water to drain off through the new channel. The careful operation of the bucket will result in the construction of a canal with smooth and uniform bottom and side slopes. Recent experience in the South and West has proved the efficiency of this type of excavator in the construction of dikes and earthen dams on reclamation projects and embankments on railroad work. The machine moves parallel to the work and borrows the material from one side, or moves ahead of the work and borrows the material from both sides.



	Type No.1	Type No.2	Type No.3	Type No.4	Type No.5	Type No.6
A	76′0″	128′0″	142′0″	168′0″	184′0″	198′0″
B	5′0″	8′0″	8′0″	10′0″	10′0″	10′0″
D	10′0″	12′0″	12′0″	14′0″	15′0″	15′0″
H	13′0″	20′0″	21′0″	25′0″	27′0″	29′0″
W	20′0″	50′0″	60′0″	70′0″	80′0″	90′0″
P	1 Cu. Yd.	2 Cu. Yd.	2¼ Cu. Yd.	2½ Cu. Yd.	2½ Cu. Yd.	3 Cu. Yd.
L	40 Ft.	60 Ft.	70 Ft.	80 Ft.	100 Ft.	100 Ft.

Fig. 55.—Limitations of various sizes of drag-line excavator.

Earthen dams and dikes, if of large size, should be made in layers of about 6 to 8 inch depth, and each layer wetted and rolled by a heavy steam roller before the deposition of the material for the next layer. Small dikes and railroad fills can be satisfactorily built without wetting and rolling. The drag-line excavator saves the haulage equipment necessary in this class of earthwork where either an elevating grader or a power shovel is used.

The scraper-bucket excavator is very efficient in the excavation of gravel pits and in stripping soil from quarries and mines. When the power shovel has become drowned out of a pit which has been flooded, the drag-line machine can work from a higher level and excavate for a considerable distance below the water.

63. Jacobs Guided-line Excavator.—In the use of the ordinary drag-line bucket excavator, difficulty is often experienced in guiding the bucket when stiff material is encountered. This difficulty is especially noticeable when the bucket is cutting the sloping banks of an open ditch and the bucket, in its upward path, passes from stiff to loose material. Recently an excavator has been put upon the market designed to overcome this difficulty. This new machine is the Jacobs Guided-drag-line-bucket Excavator, manufactured by the Jacobs Engineering Company, of Ottawa, Illinois.

This excavator consists of a steel-framed platform made up of standard stuctural steel shapes, which are joined with fitting bolts. This upper platform revolves on a circular track, which rests on a lower steel-framed platform. The machinery consists of a three-drum hoist with steel gearing and the whole mounted on a heavy cast-iron base, which is bolted to the upper platform. The machinery is operated by either steam or gasoline power. The two swinging drums are operated by a double-cone friction and are connected to the drum shaft of the hoisting engine by a sprocket and bushed chain.

The distinctive feature of the machine is the guide boom, which consists of a steel girder shaped like a figure J, with the hook end hanging vertically from a straight boom. Both booms are pivoted at the front end of the upper platform. The bucket, which is a rectangular steel box, open at the end toward the machine, is attached to a trolley which travels on the guide boom, having two double-flanged wheels riding on the upper flange and a third wheel bearing against the lower flange to keep the bucket from kicking upward.

"In making the cut, the bucket is hauled inward by a cable leading directly from the trolley to the engine. For dumping, it is hauled outward by the back haul cable, which leads from the trolley to the head of the main boom and back to the engine. The bucket is dumped by continuing its travel to the vertical end of the guide boom, the boom being first swung around to the position at which the load is to be deposited."

The machine is self-propelling and travels on a track, which is made in sections and is moved by the machine itself.

This machine has been used for the construction of open ditches, tile ditches and back filling same, levees, roads and highways, etc.

This excavator is built in various sizes, from one having a ¾-yd. bucket and 25-ft. boom to one with a 1⅓-yd. bucket and a 40-ft. boom. The cost of the machines varies from $3500 to $6000, depending on the length of the boom and the capacity of the bucket.

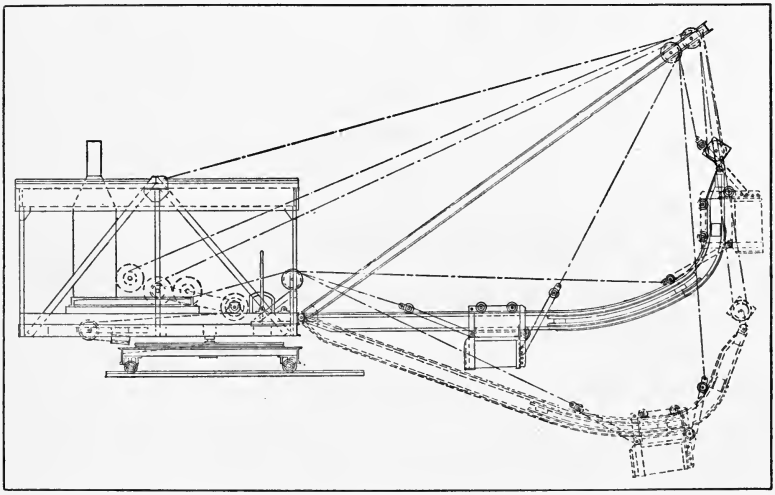


Fig. 56.—Jacobs guided-drag-line bucket excavator.

A line drawing showing the construction of the Jacobs Guided-drag-line-bucket Excavator and the boom and bucket in digging and dumping positions, is given in Fig. 56.

64. Walking Drag-line Excavator.—The walking excavator is an adaptation of a walking traction device to the drag-line excavator. It is especially adapted to use on drainage and irrigation projects where several ditches are to be built in one locality. Ordinarily, when an excavator is through with one job and is ready to start another piece of work, it is necessary to dismantle the machine, transport the parts to the new site, and reassemble them. This involves a considerable expenditive of time, labor, and money. The machine can be erected at the point where it is unloaded from cars or boats and can walk to the job at the rate of about 3 miles per 10-hr. day.

The walking drag-line excavator differs from the ordinary drag-line machine principally in its substructure construction. The customary lower frame and truck rollers or caterpillar tractors are replaced by the walking device which is quite different in design and operation from that described above for the walking scoop dredge.

FIG. 57.—Walking drag-line excavator. (*Courtesy of Monighan Machine Co.*)

The superstructure of this excavator is very similar in design and construction to the ordinary drag-line excavator. Three sizes of machine are in regular use: the smallest, equipped with a 40-ft. boom, a 1-yd. bucket, and operated by a 45-h.p. kerosene engine; the medium, equipped with a 50-ft. boom, a 2-yd. bucket, and operated by a steam plant; and the largest, provided with a 60-ft. boom, a 2½-yd. or 3-yd. bucket, and operated by a steam plant.

The walking device consists of two large shoes or platforms, one on each side of the central circular support, and two wheel segments or cams, each of which is keyed to the end of a heavy shaft extending across the machine. On the lower end of each cam is pivoted a beam whose ends are chain connected to the ends of each platform. A view of this mechanism is shown in Fig. 57. A large gear wheel on the shaft meshes with a pinion on the loading-drum shaft of the main engine. The pinion is controlled by a jaw clutch and brake.

To move the machine, the pinion clutch is thrown in and the engine started. As the shaft revolves, the cams and pivoted beams lift the platforms and swing them forward to a resting place on the ground. As the shaft revolves, the cams move over the upper surfaces of the platforms until they come into contact with the stop blocks, when the motion is stopped, and the machine is moved forward and downward to the surface. When futher movement is not desired, the cams are revolved until the beams and platforms are elevated above the ground, and the machine then rests entirely on its circular base, about which it may revolve as a pivot for the purpose of excavating. The pinion is now locked by a brake and the drum clutch released to commence digging.

The walking scoop dredge operates at about the same cost as the floating dipper dredge. A machine equipped with a 1½-cu.yd. dipper and operated by a 40-h.p. gasoline engine, can handle about 1500 cu.yd. of loam and clay per 10-hr. day, at an average cost of about 4 cents per cubic yard.

65. Locomotive Crane Excavator.—The traveling derrick or locomotive crane is a very useful and adaptable type of excavating, hoisting, and conveying machine. It has been serviceable in many lines of construction work as the machine may be used for excavation, transportation of various kinds of materials, loading and unloading wagons, cars, barges, etc.

The essential parts of a traveling derrick are the car, the hoisting engine, and the derrick. The machines are made in capacities varying from 3 tons to 20 tons. A machine in operation is shown in Fig. 58.

The car is a steel-frame platform which supports directly the cast-iron turntable bed and the counterweights. The platform is mounted on a four-wheel truck, equipped either with broad-tired wheels for road traction, or with standard railroad wheels for the smaller sizes of crane. The larger sizes, generally 10-ton capacity, are mounted on two four -wheel trucks, equipped above with standard railroad wheels. The car is provided with draw-bars for the four-wheel type, and couplers, steam brake, grab handles, steps, etc., for the 8-wheel type.

The power for the cranes may be steam, electric, or that furnished by an internal combustion engine. Ordinarily steam power is used, but the other kinds would be more economical when the cost of coal or wood is high compared with electric power and gasoline.

The steam equipment consists of a boiler, engine, hoisting mechanism, rotating mechanism, and traveling mechanism. The boiler is of the vertical, tubular type, and should be capable of working at a pressure of 100 lb. with quick-steaming qualities and large steam capacity. The engine is usually of the vertical, double-cylinder type, provided with link-motion reversing gear, wide-ported slide valves, etc. The hoisting mechanism consists of a double-drum winch. The hoist drum is driven from a friction clutch on the main engine shaft. The bucket drum is operated from the hoist drum by a slip friction. Both drums are controlled by friction-clutch brakes, lever operated by one man. The rotating mechanism consists of two friction clutches driving a chain of gears. The upper platform, which supports the operating and excavating equipments, can be revolved in either direction through a complete circle. The traveling mechanism consists of a set of gears driven by a

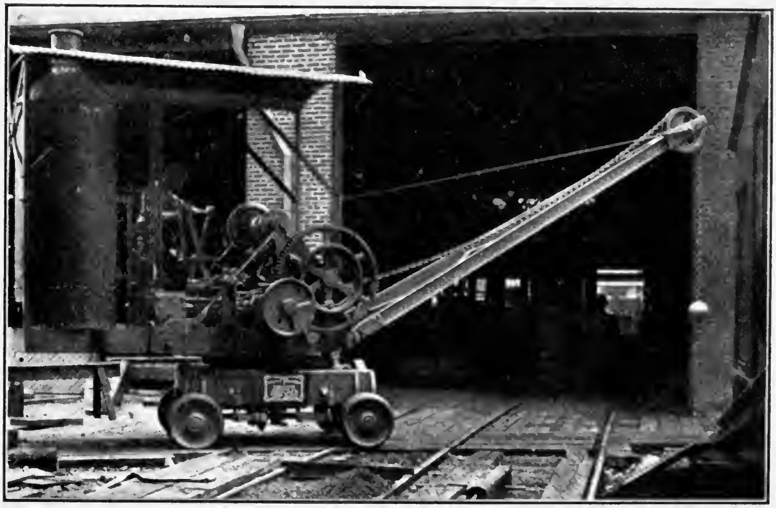


FIG. 58.—Locomotive crane. *(Courtesy of the Brown Hoisting and Conveying Machinery Co.)*

friction clutch on a shaft geared to the crank shaft of the engine. The machine may be moved in either direction.

The excavating equipment consists of the boom or crane, and the dipper or bucket. The boom is a steel-frame structure, hinged at its lower end to the front of the upper platform, and supported at its outer and upper end by guys extending to the rear corners of the platform. At the outer end of the crane is the sheave over which the hoist line passes on its path from the drum to the bucket.

The bucket or dipper may be a grab bucket, of the orange-peel or clam-shell type, or a drag-line dipper. The former is used for the excavation of softer soils while the latter is more serviceable in the removal of the denser and harder soils. In the latter case, a separate drag-line drum must be provided in the hoisting mechanism.

66. Method of Operation.—A traveling derrick is operated by a crew of 3 to 10 men, depending on the amount of extra labor necessary. An engineer controls all the operations of excavating, rotating, and traveling, a fireman operates the boiler, a signalman is often necessary for deep-trench work, and one or more laborers are used for general service about the machine and in the excavation. When a skip is used, shovelers are required.

The method of operation is very similar to that of a revolving shovel and the reader is referred to that section of the book for a complete discussion of this subject.

On trench excavation, one machine may be used for excavation only, or may excavate and later return to back fill. On large works, it has been found advantageous to use two or more machines coördinately; one for the rough excavation, one for the finished excavation and for handling pipe and materials, and one for the back filling.

67. Cost of Operation.—The cost of operation would vary greatly with the size of the machine, the efficiency of its operation, the character of the material, etc. The following statement is given as an approximate idea of the cost of operation under average conditions.

A 10-ton machine, equipped with an automatic clam-shell bucket of 1 yd. capacity, and moving on a track along the side of the trench, will be considered. The material is clay for a depth of 8 ft., and is underlaid by a substratum of gravel. Following is an estimate of the cost of operation for a 10-hr. working day:

OPERATING COST OF TRAVELING DERRICK

Labor:			
1 engineer	$5.00		
1 fireman	3.00		
3 laborers, @ $2.00 each	6.00		
Total labor cost, per day		$14.00	
Fuel and Supplies:			
1 ton coal	$4.00		
Oil, waste, and repairs	1.50		
Total fuel and supplies		$5.50	
General and Overhead Expenses:			
Depreciation (5 per cent. of $5000)[1]	$1.25		
Interest (6 per cent. of $5000)[1]	1.50		
Incidental expenses	2.25		
Total general expenses		$5.00	
Total cost of work for 10-hr. day			$24.50
Total excavation for 10-hr. day (cu. yd.)			400
Unit cost of traveling derrick excavation, per cu. yd., $24.50 ÷ 400 =			$00.061

68. Field of Usefulness.—The traveling derrick is serviceable in the excavation of wide trenches and channels where the soil conditions are favorable for the use of a grab or scoop bucket. In trench work this machine is especially useful where the width of the excavation is over 5 ft. and other forms of excavators are not adaptable. With good management this machine may be used very efficiently for a combination of excavation, back filling and the removal of sheeting and bracing.

69. Résumé.—The scraper-bucket excavator has come in general use for various forms of earthwork; ditch and canal excavation, the construction of earthen embankments and dykes, the operation of gravel pits and open-cut mines, the dredging out of natural channels, etc.

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[1] Based upon 200 working days in a year and a 20-year life.

For reclamation work, where the magnitude of the work is less than about 10,000 cu. yd. and where the ditch is of small cross-section, some type of light, drag-line excavator should be used. For channels of large cross-section and where the amount of work is greater than 50,000 cu. yd., a drag-line machine with a bucket of from 1½ cu. yd. to 2½ cu. yd. capacity, can be efficiently used. Where the top width of the channel is over 80 ft., two machines, one on each side of the channel, will be necessary.

For the removal of sand, silt and loose gravel from natural streams or artificial channels, the excavator can work most efficiently with a long boom and a clam-shell or orange-peel bucket.

With the successful application of gasoline power to a scraper bucket excavator, the fuel problem is considerably lightened for the use of a large machine at a distance from a railroad. The use of electric power is the ideal method of operation, when such power can be economically secured from a local transmission line.

The walking excavator is adapted to reclamation work where there are a number of channels to be excavated in one locality. The walking scoop dredge has proved to be efficient in large drainage canal construction where the soil was soft and wet. The walking drag-line excavator is best adapted to operating where the soil conditions are more favorable.

The recent adaptation of the caterpillar tractor to the scraper-bucket excavator has made possible the use of this type of machine for the reclamation of low, wet lands.

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CHAPTER VIII

TEMPLET EXCAVATOR

71. Preliminary.—Many types of excavators construct open channels with rough bottoms, uneven slopes, and steep banks which are subject to subsequent caving. These irregularities in the surfaces of the channels retard the flow of the water and greatly increase the deposition of silt, dèbris and other materials carried by the water in suspension. During recent years an excavator has come into use for the construction of open channels with true and smooth side slopes and grades. Since 1900, a unique type of excavator has been devised for the construction of levees and these two types will be discussed in this chapter.

OPEN-CHANNEL EXCAVATOR

72. General Description.—A double-faced, reversible, positive-cleaning bucket moves along a guide frame, which is shaped at its lower section to the desired cross-section of the ditch. The guide frame is supported on a platform or framework composed of structural steel members, strongly braced and bolted together. This platform is supported on wheel trucks or caterpillar tractors, which are necessary for soft, wet soils. Templet excavators with wide and with narrow frames are shown in Figs. 59 and 60, respectively.

Power for the operation of the machine may be furnished by a steam-power equipment or by an internal combustion engine. The latter type of power equipment has generally been found to give very satisfactory results and to be cleaner, cheaper, and simpler in operation than the ordinary steam plant. If a steam engine and boiler are used, a 25-h.p. to 40-h.p. engine will be required, while a gas engine for the same machine should have from 50 h.p. to 80 horse power. The power plant is mounted on the central part of the platform and is operated with a set of levers by one man.

The excavating equipment consists of the guide frame and the bucket. The guide frame is made up of two steel members which are placed parallel and form a track over which the bucket moves. This frame is made in two shapes at its bottom section to provide for the excavation of narrow and of wide ditches; the side slopes are nearly 1 : 1. The frame is well braced by steel-frame members and can be raised and lowered through the platform.

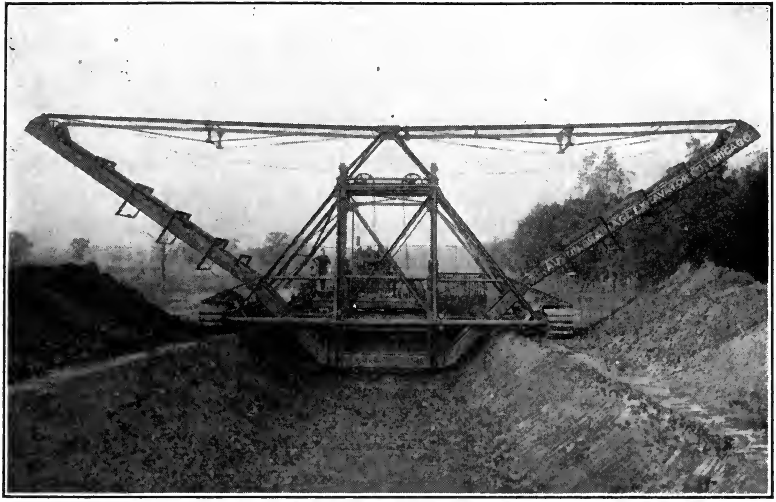

Fig. 59.—Austin templet excavator with wide bottom frame. (*Courtesy of F. C. Austin Co.*)

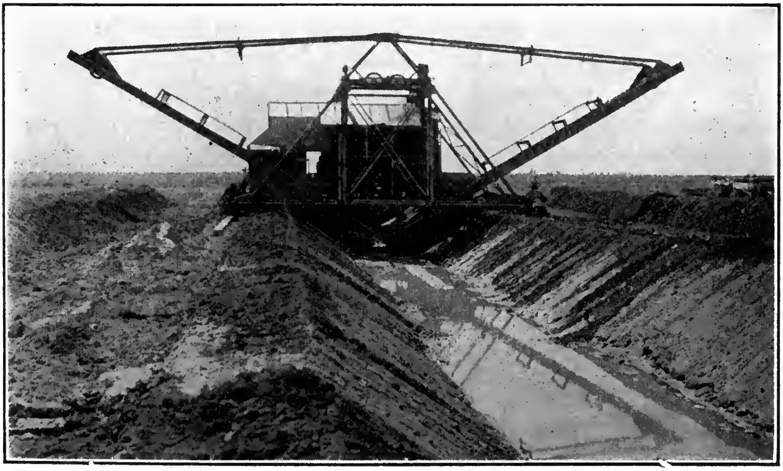

Fig. 60.—Austin templet excavator with narrow bottom frame. (*Courtesy of F. C. Austin Co.*)

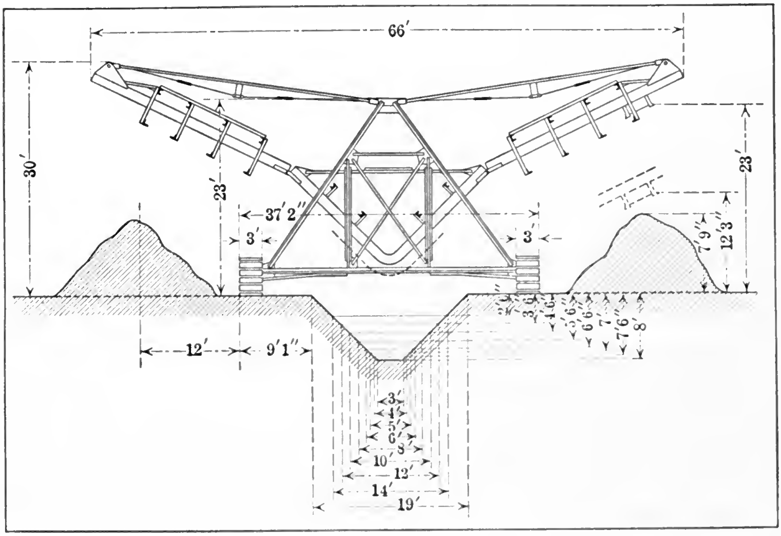

Fig. 61.—Limitations of Austin templet excavator with narrow bottom frame. (*Courtesy of F. C. Austin Co.*)

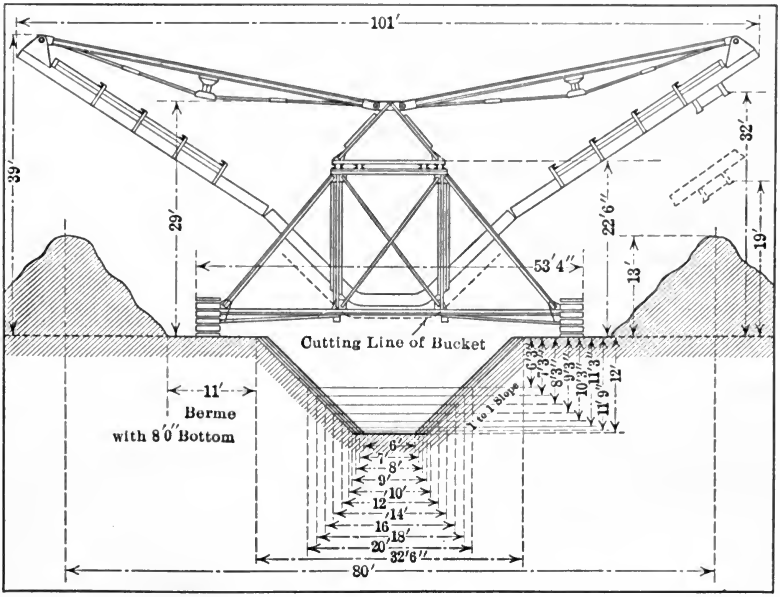

Fig. 62.—Limitations of Austin templet excavator with wide bottom frame. (*Courtesy of F. C. Austin Co.*)

The bucket is a rectangular-shaped box with two open ends and cutting edges. A plunger head fits inside the box section.

73. Method of Operation.—The guide frame is lowered to the ground surface and the bucket drawn down and along the bottom of the frame. As it moves along it cuts a thin slice of earth which is carried on to the upper section of the frame. Here trips are located and they push the plunger head through the bucket and thus the contents are discharged into either wagons or cars or upon a spoil bank below. As the bucket moves back and forth along the frame, the latter is lowered so as to gradually feed the bucket into the earth and increase the depth of cut. Thus a section of ditch prism about 3½ ft. in length is made with one position of the machine. The machine then moves ahead and cuts another section of ditch, and so on. The limitations of the two types of templets—narrow and broad bottoms—are given in Figs. 61 and 62.

74. Cost of Operation.—The gasoline-power machine equipped with caterpillar tractors is the type of templet excavator, which is most generally used in the excavation of channels in loose and soft soils. For the operation of this machine a crew of three to four men would be required; an engineer, an assistant, a laborer, and a teamster. A steam-operated machine, run on a track would require the services of one or two extra men to haul fuel, move track, etc. The engineer operates the bank of levers which control the movement of the bucket, the raising and lowering of the frame, and the tractive movement of the machine along the surface. The assistant keeps the machinery oiled and in good working order. The laborer provides planking or tracking where necessary, and does general service about the machine. The teamster hauls the gasoline, water, and supplies necessary for the work.

The cost of operation of a typical machine in the construction of a drainage channel through alluvial soil under favorable conditions would average about as follows for a 10-hr. day:

Operating Cost of Templet Excavator

Labor:		
1 engineer	$4.00	
1 assistant	3.00	
1 laborer	2.00	
1 team and driver	3.50	
Total labor cost, per day		$12.50

Fuel and Supplies:			
35 gallons of gasoline @ 25¢	$8.75		
Oil, waste, etc.	1.25		
Total fuel and supplies		$10.00	
General and Overhead Expenses:			
Depreciation (12½ per cent. of $12,000)[1]	$10.00		
Interest (6 per cent. of $12,000)[1]	4.80		
Repairs and incidentals	4.20		
Total general and overhead expenses		$19.00	
Total cost of operation for 10-hr. day			$41.50
Total excavation (cu. yd.)			700
Unit cost of templet excavation, per cu. yd., $41.50 ÷ 700 =			$0.059

75. Field of Usefulness.—A water channel, to secure highest efficiency of operation, should have a true grade and uniform and smooth side slopes. On irrigation and drainage projects, the distribution canals and open ditches are peculiarly susceptible to filling up with silt, débris, and vegetable matter during seasons of low flow. In the case of small ditches, this filling up may become so great in a few years as to render the channel practically useless. This means that these artificial waterways must be cleaned out every few years in order to maintain their efficiency and capacity. In order to reduce this maintenance expenses to a minimum, it is advisable to construct the channels as nearly mechanically perfect as possible.

The templet excavator is the best form of excavator for the construction of an open channel, where the soil conditions are favorable. In alluvial soils, such as loam, clay, sandy loam, and marl, the machine does very satisfactory work. But in hard soils, such as hard-pan or indurated gravel, and in lands where many obstructions such as stumps, boulders, and roots occur, the progress is slow and difficult and the work expensive.

LEVEE BUILDER

76. General Description.—The templet levee builder is a simple modification of the open-channel excavator described in the preceding articles. The machine consists of a platform,

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[1] Based on 150 working days in a year and an 8-year life.

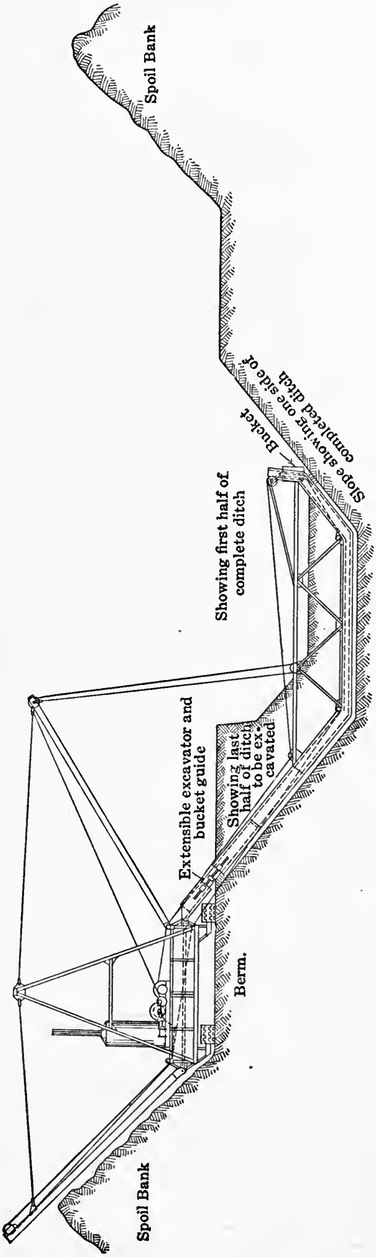

Fig. 63.—Templet levee builder. (*Courtesy of F. C. Austin Co.*)

which supports an excavator frame at one end and a levee runway at the other end. The platform is built of timber or steel and has a length of 22 ft. and a width of 20 feet. Upon the platform is placed the power equipment which is generally housed in. The platform moves on a track made up of 12 × 12 in. timbers, 200 ft. in length. On the tops of these timbers are spiked T-rails which support the flanged wheels of the platform trucks. For soft soils, caterpillar tractors are used.

The power equipment consists of a steam boiler and engine. The former is a 50-h.p. fire-box locomotive type of boiler weighing 10,500 pounds. The engine is a 40-h.p. reversible, double-cylinder, double-friction drum, hoisting engine, provided with steel gearing. The engine weighs about 12,000 pounds. A gasoline engine may be used instead of the steam equipment when desirable.

A four-legged A-frame, made up of structural steel members is supported on the platform. From the top of this frame, cables pass over steel sheaves to the outer ends of the excavator frame and the levee runway. These cables are connected to the drum of the hoisting engine and thus control the raising and lowering of these two frames. See Fig. 63.

On the outer or borrow-pit end of the platform is hinged a steel frame or guideway, which has the general shape of a ditch cross-section, and can be raised and lowered by means of cables passing over a sheave at the outer end of the frame, thence over a sheave at the top of the A-frame and thence to the engine. This frame forms a track over which a bucket passes. The bucket is made of steel plate with a heavy manganese steel cutting edge. Its length is 48 in., depth 36 in., and width 43 inches. Buckets having capacities of from 1⅓ to 2½ cu. yd. each can be used on this machine. The approximate weight of a 2-yd. bucket is 3000 pounds.

77. Method of Operation.—The process of excavation begins with the bucket at the farthest outside bearing of the runway. From this point the bucket is drawn by a cable over the guideway and then across the berm and up the levee runway and is dumped. Thus, the bucket in its path moves over a continuous guideway which extends from the outer point of the borrow pit, to the front of the platform and thence to the center of the levee. The bucket after dumping is pulled back along its track to the outer point of the cutting frame, where it commences the excavation of another slice of earth. The frame is gradually lowered as the bucket excavates, until the bottom of the frame is horizontal. Then the frame is raised and the whole machine moves ahead about 3 ft. to its position for the excavation of another section of the ditch.

78. Cost of Operation.—Under favorable conditions this machine will excavate and dump about 1000 cu. yd. of earth per 10-hr. day. The labor required is an operator, a fireman, a track gang composed of two men and a team of horses and a man and team for hauling fuel, supplies, etc. When caterpillar tractors are used the track gang is unnecessary, except when the soil is very soft and one or two extra laborers are required for planking. About two tons of coal are used in a 10-hr. shift. The operating cost for a 10-hr. day will vary from $25 to $30, when the soil conditions are favorable.

79. Field of Use.—The levee builder is made to excavate borrow pits with 1½:1 or with 1:1 side slopes. With

1½ to 1 slope, the machine can excavate a pit having a maximum depth of 20 ft. and bottom width of 20 ft. and a minimum bottom width of 5 feet. With 1 :1 side slopes, the maximum depth would be 30 ft. and corresponding maximum bottom width of 30 ft., and a minimum bottom width of 6 feet. The width of berm varies from 20 ft. to 40 ft. depending on the amount of material to be placed in the levee and upon local conditions.

This type of levee builder operates satisfactorily when the soil conditions are favorable. It is not adapted to hard soil or where there are many large stones, stumps, or other obstructions. It makes a borrow pit of smooth and uniform cross-section and deposits the material by means of an adjustable belt conveyor, at any desired distance from the pit. The work which this machine does is nearly mechanically perfect, and has a much more finished appearance than that done with a dredge.

80. Résumé.—A ditch should be made to a true grade and with uniform and smooth side slopes in order to ensure high working efficiency. Drainage and irrigation ditches are peculiarly susceptible to filling up with silt, débris, and vegetation during seasons of low flow. The author has seen very few ditches, whose capacity and efficiency, after 3 to 5 years use, were not considerably reduced. In the case of small ditches this often becomes a serious matter, sometimes rendering the ditch practically useless. The only remedy in such a case is the re-excavation of the ditch. Large channels generally require cleaning out every few years in order to maintain their efficiency and usefulness. In order to reduce this expense and labor to a minimum, ditches should be excavated as nearly mechanically true and uniform as is possible under existing conditions.

The templet excavator is the best form of excavator to use where soil conditions are favorable. It is not suited to the excavation of very wet land, or where trees, stumps and large stones abound. The use of caterpillar tractors enables the machine to work on soft soil by commencing at the outlet and working up-stream.

The templet excavator in the excavation of clay and loam, under average working conditions, has an average daily output of from 500 to 800 cubic yards. The operating cost will vary from 4 to 10 cents per cubic yard.

81. Bibliography.—For further information, the reader is referred to the following:

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CHAPTER IX

TRENCH EXCAVATORS

82. Classification.—The rapid development of sanitary and drainage engineering during the past 30 years has led to the general construction of sewer, water-supply and drainage systems. The great amount of trench excavation made necessary for the installation of these improvements has led to the use of special types of excavators. In work of any magnitude, these machines are more efficient and economical than hand labor.

Trench excavators may be divided into two general classes, viz.:

1. Sewer and water-pipe excavators.
2. Drainage tile-trench excavators.

I. PIPE-TRENCH EXCAVATORS

This class of excavators will be considered under the following classifications:

A—Continuous bucket excavator.
  (*a*) Endless chain type.
  (*b*) Wheel type.
B—Trestle cable excavator.
C—Trestle track excavator.

A—CONTINUOUS BUCKET EXCAVATOR

83. Preliminary.—There are two general types of excavators which are used for the construction of trenches with vertical sides; the chain and sprocket type and the wheel type. The wheel machine may be easily adapted to the excavation of open channels with sloping sides by the addition of a cutting device.

84. Endless Chain Excavator.—This form of excavator is built on the principle of the continuous excavator or ladder dredge and the several makes differ only in details of construction. The essential parts are a frame supported on wheel trucks, the operating mechanism and the excavating equipment.

The platform is built of steel members strongly braced and framed together. It may be supported on two trucks equipped with broad-tired wheels, or made in two sections and supported on three trucks. In the latter case, the rear section which carries the excavating chain is hinged to the main section which is supported on one truck. Figure 64 shows a diagrammatic view of this type, and Fig. 65 shows a view of the single-platform machine.

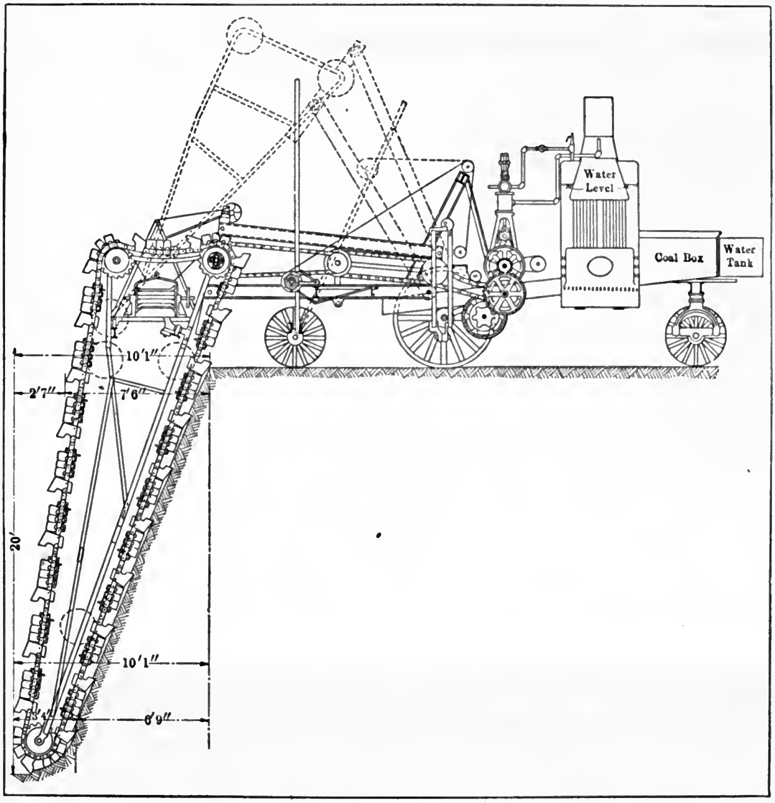

Fig. 64.—Parsons trench excavator. (*Courtesy of the Parsons Co.*)

A steam or internal-combustion engine may be used. The latter is more economical in sections of the West where coal is expensive, and is cleaner, more compact, and does away with the use of a fireman and the discomfort of a boiler in warm weather.

A steam-power equipment consists of a boiler, an engine, and the transmission mechanism. The boiler is of the vertical, tubular type and is placed near the front end of the platform. The engine is placed behind the boiler and is of the single-cylinder, vertical type. Power is transmitted to the bucket chain, the disposal conveyor, and the central axle, for traction through gears and sprocket chains.

The excavating equipment consists of the bucket chain, and the disposal conveyor. The bucket chain in one type of machine comprises an endless chain moving over sprocket wheels on the ends of an arm, which is suspended from the rear end of the platform and is adjusted to permit of the excavation to the proper grade regardless of inequalities of the surface over which the machine passes. In the other type of trench machine, a circular wheel is suspended from the rear of the platform and revolves on a central axle.

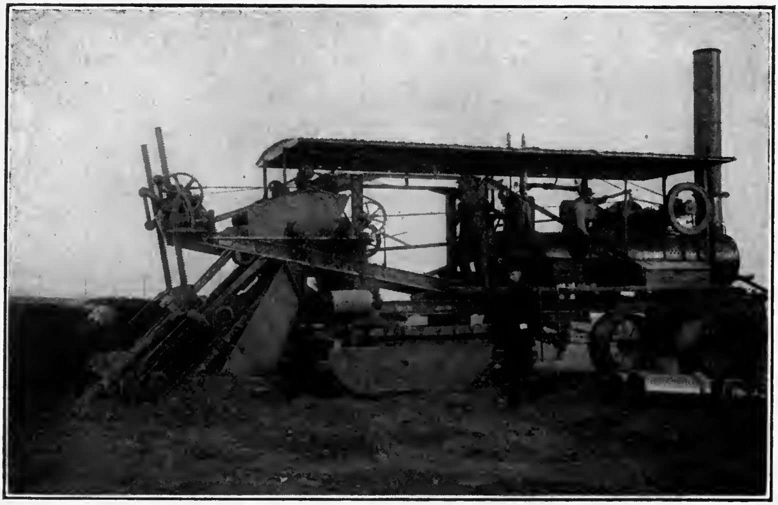

Fig. 65.—Chicago trench excavator. (*Courtesy of F. C. Austin Co.*)

The buckets are attached to the sprocket chain or to the periphery of the wheel. They are scoop shaped and provided with cutting edges or teeth, depending upon the nature of the material to be excavated. The width of the trench is governed by the width of the buckets, which are made in several widths and can be easily removed and changed. In one make of machine, an increased width of trench can be secured by moving the whole bucket chain sideways along the supporting frame. This arrangement provides for the excavation of a trench up to 6 ft. in width without changing the buckets and also the excavation of a manhole at any point without delay. Figure 66 shows a sectional bucket used on the Parsons Trench Excavator.

The disposal conveyor consists of a belt conveyor placed at the rear of and transversely to the platform. Its elevation is below the top of the bucket chain. At the top sprocket, the buckets turn over and deposit the material on this moving belt, which conveys it to one side of the trench and deposits it in a spoil bank.

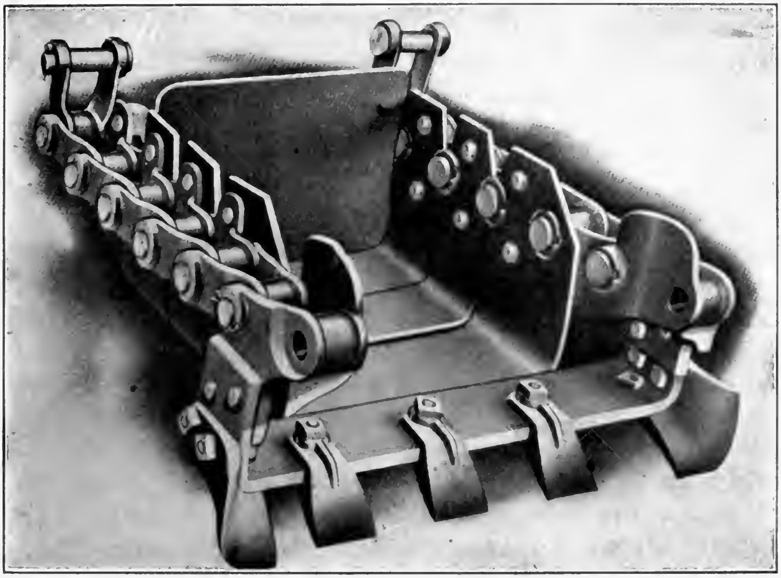

FIG. 66.—Bucket of the Parsons trench excavator. (*Courtesy of the Parsons Co.*)

85. Method of Operation.—The labor crew necessary to operate a trench excavator depends on the character and magnitude of the work and the kind of power used. With a steam-power equipment, an engineer or operator, a fireman, and one or more helpers will be required. The operator has direct charge of the operations of excavation and traction. The fireman operates the boiler and has general supervision of the engine. The helpers are of general service in furnishing the machine with fuel, water, and supplies, in bracing the trench when necessary, and in general service about the work.

The bucket chain moves downward and inward and removes a thin slice of material as each bucket comes in contact with the soil. The depth of cut is regulated by raising and lowering the free end of the frame. When obstructions, such as cross pipes, large boulders, etc., occur, the chain may be raised over them and fed down into the earth on the other side. The material, from the top of the revolving chain or wheel, falls upon the belt conveyor and is carried to either side of the trench, making a continuous spoil bank.

When one section has been excavated, the machine moves ahead and starts another slice. The excavating chain or wheel can be raised clear of the surface and the machine moved over ordinary roads at a speed of about 1 mile per hour. Table VI gives the dimensions, weights, capacities, and costs of three different makes of trench excavator. See page 129.

86. Cost of Operation.—The following comparison of the cost of excavation of a trench by hand and by machine labor will be of interest to the reader.

The soil is clay and loam and the ground surface fairly level and solid enough to support a trench machine. The trench has a width of 28 in. and an average depth of 12 feet. Each laborer will excavate 7 cu. yd. per 10-hr. day and as the material must be rehandled for the last 3 ft. of depth of cut, we will assume five extra men for the work and not include their output. A crew of 45 men will dig 350 ft. of trench during a 10-hr. day and the total excavation will be about 315 cubic yards. The same crew will back fill at a cost of 7 cents per cubic yard. The machine will excavate 250 ft. of trench per 10-hr. day. The back filling will be done by teams and scrapers. Following is a detailed statement of the cost of the work for the two methods, based on a 10-hr. day.

COST OF TRENCH EXCAVATION BY HAND

Labor:			
1 foreman	$4.00		
1 timberman	3.00		
1 helper	2.50		
1 pipe layer	3.00		
1 helper	2.50		
50 laborers @ $2.00 each	100.00		
Total labor cost for excavation		$115.00	
Back filling 315 cu. yd. @ 7¢		22.00	
Total cost of hand work for 10-hr. day			$137.00

COST OF TRENCH EXCAVATION BY MACHINE

Labor:		
1 foreman	$4.00	
1 timberman	3.00	
1 helper	2.50	
1 pipe layer	3.00	
1 helper	2.50	
1 engineer	4.00	
1 fireman	2.50	
3 teams @ $4.00 each { 1 hauling for excavator 2 back filling trench	12.00	
2 laborers @ $2.00 each	4.00	
Total labor cost, per day		$37.50
Fuel and Supplies:		
1 ton coal	$4.00	
Oil, and waste	1.00	
Water	1.00	
Total fuel and supplies		$6.00
Overhead and General Expenses:		
Interest (6 per cent. of $6000)[1]	$1.80	
Depreciation (10 per cent. of $6000)[1]	3.00	
Repairs	2.70	
Incidentals	4.50	
Total general and overhead expenses		$12.00
Total cost of operation for a 10-hour day		$55.50

Total cost of excavation of 350 ft. of trench, pipe laying, and back filling by hand work, for a 10-hr. day, is $137.00.

Total cost of excavation by machine of 225 ft. of trench, pipe laying by hand work, and back filling by scrapers is $55.50.

A comparison of the above results shows that during a 10-hr. day, a trench excavator will do about 70 per cent. of the amount of trench excavation that can be done by hand labor and at 40 per cent. of the cost.

87. Field of Usefulness.—The continuous bucket excavator is especially adapted for trench excavation, where the width does not exceed 72 in. and the depth 20 ft., and the soil conditions are favorable. This is especially true through the Middle West,

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[1] Based upon 200 working days in a year and a 10-year life.

where clay and loam with few obstructions such as boulders, roots, etc., predominate up to shallow depths.

On account of the great weight of the machines, they are not practicable for use in soft wet soils, unless mounted on caterpillar tractors. For the excavation of hard soils, considerable trouble is often experienced on account of the breaking of the bucket chain. Hence, it is desirable to use a machine with a strong, heavy chain for the digging of hard-pan, blue clay, and other hard, tough materials.

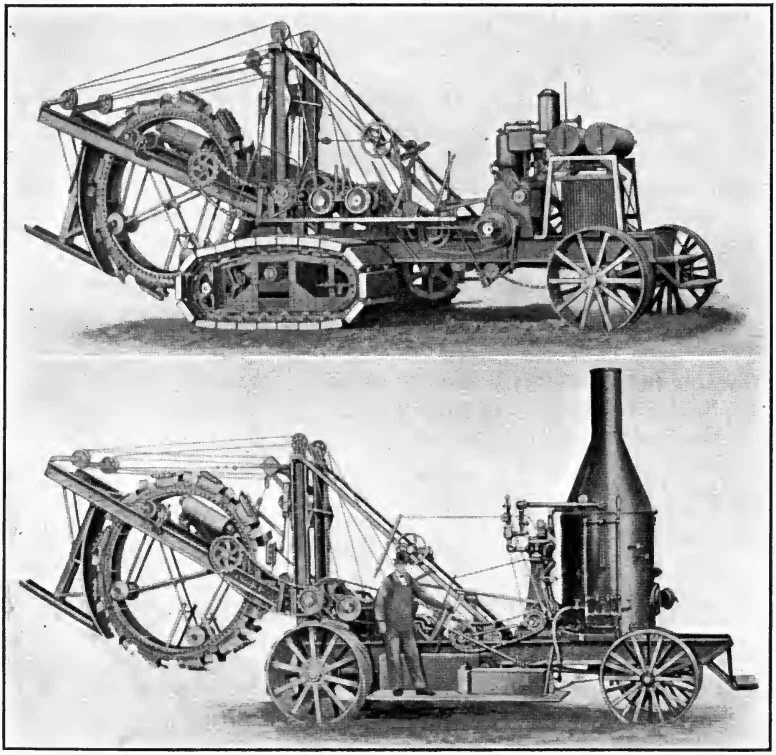

FIG. 67.—Buckeye traction ditcher. (*Courtesy of Buckeye Traction Ditcher Co.*)

The trench excavator is efficient and economical for the excavation of trenches 24 in. and over in width and over 6 ft. in depth, and one machine can do the work of from 80 to 200 men.

88. Bucket Wheel Excavator.—A well-known type of trench excavator uses a wheel instead of a chain for the support of the buckets. The principal parts of this machine are a traction engine and a frame which supports the excavating equipment.

The traction engine or power equipment consists of a vertical steam boiler and engine or a gasoline engine. The size of engine varies from a 12-h.p. gasoline engine on the smallest size machine to a 90-h.p. multiple-cylinder engine of a 55-h.p. two-cylinder vertical steam engine and boiler on the largest size machine. See Table VI, page 129.) Figure 67 shows a No. 5 Buckeye traction ditcher equipped with the two kinds of power plant.

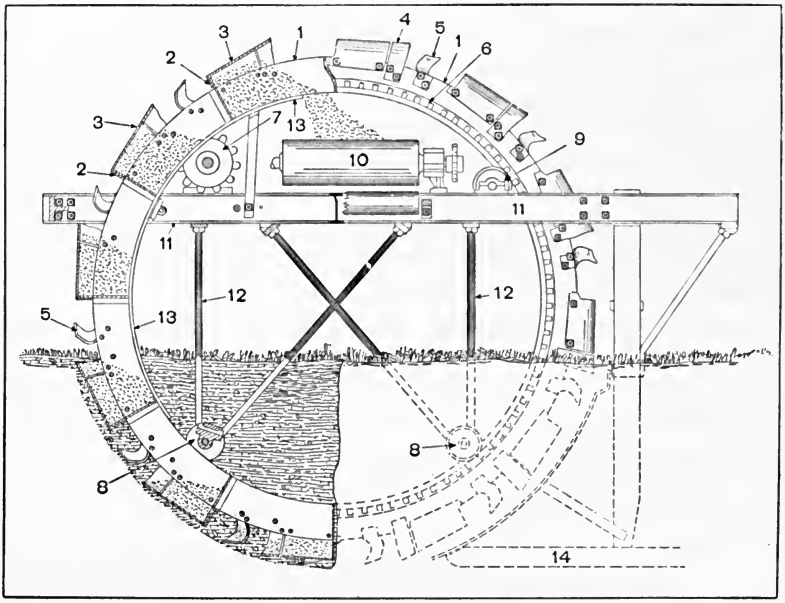

Fig. 68.—Diagram of excavating wheel of Buckeye traction ditcher. (*Courtesy of Buckeye Traction Ditcher Co.*)

Attached to the rear end of the truck or engine frame is the wheel frame, connected with a cross-bar, which moves vertically between two posts. The front part of the frame can be raised and lowered by means of a ratchet wheel. The rear part of the frame is connected to sheaves at the top of the vertical frame by cables, which may be operated to raise the wheel from the ground when it is desired to move the machine from one trench to another.

The wheel frame carries an open wheel 8 ft. in diameter and 12½ in. wide. This wheel has no axle, but revolves by means of four anti-friction wheels placed inside the rim. See (8) and (9) in Fig. 68.

On the outer rim of the wheel are placed 14 buckets as shown by (3). These buckets have a top and back, but not a bottom.[1] They are shaped somewhat like the bowl of a drag-scraper; and in fact, thay act very much like a drag-scraper in digging; for as the excavating wheel revolves, each bucket cuts off a slice of earth of its own capacity. Now, this earth would fall out when the bucket rises above the surface of the ground if it were not for the high-carbon steel arc, marked (13) in Fig. 68. This arc does not revolve, as it is not fastened to the wheel. When an excavating bucket reaches the end of the arc near the top of the wheel, the dirt falls out of the bucket upon the belt conveyor. This conveyor, which is marked (10), carries the dirt off outside of the trench where it piles up. It will be noted that the dirt slides over the stationary arc (13) only a short distance near the top of the wheel, hence there is very little wear on the arc. As we have said, the excavating wheel does not have an axle; it is made to revolve by a pair of driving sprockets (7), which mesh with the segmental gearing (6). It should be noted that the driving sprocket (7) is directly above the point where the earth is being excavated, so that the force is applied directly. Thus the weight of the excavating wheel is far less than would be necessary were it driven from an axle, involving also great torsional strain. What is even more important, the excavating wheel can dig into the ground to a depth of nearly two-thirds its diameter, so that with a comparatively small wheel a great depth of trench is secured.

"It will be seen that the excavating wheel is supported between two beams, marked (11), which can be raised and lowered. The rear end of the frame is supported by a post, to the lower end of which is fastened a shoe (14). This shoe slides along the bottom of the finished trench, thus giving great stability to the wheel and preventing wabbling. The side cutters (5), are bolted to the rims of the excavating wheel. They serve to slice the earth from the sides of the trench, and prevent the excavating buckets from sticking or becoming bound in the trench. Moreover they scrape all the dirt toward the center of the trench, where the buckets pick it up, leaving a perfectly clean cut."

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[1] This description and Fig. 68 are taken from the catalogue of the Buckeye Traction Ditcher Company.

TABLE VI.—SIZES AND CAPACITIES

Austin Trench Excavators

Size No.	Power, kind	Weight (tons)	Excavation		Digging speed maximum (ft. per minute)	Traction bearing		Dimensions over all		Wheel base (ft.)
			Depth maximum (ft.)	Width (in.)		Sizes each (in. × in.)	Area total (sq. ft.)	Width (ft.)	Length (ft.)	
000	Gasoline	9.0	6	12, 15, 18	10	24 × 60	20	8	33	12½
00	Gasoline or steam	11.3	8	15, 18, 24	9	30 × 60	25	9	36	13
0	Gasoline or steam	20.0	10	18, 24, 30, 36	10	30 × 72	30	10	45	16
1	Gasoline or steam	24–25	15	24 to 36	6	30 ×108	45	10	44	16
10	Steam	33.0	20	24 to 72	3	28½ ×132	52¼	10	57	21½

Parsons Trench Excavators

Type	Power	Weight (tons)	Excavation		Buckets			Wheels (No.)	Traction, kind	Dimensions over all	
			Depth (ft.)	Width (in.)	Length (in.)	Width (in.)	Depth (in.)			Width (ft.)	Length (ft.)
KO.......	Gasoline or steam	11	8	22	24	22	9	2	Caterpillar	9½	42
K........	Gasoline or steam	14	12	22 to 42	24	22	9	2	Caterpillar	9½	46
E.........	Steam	24	20	28 to 60	....	28	....	6	Wheel or caterpillar	10	35
F........	Steam	26	20	28 to 78	....	28	....	6	Wheel or caterpillar	10	35

Buckeye Traction Ditchers

Type	Power	Weight (tons)	Excavation		Wheel base (ft.)	Tread front wheels (ft.)	Width rear tires (in.)	Cost	
			Depth (ft.)	Width (in.)				Wheel	Caterpillar
5	Gasoline or steam	15	5½	20, 24, 28	14½	8⅓	20	$5,100	$6,400
6	Gasoline or steam	16	6½	20, 24, 28	14½	8⅓	20	7,600	8.200
7	Gasoline or steam	17½	7½	20, 24, 28	17½	7½	20	8,400	9,000
8	Gasoline or steam	21	7½	24, 28, 32, 36	17	8⅙	24	8,900	9,500
9	Gasoline or steam	33	10	28, 36	20	8¾	28	11,000	11,600
10	Gasoline or steam	38	12	28, 36	22	8¾	30	12,600	13,250

When excavating in a trench the machine moves continuously forward, and thus gradually feeds the wheel into the soil. The cutting speed can be varied by shifting the sprocket wheels. The depth of cut is regulated by the operator, who sights over a sight-arm, on the side of the wheel frame, at a series of targets on flag-poles. By turning a hand wheel he raises and lowers the excavating wheel until the sight-arm is at the proper level. The alignment is kept by lining in the centers of the front and rear wheels with the flag-poles. Where the ground is fairly level, a true line and grade can be easily kept, but when the surface is rolling or uneven, constant attention is necessary.

The traction speed of an excavator, when digging, is 1 mile per hour but on account of the necessary stops to take on coal and water, to fill dead furrows, etc., an average speed of ¾ mile per hour is all that can be attained. Two men are generally necessary to run a steam-operated machine, one to tend the boiler and engine and the other to operate the excavating wheel. It is often more economical of fuel and labor to use a machine operated by a gasoline engine.

The cost of operation and the field of usefulness is about the same as explained above in Articles 86 and 87.

B—TRESTLE CABLE EXCAVATOR

89. Trestle Cable Excavator.—The trestle cable excavator has been in general use, especially in the eastern section of this country, during the past 30 years, for the excavation and back filling of large trenches for waterworks and sewer systems. It has many admirable features and is especially well adapted to large sewer trench work in hard soils. A trestle cable excavator on sewer-trench construction is shown in Fig. 69.

This type of excavating machine consists of a series of trestles supporting an overhead track. The trestles or bents are connected by rods at the bottom and by the beam track at the top and rest upon a plank or rail track. The operating machinery is carried by a platform located at one end of the structure. The overhead track supports several carriers which carry the buckets or tubs. The whole framework is self-contained and can be moved ahead as a unit from one section of the work to another.

The trestles are made of timber framed together to form square or A-shaped bents. They are from 15 ft. to 20 ft. in height and are equipped with castor frames, wheels, etc. These bents are connected together at the bottom by bars of tubular steel of from 1 in. to 2½ in. in diameter. The bents rest on T-rails which are spiked to sections of planking, and enough track is provided to move the whole machine ahead 100 ft. at a time.

The track or support for the travelers or carriers is made up of sections of I-beams or channels which are bolted to or hung from the head blocks of the bents.

The operating equipment consists of the boiler, engine, and car upon which the machinery is placed.

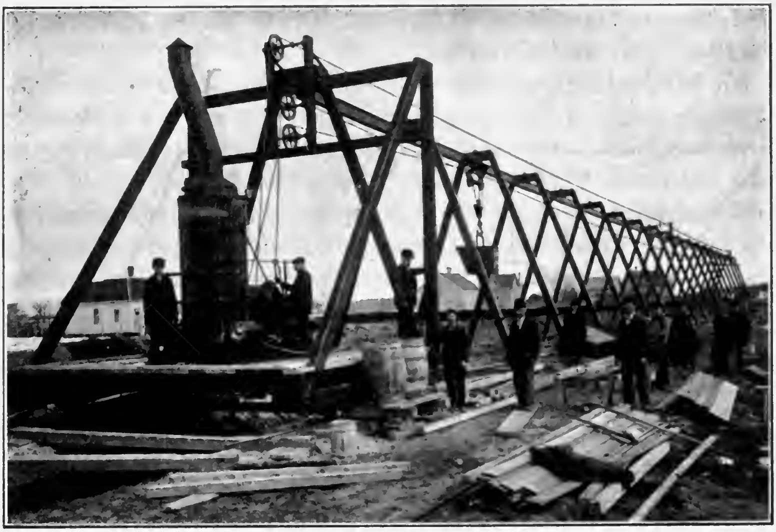

Fig. 69.—Trestle cable excavator operating in sewer trench construction. (*Courtesy of Carson Trench Machine Co.*)

The boiler is of the vertical, tubular type, and is equipped with all appliances for efficient operation and control. It is usually operated at a steam pressure of about 100 pounds. The engine is a 2-drum, double-cylinder, hoisting machine with reversible link motion. The drums are controlled by friction-clutch brakes; one carries the hoisting rope, and the other carries the endless rope which operates the carriers and buckets. The drums are independent, and so arranged that they may be operated in unison or separately. The boiler and engine are generally mounted on the same bed plate which is supported by a platform mounted on rollers or wheel trucks. The front end of the car supports the head trestle. A suitable house is usually built, in sections, over the platform and may be used completely or partly, depending on climatic conditions.

The excavating equipment consists of the tubs, the carriers, and the cables.

Upon the overhead track run several carriages, travelers, or carriers, which are provided with wheels made to fit the flanges of the structural sections. From each carrier is suspended a tub which is equipped with an automatic catch and is self-dumping and self-righting. The carriers are connected by a continuous rope which is operated by a drum on the engine, and are raised and lowered by hoisting ropes controlled by a rope operated by another drum on the engine.

90. Method of Operation.—The labor crew necessary to operate a trestle cable excavator consists of an engineer, a fireman, a latchman, and a tubman. The engineer operates the engine and has general charge of the work. The fireman supplies the boiler with fuel, and oils the machinery. The latchman operates the latches, which release and grip the tub lines for raising and lowering the buckets. The tubman hooks and unhooks the tubs, and has general charge of their filling and emptying.

The machine being set up in position, the engineer operates the hoisting line and releases the jaw clutches on the tub ropes, thus allowing the tubs or buckets to drop into the excavation. The tubs are unhooked and another set of filled tubs hooked on. The loaded tubs are then hoisted up to the locks on the carriers, and the whole set is moved to the disposal place by the operation of the continuous traversing line. Usually one section of the trench is being excavated while another section is being back filled, so that the material removed at the former place can be utilized directly in the latter. It may be necessary at the beginning of the work, or in special cases of crossings, etc., to dump the material into temporary spoil banks, or into carts for removal from the site. As soon as one section is completed, the machine pulls itself ahead by means of a winch on the engine and a rope passing through a snatch block attached to a dead man set ahead.

Machines may be had with double and single upper tracks. The nominal capacity of a double-track machine is 50 per cent. greater than that of a single-track machine, as one set of buckets is being raised loaded, while the other set is being lowered empty.

Thus, three sets of buckets are continually in use, one set being filled, one hoisted and carried to the dump, and the other dumped and returned to be loaded. A double-track machine is more economical for trenches over 5 ft. in width.

The average output for a 6-bucket, single-track machine is about 125 cu. yd. for a 10-hr. day.

91. Cost of Operation.—The rental charge of a 6-bucket single-track machine is about $200.00 per month. The cost of transportation, setting up, and dismantling will vary with the distance, length of haul, experience of men, etc., and will range from $100.00 to $500.00.

About ¼ ton of coal per day will be used, and the cost of oil, waste, supplies, etc., will vary from $1.00 to $5.00 per day. The net cost of operation of the machine would be about $25.00 per day. Assuming an average output of 100 cu. yd., the cost of the work exclusive of sheeting, pumping, loosening of material in trench, etc., would be about 25 cents per cubic yard.

92. Field of Usefulness.—The trestle cable excavator is especially adapted to the excavation of trenches for large sewers and water mains in hard soils, and in city streets. The work is restricted to the immediate area of the trench, leaving part of the street unobstructed for traffic. The method of operation is efficient, as the excavated material is generally used directly in back filling. The method of operation is also easy, simple, and safe.

93. Carson-Trainor Excavator.—For trenches through sand, gravel and clay where the cableway type of machine is desirable but impracticable on account of the anchorages, a special type of machine, known as the "Carson-Trainor Machine," has been devised. This excavator is a hoisting and conveying device similar to the regular trench machine. A series of A-shaped or rectangular trestles, resting on a track, support an overhead trackway made up of a double-channel beam. A traveler runs upon the lower flange of this girder, and is held in position or moved backward and forward by an endless steel traversing rope attached to a special drum of the engine. The hoisting is done by a separate steel cable attached to the main drum of the engine. The machinery, consisting of the boiler and the engine, is mounted on a covered car, placed at the head of the excavation. The whole framework has a gage of 16 ft., a height from ground to peak of 20 ft., and a working section of a length of 288 feet.

TABLE VII.—SPECIFICATIONS OF "CARSON-TRAINOR" EXCAVATOR

I. Single Traveler, Hoisting One Tub at a Time

Name	Distance between trestles	Length of machine	Height of trestles	No. of tubs used	Size of tubs	Lifting capacity of engine	Size of engine, double cylinders	Size of boiler on engine bed	Size of car or engine house
Empire State..............	16 ft.	288 ft.	20 ft.	5	27 cu. ft.	8000 lb.	8¼×10 in.	42×90 in.	16×18 ft.
Bay State.................	16 ft.	240 ft.	20 ft.	5	21 or 27 cu. ft.	8000 lb.	8¼×10 in.	42×90 in.	16×18 ft.

II. Double Traveler, Hoisting Two Tubs at a Time

Name	Distance between trestles	Length of machine	Height of trestles	No. of tubs used	Size of tubs	Lifting capacity of engine	Size of engine, double cylinders	Size of boiler on engine bed	Size of car or engine house
Chicago Limited............	16 or 18′	288 ft.	20 ft.	10	27 cu. ft.	8000 lb.	8¼×10 in.	42×90 in.	16×18 ft.
Philadelphia Special........	16 or 18′	240 ft.	20 ft.	10	20 cu. ft.	8000 lb.	8¼×10 in.	42×90 in.	16×18 ft.

Table VII gives the dimensions and capacities of the various sizes of machine. A view of a Carson-Trainor excavator in operation on sewer-trench construction is shown in Fig. 70.

Fig. 70.—"Carson-Trainor" trench excavator on sewer trench construction. (*Courtesy of Carson Trench Machine Co.*)

C—TRESTLE TRACK EXCAVATOR

94. General Description.—The trestle track excavator is very similar in its method of operation to the trestle cable excavator. The principal difference is the suspension of the carriers from a car or carriage which moves along a track supported on the tops of the trestles.

The construction consists of a series of light, steel-frame trestles, of trapezoidal shape and 6 ft. in height, spaced about 10 ft. on centers. These trestles are mounted on double-flanged wheels, which run on rails. The tops of the trestles are connected by steel channels which form a continuous track on which the carriage runs.

The operating equipment consists of a vertical, tubular boiler, and a double-drum hoisting engine, carried on a car at the forward end of the machine.

The excavating equipment consists of a steel-frame car supported on four wheels which run upon the trestle track. The car is operated by cables which connect to the hoisting engine.

On the car is a hoist which raises and lowers two steel buckets. The buckets are made in three sizes; ⅓, ⅔, and 1 cu. yd. capacities. A view of a car in operation is shown in Fig. 71.

95. Method of Operation.—The machine requires a crew of three men; one to operate the hoisting engine, and two to operate the bucket hoists on the carriage.

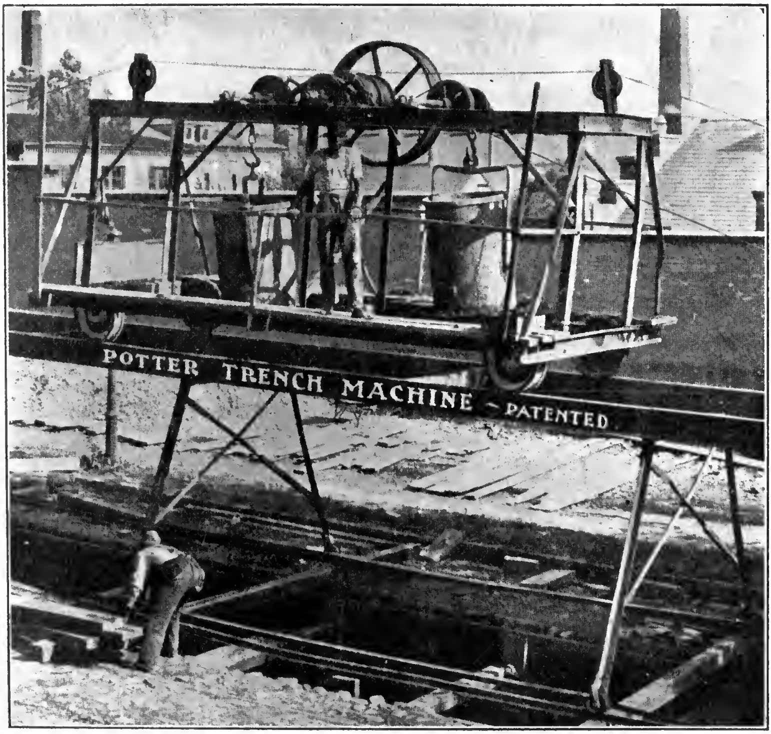

Fig. 71.—Trestle track excavator. (*Courtesy of Potter Mfg. Co.*)

The carriage is moved by a cable from the hoisting engine to the place of excavation, where either one or both buckets are lowered into the trench, filled by the laborers in the trench, and raised above the floor of the car. The car is then moved to the place of back fill or dump, where the buckets are lowered and dumped.

96. Cost of Operation.—The following statement is given as a typical case of the cost of excavation with a trestle track machine.

The trench had a width of 21 ft. and an average depth of 30 feet. The material excavated consisted of a shallow top layer of loam, then 15 ft. of soft blue clay, 6 to 8 ft. of stiff blue clay, 1 ft. of sandy loam, and then about 2 ft. of hard blue clay. The trench machine was equipped with 6 buckets of ½ cu. yd. capacity, and four were filled while the remaining two were being removed and dumped. The excavator removed the lower 12 or 14 ft. of the trench.

The following gives the cost of operation based on an 8-hr. day.

OPERATING COST OF TRESTLE TRACK EXCAVATOR

Labor:			
1 foreman	$5.50		
1 engineer	5.00		
1 fireman	3.00		
1 car operator	3.50		
1 car helper	2.00		
20 laborers in trench @ $2.00 each	40.00		
1 laborer on dump	2.00		
Total labor cost, per day		$61.00	
Fuel and Supplies:			
½ ton coal @ $4.00	$2.00		
Oil, waste, etc.	1.00		
Repairs	1.50		
Total fuel and supplies		$4.50	
General:			
Rent of machine @ $125 per month		$5.00	
Total cost of operation for an 8-hr. day			$70.50
Average daily excavation (cu. yd.)			175
Unit cost of trestle track excavation, per cu. yd., $70.50 ÷ 175 =			$0.40

97. Field of Usefulness.—The trestle track excavator has the same scope and advantages as the trestle cable excavator. It is especially efficient in trench excavation in congested city streets where the demands of keeping at least part of the street open to public traffic requires the restriction of the work to as limited an area as possible.

On very wide trenches, it is advisable to use a machine equipped with a double track and two cars in order to facilitate the work.

II. DRAINAGE-TILE TRENCH EXCAVATORS

98. Preliminary.—Until about 18 years ago (1900), a large part of the trench excavation for tile drainage was done by hand labor. As this class of reclamation work became more general, especially in the Middle West, various forms of machinery were devised to meet the demand for power excavators. These tile-trench excavators may be classified under the same divisions as the "Pipe-Trench Excavators;" (*a*) Endless-chain type and (*b*) Wheel type.

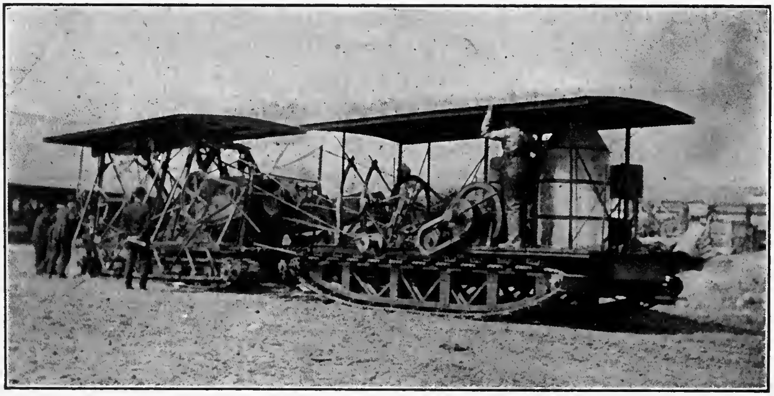

Fig. 72.—Hovland tile ditcher. (*Courtesy of St. Paul Machinery Co.*)

99. Endless-chain Type.—There are several makes of this type of tile-trench excavator and the following description is given of a typical make which has been devised and is used for the laying of the tile as well as for the excavation of the trench.

The Hovland tile ditcher is made in two sections; a front platform which carries the power equipment, and a rear platform which carries the excavating chain. Both platforms are made of steel framework supported on two large caterpillar tractors. Fig. 72 shows a general view of the Hovland tile ditcher.

It will be noticed that the forward tractor carries the power equipment which consists of a vertical, three-cylinder gasoline engine. The main shaft of the engine is connected by sprocket chains to the driving shafts of the excavating belt of the tractions, and of the belt conveyor.

The excavating equipment is carried on the rear platform and consists of an excavating chain and its supporting framework.

The excavating chain is made up of two continuous chains which carry an endless set of hinged links. To the vertical sections of these links are bolted the knives or cutters of any width from 5 in. to 30 inches. The links are hinged in such a way that when a cutter strikes a stone or other obstruction in a trench, the chain gives, and the cutter slides over the obstruction without injury. An automatic cleaning device consisting of a projecting arm, is placed above the upper end of the chain and scrapes over the surface of each bucket as it passes. The excavated material is thus removed from the buckets and falls upon a moving belt conveyor which is located under the excavating chain at its upper end.

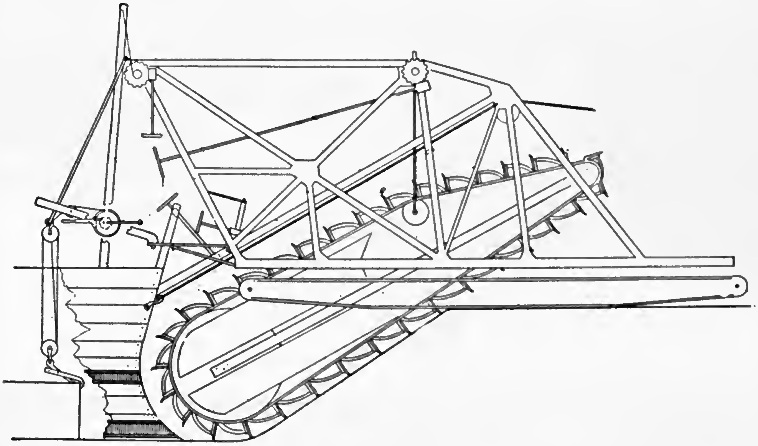

Fig. 73.—Diagram of excavating chain of Hovland tile ditcher. (*Courtesy of St. Paul Machinery Co.*)

The framework which supports the excavating chain is shown in Fig. 73. It comprises a small, upper wheel and a large, lower wheel, or drum, about which the chain revolves. The lower wheel is suspended by chains from the rear of the frame and can be raised and lowered by a gear-operated shaft. The upper wheel is on a shaft which is chain driven from the engine located on the forward platform.

An adjustable steel-frame curbing can be fastened to the rear of the excavating tractor and drawn along the completed trench.

This curbing can be adjusted to the width of the trench and made high enough to project above the ground surface. A steel spout is placed on the inner and curved portion and as the machine progresses, a man places a tile in at the top of the spout, which is curved so as to allow the tile to slide out in place along the bottom of the finished trench.

100. Method of Operation.—A crew of three or more men are necessary to properly operate a tile-trench excavator an engineer who has charge of the operating equipment, an operator who manipulates the excavating wheel, a tile layer and one or more laborers to supply fuel, water, and supplies for the machine and for general service about the work.

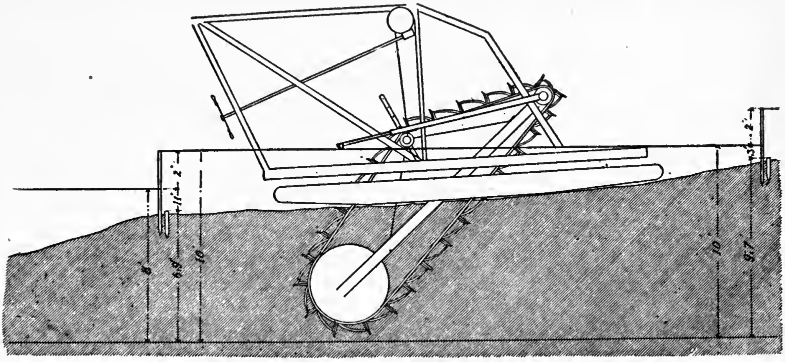

Fig. 74.—Diagram showing the operation of the excavating chain of the Hovland tile ditcher. (*Courtesy of St. Paul Machinery Co.*)

The revolution of the excavating chain or wheel brings a series of knives or buckets into contact with the soil and each bucket removes a slice of earth, which is dumped upon the belt conveyor and carried to the spoil bank, at the sides of the trench. See Fig. 74. The operator lowers the wheel or chain into the soil as the excavation proceeds and governs the depth by a sight rod, placed on the machine. As soon as the required depth is reached the engineer sets the tractor chain in motion and the machine moves ahead to the next position.

With the Hovland tile ditcher the drain tile can be laid as the excavation is completed, by placing the tile in the curb which follows directly behind the excavating chain, Fig. 183. It is often necessary to reset the tile after it leaves the curb in order to secure proper alinement and close-fitting joints.

One manufacturer has devised a longitudinal belt conveyor, which carries the excavated material to a point behind the machine and dumps it back into the trench. This device has not been satisfactory because it does not allow enough time after the excavation for the placing of the tile.

101. Cost of Operation.—An approximate estimate of the capacity and cost of operation of a tile ditcher will be given in the following statement.

A trench machine has gasoline power equipment and an excavating chain or wheel capable of digging a trench 14½ in. wide and 4½ ft. deep. The soil is loam and clay with gumbo in places. The average depth of cut is 4½ ft., and the average progress is 1300 ft. per 10-hr. day.

Operating Cost of Tile Ditcher

Labor:			
1 operator @ $125 per month	$5.00		
1 fireman	3.00		
1 helper	2.00		
1 team and driver	3.50		
Total labor cost, per day		$13.50	
Fuel and Supplies:			
10 gal. gasoline @ 25¢	$2.50		
Oil, waste, etc.	0.50		
Total fuel and supply cost		$3.00	
General and Overhead Expenses:			
Interest (6 per cent. of $5200)[1]	$2.00		
Depreciation (12½ per cent. of $5200)[1]	4.25		
Repairs and incidentals	2.75		
Total general expense		$9.00	
Total operating cost per 10-hr. day			$25.50
Average progress per day (ft.)			1300
Average daily excavation (cu. yd.)			260

Unit cost of tile-trench excavation, per
ft. $25.50 ÷ 1300 = $0.019
per cu. yd. $25.50 ÷ 260 = 0.098

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[1] Based upon 150 days per year and an 8-year life.

102. Field of Usefulness.—The tile-trench excavator is a very efficient and practicable machine for ordinary soil conditions in fairly level land with few obstructions. Where the soil is low and wet, the machine must be supported on caterpillar tractors to distribute the weight over the soft soil. Where obstructions such as large stones, roots, etc., abound, a large amount of extra hand labor is required.

For work of considerable magnitude, the tile ditcher can excavate a trench at about one-half the cost of hand labor.

103. Wheel Type.—This type of tile-trench excavator has been described in the early part of this chapter under Article 88 and the reader is referred to this article for further information.

104. Résumé.—The type of excavator to be used on any particular job of pipe-trench construction depends on the character of the soil, the extent of the work, the width and depth of trench, the available operating space and other conditions.

Where soil conditions are favorable and the width of the trench is not over 36 in., the wheel type of machine can be economically used. For trenches having a width greater than 36 in. and a depth greater than 12 ft., the endless-chain type of excavator is required. The use of either of these two types is impracticable in caving or very hard, dense, soils. The parts of the excavating equipment should be properly proportioned for strength and the best of material combined with simplicity of design.

Where trenches are over 6 ft. in width and 8 ft. in depth, the continuous bucket type of excavator cannot be used. The trestle cable or trestle excavators are especially devised to meet the requirements of wide trench excavation, especially in the restricted areas of city streets.

The tile-trench excavator has become a thoroughly practical and efficient machine for the excavation of drainage tile trenches. In the loam and clay soils of the ordinary low, wet land, this type of excavator equipped with caterpillar traction is a very efficient machine. Where obstructions such as large stones, stumps, etc., abound, a large amount of extra hand labor is required.

The tile box or templet which follows the machine and automatically lays the tile in the bottom of the trench, is a useful device but for successful operation, requires careful attention and adjustment. As a general thing hand-laid tile is more accurate as to alinement and fitting of joints than when laid by machine.

Although the use of the longitudinal carrier or conveyor has not proved very efficient or economical, improvements may be made in its operation so that less power may be required and more allowance made for laying the tile.

The wheel type of machine is more generally used for the excavation of trenches for the smaller sizes of tile; 8 in. and under, while the endless-chain machine has a greater range in size and capacity and is better adapted to the larger work.

The internal combustion engines are generally used on the smaller size machines on account of light weight and economy of labor and fuel. Where wood or coal are plentiful and cheap, steam machinery is more desirable.

Farmers and contractors doing a small amount of trenching will find it advisable to use a type of machine with a detachable tractor which can be easily detached from the digging equipment and used for general purposes.

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CHAPTER X

WHEEL EXCAVATORS

106. Preliminary.—There has been a great demand, especially during the past decade (since 1907) for a machine that would construct small, open ditches on reclamation work. Most types of excavators are unfitted on account of size and method of operation to construct the smaller size ditches of drainage and irrigation systems, and this condition has resulted in the introduction of some light, portable machines, one of which is the templet excavator.

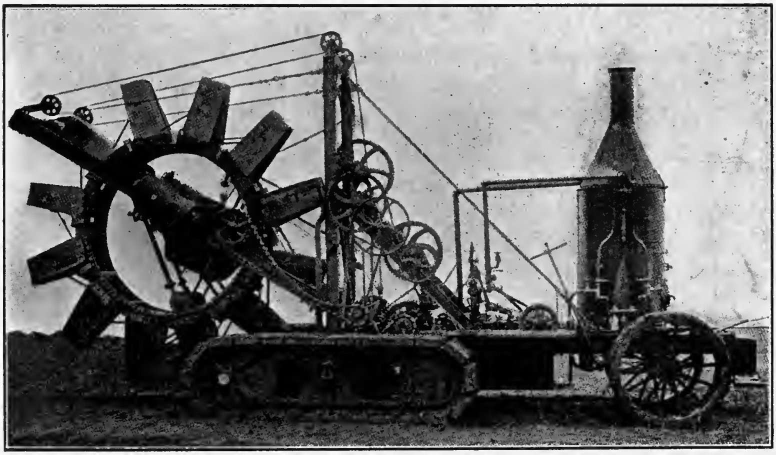

FIG. 75.—Wheel excavator. *(Courtesy of Buckeye Traction Ditcher Co.)*

107. General Description.—The ditcher consists of a frame which supports the power equipment on the front end, and a pivoted frame-work containing the excavating wheel on the rear end. The platform is supported at the front on an axle which has two broad-tired steel wheels, and at the rear by two caterpillar tractors, which allow the machine to operate in wet, soft soils. A view of a wheel excavator is shown in Fig. 75.

The power may be supplied either by a steam or internal combustion engine. The earlier machines were supplied with the former type of engine but the more recent machines are nearly all equipped with gasoline engines. These gasoline engines are generally of the marine type and made with four-cycle multiple cylinders, ranging from 20 h.p. to 90 horse power. They are provided with high-tension magneto and dual ignition.

The motive power is transmitted to the wheels either by sprocket-chain or bevel-gear drive.

The excavating equipment consists of the excavating wheel and belt conveyor. The wheel is an open steel frame, around the periphery of which are attached from 8 to 12 buckets of scoop shape. At the rear and near the upper part of the wheel is placed the belt conveyor, which projects out a considerable distance either side of the machine.

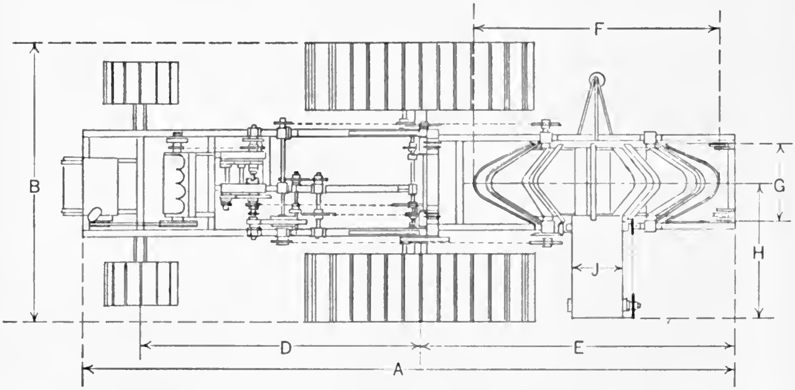

Fig. 76.—Diagram of general dimensions of wheel excavators. (*Courtesy of Buckeye Traction Ditcher Co.*)

108. Method of Operation.—The excavating wheel revolves either on a central axle or anti-friction wheels placed along its rim and each bucket cuts out a thin slice of earth which is deposited on the machine end of the belt conveyor, when the bucket reaches the top of the wheel. The operator gradually feeds the wheel into the ground as the wheel revolves. After one section has been dug to the required depth, the machine moves ahead several feet under its own power and another section is dug, and so on. The sizes, limitations, and capacities of the various sizes of a well-known make of wheel excavator are given in Fig. 76 and Table VIII.

TABLE VIII.—GENERAL DIMENSIONS OF WHEEL EXCAVATORS

Size No.	1	2	3	4	5	6	7	8	9
Length over all, A	35′	41′	42′	44′ 6″	48′	49′ 6″	53′	55′	55′
Width over all, B	14′	16′	19′ 3″	20′	21′	22′ 6″	24′ 8″	26′ 8″	28′ 8″
Height over all, C	16′	18′	18′	18′	18′ 6″	19′	19′	19′ 6″	19′ 6″
Wheels center to center, D	14′ 6″	16′	16′	18′ 6″	20′	21′ 3″	24′	26′	26′ 3″
Traction aprons	3½′×10′	4′×10′	5′×10′	4¾′×12′	5½′×12′	6′×12′	6′×14′	6½′×14′	7′×14′
Rear axle to rear end, E	19′	20′ 6″	21′	23′	23′ 6″	24′	24′	24′	24′
Cutting wheel diameter, F	14′	15′	17′	18′ 4″	19′	19′	19′	19′	19′
Cutting wheel width, G	2′ 6″	4′ 6″	6′	7′	8′	9′	10′	11′	12′
Wheel cut, greatest depth	5′	6′	6′	6′	6′ 6″	6′ 6″	6′ 6″	6′ 6″	6′ 6″
Ditch center to Conveyor end, H	4′ 6″	7′	9′ 6″	11′	12′ 6″	14′	15′ 6″	16′ 6″	18′
Conveyor belt width, J	24″	30″	30″	30″	36″	36″	36″	36″	36″
Machine weight, net (lb.)	36,000	42,000	50,000	58,000	66,000	75,000	83,000	91,000	100,000
Export (Gross (lb.))	42,400	49,500	58,800	68,300	77,700	88,300	97,800	107,200	117,800
Weight (Tare (lb.))	6,400	7,500	8,800	10,300	11,700	13,300	14,800	16,200	17,800
Export volume, knocked down and crated (cu. ft.)	900	1,050	1,250	1,450	1,650	1,875	2,075	2,275	2,500
Cost, f.o.b. factory	$7,200	$8,300	$10,000	$11,500	$13,200	$15,400	$16,300	$17,100	$19,300

TABLE IX—SPECIFICATIONS OF AUSTIN WHEEL DITCHER

Size No.	Horse power		Maximum depth	Width of cuts[1]	Traction speed per hour	Delivering dirt	Height of machine[2]	Approximate gross weight
	Steam	Gasoline						
No. 00 with bank sloping attachment......	12	24	5 ft.	90 in.	.... 1½ miles	Either side	11 ft.	29,000 lb.
No. 00 with bank sloping attachment......	20	40	6 ft.	Any slope up to 10 ft. 1 : 1	....	....	11 ft.	39,000 lb.

[1] NOTE.—The digging cuts are the widths of the buckets only. Buckets should never be used without side cutters except in very soft ground. Side cutters will increase the width of cut from 1½ to 4 inches.

[2] NOTE.—We give only approximate figures on width, height, and weight. Different equipments change these figures.

One type of wheel excavator is convertible, so that by removing the side supports, the bank sloping attachment is eliminated and the machine becomes a trench excavator. Table IX gives the capacity, weight, etc., of the two different sizes of this excavator. A view of one of these machines constructing a small drainage channel is shown in Fig. 77.

Fig. 77.—Wheel excavator constructing small ditch. (*Courtesy of F. C. Austin Co.*)

109. Cost of Operation.—The cost of operation depends on the size of the job, the size and make of excavator, the character and condition of the soil, the efficiency of the operator, etc.

With a machine which digs a ditch with a top width of 4 ft. 6 in., an average depth of 3 ft. 6 in., bottom width rounded to 12 in., and side slopes of about ½ : 1, the average cost of operation for a 10-hr. day would be about as follows:

Operating Cost of Wheel Excavator

Labor:		
1 operator @ $125 per month	$5.00	
1 assistant	3.00	
2 laborers @ $2.00	4.00	
1 team and driver	3.50	
Total labor cost, per day		$15.50

Fuel and Supplies:			
30 gal. gasoline @ 25¢	$7.50		
Oil, waste, and supplies	1.50		
Total fuel and supplies		$9.00	
General and Overhead Charges:			
Depreciation (12½ per cent. of $6000)[1]	$5.00		
Interest (6 per cent. of $6000)[1]	2.40		
Repairs and incidentals	4.60		
Total general and overhead expense		$12.00	
Total operating cost per 10-hour day			$36.50
Average progress per day (ft.)			2300
Average daily excavation (cu. yd.)			800
Unit cost of wheel excavation, per cu. yd., $36.50 ÷ 800 =			$0.046

110. Résumé.—The wheel excavator is the most practical form of excavator for small ditches where the soil conditions are favorable. This machine cannot excavate economically very hard, dense soils, or where large quantities of stumps, boulders, and other obstructions are present. In glacial clay, alluvium, marl, and similar soils, this excavator operates very smoothly and satisfactorily.

In irrigation and drainage systems, where the smaller ditches run full only a small part of each year, a large amount of silt, débris, and vegetation gradually accumulates. These obstructions in the course of a few years will gradually fill up and greatly reduce the carrying capacity of the channels. Hence, it is necessary to construct the smaller channels to as near true grade and cross-section as is practicable. In open, porous soils, such as occur often on irrigation projects, it becomes necessary to line the ditches with some impervious material such as concrete to prevent large seepage losses. In such cases it is a great advantage to excavate a channel, which is to be subsequently lined, with a true grade and smooth side slopes, so that the form work for the concrete may be set without the extra labor and expense of trimming and shaping the excavation.

111. Bibliography.—For further information, the reader should consult Articles 105 and 221, pages 143 and 330.

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[1] Based on 150 working days a year and an 8-year life.

CHAPTER XI

CABLEWAYS

112. Preliminary.—The tower cableway is an excavating, hoisting and conveying device, first utilized about 1875, in the slate quarries of eastern Pennsylvania. For a period of about 20 years, the cableway was used largely in quarry and logging operations. Recently, this machine has been adapted successfully to the conveying of materials on construction work, the excavation of the lighter and softer soils, the hoisting and conveying of the harder soils excavated by other machinery, the excavation of sand and gravel pits, etc.

There are two general classes of cableway excavators; the drag-line cableway and the fall-line cableway.

A. DRAG-LINE CABLEWAYS

113. General Description.—The drag- or slack-line cableway excavator was developed and used successfully several years ago on the Chicago Drainage Canal and more recently on the New York State Barge Canal. This machine was termed the tower excavator from its principal part which was a movable tower. See Fig. 78.

The essential features of this machine are, the tower or mast which may be either fixed or movable, the operating equipment and the excavating equipment.

The mast is used in a quarry or pit where one end of the machine may be fixed. The height of the mast should be sufficient to give a fall of from 10 to 15 ft. in each 100 feet. For heights of 50 ft. or less, a pole or tree may be used, while for greater lengths, a mast of built-up lumber or steel is desirable. These structures must be supported by guy lines anchored back to the ground.

When it is necessary to have a movable support, as in the operation of a cableway excavator, along a pit or channel, a tower should be used. The tower is a framed, timber structure, the height of which is determined by the width of the area to be excavated. The tower rests on a platform or car, which is braced by overhead, horizontal-chord, combination trusses. This car is mounted on four solid, double-flanged, cast-steel wheels, generally about 12 to 16 in. in diameter and with 4-in. treads. The wheels run on a track, which consists of 80–90-lb. rails spiked to cross ties bolted to 30-ft. planks. The car and tower are moved about by a cable which passes over a sheave on the car and thence to a "dead man" or anchorage placed at a suitable point ahead of the car, and then back to a drum on the engine. The tower is braced to the car by cables which extend from the top of the tower to the rear corners of the car.

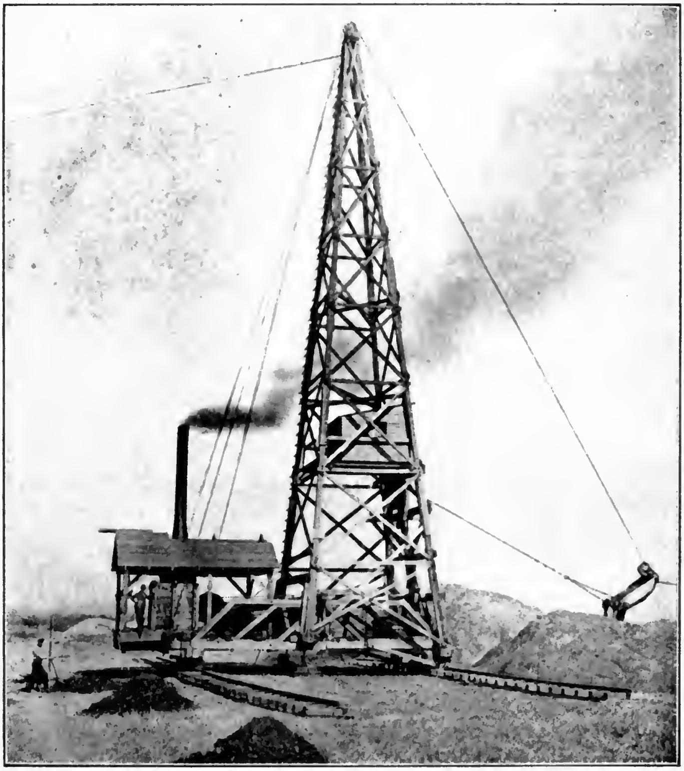

Fig. 78.—Tower excavator.

The power equipment is placed near the mast or on the rear of the car and consists of a vertical boiler and a double-drum hoisting engine. The engine is generally of the vertical, reversible type, with double cylinders and equipped with friction-clutch control for the drums. When electric current is available the cableway can be efficiently operated by a two-drum electrically driven hoist.

The early type of excavating equipment consisted of a two-line scraper bucket. At the rear of the bucket is a frame carrying two sheaves at right angles to the cutting edge, which is strongly reinforced and provided with teeth for the excavation of hard material. See Fig. 79. On the bottom of the bucket are two curved shoes or shims. The front of the bucket is connected to the drag-line drum of the engine by a cable which passes over a sheave suspended on the front side of the tower about one-fourth of its height from the base. Another cable extends from the hoisting drum of the engine over a sheave at the top of the tower, then between the sheaves on the bail of the bucket and thence to an anchorage, at the far side of the excavation.

Fig. 79.—Scraper bucket of tower excavator.

114. Method of Operation.—The bucket is lowered over the hoist line by allowing it to slide down the cable by its own weight, to the far side of the cut. Then the bucket is loaded by pulling it toward the tower by winding up the drag-line cable.

When the spoil bank is reached, the hoisting cable is raised and the bucket is overturned and dumped. The bucket is returned to the excavation by still further tightening the hoisting cable and releasing the drag-line cable, whereby the busket rises and slides back to the starting point. Where a tower of 65 ft. in height was used, a reach of 210 ft. from the far side of the excavation to the near side of the spoil bank was attained with efficiency of operation. A bucket of 2 cu. yd. capacity, made an average output of 3 cu. yd. and was operated at the rate of 4 cu. yd. per minute.

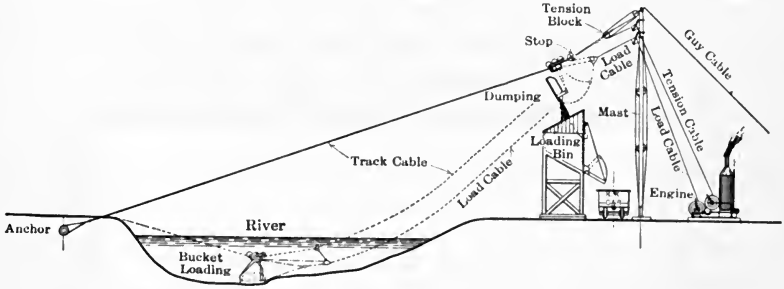

FIG. 80.—Diagrammatic view of drag-line cableway. *(Courtesy of Sauerman Bros.)*

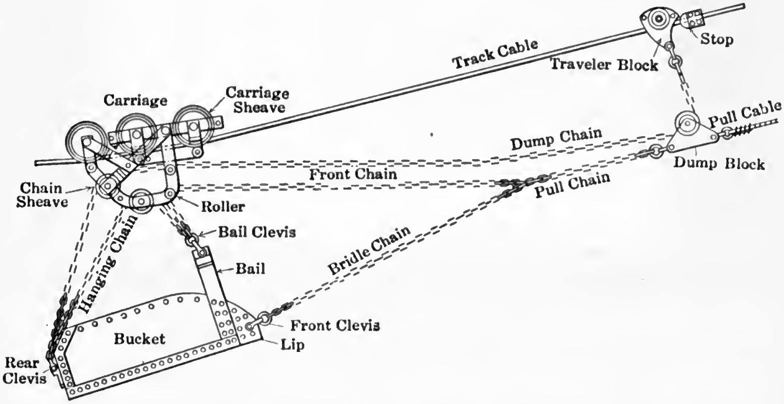

FIG. 81.—Shearer and Mayer drag-line cableway bucket.

A recent form of excavating equipment is shown in Figs. 80 and 81. The bucket is lowered into the excavation by slackening the cables. It is then drawn forward until filled when the track cable is tightened and the drag line is drawn in. The bucket is thus lifted and pulled in to the dumping point simultaneously. When the bucket reaches the dumping point, a block running on the track cable is arrested by a stop clamped on the cable. The pull on the load chains is then transferred to the dump chains connected with the rear of the bucket which is dumped by the continuous forward pull on the load cable.

A simple form of excavator which came into use about 9 years ago (1910) is shown in Fig. 82. The peculiar feature of this bucket is the latch and engaged arms on the front end. When the arms of the latch come into contact with the stop on the track cable, at the dumping place, the hook is disengaged and the latch line takes the load. As the cables are slacked by the operator, the front end of the bucket swings down, the weight pulling on the latch line causing the bucket to press against the stop and the bucket is discharged. If the load line is entirely released, the bucket starts backward and the bucket swings to a vertical position, discharging the load in a mass.

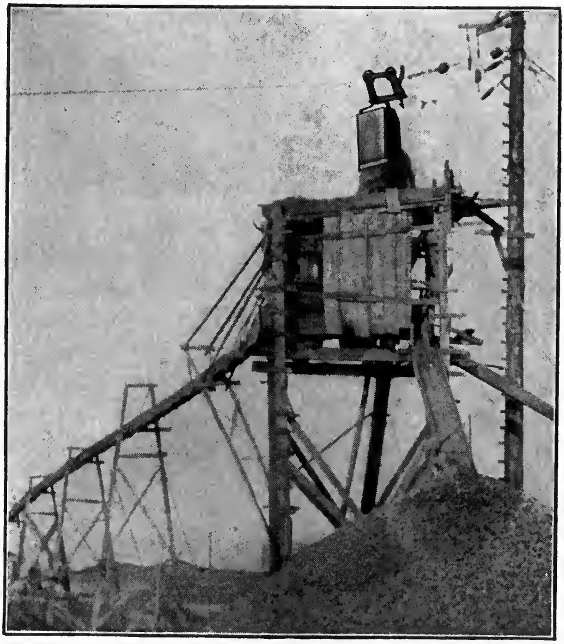

Fig. 82.—Cableway excavator operating at gravel pit. (*Courtesy of Indianapolis Cable Excavator Co.*)

A crew of from 4 to 9 men is required to operate a tower excavator, depending on the magnitude of the job, the character of the material to be excavated, etc. Under average conditions, there will be required an operator, a fireman, a team and driver, and three laborers. The operator is stationed near the hoist, and where a tower is used stands on a platform on its rear side and at about one-third its height. He controls the machinery by a set of levers and brakes and has an unobstructed view of the work. The fireman keeps the boiler and machinery supplied with fuel, water and oil, and in proper working condition. The team and driver haul fuel, water and supplies to the work. The laborers move the track and perform general service about the work.

115. Double-tower Excavator.—A double-tower excavator was used some years ago on a section of the Chicago Drainage Canal. A diagrammatic view of this excavator is shown in Fig. 83. As will be noted from the plan, the inclined booms were so designed that a straight line from the apex to either tower to the point of the opposite boom, clears the side of the tower. This allowed each bucket to clear the tower and empty directly on the adjacent spoil bank.

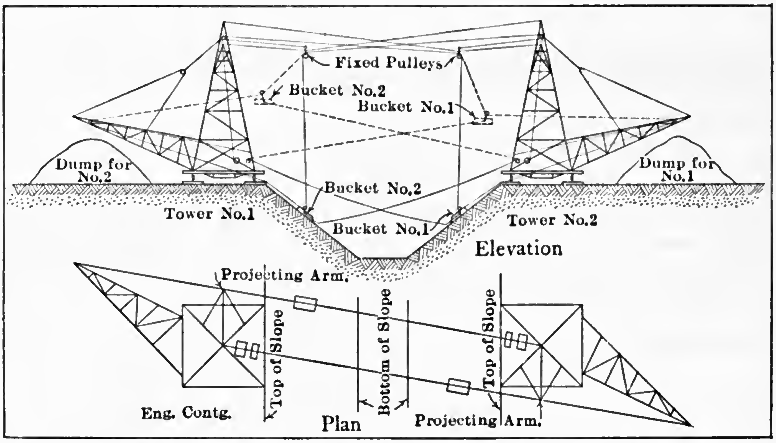

FIG. 83.—Diagram of double tower excavator. (*Courtesy of Engineering and Contracting.*)

A double-drum hoisting engine was located on the side of the platform of each tower. Each bucket was operated by a drag line and a hoisting line. The buckets were loaded, dumped, and returned to the excavation as is described above for the single-tower excavator. By changing the location of the suspended sheaves the position of the bucket in digging was altered so as to reach the entire half width of the canal prism. This machine, in the excavation of a canal section having a bottom width of 26 ft., side slopes of 2:1, and an average depth of 27 ft., through a clay soil, did very satisfactory work.

116. Cost of Operation.—The following may be taken as an estimate of the cost of operation of a single-tower excavator, equipped with a 75-ft. tower, controlling a 250-ft. width excavation, a 2-yd. scraper bucket, and a 10 × 12-in. double-drum, vertical hoisting engine. The excavated material would be dumped upon a spoil bank at the tower side of the excavation and into wagons or dump cars by means of a loading platform. A train of four 5-yd. dump cars would be loaded in about 15 minutes. An average output of 600 cu. yd. would be attained in the excavation of a glacial clay under average working conditions during a 10-hr. working day:

OPERATING COST OF SINGLE-TOWER EXCAVATOR

Labor:			
1 engineer	$4.00		
1 fireman	3.00		
1 team and driver	3.50		
3 laborers @ $2.00 each	6.00		
Total labor cost, per day		$16.50	
Fuel and Supplies:			
⅞ ton of coal @ $4.00	$3.50		
Oil, and waste	0.50		
Total fuel and supplies		$4.00	
General and Overhead Expenses:			
Depreciation (10 per cent. on $2000)[1]	$1.40		
Interest (6 per cent. of $2000)[1]	0.80		
Repairs, and incidentals	5.50		
Total general expense		$7.70	
Total cost of operation for 10-hr. day			$28.20
Average excavation per 10-hr. day (cu. yd.)			600
Unit cost of single-tower excavation, per cu. yd., $28.20 ÷ 600 =			00.047

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[1] Based on a 10-year life and 150 working days per year.

117. Field of Usefulness.—The tower excavator was originally used in canal excavation where the cross-section was very wide with a comparatively shallow depth. When the top width of a channel is over 80 ft., it becomes necessary to use drag-line excavators in pairs, one along each bank, or a floating dipper dredge which shifts from one side of the channel to the other. The tower excavator can cut the full width of the channel at one set-up and complete the section as it moves along. This type of excavator could not be used satisfactorily in very wet soils, or where rock occurred in great quantity.

The tower excavator is especially efficient in the excavation of large, shallow areas such as reservoirs, athletic fields, and the basements of large buildings. In such cases, it might be advisable to have the tower or towers move over curved tracks; the center of curvature being the point of anchorage of the hoist cable.

Quarries, surface mines, and gravel pits can be economically stripped with a tower excavator, when the area covered is sufficient to warrant the installation of the plant and the soil conditions are favorable to uniform scraper-bucket operation.

B. FALL-LINE CABLEWAY

118. Preliminary.—The fall-line or suspension cableway may be inclined or horizontal. The latter is the type used on construction and excavation work and will be described in this chapter. Cableways are used for the transportation of materials across a valley or stream, the hoisting and removal of excavated material, the transporting and placing of stone, concrete, etc., in structures and the excavation of foundations, pits, quarries, etc.

119. General Description.—The essential features of a cableway are the towers, the power equipment and the operating equipment.

The terminals of the cableway are generally wooden-framed towers which may be arranged in the following manner:

(*a*) Two fixed towers.

(*b*) One tower fixed and the other mounted on a barge in water or traveling on a circular track.

(*c*) Two movable towers traveling on parallel tracks. Fig. 84 shows one terminal of two cableways used on the construction of a large masonry dam.

The power equipment consists of a boiler and an engine.

The boiler is generally of the vertical, tubular type, and equipped with the necessary accessories for operation at a pressure of about 100 pounds.

The engine is a two-drum, double-cylinder machine, fitted with reversible link motion. The drums are of the friction-brake type; one for the hoisting rope, and the other for the endless, traversing rope or cable. The drums can be operated simultaneously or independently.

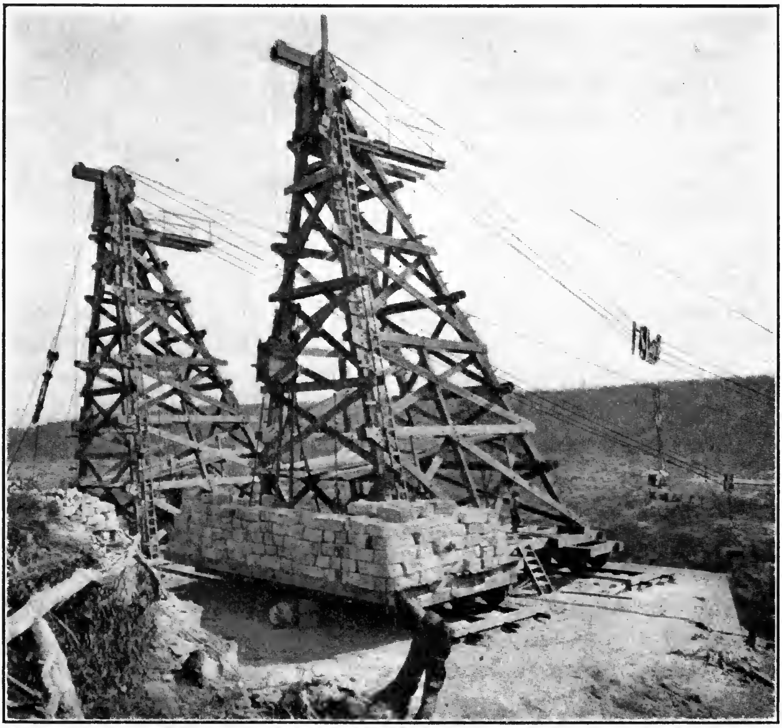

Fig. 84.—Cableways on construction of dam. (*Courtesy of the Lidgerwood Mfg. Co.*)

The cableway may be operated also by either compressed air or electric power. The latter method has been recently used with great success on several large contracts; the Panama Canal and several Reclamation Service projects. Either direct- or alternating-current apparatus may be used. For the former, the type of motor is the interpolated pole series railway for 550-volt direct-current circuit with current limit automatic and hand control and for the latter an alternating-current motor-wound for three-phase, 60-cycle, 440 volts with magnetic control.

The operating equipment comprises a traveler, the tubs, buckets or skips, and the cables. The main cable is made of crucible steel and of a diameter depending upon the span, load, elevation, and type of work. It passes over sheaves and saddles on the tops of the towers and is anchored behind them. This cable is the track over which the carrier travels. The hoisting and traversing ropes are crucible steel cables of from ⅝ in. to ⅞ in. in diameter and extend from their respective drums on the engine over the sheaves at the tops of the towers and thence to the carrier. A high-speed carrier used on the construction of the Panama Canal locks is shown in Fig. 85.

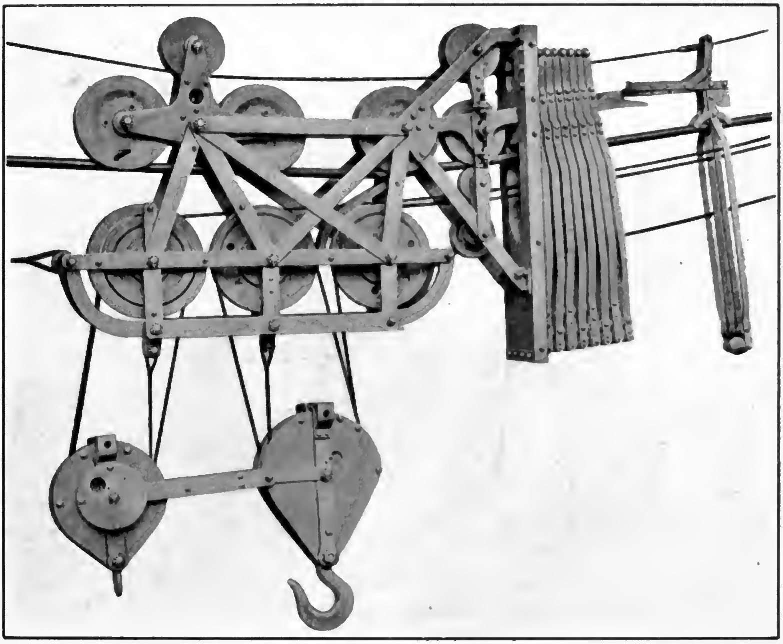

FIG. 85.—High speed cableway carriage. (*Courtesy of S. Flory Mfg. Co.*)

120. Method of Operation.—For trench excavation, a cableway having a length or span of from 200 ft. to 400 ft. is generally used. The length of excavation will be about 50 ft. shorter than the distance between towers.

The labor crew required consists of an engineer, a fireman, a signalman and two or more laborers. The engineer operates the engine and has general charge of the work. The fireman provides the boiler with fuel and water, and looks after the oiling of the machinery. The signalman signals to the engineer for the raising and lowering of the bucket or tub. The laborers are used in filling and in dumping the tub, and in general service about the job.

The bucket is lowered into the trench, filled by the shovelers, and then raised above the excavation by the operation of the hoisting drum, which is thrown out of gear and held by a brake. The traversing line is then operated and the carrier moved in either direction until the bucket is over the place for dumping. Then the bucket is lowered by means of the brake band on the hoisting drum. The material may be used for back fill in a section of trench where the pipe is laid, or dumped into a spoil bank or into wagons for removal to a distant place of disposal. A small crane or derrick may be used to advantage, adjacent to the excavation, for the transfer of buckets from the cableway to the dumping board or hopper.

Fig. 86.—Cableway excavator digging a sewer trench.

121. Cost of Operation.—A typical case of sewer-trench construction will be considered in the following statement of the cost of excavation with a cableway.

The trench is 12 ft. wide and with an average depth of 20 feet. The soil varies from a surface layer of loam of 2 ft. depth, through a clay substratum of 8 ft., to a hard gravel deposit. The machine has two 30-ft. towers placed 300 ft. apart and is equipped with 1-yd. tubs or buckets. See Fig. 86. Bracing and sheeting were carried on at the same time as the excavation, and the sewer construction followed closely to allow for back filling at one end of the section with the material from the other end.

Following is an estimate of the cost of excavation under average working conditions, during a 10-hr. day. A crew of 30 men are required to pick and shovel the material into the buckets and the average daily output will be taken as 300 cubic yards.

Operating Cost of Tower Cableway

Labor:			
1 foreman	$4.00		
1 engineer	5.00		
1 fireman	3.00		
1 signal	2.50		
2 dumpers @ $2.00 each	4.00		
30 laborers @ $2.00 each	60.00		
Total labor expense, per day		$78.50	
Fuel and Supplies:			
½ ton coal @ $4.00	$2.00		
Oil, waste, etc.	1.00		
Repairs	1.50		
Total fuel and supplies		$4.50	
General and Overhead Expenses:			
Interest (6 per cent. of $8000)[1]	$2.40		
Depreciation (10 per cent. of $8000)[1]	4.00		
Incidental expenses	2.60		
Total general expense		$9.00	
Total cost of operation for a 10-hr. day			$92.00
Total output for a 10-hr. day (cu. yd.)			300
Unit cost of tower cableway excavation, per cu. yd. of material handled, $92.00 ÷ 300 =			0.30
Unit cost of hoisting, conveying, and dumping, (excluding pick and shovel labor), per cu.yd. of material handled, $29.00 ÷ 300 =			$0.097

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[1] Based upon 200 working days in a year and a 10-year life.

122. Résumé.—The cableway excavator has a wide and important field of usefulness. It is especially efficient in the handling of materials across large waterways, valleys, quarries, pits, etc., where surface transportation would be difficult and very expensive. In the excavation of large quarries, gravel pits, surface mines, dam foundations, reservoirs, etc., the cableway can be used as a tower excavator directly or to convey skips, tubs, or buckets which contain the material previously excavated by other machines. The same cableway can of course be used for the transportation of concrete, stone, timber, and other building materials, as well as tools, men, etc., during the construction work which follows the excavation.

The cableway can be satisfactorily used in trench excavation when the excavation is of large extent, generally over 6 ft. in width and 10 ft. in depth. With the use of this type of excavator, the weight of the machinery is largely concentrated at the ends of the trench, the cable is at a considerable height above the work and allows space for storage, handling of materals, etc. The principal objection to the use of the cableway on trench work is its lack of lateral control. It is almost impossible to avoid the swinging of the buckets during the raising and lowering, and this is liable to result in some displacement of and damage to the sheeting, forms, etc.

123. Bibliography.—The following books and articles contain further information:

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2. Double Dragline Cableway Excavator for Canal Work. *Engineering Record,* January 13, 1914. Illustrated, 700 words.
3. Dragline Cableway is an Effective Tool for Sand and Gravel Plants. *Engineering Record,* June 5, 1915. Illustrated, 3500 words.
4. Dragline Excavation Methods in Construction of Winnipeg Aqueduct. *Engineering & Contracting,* March 21, 1917. Illustrated, 1000 words.

5. Dragline Excavator Does Speedy Work in Dredging Channel. *Engineering Record*, February 13, 1915. Illustrated, 300 words.

6. Excavation for the Arrowrock Dam, Idaho. *Engineering News*, July 17, 1913. Illustrated, 4500 words.

7. Excavation for Foundation of Elephant Butte Dam. *Engineering News*, January 14, 1915. Illustrated, 3500 words.

8. Machines for Building Levees. *Engineering News*, May 25, 1916. Illustrated, 2500 words.

9. Portable Dragline Cableway Excavator for Concrete Aggregates. *Engineering Record*, November 15, 1913. Illustrated, 1300 words.

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CHAPTER XII

DIPPER DREDGES

124. Classification.—Floating excavators are those types which move along a stream like a boat. They are classified as to construction and method of excavation of material, as follows: dipper dredges, ladder dredges and hydraulic dredges.

Dipper dredges will be discussed in this chapter and the other two classes in succeeding chapters.

125. Preliminary.—Dipper dredges may be classified as to field of work as follows: dredges for the excavation of drainage and irrigation channels, dredges with narrow hulls and side floats for the excavation and maintenance of channels, and marine dredges for river and harbor improvements.

These three classes comprise many types and sizes of dredges depending upon the service for which the machines are intended. The general details of construction and method of operation are very similar for all the tyes.

126. General Description.—The type of dredge which is best known and commonly used for the excavation of drainage ditches is the floating-dipper dredge. The principal parts of a dipper dredge are the hull or boat, the power equipment, the hoisting engines, the swinging engines, A-frame, spuds, boom and dipper. All of these parts are used in some form in every dredge. Each manufacturer uses the same principles of operation but varies the details of construction to suit his ideas and generally claims therefor certain points of superiority. Figure 87 shows the principal parts of a floating-dipper dredge with vertical spuds and Fig. 88 those of a dredge with bank spuds. It is the general custom to set up the machinery of each dredge complete on the testing floor of a factory and to give it a thorough test before it is shipped to the purchaser. This test is of value in so far as it assembles all of the parts and proves their ability to work in coördination up to certain stand-

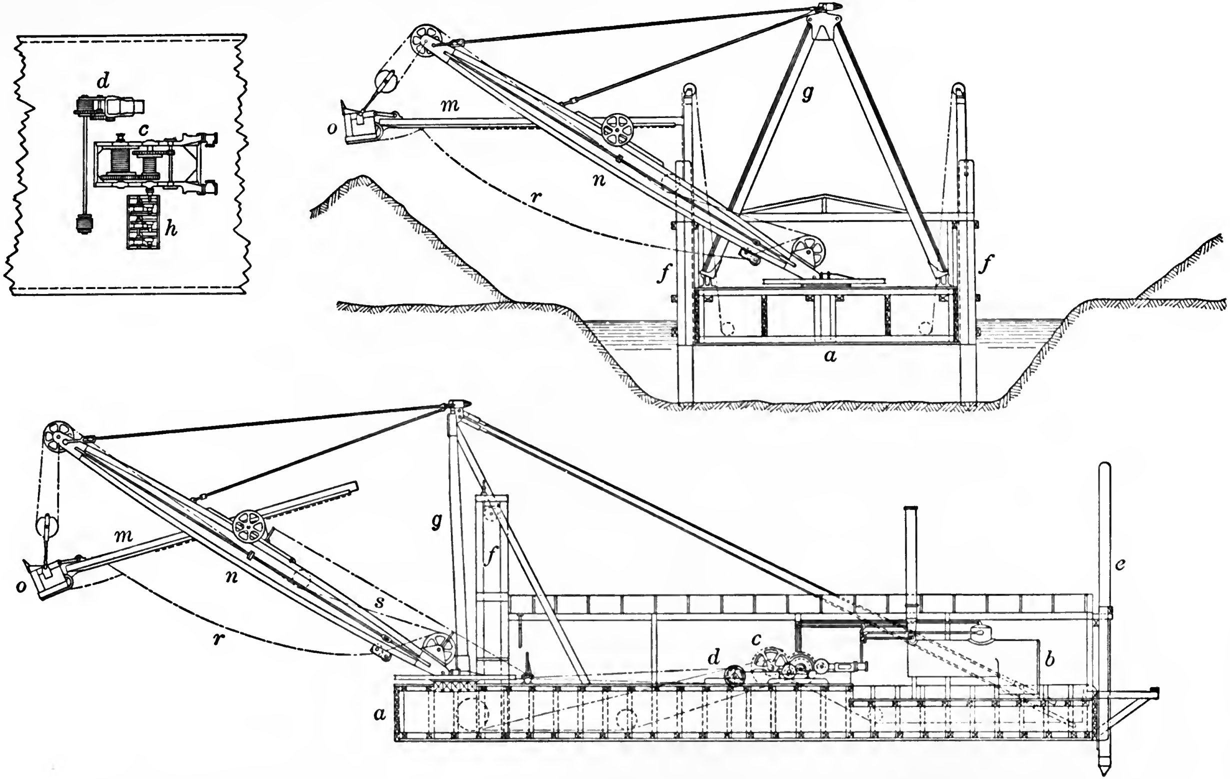

FIG. 87.—Diagram of floating dipper dredge with vertical spuds. (*Courtesy of Marion Steam Shovel Co.*)

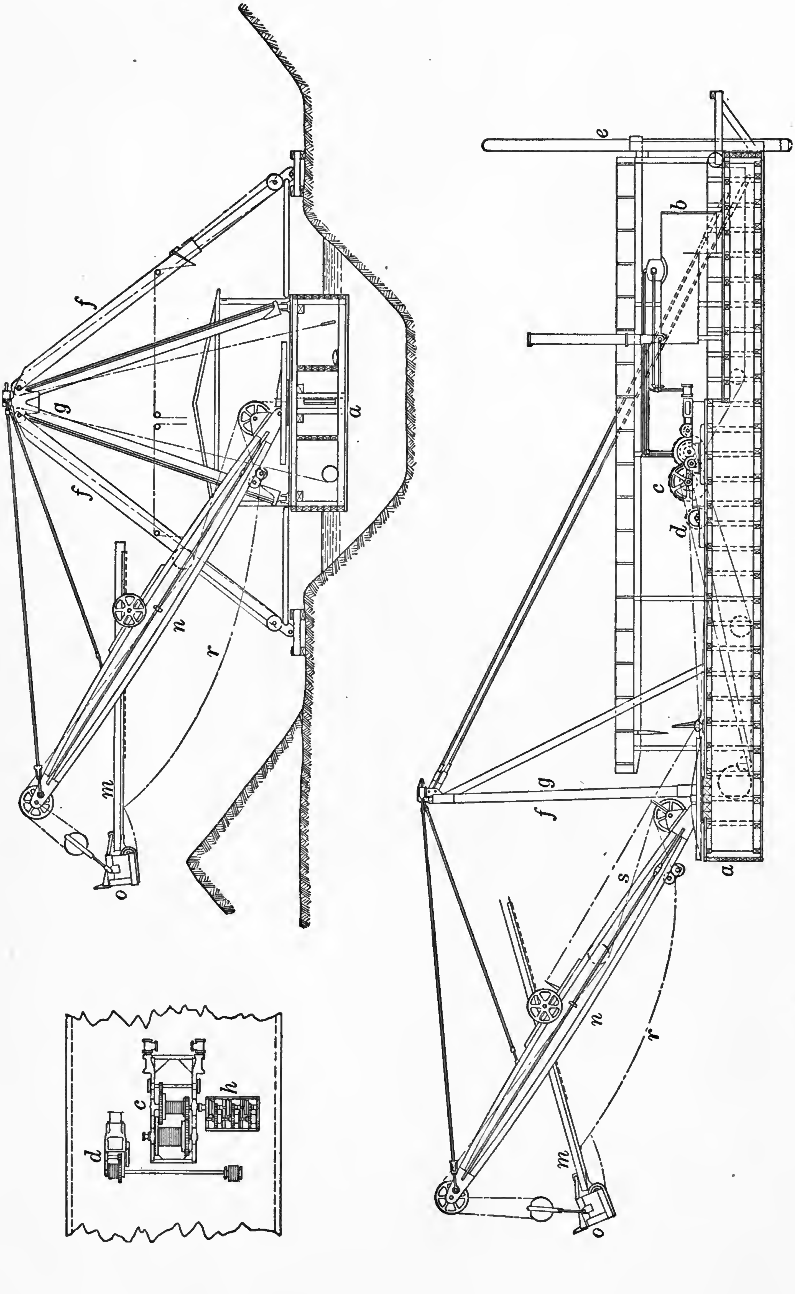

FIG. 88.—Diagram of floating dipper dredge with bank spuds. (*Courtesy of Marion Steam Shovel Co.*)

ard requirements. However, as such a test is conducted under the most favorable conditions, with good fuel, pure water, stable foundations, light and uniformly applied loads, it does not show how the machinery will stand up under the actual conditions of low-grade fuel, impure water, unstable foundations, and vibratory and repeated loads. The only satisfactory method to become acquainted with the weak as well as the strong points of any piece of machinery is to give it a severe test or series of tests under actual working conditions.

HULL

The hull or boat is generally built of wood and of such dimensions as the size of the machinery, length of boom, size of dipper, and the width of the ditch may require. If practicable the width of the dredge should be nearly the width of the ditch so that the stability of the whole dredge may be enhanced by the use of the bank spuds. In the construction of ditches, the top width of which exceeds 60 ft., it is not practicable to use bank spuds. The width of the hull depends solely on the size of the machinery to be used, the length of the boom, and the size of the dipper. The width of the hull of a dredge using bank spuds is generally made less than that of a machine using vertical spuds. It is evident that the tendency of the hull of a dredge to tip sideways, as the boom is swung to one side, will depend on the distance that the dipper is from the center of the hull or upon the length of the boom. Hence, the width of the hull should bear some relation to the length of the boom. When bank spuds are used the width of hull is generally made about one-half the length of the boom, while with vertical spuds the hull width is generally made about five-eighths of the length of the boom. See Tables X and XI on pages 170 to 172. The length of the hull must be sufficient to provide suitable space for the boiler, the machinery, "A"-frame and boom, but principally it must provide sufficient stability to balance the weight of the boom and dipper in their various positions. The depth of the hull must be built to furnish sufficient displacement, but with as light draft as possible so as to float in shallow water. The early practice in dredge building was to make the hull wider on top than on the bottom, thus giving the sides a slope which would partially conform to the side slopes of the ditch. However, this involves extra labor in construction with no material benefit,

TABLE X.—DITCHING DREDGES WITH VERTICAL SPUDS

Dippers—¾ to 4 yd.

Booms—30 to 100 ft. long

Size of dipper	Length of boom	Height dump above water	Depth dig below water	Center hull to center dump	Size of hull	Hoisting engines	Swinging engines	Capacity	M-feet lumber for hull
4	100	36–40	28	85–100	120×50×8½	2–12×16	2–9×9	1500–3000	195
4	90	32–36	26	75–90	120×46×8½	1–12×16	2–9×9	1500–3000	180
2½	80	30–34	24	67–80	100×42×8	2–10½×12	2–8×8	1000–2000	135
2½	75	28–32	23	63–75	100×40×8	2–10½×12	2–8×8	1000–2000	128
2½	70	26–30	22	60–70	100×38×8	2–10½×12	2–8×8	1000–2000	122
2½	65	24–28	21	55–65	90×36×7½	2–10½×12	2–8×8	1000–2000	98
2½	60	22–26	20	51–60	90×34×7½	2–10½×12	2–8×8	1000–2000	92
2½	55	20–24	18	47–55	90×32×7½	2–10½×12	2–8×8	1000–2000	87
2½	50	18–22	16	43–50	90×30×7½	2–10½×12	2–8×8	1000–2000	81
2½	45	16–20	14	39–45	90×28×7½	2–10½×12	2–8×8	1000–2000	76
2	65	24–28	21	55–65	85×36×7	2–9×11	2–7×8	800–1600	86
2	60	22–26	20	51–60	85×34×7	2–9×11	2–7×8	800–1600	81
2	55	20–24	18	47–55	80×32×7	2–9×11	2–7×8	800–1600	76
2	50	18–22	16	43–50	80×30×7	2–9×11	2–7×8	800–1600	68
2	45	16–20	14	39–45	80×28×7	2–9×11	2–7×8	800–1600	63
2	40	15–18	12	35–40	80×26×7	2–9×11	2–7×8	800–1600	59

TABLE X.—DITCHING DREDGES WITH VERTICAL SPUDS—(*Continued*)
Dippers—3/4 to 4 yd.
Booms—30 to 100 ft. long

Size of dipper	Length of boom	Height dump above water	Depth dig below water	Center hull to center dump	Size of hull	Hoisting engines	Swinging engines	Capacity	M-feet lumber for hull
1½	55	20-24	18	47–55	75×32×6½	2–8×10	2-6×7	600–1200	63
1½	50	18–22	16	43–50	75×30×6½	2–8×10	2-6×7	600–1200	59
1½	45	16-20	14	39–45	70×28×6½	2–8×10	2-6×7	600–1200	51
1½	40	15–18	12	35–40	70×26×6½	2–8×10	2-6×7	600–1200	48
1½	35	14–16	10	30–35	70×24×6½	2–8×10	2-6×7	600–1200	44
1¼	45	16-20	14	39–45	65×28×6	2–8×8	2-5½×6	500–1000	44
1¼	40	15–18	12	35–40	65×26×6	2–8×8	2-5½×6	500–1000	41
1¼	35	14–16	10	30–35	65×24×6	2–8×8	2-5½×6	500–1000	38
1	40	15–18	12	35–40	60×24×5½	2–7×8	Friction	400– 800	32
1	35	14–16	10	30–35	60×22×5½	2–7×8	Friction	400– 800	29
1	32	13–15	9	27–32	60×20×5½	2–7×8	Friction	400– 800	27
¾	35	14–16	10	30–35	55×22×5	2–6½×8	Friction	300– 600	25
¾	32	13–15	9	27–32	55×20×5	2–6½×8	Friction	300– 600	22
¾	30	12–14	8	25–30	55×18×5	2–6½×8	Friction	300– 600	20

TABLE XI.—DITCHING DREDGES WITH BANK SPUDS
Dippers—¾ to 2½ yd.
Booms—30 to 80 ft. long

Size of dipper	Length of boom	Height dump above water	Depth dig below water	Center hull to center dump	Size of hull	Hoisting engines	Swinging engines	Capacity	M-feet lumber for hull
2½	80	30–34	24	67–80	100 × 36 × 8	2–10½ × 12	2–8 × 8	1000–2000	115
2½	75	28–32	23	63–75	100 × 34 × 8	2–10½ × 12	2–8 × 8	1000–2000	109
2½	70	26–30	22	60–70	100 × 32 × 8	2–10½ × 12	2–8 × 8	1000–2000	103
2½	65	24–28	21	55–65	90 × 30 × 7½	2–10½ × 12	2–8 × 8	1000–2000	81
2½	60	22–26	20	51–60	90 × 28 × 7½	2–10½ × 12	2–8 × 8	1000–2000	76
2½	55	20–24	18	47–55	90 × 26 × 7½	2–10½ × 12	2–8 × 8	1000–2000	70
2½	50	18–22	16	43–50	90 × 24 × 7½	2–10½ × 12	2–8 × 8	1000–2000	65
2½	45	16–20	14	39–45	90 × 22 × 7½	2–10½ × 12	2–8 × 8	1000–2000	60
2	65	21–28	21	55–65	85 × 30 × 7	2–9 × 11	2–7 × 8	800–1600	72
2	60	22–26	20	51–60	85 × 28 × 7	2–9 × 11	2–7 × 8	800–1600	67
2	55	20–24	18	47–55	85 × 26 × 7	2–9 × 11	2–7 × 8	800–1600	62
2	50	18–22	16	43–50	80 × 24 × 7	2–9 × 11	2–7 × 8	800–1600	54
2	45	16–20	14	39–45	80 × 22 × 7	2–9 × 11	2–7 × 8	800–1600	50
2	40	15–18	12	35–40	80 × 20 × 7	2–9 × 11	2–7 × 8	800–1600	45

TABLE XI.—DITCHING DREDGES WITH BANK SPUDS—(*Continued*)
Dippers—¾ to 2½ yd.
Booms—30 to 80 ft. long

Size of dipper	Length of boom	Height dump above water	Depth dig below water	Center hull to center dump	Size of hull	Hoisting engines	Swinging engines	Capacity	M-feet lumber for hull
1½	55	20–24	18	47–55	75 × 25 × 6½	2–8 × 10	2–6 × 7	600–1200	49
1½	50	18–22	16	43–50	75 × 23 × 6½	2–8 × 10	2–6 × 7	600–1200	45
1½	45	16–20	14	39–45	70 × 21 × 6½	2–8 × 10	2–6 × 7	600–1200	39
1½	40	15–18	12	35–40	70 × 19 × 6½	2–8 × 10	2–6 × 7	600–1200	35
1½	35	14–16	10	30–35	70 × 17 × 6½	2–8 × 10	2–6 × 7	600–1200	31
1¼	45	16–20	14	39–45	65 × 20 × 6	2–8 × 8	2–5½ × 6	500–1000	32
1¼	40	15–18	12	35–40	65 × 18 × 6	2–8 × 8	2–5½ × 6	500–1000	28
1¼	35	14–16	10	30–35	65 × 16 × 6	2–8 × 8	2–5½ × 6	500–1000	25
1	40	15–18	12	35–40	60 × 18 × 5½	2–7 × 8	Friction	400–800	24
1	35	14–16	10	30–35	60 × 16 × 5½	2–7 × 8	Friction	400–800	22
1	32	13–15	9	27–32	60 × 15 × 5½	2–7 × 8	Friction	400–800	20
¾	35	14–16	10	30–35	55 × 15 × 5	2–6½ × 8	Friction	300–600	17
¾	32	13–15	9	27–32	55 × 14 × 5	2–6½ × 8	Friction	300–600	16
¾	30	12–14	8	25–30	55 × 13 × 5	2–6½ × 8	Friction	300–600	15

and it is now the universal practice to build hulls with vertical sides. The dimensions of the hulls of various-sized dredges are given in Tables X and XI on pages 170 to 172. These tables were compiled by the Marion Steam Shovel Co., of Marion, Ohio.

The hull is composed of a framework of heavy timbers, which should be of continuous length as far as is practicable. The writer has seen timbers 14 in. square and having a length of 87 ft., used for the longitudinal bracing of a hull, which had an overall length of 110 feet. Transverse timbers should always be the full width of the hull. In the construction referred to above, transverse sills and caps were used and were 30 in. square with a length of 40 feet. The framework is covered on the sides, top and bottom with 3-in. plank. In the case of a large hull with very heavy machinery, the sides and ends may be made of heavy timbers, placed one on another. All timbers should be well bolted together; although in small hulls of light construction, the planking is generally used and as both woods are about equal in strength, the preference is given to the cheaper. Great care should be taken in framing and splicing timbers, so as to secure strong joints, which should stagger where practicable.

Too much care cannot be taken in the construction of the hull to secure the greatest strength and rigidity possible. When a dredge is in operation, extremely severe strains of every kind are being applied in rapid succession. The joints of the planking on the sides, ends and bottom must be made watertight. This is done by fitting the adjacent planks together so as to leave a V-shaped joint, with an opening of about 1/8 in. on the outside surface. Three threads of oakum should be driven tightly into the joints, until the surface of the oakum is about 1/2 in. below the outside surface. This space should then be filled with hot coal-tar. It is not necessary to calk the deck joints, unless the dredge is to be towed through rough water.

It is rarely practicable to move a dredge from one job to another and so it is generally dismantled for shipment by railroad.

If the length of shipment is great, it is more economical to build a new hull, rather than to move the old one. Recently, the manufacturers of a steel dredge have constructed a steel hull, which is made in sections, which can be readily bolted together.

On deep-water dredges the boiler, coal bunkers and heavier machinery are placed on the bottom of the hull to secure maximum stability. On ditching dredges, however, it is the custom to place the boiler, coal bunkers, water tank, condenser, etc., on the rear end of the deck, which is from 1 to 2 ft. lower than the main deck. See Figs. 87 and 88.

BOILER

The use of a boiler on a floating-dipper dredge is very similar to that on a drag-line excavator and the reader is referred to the description on pages 83 and 84 of boilers for dry-land excavators.

It would be well to emphasize a few important points and recommendations, which have been previously mentioned.

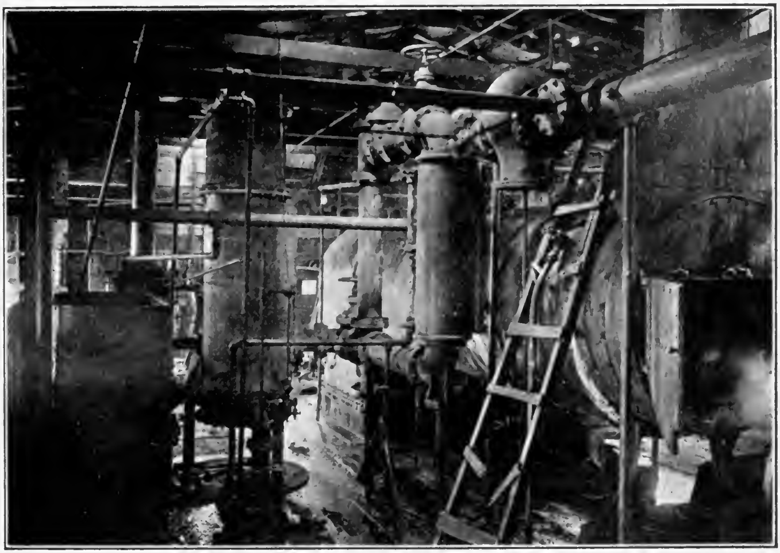

Fig. 89.—Boiler and piping system of floating dipper dredge. (*Photo by Author.*)

The locomotive fire-box type has been generally found to be the most satisfactory to meet the exacting conditions of dredge work. It is easily adaptable to the consumption of various grades and kinds of fuel and can be easily cleaned. The Scotch-marine type of boiler is usually considered to be the more economical of fuel, the more durable and the safer of these two types, which are used on dredges. However, the writer has often seen the two types used on two dredges on the same job, and the locomotive type always gave the more efficient and economical service. See Fig. 89.

It is generally necessary to use a water purifying system on a dredge, because the available water supply is either surface water from swamps or marshes or from shallow wells. This water is usually highly impregnated with magnesia, lime, or the sodium salts. These are all serious scale-forming materials and they should be removed from the water before it is fed into the boiler. A feed-water heater and purifier is the best means of accomplishing this result.

The writer has seen two boilers used on one dredge. These were placed side by side and connected so that the two could be used together or singly. The advantages of such a duplicate equipment are facility for cleaning without stopping the operation of the dredge and the use of extra power when needed for heavy or frozen-soil excavation. This novel installation means a greater initial cost, but cases could be cited where it would have saved the extra expense several times over.

ENGINES

The hoisting and backing machinery are of three different types, depending on the method of transmitting the power; single, double and triple hitch. These three classes are provided for by the use of a single, a two-part, or a three-part hoisting line. In the first class, the power developed by the engine is compounded through gears, the hoisting rope being connected directly to the dipper handle. In the two latter classes, the power is compounded by means of a sheave attached to the bail of the dipper.

The main engine for a dipper dredge is very similar to that used on a drag-line excavator. It should be some standard type of horizontal, double-cylinder, friction-drum engine, which must be self-contained on a cast-iron or structural-steel bed plate. There must be two drums, one for the hoisting cable and one for the backing cable. These drums are generally grooved to hold the first layer of cable in place, and are controlled by outside friction bands, which are operated by steam-actuated rams attached to the spokes of the large gear wheel. Provision should be made in these rams for the automatic compensation of contraction and expansion in the wheel. The backing drum should be provided with a reducing valve which automatically regulates the steam pressure to the load applied. This eliminates the jerking and snapping of the backing cable.

The size and power of engine required depends upon the size of the bucket and the length of the boom. The power of an engine is determined by the dimensions of its cylinders. These required by the various size dredges are shown in Tables X and XI, pages 170 to 172. As the engine on a dredge is run intermittently and at low speed it is preferable to have an engine cylinder of small diameter and long stroke. Too much emphasis cannot be put upon the necessity of having all the parts of the engine very strongly built. The continual application and removal of the load brings vibratory strains upon the machinery, which, unless built of the very best material and of ample strength, will be subject to frequent breaks. The latter mean shutting down dredging operations and the expenditure of time and expense in repairs. A frequent cause of trouble and delay in the operation of a dredge engine is the binding of the friction clutches. This is caused by the excessive heating of the friction surfaces, which are usually composed of hard-wood blocks or a vulcanized fiber. Experience has shown that little trouble is derived from this source if the diameter of the friction section is made from two and one-half to three times that of the main barrel of the drum. The main engine of a well-known make of floating-dipper dredge is shown in Fig. 90.

The swinging engines of dredges which have a dipper capacity greater than 1 cu. yd. are generally independent of the main engine. For the ½ cu. yd., the ¾ cu.yd., and 1 cu. yd. sizes of dredge the swinging mechanism consists of two independent swinging drums, which are attached to a long shaft, geared to the main. engine. This method of operation is shown in Fig. 91. A chain or wire rope extends from one drum around the turntable or swinging circle to the other drum. After the dipper is raised out of the channel to the proper point, the hoisting drum is shut down and power applied to revolve the swinging-drum shaft. One drum is set by the friction and winds up the chain or cable, which in turn unwinds from the other or loose drum. The advantages of this method are the cheapness of construction and economy of space in using one engine. The disadvantages are the necessity of using the hoisting engine in order to operate the swinging device, the difficulty of keeping the swinging cable or chain taut and the waste of power.

In nearly all makes of dredges over 1 cu. yd. capacity a separate swinging engine is used. The type of engine used is one which is reversible and operated by a balanced throttle valve. The engine is compound geared to a long shaft, having two drums placed at such distance apart so as to give a direct pull to the swinging circle on either side. A chain or steel cable extends from the bottom side of one drum to the swinging circle or turntable and thence to the top side of the other drum. Where it is desired to swing the boom, the swinging engine is operated and the cable or chain winds up on the one drum as fast as it unwinds on the other. A typical swinging engine is shown in Fig. 92.

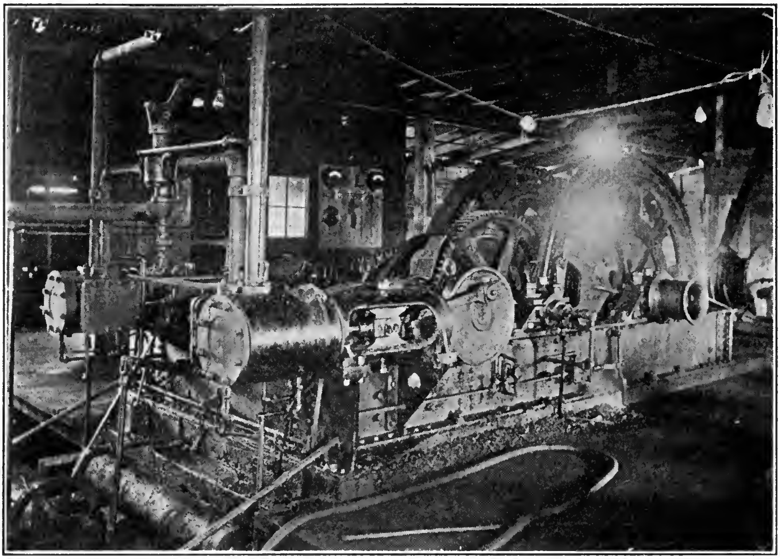

FIG. 90.—Hoisting engine of floating dipper dredge. (*Photo by Author.*)

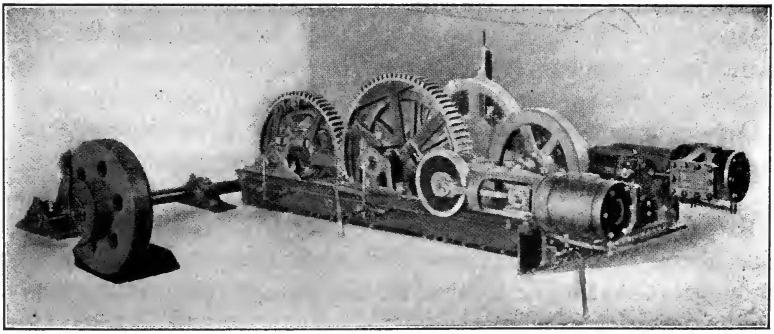

FIG. 91.—Combined hoisting and swinging engine of floating dipper dredge.

The swinging circle or turntable may be either fixed or movable and may be placed either just above or several feet above the deck.

For dredges of dipper capacity up to 2 cu. yd. most manufacturers use a solid deck swinging circle. This consists of a drum-shaped framework of steel plates and a side web of channels. In the center of the circle is a large cast ring, which rests and revolves upon the main base casting, which is fastened to the front edge of the deck. The lower end of the boom is pivoted on this cast ring and revolves with the swinging circle. Several loop rods are generally used to connect the outer rim of the circle at the ends of its transverse diameter with the boom at points on either side and about one-fourth of its length. The diameter of the swinging circle should be sufficient to give a direct pull from the drums of the swinging engine and also not less than one-fifth of the horizontal reach of the boom. Since the rim of the swinging circle, where the pull from the cable is applied, is several feet lower than the points on the boom where the pull is transferred from the rim of the circle to the boom by the rods or braces, there results a tilting action. This causes a loss of power and a warping of the swinging circle. To overcome

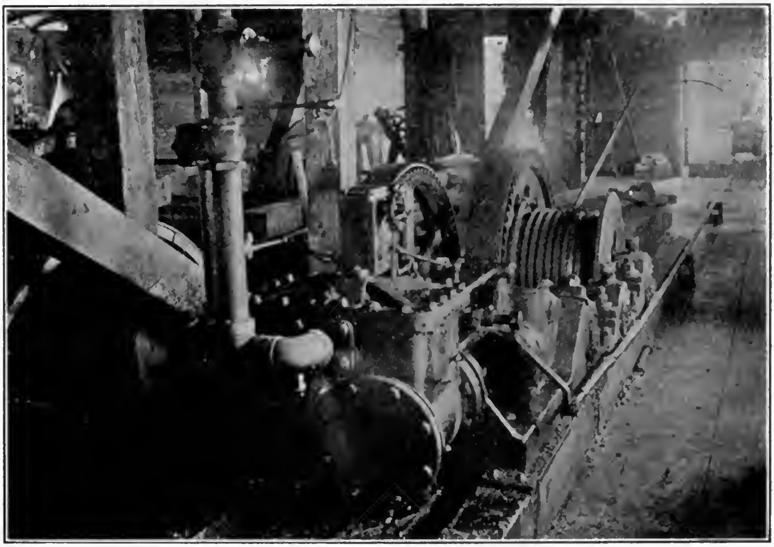

FIG. 92.—Swinging engine of floating dipper dredge. (*Photo by Author.*)

this eccentricity in the transference of the pull, the swinging circle is often placed on the upper end of a mast, which rests on the lower pivot casting and revolves the circle in a plane 8 or 10 feet. above the deck. The circle, in this case, is braced to the boom in the plane of the rim and thus a direct pull is obtained. This method is advantageous when the boom is longer than 60 feet. The objections to this method are first, it places considerable weight above the deck and decreases the stability of the dredge; second, it requires a special arrangement of sheaves to lead the swinging cable from the drums to the circle and a resulting loss of power and increased wear on the cable.

Where the dipper is of large capacity and the boom of great length (over 70 ft.), a stationary turntable is generally used. The turntable is placed just above the deck or several feet above, as has been explained for the swinging circle. The stationary circle consists of a circular rim and several spokes, which are of structural steel and fastened to the central cast pivot and the deck of the hull. The swinging chain or cable leads from drums to the turntable where it passes over small sheaves placed in the rim. In this case, since the circle is fixed in position, its diameter is not dependent on the reach of the boom, but should be large enough so that the power may be applied at a distance from the foot of the boom to give a direct and uniform pull. The boom is connected to the axis of rotation by a large timber fastened to a swinging chain or cable at the point where they cross. Then the movement of the chain or cable drives the boom, which is pivoted at its lower end.

A-FRAME

The A-frame is a tower or frame composed of large timbers securely seated on the top of the hull at each side near the front and joined together at the top with a cast-steel head and yoke. This frame is generally composed of two main legs in a nearly vertical plane, inclined toward the front at a slope of about 1 in 6, and stayed by guy rods extending from the head block of the frame to the sides of the hull near the rear end. Some dredge builders use two rear legs or timbers as braces and in this case the too main legs are set in a vertical plane. It is necessary that the A-frame be strongly braced and held rigidly in position as the pull from the outer and loaded end of the boom is largely borne by the top of the A-frame. A break or failure of any part of this frame would probably result in serious loss of life and damage to the dredge. The height of the A-frame is largely governed by the maximum required elevation of the end of the boom which will be determined by the depth of excavation and distance away from the ditch to the place where the excavated material must be deposited. The top of the head block is a large pin on which the yoke revolves. The yoke is a short-trussed beam to the ends of which are attached the cables which support the outer end of the beam. See Fig. 93 for typical A-frame details.

Fig. 93.—A-frame of floating dipper dredge. (*Photo by Author.*)

SPUDS

To hold the hull horizontal and to prevent its being tipped about while the dredge is in operation, three leg braces or spuds are provided. One is placed in the middle of the rear end of the hull and one on each side near the front. When the ditch is narrow and the dredge has a hull nearly the width of the ditch, bank spuds are used. As shown in Fig. 99, these inclined bank spuds are pivoted to the head block of the A-frame and the lower ends are pivoted to large platforms which transmit the pressure to the soil. Some manufacturers use a rectangular spud frame,

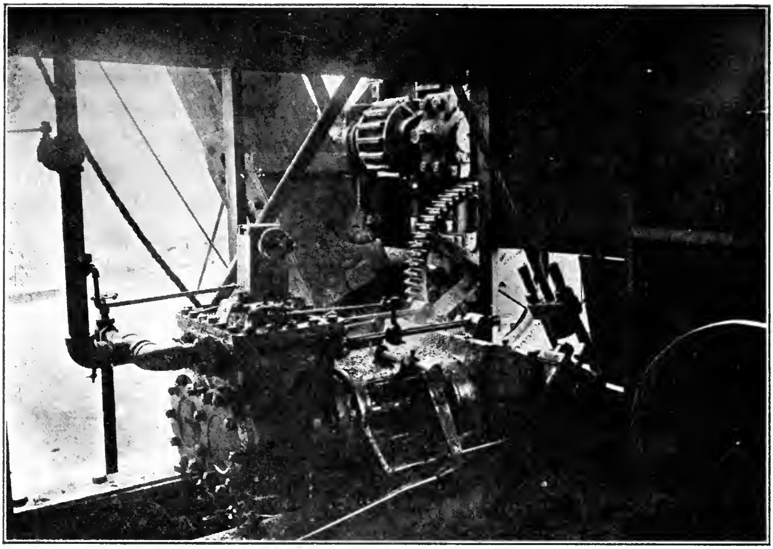

FIG. 94.—Spud engine of floating dipper dredge. (*Photo by Author.*)

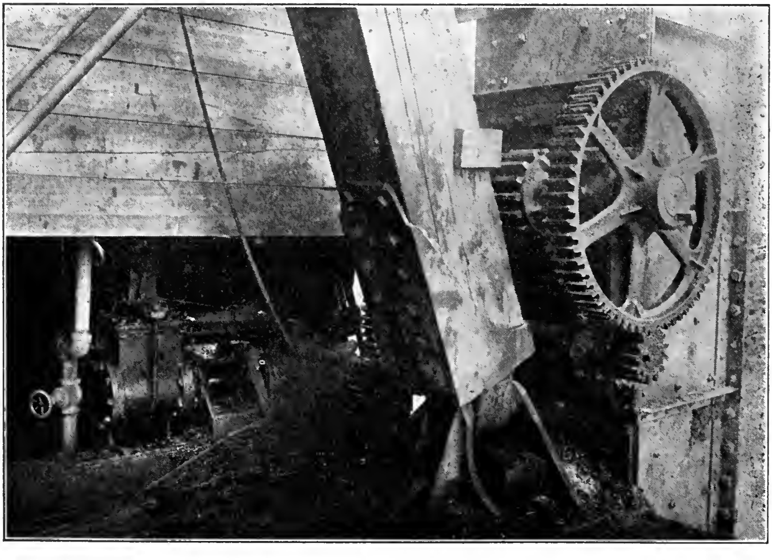

FIG. 95.—Spud hoisting mechanism of floating dipper dredge. (*Photo by Author.*)

which is placed just behind the A-frame. At the upper corners of the spud frame are bolted plates supporting pinions or dogs, which engage the teeth of racks fastened to the lower sides of the spuds. This simple mechanism serves to lock the spuds in place. Short braces connect the lower ends of the spuds with the sides of the hull at the feet of the A-frame. Vertical side spuds are used in a wide ditch and their lower ends bear directly on the bottom of the ditch. The rear spud is always vertical and is used to prevent the dredge from swinging about during its operation. Each spud is a large solid timber which moves inside of an iron or timber box or guide frame. This is the new form of telescopic spud. Teeth on a rack fastened to the lower side of the spud engage a pinion on the lower side at the end of the box section.

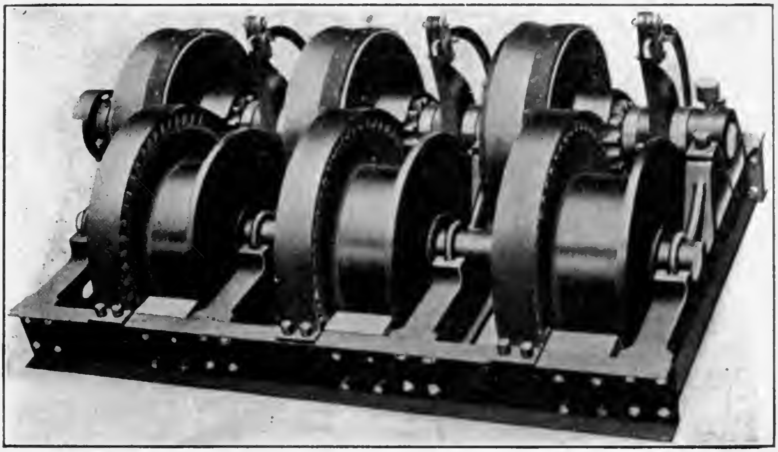

FIG. 96—Spud hoist of floating dipper dredge.

The spuds are raised and lowered by means of steel-wire ropes passing over sheaves and controlled by special drums. These drums are mounted on a separate bed plate and their shaft is connected to the end of the backing drum shaft by a jaw clutch, which is disengaged when the spuds are not to be operated. Figure 96 shows a typical spud hoist. In large dredges, where vertical spuds are used, they are often operated by a steam cylinder fastened to the front of each spud and controlling a brake or clamp, which encircles the spud and is attached to the piston of the cylinder. This method is cumbersome, troublesome to operate, and uneconomical of power. This has been replaced by the installation of a separate engine to operate each of the front spuds. This allows each spud to be operated independently and without using the main engine. The details of such a spud engine are shown in Figs. 94 and 95.

Wherever it is possible it is best to use the inclined bank spuds of the telescopic type. These braces take the load from the top of the A-frame to the banks along the sides of the ditch and thus remove much strain from the hull of the dredge. As the stability of the dredge when in operation depends to a great extent upon the strength and proper working of the spuds, it is necessary that they be made amply large and provided with a strong and reliable locking device. The spuds must be raised and lowered each time the dredge makes a move, hence, it is evident that the ease and rapidity of their operation will greatly affect the progress of the work.

BOOM

The boom or crane is a fish-bellied shaped beam, usually constructed of wood. It is made in two equal parts or sections and so spaced apart that the dipper handle may work between them. When the length of the boom is over 70 ft., it is often made of trussed timbers to secure lightness with strength. See Fig. 97. For lengths up to 70 ft., however, the webs of the booms are generally made solid. See Fig. 99. When the capacity of the dipper is over 2½ cu. yd., dredge builders often use a steel-trussed beam, similar in construction to those used on the drag-line excavators. The length of the boom depends on the capacity of the dredge, the cross-section of the ditch to be excavated, and distance from the center of the ditch to the place where the excavated material must be deposited. The width of the boom at the ends need only be enough to provide sufficient bearing for the end castings. The width at the center should be from one-tenth to one-twelfth of the length of the boom. As has been stated under "Hull," the length of boom should bear a definite relation to the width of the hull. When vertical spuds are used the length of boom should be about one and one-half times the width of the hull, while with the use of bank spuds, the length may be increased to twice the width of the hull. The lower end of the boom is pivoted to the swinging circle or upper section of the cast pivot. The outer end is connected to the yoke at the top of the A-frame by means of adjustable wire cables. At the outer end of the boom is the sheave over which the hoisting cable passes on its way from the sheave attached to the bail of the dipper to the fair lead sheaves at the lower end of the boom and thence to the drum of the main engine. On top of the boom and a little below the center is placed the brake shaft, upon which the dipper handle moves. This mechanism consists of two large wheels whose motion is controlled by friction brakes. These wheels connect a pinion over whose periphery moves a toothed rack fastened to the lower side of the dipper handle. When the friction bands are released the weight of the dipper and its handle allows the latter to move downward as fast as the hoisting cable is paid out. When the dipper is filled and has been raised to a suitable position for swinging the boom, the application of the friction brakes holds the dipper handle in place while the boom is being swung to one side. For ease of operation the diameter of the brake wheels should be about one-twentieth of the length of the boom.

Fig. 97.—Boom and dipper handle of floating dipper dredge. (*Photo by Author.*)

DIPPER HANDLE

The dipper handle works in conjunction with the boom and carries the excavator or dipper at its lower end. Usually it is a large square timber whose corners are reinforced with angle irons. See Figs. 97, 98 and 99. The lower side is provided with a cog rack, which moves over the pinions, mounted on the top of the boom. The cross-section of the handle depends on the size of the dipper and the resulting maximum load to be carried. Its length should be about two-thirds that of the boom. It should be made amply large to resist the bending caused by the prying action of the dipper in loosening hard or tough material.

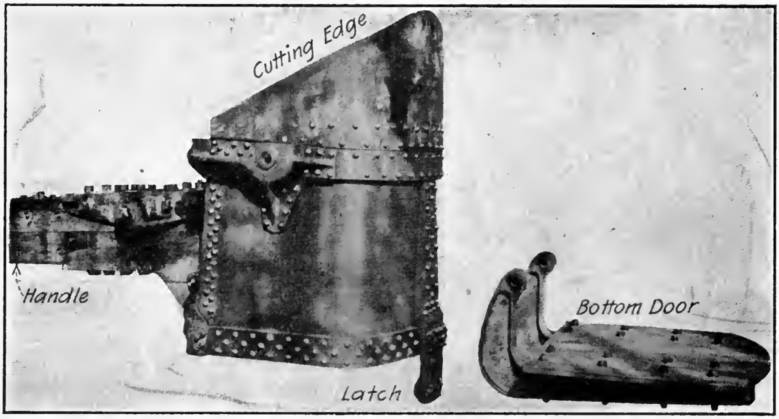

Fig. 98.—Dipper of floating dipper dredge.

DIPPER

The dipper or bucket is of the same type as that used on steam shovels. A reference to Fig. 98 will clearly show the details of construction. The sides are made of heavy steel plates which are strongly reinforced by steel bars at the top and bottom. For ordinary material the cutting edge is made of a single bent plate, which can be easily replaced when worn out. When compact and hard soils are to be excavated, large steel teeth are used to reinforce the cutting edge. The bottom is a heavy steel plate, which is hinged to the back of the dipper and is held in place by a spring latch riveted to the front of the dipper. The latch is opened by the pulling of a cable or chain, which extends back along the boom to the cranesman. As soon as the dipper is lowered the weight of the door causes it to automatically close and latch. The size or capacity of the dipper varies from ½ to 15 cu. yd., and this element is governed by the size of the dredge. This is dependent on the size of the ditch to be excavated, the amount and character of the material, and the amount of money available for the construction of the dredge. Generally, the dredge contractor builds his hull, when practicable nearly as wide as the ditch so as to use bank spuds, or in the case of wide ditches or canals (over 50 ft. wide on top), he makes the boat wide enough to excavate the canal in two cuttings. He then uses the largest size dipper which can be used with the size and strength of hull. The larger the dipper used, the larger the machinery and boiler required to operate the dredge, but it should be noted that 6 men can operate a 3½-cu. yd. dredge as well as a 1¾-cu. yd. machine. The principal difference in the cost of operation would be in the amount of fuel used.

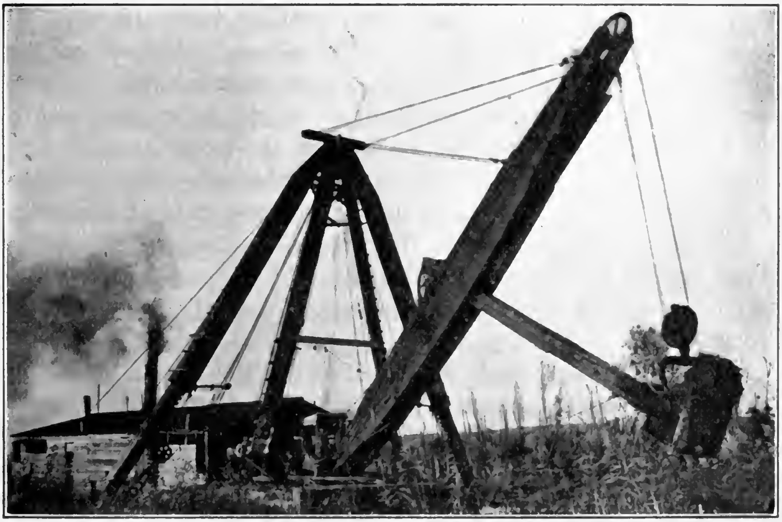

Fig. 99.—Dipper dredge with bank spuds excavating drainage ditch. (*Photo by Author.*)

Large sea-going dredges equipped with dippers of from 5 to 10 yd. capacities have been used for several years on harbor improvements, and in 1914 two mammoth dredges, each equipped with 15-yd. dippers, were used on the Panama Canal for the removal of slides.

For the excavation of loose sand, silt and gravel, the clam-shell and orange-peel buckets are very efficient. These are single-line buckets and the backing cable would not be used. The details and dimensions of a standard make of these two types of bucket are given in Figs. 24 and 25, pages 42 and 43.

GENERAL DETAILS

The general principles of design and construction which apply to any piece of machinery are especially noteworthy in the case of a floating-dipper dredge. Care must be taken to have all parts rightly proportioned and coördinated. Always use the simplest details and make them amply strong. The output, and therefore the profitableness of a dredge, is proportional to the time that the dipper is working and the forge is not in use. Breakdowns and repairs are not only troublesome and expensive in themselves, but they mean loss of working time and income.

All gears, pinions, racks, important castings and cutting edges should be made of cast steel. All straps, bands, rods, and bolts should be made of first-grade wrought iron, such as Norway iron.

All solid timbers, such as are used for the spuds, A-frame, and dipper handle, should be of heart wood, straight grained, free from shakes, twists, decay, large pitch pockets, or other defects. Long-leal yellow pine, Douglas fir, or white oak should be used.

Wire rope or cable made of plow steel wire is generally used in preference to chain. The wire rope is cheaper, lighter, takes up less room on the drums and sheaves and gives warning of failure by the preliminary breaking of a few strands. The chain, however, will break a link and pull apart suddenly and often cause a bad accident. Some dredge builders still use a chain for operating the swinging circle or turntable. The friction of a wire rope is less and more uniform than that of a chain.

The sheaves should be of as large diameter as possible, usually not less than 30 times the diameter of wire cable used on it. They should be made of an excellent grade of gray cast iron and be provided with phophor-bronze bushings. The pins must be of the highest grade of medium steel and turned to fit accurately bored holes in the sheaves. The groove in the rim of the sheave should have a depth not less than three times the diameter of the wire rope. Where the cable is subject to jumping off the sheave, a suitable guard or housing should be provided.

As a chain is "as strong as its weakest link," so a dredge is as strong as its weakest part. Too much care cannot be taken in the building of a dredge to make every part amply strong, stronger than is estimated or required. It is an unwise and short-sighted policy to spare initial expense in the construction of any form of excavator. When economy is thus early practised, vexations and costly breaks and delays are almost sure to follow. The writer has seen cases of this kind when a fundamental weakness in a dredge caused break after break, until the men working on the machine actually came to believe that it was "hoodood" and refused to continue their work.

In order to avoid long delays due to breaks and repairs, duplicate parts of all the important sections of the machinery should be kept always on the dredge. Such parts would include cables, sheaves, bolts, pins, shafts, etc.

127. Method of Operation.—The method of operation of a dipper dredge is very similar to that of a steam shovel, which has been previously described in Chapter VI on Power Shovels. The crew of a dipper dredge consists of an engineer, a cranesman, a fireman, and from two to four laborers, for each shift. A dipper dredge is ordinarily run on two 11-hr. shifts, and hence two complete crews are necessary. The engineer operates the levers and brakes which control the motions of hoisting, backing, swinging, and moving the dredge. The cranesman stands on a little platform just above the swinging circle on the right side of the boom, and controls the operation of the dipper as to loading and dumping. The fireman supplies the boiler with fuel and has general charge of the oiling and care of the machinery. The laborers supply the dredge with fuel, oil, and supplies, and perform the necessary general work around the machinery.

As the dipper and dipper handle slide downward toward the face of the excavation, the bottom of the dipper closes of its own weight and latches. When the dipper reaches the bottom of the channel, the engineer applies the friction clutch to the hoisting drum and throws a lever, starting the drum to wind up the hoist line. This pulls the dipper upward, and the forward motion is regulated by the tension on the backing line. As soon as the dipper is clear of the surface and has completed the cut, the engineer throws the hoisting drum out of gear and sets the friction clutch, thus bringing the dipper to a stop. Then the swinging engine is started and the boom is swung around to one side until the dipper is over the dumping place. With a foot brake, the engineer sets the friction clutch and stops the revolution of the swinging drums. The cranesman then pulls the latch rope, and this opens the latch, releasing the bottom which drops and allows the dipper contents to slide out. The engineer then releases the friction clutch and reverses the swinging engines, pulling the boom and dipper back into position for the next cut. As the boom swings around, the engineer slowly releases the friction clutch of the hoisting and backing drums and simultaneously slightly pulls in the dipper toward the dredge and lowers it into the cut, so as to produce a prying action. As the latter part of the drop is reached, the backing cable is released gradually and the dipper allowed to move forward toward the face of the cut. The time required for a complete cycle of operations depends upon the skill of the operator and the nature of the material excavated. The average time for a complete swing should be about 40 seconds. The most efficient results are secured when the operations are made smoothly and uniformly so as to cause the least amount of lost motion and wear and tear on the machinery.

After the entire face of the cut has been removed within reach of the dipper, the dipper is raised and the boom slowly swung from side to side to relieve the pressure on the spuds. With the boom remaining in a central position, the spud hoists are put in operation and the spuds raised from their resting places, thus allowing the hull to float ahead toward the face of the cut. With each move, the dredge makes an advance of about 6 feet. The spuds are then lowered by releasing the drums, or by reversing gears, and the dredge is ready for the next cut.

128. Cost of Operation.—The cost of operation of a dipper dredge will depend on the size and type of dredge used, the character and magnitude of the work, the kind of material to be excavated, the efficiency of the operator, etc.

As a typical case, the following is a detailed statement of the expense connected with the operation of a dipper dredge, equipped with a 1¾-yd. dipper and a 70-ft. boom, on the construction of a drainage channel along the bottom lands of a central western river. The soil is loam and clay with no stone and a small amount of stumps to be removed. The channel will be assumed to contain about 2500 cu. yd. per station of 100 feet. Two crews work on 11-hr. shifts and live on a houseboat, which floats along behind the dredge. The following statement is based on the average output for an 11-hr. shift.

OPERATING COST OF DIPPER DREDGE

Labor:			
1 engineer @ $125 per month	$5.00		
1 fireman @ $75 per month	3.00		
1 cranesman @ $75 per month	3.00		
2 laborers @ $50 each per month	4.00		
1 cook @ $40 per month	1.60		
Total labor cost, per day		$16.60	
Fuel and Supplies:			
2 tons coal @ $6.00	$12.00		
Oil, waste, grease, etc.	2.00		
Total cost of fuel and supplies		$14.00	
General and Overhead Expenses:			
Board and lodging for crew of 10 men, per day	$3.50		
Repairs and incidentals	4.00		
Interest on investment (6 per cent. of $10,000)[1]	1.50		
Depreciation (10 per cent. of $10,000)[1]	5.00		
Total general expense		$14.00	
Total cost of operation for 11-hr. shift			$44.60
Average output (cu. yd.)			1200
Unit cost of dipper dredging, per cu. yd., $44.60 ÷ 1200 =			$0.037

129. Field of Usefulness.—The dipper dredge is the best known and most popular type of excavator used in the construction of drainage channels. Most of this class of work must be done on low, swampy land, where it is difficult for anything but a boat to move about. The dipper dredge with its large bearing area and shallow draft is especially adapted to operating under these conditions. Where the soil is too soft to support the smaller types of dry-land excavators, and a considerable number of large stumps must be removed, the smaller lateral ditches of a drainage system can be excavated more economically with a small dipper dredge than with any other type of excavator.

[1] Based on 200 days in a year and a 10-year life

The great thrusting and prying power of the dipper dredge makes it an efficient machine for the removal of stumps and similar obstructions. However, in heavily timbered country it is advisable to blast out or loosen up large stumps before the dredge reaches them.

Orange-peel and clam-shell buckets are most useful in handling sand, gravel and muck. In dense, packed sand the clam-shell bucket is the most serviceable, and in hard material, manganese-steel teeth should be placed on the cutting edges of the bucket. Orange-peel buckets exert considerable prying and tearing power and are well adapted to stump pulling. For the cleaning out of old canals, where the material is largely muck and sticky clay, the grab bucket may be used but care should be taken to secure tight closing of the loaded bucket to prevent leakage and "dropping off."

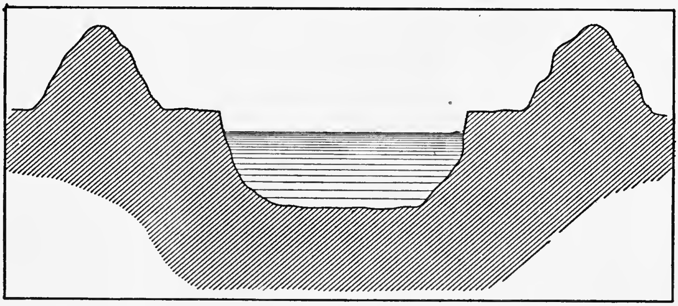

Fig. 100.—Cross-section of ditch excavated with floating dipper dredge.

In many cases it is cheaper to use one of the smaller sizes of dipper dredge (having a 16-ft. width of hull, a 40-ft. boom and a 1-yd. dipper), and to excavate a ditch twice the necessary size, than to use a smaller machine of another type to dig a channel the size required. The most economical size of channel for the operation of a dipper dredge is one with a bottom width of 40 ft. and an average depth of 10 feet. When the cross-section of the channel becomes greater than this, the cost increases until a channel having a cross-sectional area of about 1200 sq. ft. is reached, when the use of the dipper dredge is no longer efficient or practicable.

The channel which a dipper dredge excavates is rather uneven in cross-section and does not have smooth side slopes and true bottom grades. The form of ditch excavated by this machine is shown in Fig. 100. After several years' use the channel will assume a general semicircular section. In shallow channels, or those where the stream flow is small during a large part of the year, considerable reduction of the cross-section may be caused by the deposition of silt and débris and the growth of vegetation.

The dipper dredge is one of the most versatile of modern excavators as it can excavate all kinds of soil from silt to loose rock, pull stumps, remove boulders, bridges, and other obstructions, drive piling, build earthen dams, and perform many other duties which may arise during the coarse of operation.

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CHAPTER XIII

LADDER DREDGES

131. Preliminary.—The dipper dredge which is discussed in Chapter XII is essentially an American machine and is very little known and used in Europe. On the other hand, European and South American dredging contractors have developed and utilized to a high degree of efficiency a type of dredge which until about 1900 was practically unknown in this country; the ladder dredge. In California and Alaska, this form of dredge has been used for placer mining; on the Chicago Barge Canal, the Welland Canal, the New York State Barge Canal and the Panama Canal for the construction of large artificial waterways and very recently for the cleaning out of channels in the harbors of Boston, St. John, N. B., and Vancouver, B. C.

132. Classification.—Ladder or elevator dredges may be classed as to the location of the elevator; (*a*) bow-well and (*b*) stern-well, and also as to the method of disposal of the excavated material; (*c*) hopper and (*d*) barge loading. Recently (1914) a type of dredge with the elevator carried in a well at the side of the hull, has been devised for use in the removal of sand and gravel from the beds of mid-western rivers. Some ladder dredges are equipped with centrifugal pumps for use in dredging or for unloading the excavated material from hoppers or barges and its removal to the shore.

133. Construction.—The ladder dredge consists of a hull on which is placed the operating machinery and the excavating equipment. The former includes the engines for the operation of the bucket chain, the belt conveyors, the hydraulic monitor, the spuds, etc. The latter comprises the ladder frame and ladder or bucket chain and the method of disposal of the excavated material, consisting of a hopper and a discharge channel, or of belt conveyors. The placer dredge is also equipped with revolving screens and distributing channels for the separation of the gold from the gravel. A detailed view of a steam-driven placer dredge

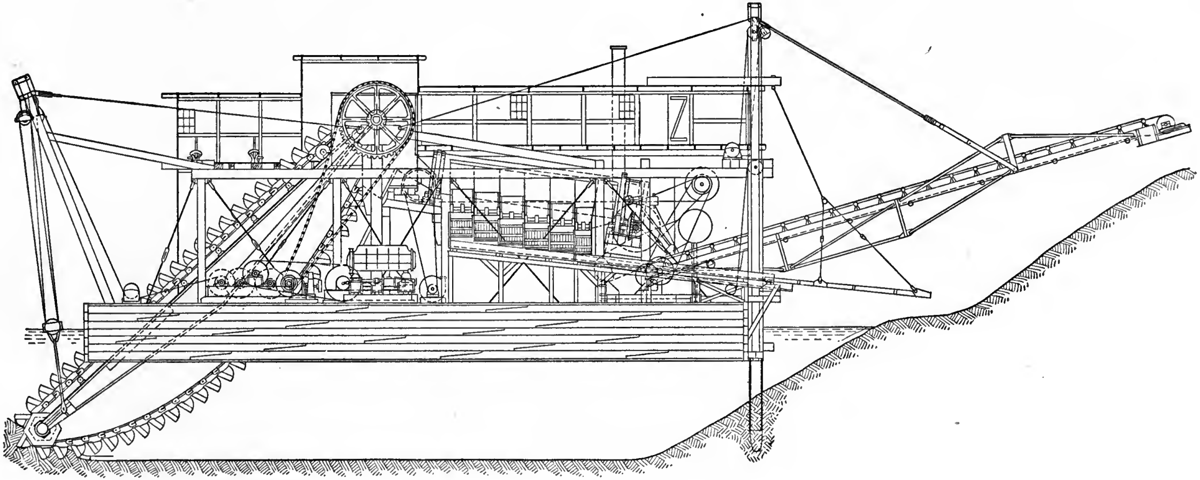

Fig. 101.—Steam-operated ladder dredge used in placer mining. (*Courtesy of the Bucyrus Co.*)

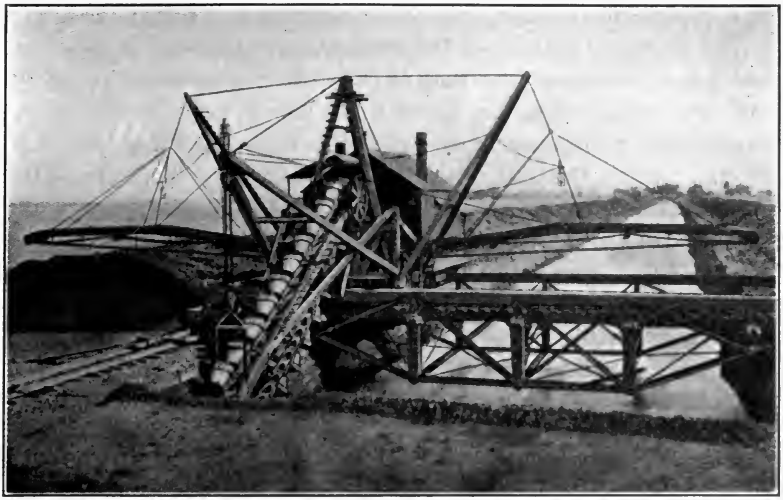

FIG. 102.—Ladder dredge for canal excavation. (*Courtesy of the Bucyrus Company.*)

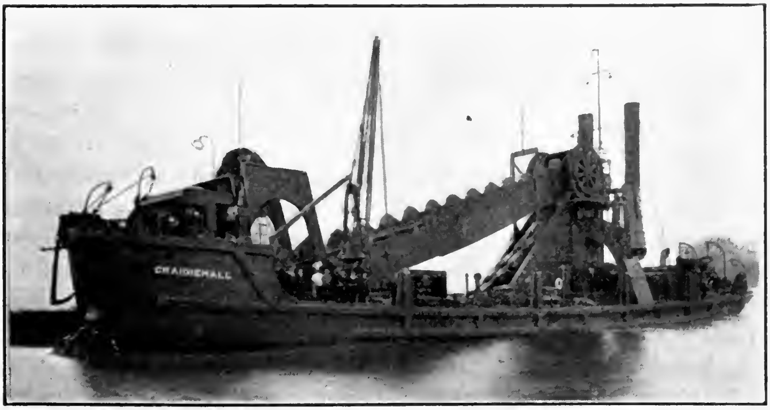

FIG. 103.—A deep-water ladder dredge.

is shown in Fig. 101, detailed views of a ladder dredge especially designed for canal excavation are given in Fig. 102, and a view of a typical deep water channel dredge is given in Fig. 103.

The principal feature of the excavating equipment is a ladder, which is a framework, carrying at each end two sheaves over which run two endless chains. Along these chains are placed buckets or scrapers at intervals of about 3 to 6 ft. each holding from 3 to 15 cubic feet. One end of the ladder is hinged to the hull and the other end is suspended from a frame placed at the bow of the hull. By means of wire rope running over sheaves, the outer end of the ladder may be raised and lowered to any desired depth. The buckets in passing around the ladder scrape the material from the bottom and front of the excavation and bring it to the upper end of the ladder above the deck. Power is applied from an engine to a shaft, which passes through the ladder and drives the chains to which the buckets are attached. The material is automatically discharged from the buckets upon belt conveyors, which carry it to the spoil banks or to barges for removal. In some cases the excavated material falls into a hopper, where it is mixed with water and the resulting fluid mass flows through spouts or troughs to the spoil areas. The horizontal movement of the dredge is generally secured by a single spud which is placed and operated at the stern of the hull. In some ladder dredges the heel of the ladder is pivoted to the hull, so that the ladder may be rotated. However, the ladder is generally fixed to the hull and passes through a well in the bow.

HULL

The hull or barge is rectangular in shape and generally constructed of heavy timbers. The hull may be built as one structure with a well through the bow or stern for the ladder, or as two structures with a space between for the operation of the ladder. The latter type of construction was used for the New York State Barge Canal dredges so that they might pass through the locks of the Erie Canal.

The size of the hull depends on the capacity of the dredge. The length, which varies from 60 to 120 ft. is generally about five and one-half times the width, which varies from 30 to 50 ft., and the depth varies from 6 to 10 feet. The draft of a completed dredge is from 4 to 6 feet. Suitable cross-frames of timber or steel are used to brace the hull and heavy planking with well-calked joints forms the outer covering.

A few ladder dredges have had hulls composed of two steel pontoons, which were held parallel, at a suitable distance apart, by steel cross-frames.

LADDER

The ladder is composed of the chain of buckets and the frame upon which it revolves. The ladder frame is generally a structural-steel framework or trussed wooden beam. The length of the ladder frame varies with the size and capacity of the dredge and the depth of excavation to be made. The upper end of the ladder frame is hinged to the upper tumbler-shaft, while the lower end is suspended by heavy tackle, from the bow gantry. The frame carries at its two ends tumblers or large metal barrels. The upper tumbler is revolved by power supplied from the main engine through a shaft, while the lower tumbler is revolved by the friction of the bucket chain.

The upper tumbler is pentagonal, while the lower tumbler is often made hexagonal. The five-sided tumbler is the most practical shape for both tumblers, as it allows three adjacent sets of links to come into contact with the tumbler at a time and with continuous operation of the chain.

CHAIN AND BUCKETS

The chain is composed of buckets, links, and the connecting pins. The chain may be arranged in two different ways, depending on the material to be excavated. For hard material, the buckets are joined directly, following each other closely, as shown in Fig 104.

For softer materials, such as would ordinarily be encountered in the excavation of drainage and irrigation ditches, the buckets are separated by a link connection, making a space between the adjacent buckets.

The buckets are generally made in three parts and riveted together. The bottom is made of a specially treated, open-hearth, basic-steel casting, the sides of pressed steel and the cutting edge of manganese steel. A continuous lip or cutting edge is generally used for the excavation of soft material, while teeth are used when hard material is to be excavated.

The pins are made of steel and have a continuous bearing along the rear edge of the bucket. The outer ends of each pin are fixed by set screws in the bushings of the outer ends of the links. The buckets are fastened to the links by rivets and the whole chain is made of such strength that if the buckets encounter an obstruction that they are unable to move, the chain and machinery will be stopped. The buckets have a capacity from 3 to 13 cu. ft., the ordinary sizes being 3, 5 and 8½ cubic feet. The movement of the buckets is slow and uniform, the chain moving at a rate of 18 to 20 buckets per minute.

Fig. 104.—Bucket chain and gantry of ladder dredge.

GANTRY

The lower end of the ladder frame is suspended from a gantry or inclined framework, which is placed at the bow of the hull. This gantry is generally built of heavy timbers or structural-steel shapes. The framework may be made with either parallel or inclined posts. At the top of the frame are hung suitable sheaves over which run the wire cable supporting the lower end of the ladder frame. See Fig. 104. The gantry has a height of from 15 to 25 ft.

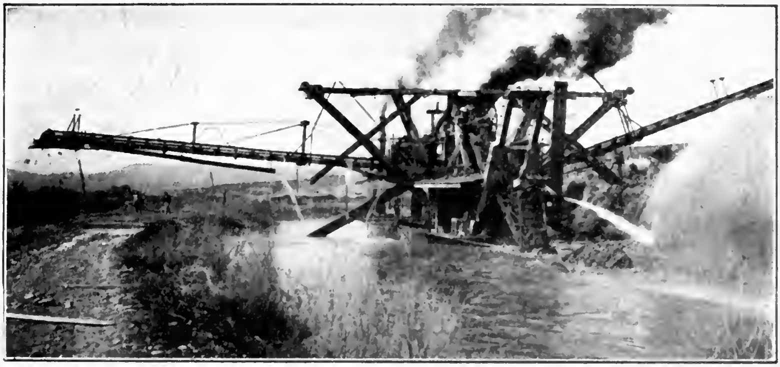

Fig. 105.—Elevator dredge excavating large irrigation canal. (*Courtesy of U. S. Reclamation Service.*)

Fig. 106.—View of elevator end of steel pontoon dredge operating on New York State barge canal. (*Courtesy of N. Y. State Engineer.*)

SPOIL CONVEYORS

The material contained in each bucket is automatically deposited when the bucket turns over the upper tumbler and starts on its downward path. The material either falls into a hopper or upon a moving belt. The latter type is generally used in reclamation work. The moving belt is either leather or canvas and rubber, from 2 to 4 ft. in width, and is supported on a series of small wheels, which are spaced along a light steel frame. This frame extends from the hull to each side of the ditch or canal and is supported as a cantilever, from an A-frame. See Fig. 105. Where the excavated material has to be carried to a distance, the conveyor is often placed at the stern of the hull and a series of conveyors supported on pontoons are used. See Fig. 106.

SPUDS

One or two spuds are placed at the stern of the hull to secure stability of the dredge in operation, but principally to provide for the horizontal movement of the dredge. The spuds are generally built of a single timber with a pointed iron shoe at the lower end, and are usually operated by separate engines of the type used on floating-dipper dredges as explained in Chapter XII.

ENGINES

The engines are of the horizontal, double-cylinder type, as described in detail in Chapter XII for dipper dredges. These engines are gear connected to the drum or winch machinery. The drums are controlled by outside friction clutches actuated by small rams. Independent gear drives for the revolving screen and the ladder are often operated from the main engine by belt and pulley connections. However, separate engines are generally used for the operation of the spoil conveyors and the spuds.

A centrifugal pump, driven by an independent engine, is generally used to furnish water for a hydraulic motor, for the hoppers (if there are any) and for perforated pipes, which extend along the sides of the belt conveyor for cleansing purposes. Steam pumps of standard type are used to supply the condensers, feed-water heaters, and the boilers with a suitable water supply.

When electric power is used, individual motors are generally mounted on the winch drum or drive frame and gear connected by a pinion. These motors may receive current from a generator operated by a steam plant on the dredge or from a steam or water-power plant located on the shore.

BOILERS

The boiler is generally of the Scotch marine type and is mounted on the floor of the hull at the rear of the dredge. It should be of more than the estimated capacity to supply the engines and be operated at a working pressure of about 125 pounds. See Chapters VI and XII, pages 38 and 175.

DISPOSAL EQUIPMENT

The disposition of the excavated material depends upon the character of the work. In placer-mining operations, the dredge is provided with a hopper into which the material falls. Then the material passes through a revolving screen and upon a screen trough where the gold is collected by amalgam plates. In the excavation of canals or stream beds the materials pass from the hopper into a chute or trough which discharges into barges, as shown in Fig. 107, or directly from the bucket chain to belt conveyors which carry it to the spoil banks along either side of the channel, Fig. 105. In some cases, when the material is to be conveyed for some distance, the conveyor is placed at the stern of the hull and this charges into a series of other conveyors supported on pontoons. See Fig. 106.

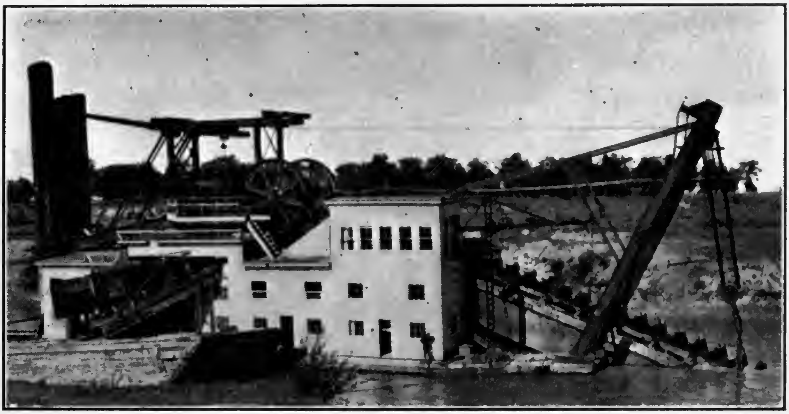

Fig. 107.—Ladder dredge provided with trough for discharging excavation into barges. *(Courtesy of the Bucyrus Co.)*

134. Method of Operation.—The outer end of the ladder is lowered until the bucket chain is in contact with the bed of the stream. Each bucket in the revolution of the chain, removes a slice of material as it comes into contact with the soil. At the top of the ladder, the buckets in turning over the upper tumbler, dump their contents into a hopper which discharges into a screen or directly upon a belt conveyor. The ladder is gradually lowered as the excavation proceeds.

The dredge is swung from side to side across the channel by wire cables attached to trees along the shore and to winch drums on the hull. To move the dredge ahead the spuds are alternately raised and lowered as the dredge is swung from one side to the other.

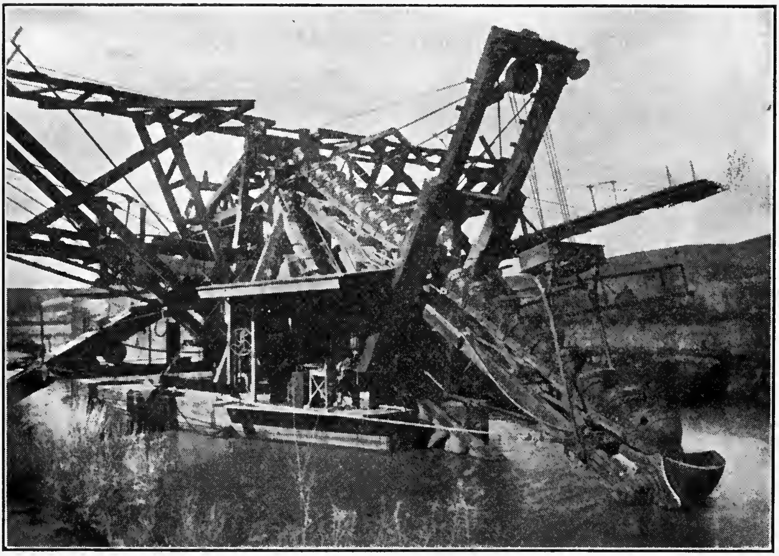

Fig. 108.—Ladder dredge excavating irrigation canal. (*Courtesy of the Reclamation Service.*)

When high banks are to be removed it is customary to use a large hydraulic monitor, which is placed near the ladder frame, and above the deck of the hull at the bow. Figure 108 shows an elevator dredge, equipped with a monitor, excavating a large irrigation canal in the West.

The machinery of the dredge is usually controlled by an operator, who is located in a small cabin placed near the bow and above the machinery house. Besides the operator there are required an engineer, who has general charge of the machinery, a fireman who runs the boiler of the steam equipment, an oiler, a deck hand for general service on the dredge, a man who has charge of the operation and control of the conveyors, and one or more men who have charge of the shore conveyors or barges.

Each dredge requires the service of one tug and from 4 to 8 scows, depending upon capacity of the dredge, size of channel, character of materials, etc. The scows may be of steel or timber and are generally of the bottom-dumping type with several independent compartments.

135. Cost of Operation.—As elevator dredges are generally built to meet special conditions of service, it is difficult to give any accurate statement of the average cost of operation. However, in order to suggest the cost of operation in canal excavation, the following statement of the use of the ladder dredges in the construction of an irrigation canal on a Reclamation Service project is given.

The channel had a total length of about 20 miles and in many places the banks were high on one or both sides. On fills and shallow cuts, bulkheads were built along the right of way on the lower bank to keep the wet material from flowing on to adjacent fields. The material excavated varied from a loose gravel to hard-pan, which in places had to be blasted.

The dredge used was a Bucyrus ladder dredge, equipped with steam power and a 3½-cu. ft. continuous bucket chain. The hull was built of timber, with a length of 82 ft., a width of 30 ft., a depth of 6 ft. 6 in., and drew 5 ft. of water. Steam was furnished by two locomotive-type boilers, 44 in. in diameter and 18 ft. long, and having a rated capacity of 80 horsepower. The main drive and ladder hoist were driven by an 8 × 12-in. double horizontal engine of 70 horsepower. The winch machinery for operating the spuds and swinging the dredge was driven by a two-cylinder, 6 × 6-in., double horizontal engine of 20 horsepower. The belt conveyors were operated by two 7 × 10-in., single-cylinder, center-crank, horizontal engines of 18 horsepower. A No. 1 Hendy hydraulic giant was mounted on the bow of the dredge and water was forced through it by a two-stage, 6-in., centrifugal pump, belted to a 10 × 12 in., single-cylinder, upright engine of 80 horsepower. The giant was used to remove banks above the water level and beyond the reach of the bucket chain. See Fig. 105. Two belt conveyors, one on each side of the dredge, were used for the disposal of the excavated material. Each conveyor was 72 ft. long and consisted of a steel framework supporting a 7-ply, 32-in., rubber conveying belt. Figure 108 shows the dredge in operation.

The operating force consisted of 8 men and 4 horses. Following is a schedule of the labor expense per day:

Expense Schedule of Daily Labor

Labor	Day rate
Superintendent	$7.50
Operator	5.00
Engineer	4.67
Spudman	3.83
Fireman	3.33
Oiler	3.00
Deckman	2.50
Man and team	4.50

The following tabulation gives the total and unit cost of the work:

Cost of Work by Ladder Dredge

Division	Cost	
	Total	Unit (per cu. yd.)
Labor (dredge)	$29,960.63	$0.030
Labor (spoil bank)	31,159.06	0.034
Fuel	33,043.07	0.036
Plant maintenance	52,327.40	0.057
Plant depreciation	41,432.53	0.045
Total	$187,922.69	$0.202
Engineering and administration	28,154.41	0.031
Grand total	$216,077.10	$0.233

136. Field of Usefulness.—The elevator dredge has been universally used in Europe for harbor and canal excavation and notably on the construction of the Suez Canal, the Panama Canal, and the New York State Barge Canal. In this country the ladder dredge has not come into general use on account of the high initial cost of the plant. The average American contractor prefers to use a dipper dredge costing about $40,000, rather than a ladder dredge requiring an investment of about $100,000, in order that he may secure immediate results on a less capital charge.

The elevator dredge is efficient in the excavation of all classes of material from silt to hard-pan and the softer stratified rocks. This dredge cannot work to advantage in narrow channels, and hence is not adapted to the excavation of small canals and ditches or the dredging out of narrow rivers. In such cases the dipper dredge should be used. When the banks are high, difficulty is experienced in depositing the excavated material. When the banks are low, dikes or bulkheads must be erected to prevent the soft material from flowing back into the channel or over adjacent land. When the sides of the channel are to be sloped, the bucket chain must be gradually raised and lowered as the dredge is swung over the side. Trouble is often experienced in the operation of the spoil conveyors and water jets are required to keep them clean. The excavated material is generally so wet that the deposition of the material in uniform spoil banks along the shore is a difficult matter.

The proper sphere of usefulness of the ladder dredge is in large canal, river, and harbor work, where there are wide, long reaches and a large amount of dense material to be removed. In such cases, the scow method of removal should generally be used.

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CHAPTER XIV

HYDRAULIC DREDGES

138. Preliminary.—During the past quarter of a century, the excavation and maintenance of the rivers, lakes and harbors of this country have developed the use of the hydraulic dredge. This type of excavator like the ladder dredge has been largely developed and used in European countries and has proved to be most efficient where a machine of large capacity was required for the removal of the softer and wetter soils, such as sand and silt. The hydraulic dredge has during recent years, been used successfully in the construction of large canals and artificial waterways; notably the Chicago Drainage Canal, the New York State Barge Canal, the Panama Canal and some of the larger distribution canals of the Reclamation Service Projects.

139. Classification.—Hydraulic dredges may be classified as to the method of operation and the disposition of the excavated material; the spud dredge, the sea-going dredge and the Fruhling dredge.

The first type, the spud dredge is especially adapted for channel excavation and maintenance where the distance the material must be pumped is not greater than about one-quarter of a mile. In narrow channels or rough water the spud dredge works at a great disadvantage on account of the permanent attachment to the discharge-pipe line, which must be continually maintained while the dredge is in operation, and suitable provision made for passing vessels and stormy weather.

The spud dredge is generally used in the improvements of rivers and harbors, and to provide for the various conditions of excavation, three different types are used. This classification is based on the method of excavation of "feeding." The three types may be stated as follows:

1. Lateral feeding.
2. Forward feeding.
3. Radial feeding.

1. The best known example of lateral feeding suction dredge is the "J. Israel Tarte," designed by Mr. A. W. Robinson and

used on the maintenance of the St. Lawrence River Ship Canal. The peculiar feature of this dredge is the sideways feeding with the cutter in contact with the bottom. The lateral pressure on the girder supporting the suction pipe and cutter is taken up by extending the girder flanges so as to bear against the sides of the central well.

2. The forward feeding type of hydraulic dredge is in general use on the Mississippi River. The dredges of this type have the axis of the centrifugal pump parallel to the axis of the boat and on the center line of the dredge. The suction pipes are provided with vertical flanged joints instead of the radial joints used on the other types of dredges.

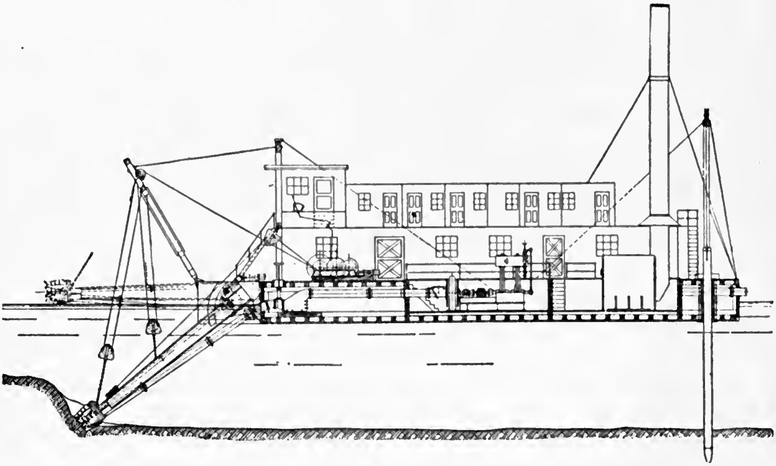

Fig. 109.—Side view of hydraulic dredge. (*Courtesy of Norbom Engineering Co.*)

3. The radial feed dredge is equipped with a cutter which describes an arc of a circle about the spud as a center. The suction pipe is provided with a universal joint so that it can swing laterally and also be raised and lowered.

Sea-going hopper dredges may be either self-contained with their own propelling machinery or use a tug boat to move them to and from the dumping grounds. This type of hydraulic dredge is best adapted to the excavation of the coarser materials such as sand and gravel in deep water and where the length of haul is greater than a quarter of a mile. The hopper dredge is also serviceable on lakes or harbors where storms and rough water conditions occasionally occur.

The Fruhling dredge is the most recent development of the hydraulic type of excavator and is especially adapted to the removal of silt and soft mud. It is essentially a sea-going hopper dredge equipped with a dredging head of special design. This head is box-shaped and is provided with a cutting edge which loosens the material as the dredge moves along at a speed of about 5 miles per hour.

140. Construction.—The essential parts of a hydraulic dredge are similar for all types; a revolving cutter, a centrifugal pump and the operating machinery. Figures 109 and 110 give detailed views of a small dredge of the spud type and Fig. 111 gives a general view of a sea-going hopper dredge.

The entire machinery is suitably mounted on a floating barge or hull. Attached to the pump is the suction pipe with a flexible, movable joint, so that the lower or outer end can be raised and lowered to any desirable depth. In some types of dredges a horizontal range is secured by swinging the hull of the dredge from side to side by means of lines attached to shore anchors. In the Von Schmidt type of hydraulic dredge, the suction pipe which extends from the end of the hull is placed on a table which rotates on a circular track. By rotating the table the suction pipe may be revolved through an angle of 120 degrees. The pipe is made of wrought iron, or steel, in sections which can be telescoped; the lower and small sections sliding up into the upper

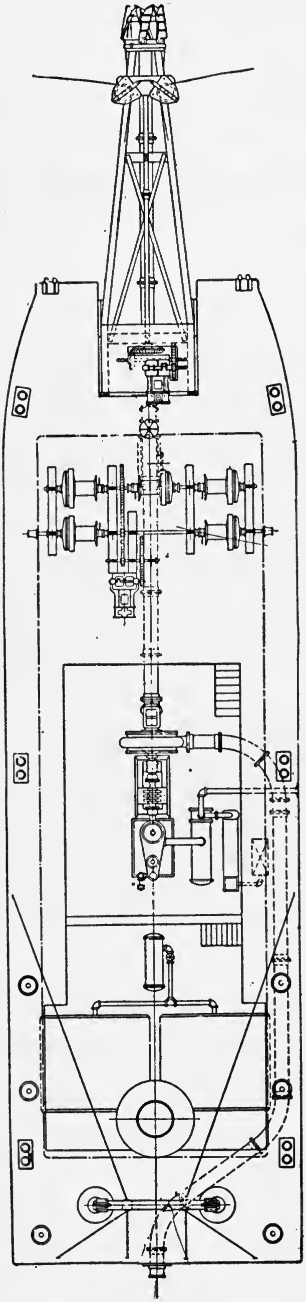

Fig. 110.—Plan of hydraulic dredge. (*Courtesy of Norbom Engineering Co.*)

and larger ones. At the lower end of the suction pipe is placed the mouth pipe, which consists of a circular hood. On the periphery of this hood are generally placed a series of knives, which form a revolving cutter. This is made to revolve by a shaft and gearing as shown in Figs. 109 and 110.

By use of the cutter the material to be excavated is loosened up and disintegrated and by dilution with the water is readily sucked up by the pump, through the suction pipe. The cutters thus allow the use of this type of dredge in the excavation of a very stiff or hard clay. A water jet has in some cases been used to remove and dissolve the material at the end of the suction pipe, but this detail has recently been chiefly supplanted by the revolving cutter.

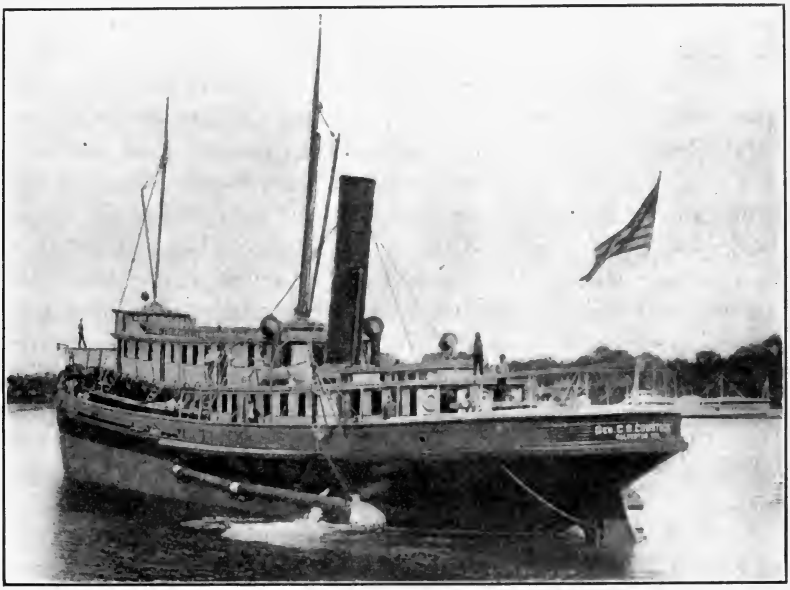

Fig. 111.—A sea-going hopper dredge.

PUMP

The most important element in the construction of a hydraulic dredge is the pump, which draws the excavated material up through the suction pipe and then discharges it through the discharge pipe to barges or to spoil banks on the shore. The pump is the governing factor in determining the efficiency of a dredge. The centrifugal pump is used exclusively for this work on account of its being of a rough and adaptable type of construction and range and ease of operation. Where large quantities of solid material pass through the pump (as high as 70 per cent. solids are often pumped) it is necessary to use a pump which does not require close adjustment of parts and where the parts are few in number, simple in operation and easy of replacement.

A centrifugal pump consists of a shell of circular form with two apertures, one on the periphery, the other at the center of one side. Inside this shell or outer casing revolves a set of vanes mounted on a shaft which extends transversely through the center of the casing. These vanes are the only part of the pump subject to great wear and the casing is generally constructed in two sections so that the top half can be removed and the shaft and runner taken out. In the so-called Edwards Cataract Pump, provision is made for the repair of the runner in the following manner. The vanes are made in two parts; the inner section, which is made as a part of the shaft extends two-thirds of the distance from the shaft to the inside of the casing, and the outer section, which is a piece of metal bolted to the inner section and forming an extension to the vane. The bolts pass through slots in the extension plate and this allows the plate to be forced to one side or bent away from a heavy body (such as a stone or piece of metal) which may come in contact with it. This prevents the breakage of the runner as a whole. The plates are made of light iron and can be easily replaced at a small cost by the removal of a hand-hole cover on the casing and the bolting on of a new plate. The opening in the side of the casing is the admission orifice to which the suction pipe is attached and through which the material enters to the casing. The steel suction pipe is generally 15 in. to 30 in. in diameter and varies in length from 10 to 60 feet. To the opening in the periphery of the casing is attached the discharge pipe, which varies in diameter from 6 to 48 inches. The following table gives the sizes and nominal capacities of a type of centrifugal pump especially made for dredging.

TABLE XII.—SIZES OF CENTRIFUGAL PUMPS

Diameter of discharge, inches	Capacity, gallons per minute	Capacity, cubic feet per second	Horse power required for each foot of total head
6	880	1.965	0.446
8	1,565	3.495	0.794
10	2,450	5.45	1.192
12	3,525	7.85	1.655
15	5,500	12.25	2.49
18	7,920	17.65	3.47
20	9,780	21.8	4.14
24	14,100	31.4	5.75
30	22,000	49.0	8.71
36	31,700	70.7	12.18
42	43,200	96.2	16.10
48	56,350	125.5	20.45

The above capacities and horse power are based upon a velocity of discharge of 10 ft. per second. For other velocities the capacities would be in proportion. Figure 112 shows a 20-in. centrifugal pump of the type used on the hydraulic dredges operating on the New York State Barge Canal.

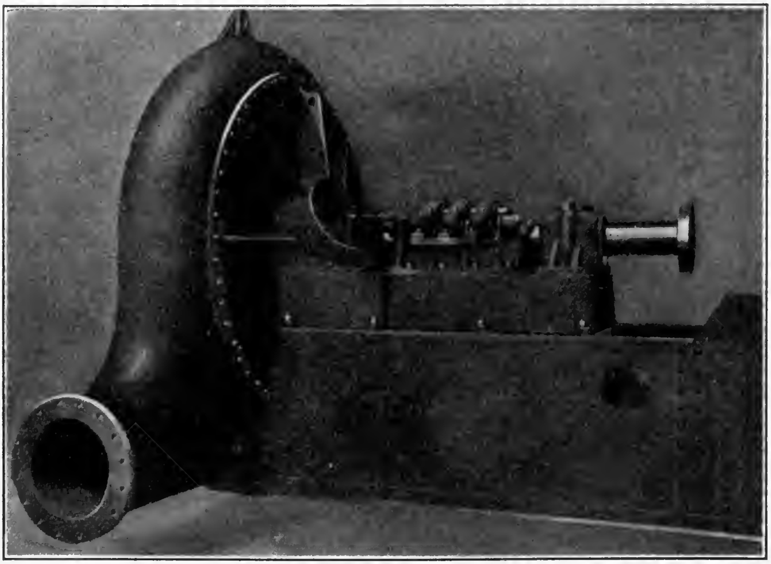

FIG. 112.—Centrifugal pump of hydraulic dredge.

ENGINES

The pump of a hydraulic dredge is generally direct connected to a steam engine of the vertical, marine type. For the small sizes and capacities compound engines are used, but where the engines are designed for hard service and to operate against high heads, the triple-expansion type is used. All marine engines for pumping service should be in excess of the requirements. They should be provided with extra large bearing surfaces and with an automatic sight-feed oil service which will allow for continuous operation. The crank shaft should be forged out of one piece of steel and especial care taken in the welding of the vanes at their junction with the shaft. The size and constructional details of the engine used depend on the size of the dredge and the work to be done. Further detailed information concerning engines, as well as the other parts of a hydraulic dredge will be given later in the description of some hydraulic dredges and their work.

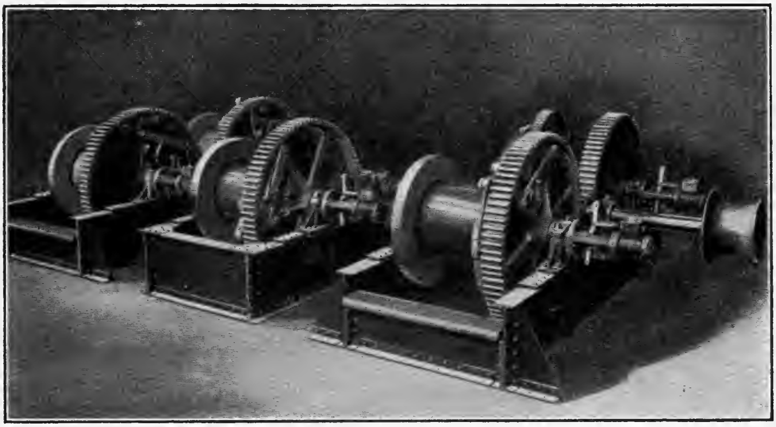

Fig. 113.—Machinery of hydraulic dredge.

Figure 113 shows the winch machinery of a 20-in. Bucyrus hydraulic dredge, used for hoisting the spuds, raising the ladder, swinging the dredge, etc.

HULL

The hull of a hydraulic dredge is rectangular in shape and with a length of about three and one-half times the width. The draft is made as small as possible and generally varies from 3 to 9 feet. This requires a depth of hull varying from 6 to 15 feet. The size of the hull depends on the capacity of the dredge. The hulls are constructed of both steel and wood, but experience has shown that steel is preferable on account of its greater strength, less cost of maintenance, and its ability to withstand the pounding and vibratory strains of the machinery. Cross-frames of steel or wood are spaced from 1½ to 2½ ft. on centers and connect the keelsons and deck beams. The framework is covered with steel plates or heavy wooden planking. The machinery is generally placed on a lower deck, while a superstructure or deck house extends over the greater part of the length and contains the living quarters for the crew and the operating house at the forward end.

SPUD FRAME

At the stern is placed a trapezoidal-shaped frame which suspends two vertical spuds by means of sheaves and cables leading to the engine drums. The spuds are generally single timbers of Douglas fir, long leaf pine or oak and are of sufficient length to reach the bottom of the excavation during high water.

BOILER

The prime mover is either steam or electricity. Steam is generated by boilers usually of the Scotch marine type. Where electricity is used the power is supplied either from a steam engine or from a power station independent of the dredge. The latter method of operation is the more economical and the more convenient to use when the dredge is operating near a steam or hydro-electric power plant.

DISCHARGE PIPE

The discharge-pipe line of the spud type of dredge extends from the pump through the stern of the hull and consists of iron or steel pipe varying in diameter from 12 to 48 inches. The pipe is supported on wooden or steel pontoons, and the adjacent sections of pipe are connected by heavy rubber sleeves fitting over the bell-shaped ends of the pipe. In recently built dredges, the joints of the discharge pipe have been formed into an iron ball-and-socket joint. Longitudinal and lateral stresses are controlled and relieved by steel springs, arranged somewhat as in the draft rigging of railway cars. Figure 114 shows a discharge pipe of a dredge operating on the New York Barge Canal.

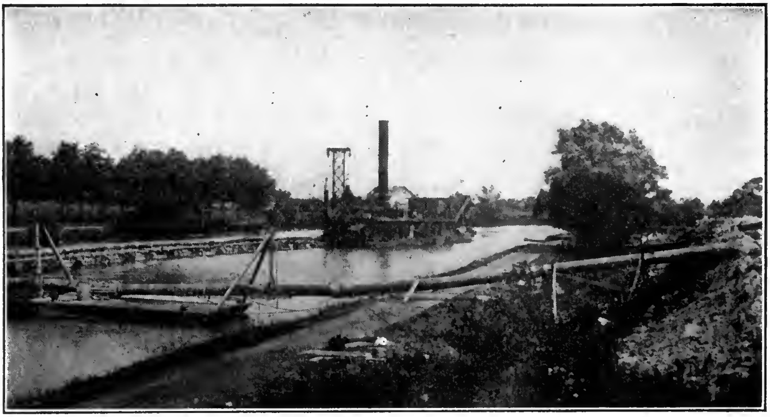

FIG. 114.—Discharge pipe of hydraulic dredge. *(Courtesy of N. Y. State Engineer.)*

141. Method of Operation.—The spud type dredge is held in position by cables which extend from the main or hoisting engine to an anchorage on either side of the bow, and by the two spuds in the stern of the hull. By alternately raising a spud

FIG. 115.—Cutter and suction pipe of hydraulic dredge. *(Courtesy of N. Y. State Engineer.)*

and winding up and unwinding the cables, the dredge may be swung from side to side so as to cover a wide area.

The revolving cutter excavates the material, which may vary from silt to hard-pan. See Fig. 115. The disintegrated material, diluted by water, is sucked up through the suction pipe into the pump and then forced out through the discharge pipe which is carried by pontoons, and discharges into scows or out upon area which is to be filled in.

The Fruhling (the latest type of sea-going hopper dredge) operates while moving at a speed of about 5 knots per hour. The outer end of the girder with its suction and pressure pipes is lowered to the bottom and as the hull moves along, the heavy head with its cutting edge is gradually filled with material. As this material is forced into the head, it is stirred up, if necessary, by jets of water furnished by a pump on the dredge, under high pressure. Thus the material is sufficiently diluted to be sucked by the pump into the hopper. The purpose of the special head is to exclude all water from the material, except an amount sufficient to give the fluidity desired for efficient pumping. The results of the use of one of a Fruhling dredge in Mobile Bay[1] showed that 60 to 90 per cent. of solid material in mud and 20 to 50 per cent. in sand was raised as compared with 10 to 20 per cent. with the ordinary cutter-head dredge equipments.

142. Cost of Operation.—It is impossible to give any accurate statement as to the average cost of excavation with a hydraulic dredge. Such a dredge on work of any magnitude is usually made especially for the particular conditions at hand and the cost of operation may vary within rather wide limits.

Following is a typical labor schedule for the operation during an 8-hr. shift of a hydraulic dredge equipped with a 20-in. centrifugal pump:

LABOR EXPENSE SCHEDULE

Labor	Monthly rate
1 operator	$100.00
1 engineer	100.00
1 engineer	80.00
3 firemen, @ $70.00 each	210.00
1 spudman	60.00
1 oiler	50.00
4 deck hands, @ $50. each	200.00

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[1] Professional Memoirs, U. S. Corps of Engineers, Capt. C. O. Sherill.

The average cost of operation would depend upon the size and capacity of the dredge, the character of the material, efficiency of operation, kind of power used, etc. Records of recent work show a range of from 4 cents to 15 cents per cubic yard for materials varying from sand to indurated gravel.

143. Field of Usefulness.—Hydraulic dredges have been in use for the last half century, but their greatest development has been during the last two decades, since 1895. In Europe their use has been largely in the maintenance of channels in the large rivers and in the construction of great canals. In this country they have been used principally in the reclamation of low, wet lands, along rivers, lakes, and harbors, the construction of great artificial waterways, such as the New York State Barge Canal and the Panama Canal, and the maintenance of channels in large inland waterways, such as the Mississippi River.

The earliest types of hydraulic dredge were provided with an agitator and water jets at the mouthpiece end of the suction pipe, and hence they could handle only the softer soils, such as silt, sand, and clay. In recent years, however, the cutter head has been developed in different forms, and very hard, dense soils can be loosened and broken up sufficiently to be discharged through the pump.

The hydraulic dredge is not an economical type of machine to use in the construction of levees or in canal excavation where the disposition of the excavated material must be made within a confined space. The material as it emerges from the discharge pipe is in such a high state of dilution that it will not remain in place unless confined within banks or bulkheads. Some method of removing the surplus water in the discharge pipe may be used effectively; one such method being the installation of overflow strainers placed at intervals in the upper sections of the pipe.

This type of dredge is unique among excavators in its ability to discharge the excavated material in any direction and at a considerable distance from the site of the excavation. This wide range of disposal is of especial value in the filling in of waste lands along waterways.

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CHAPTER XV

SUBAQUEOUS ROCK DRILLS

145. Preliminary.—The earliest known method of subaqueous rock excavation was by means of explosives which were lowered to the surface of the rock to be broken up. This method was uncertain and unsatisfactory especially in the case of a ledge. Large boulders and projecting rock can be easily fractured in this way. Later a drop bar was used to drill holes into which charges were introduced in the regular way. This method has proved to be slow and expensive.

In Europe, subaqueous rock breaking has largely been done by the use of a heavy bar, which shatters the rock by the impact of the falling point. In the United States, the early and crude methods of drilling and blasting have been developed, and have resulted in the universal use of some form of drill boat.

146. Classification.—The two general methods of rock breaking are as follows: (1) By the use of the Lobnitz Rock Cutter and (2) By some form of drill boat.

The four forms of drill boat in general use are:

(*a*) A floating barge, equipped with movable towers on which drills are mounted.

(*b*) A floating barge, equipped with drilling frames which are arranged to lower the drills to the rock surface.

(*c*) An adjustable platform which supports the drills and can be raised and lowered.

(*d*) A floating platform or barge, equipped with tripod drills.

The type of rock breaker used depends on local conditions, and special methods and devices must often be employed to solve unusual problems. Some of the conditions which affect subaqueous rock excavation and which must be investigated in selecting an equipment are; the depths of water over the various parts of the area, the shape and depth of excavation, the character of the rock to be broken up, the extent and nature of the overlying material, the nature of floods, tides, storms and climatic conditions to be encountered, etc.

I. LOBNITZ ROCK CUTTER

147. Construction.—The Lobnitz rock cutter consists of a heavy chisel of iron or steel weighing from 4 to 15 tons, and provided with a hardened steel cutting point. The cutter is usually mounted on a hull or barge which is rigidly braced by cross-frames. The details of a rock cutter are shown in Figs. 116 and 117.

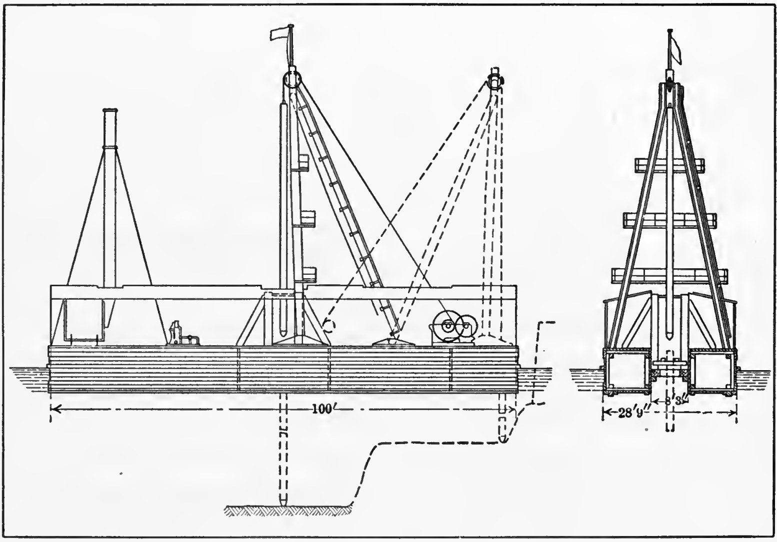

FIG. 116.—Side elevation and cross-section of Lobnitz rock cutter.

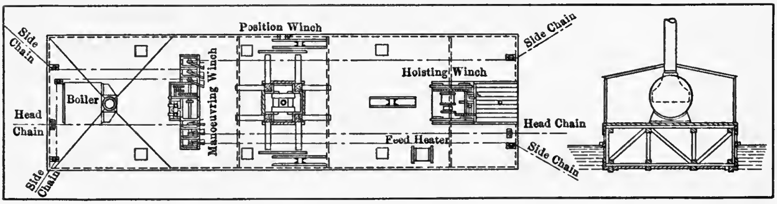

FIG. 117.—Plan of Lobnitz rock cutter.

In Europe, where this form of rock breaker is in general use, the ladder dredges are often provided with several picks or cutters, located in a well alongside of the ladder. These picks are placed about 2 feet apart and are operated singly or coördinately. The picks are sometimes made of heavy timbers which are provided with hardened steel points. The buckets of a ladder dredge so equipped are made of very heavy material and equipped with teeth on the cutting edges.

148. Method of Operation.—The cutter is raised by a winch or hoisting engine to a height of from 5 to 10 ft. and dropped upon the surface of the rock. The impact of the falling point serves to fracture rock to a depth of from 2 to 3 feet. The fragments of rock are removed by a dipper or ladder dredge. A ladder dredge provided with 10 cutters has excavated 43 tons of hard rock per hour.

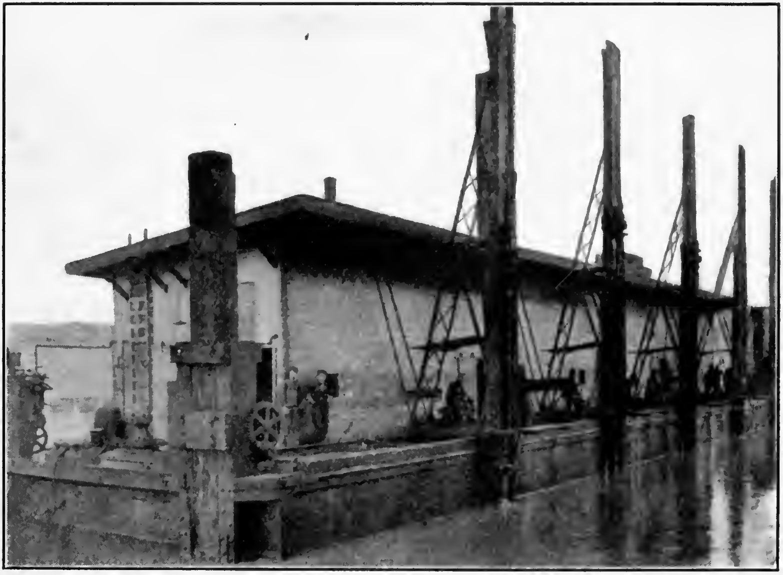

Fig. 118.—Drill boat on the Mississippi River. (*Courtesy of Great Lakes Dredge & Dock Co.*)

II. DRILL BOATS

149. Preliminary.—The Lobnitz rock cutter has never been adopted for subaqueous rock excavation in this country on account of its slow speed and cumbersome method of operation. Some form of drill boat has been in use in the waters of the United States and Canada during the past 40 years. The prototype of the modern drill boat was a barge devised in 1872 for the excavating of the harbor at Port Colborne on Lake Erie. This barge was equipped with two steam drills arranged for both longitudinal and horizontal feed and manipulated by spuds at the corners. The drill boats of the present time use these same principal features, which have been developed and improved to a considerable extent.

150. Construction.—The drill boat consists of a barge equipped with a spud at each corner and carrying one or more power drills. The details of construction depend on the uses to which the boat is to be put, and especially the character of the stream; tidal or non-tidal. Types (*a*), (*b*) and (*d*) as stated in Art. 146 are used in non-tidal waters, while type (*c*) is employed in tidal waters.

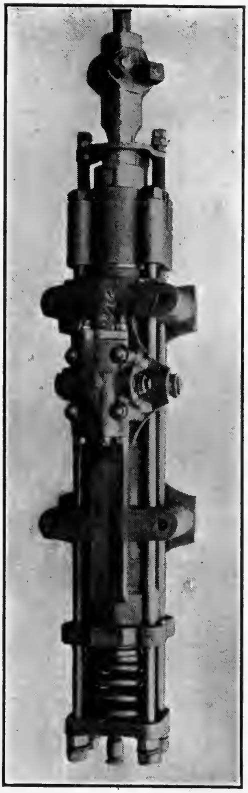

FIG. 119.—Detail view of a submarine rock drill. (*Courtesy of Ingersoll-Rand Co.*)

The boat or barge is built of either wood or steel and usually has a width of from 30 to 40 ft., a length of from 70 to 100 ft. and a depth of from 4 to 8 feet.

The drilling equipment consists of steam-operated drills which are mounted on movable towers. The latter are mounted on rails laid along one side of the barge. The towers are propelled along the track by chains operated by a separate wheel on the hoisting engine or by a cog wheel on the drill frame engaging a rack on the deck. A general view of a drill boat equipped with five drill towers is shown in Fig. 118. Means is provided for clamping the towers in any position on the track. Each tower is provided with vertical guides which carry the drill frame, the upper section of which is a heavy cast iron to which the drill is bolted. The drills vary in diameter from 1½ to 2½ in. and in length up to 50 feet. Figure 119 gives a detail view of a submarine rock drill and shows the cylinder and the spiral spring which is used as a shock absorber.

In the steam-operated type of drills, the drill frame is moved by a rope or cable which passes over a sheave at the top of the tower and connects the saddle with a drum of the hoisting engine. The power for the operation of the drills is supplied by specially constructed engines equipped with a throttle reverse. The drill feed regulation is controlled by a foot brake on the hoisting engine. The latter has gradually supplanted the hydraulic lift cylinder which was difficult to operate in freezing weather. Figures 120 and 121 show the rear and side views of a drill frame and hoisting engine.

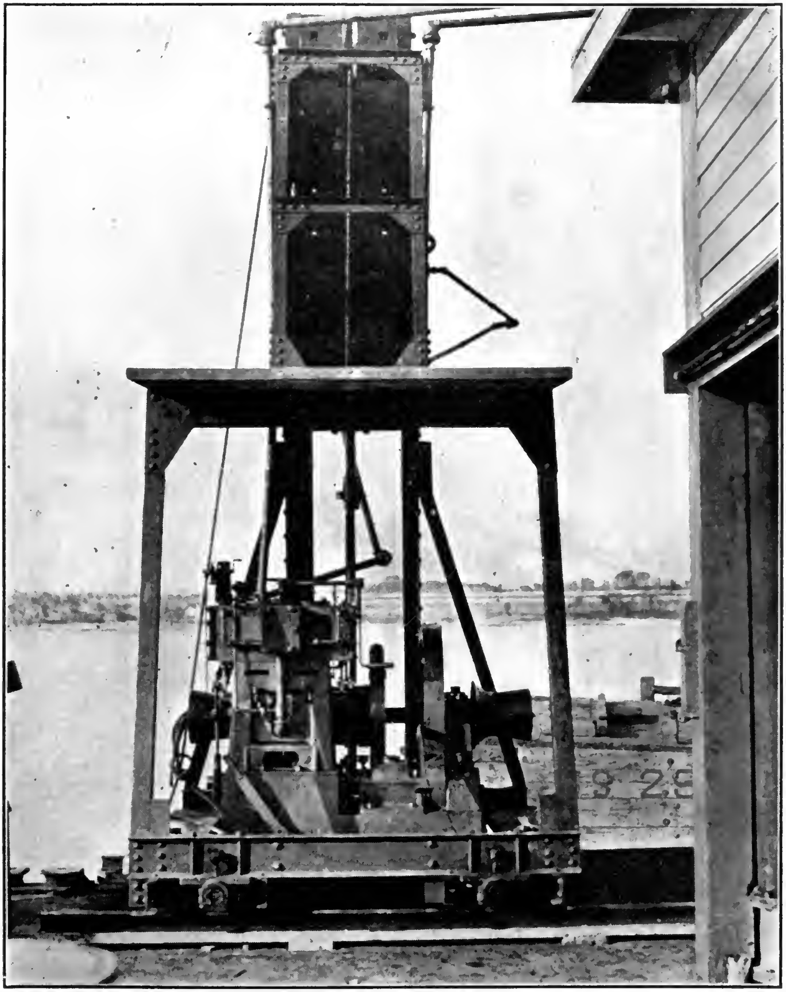

FIG. 120.—Rear view of drill frame and engine. (*Courtesy of Ingersoll-Rand Co.*)

Compressed air has been used to some extent for the operation of subaqueous drills but has not proved to be economical and satisfactory. Hence, steam is the kind of power generally used.

The pressure employed varies from 90 to 100 pounds. Provision must be made in determining boiler capacity for the supply of pumps, hoists, auxiliary engines, etc. As drill boats operate nearly continuously considerable difficulty will be experienced in the cleaning of boilers due to soot and scale. Hence it is desirable to provide suitable reserve boiler capacity. A feed water heater or some other type of water heater and purifier should be

Fig. 121.—Side view of drill frame and engine. (*Courtesy of Ingersoll-Rand Co.*)

utilized to soften and purify the water before it is fed to the boiler. In several cases, the drills have been exhausted to condensers with a considerable reduction in water saving and fuel consumption. Also the nuisance of exhaust steam was eliminated and pure boiler water secured.

In the early days of subaqueous rock drilling considerable difficulty was experienced in keeping the holes free from silt and débris washed in from the overburden or from upstream holes. To overcome this trouble the submarine drilling and charging tube was devised. The ordinary form of this tube is a telescoping pipe the lower section of which rests upon the solid rock which is being drilled, while the upper section is of large diameter and is made in two telescoping sections. The lower section of the pipe need only be slightly larger than the drill hole and is made long enough to extend through the overburden. The upper end of the tube is attached to a platform or a drill frame so that the drill may pass through it freely. Where the overburden is shallow and the water not too deep, a single size of pipe with a funnel top has been used satisfactorily. A jet pipe is necessary to force a stream of water at a pressure of about 100 lb. against the bottom of the hole to wash out the cuttings.

151. Method of Operation.—The drill boat is towed to its location and anchored by means of cables, anchors or its own spuds, depending on local conditions. The exact location may be secured by means of winches. The heavy spuds, located at the corners of the barge are lowered into position and the boat lifted until enough of its weight is carried in this manner to hold it in position. Usually a lift of about 6 in. is sufficient to hold the boat steady. Recently (1914), in the excavation of the Welland Ship Canal, a drill boat was equipped with spuds by means of which the barge could be raised several feet above the water level to secure a more rigid platform or on the approach of storms.

When the range in tide is over a foot it is difficult to make allowance variation in the operation of the spuds. This has been done in some cases by so adjusting the spud engines by additional weights on the spuds that when the tide rose the barge was lifted and when it fell the barge was lowered automatically. However, when the range of tide is large, this method is unsatisfactory and often results in the binding of the drills in their holes and subsequent damage to the drills or the frames.

(*b*) In localities where the tidal range is more than 3 ft. and the work is exposed to wave action, it has been found necessary to use specially mounted drills. The latter are fastened on long frames or shells which are bolted to heavy wooden or steel spuds. The barge on which the drills are mounted, is equipped with derricks for the placing of the spuds and attached drill frames or the latter may be housed in movable guides overhanging the sides of the boat. In the latter case, the guides are suspended from a track located several feet above the deck of the boat and are moved by means of trolleys operated by a hoisting engine. The drill frames are so mounted on the front face of the spuds that they can be raised and lowered by cables connected to the hoisting engine. Figure 122 shows a drill boat equipped with two submarine frames. The vertical motion of the drills is obtained by a feed screw which is actuated by a small, separate engine mounted on top of the frames. See Fig. 123. The relation of the boat to tidal changes or wave acton is made automatic by the operation of the spud engines. The latter are kept under a constant steam pressure and an increase in load on the spuds because of a falling tide will result in their slow-

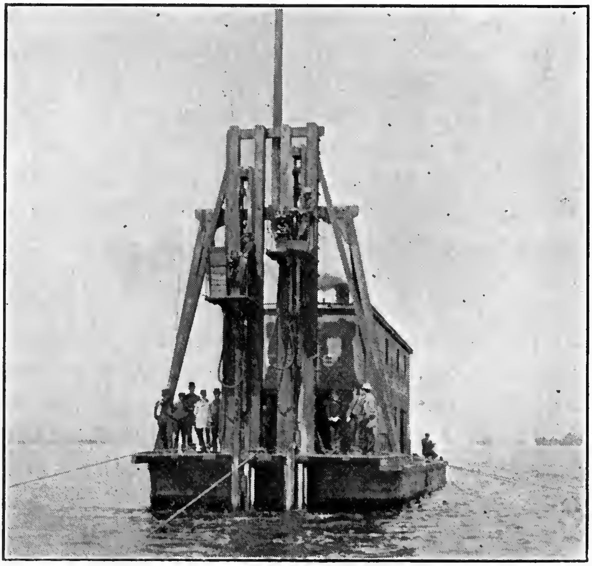

Fig. 122.—Drill boat equipped with two drill frames. (*Courtesy of Ingersoll-Rand Co.*)

ing up and any decrease in the load due to a rising tide will cause the engines to speed up against the steam pressure.

(*c*) A simple device for subaqueous drilling in shallow water, where swift currents, high tides and rough water or a combination of these conditions occur, is the use of an adjustable platform. The method of flotation is the use of barrels or pontoons and four spuds at the corners are used to support the platform as in the case of drill boats. The excavating or drilling equipment consists of two or more tripod drills which are mounted on wooden frames. The latter are arranged so that they can be moved over longitudinal slots in the platform. The slots are located in accordance with the required location of the drill holes and run continuously nearly the full length of the platform. The platform and spuds are operated by a hand winch. The power equipment is usually placed on a scow which is moored alongside the platform and consists of a boiler, accessories, forge, etc.

Fig. 123.—Detail of drill frame, drill and engine. (*Courtesy of Ingersoll-Rand Co.*)

(*d*) In shallow waters where the tidal range is small, as inland waters, drilling is often done from simple floating pontoons. The latter may be in the form of rafts which support steam tripod drills. The supports for the drills are usually A-frames made up of 4 × 12 in. timbers framed together to furnish a base for the lower ends of the tripod legs. The size of the float and the number of drills used depends on local conditions. In the construction of a channel through the Tuscumbia Bar in the Tennessee River, three floats, 25 × 77 ft. were used. Eight steam-operated drills were used on each float. Drilling was carried on through a 3-in. pipe, and the holes were spaced 4 × 6 ft.

and carried down to a depth of 9 ft. below low water. A plan and cross-sectional view of a drill platform is given in Fig. 124.

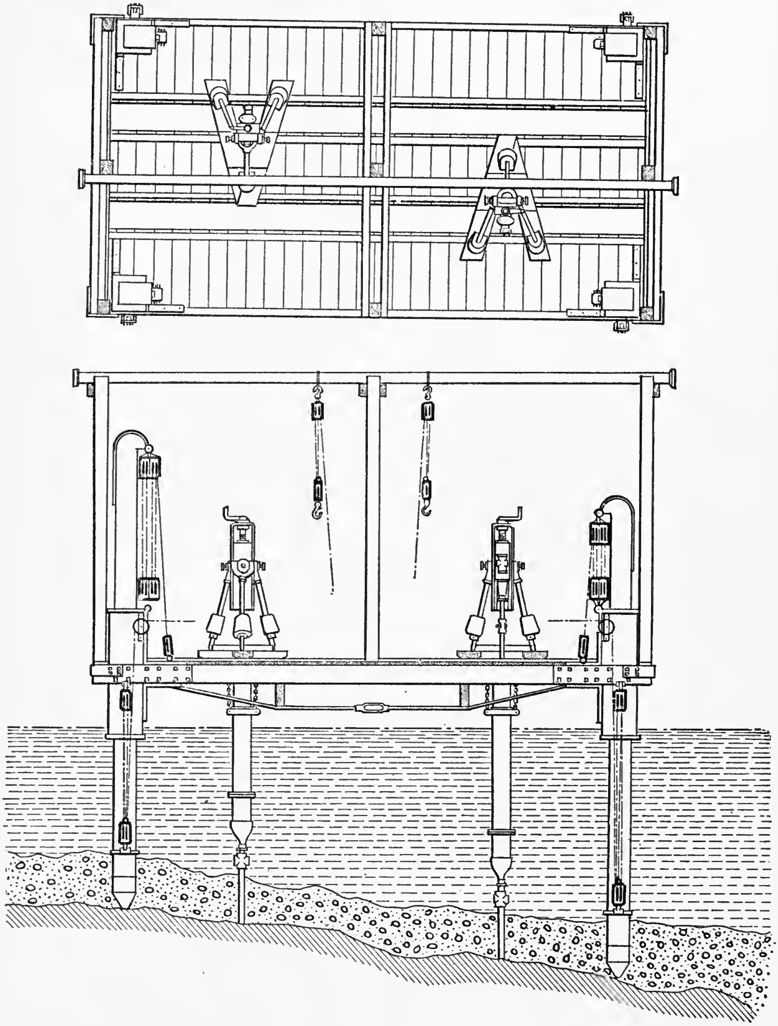

Fig. 124.—Platform for subaqueous drilling. (*Courtesy of Ingersoll-Rand Co.*)

152. Cost of Operation.—The output and cost of operation of a drill boat depends upon the number and size of drills, the character of the rock, the depth of excavation, etc. It is impossible to state any general rules which may be used in this class of work.

The following statement is given as a typical case of the use of a drill boat in channel excavation.

The work consisted in the excavation of a ship channel, 200 ft. wide and 17 ft. deep, in a large river. The material was a very hard limestone rock occurring in strata from 20 in. to 30 in. thick. The work was carried on in a stream having a current of from 8 miles to 12 miles an hour, in an area of turbulent water.

The drill boat was equipped with four 5-in. drills, which operated through four slots, each 20 ft. long and 18 in. wide, and located in the forward part of the barge. The drill frames carried steel drill spuds with pipe guides for the drill bars, and were arranged to move along tracks the length of the wells. Thus each drill made several holes at each set-up of the barge. Holes were drilled and blasted in groups of four. The rock was drilled below grade to a depth equal to half the hole spacing, which was about 6 feet. The dynamite used was proportioned on a basis of about 1 lb. to a cubic yard of rock.

The barge was supported on four 20 × 20-in. power-controlled spuds. Gear drums operated five 1¼-in. breasting chains, one leading upstream, and two over each side. Each chain was attached to an anchor weighing about 1 ton.

The monthly cost of operation is as follows:

Operating Cost of Drill Boat

Labor:

1 captain	$100.00	
4 drillers @ $75.00 each	300.00	
4 helpers @ $30.00 each	120.00	
1 fireman	30.00	
1 machinist	65.00	
1 blacksmith	70.00	
1 helper	30.00	
1 blaster	60.00	
1 helper	35.00	
1 cook	30.00	
Total labor expense, per month		$840.00

Board and Lodging:

16 men, @ $12.00 each, per month	$192.00

Fuel and Supplies:

60 tons coal @ $4.00	$240.00	
Oil and waste	40.00	
Blacksmith's coal	15.00	
Steel, iron, and supplies	52.00	
		$347.00

Grand total, per month		$1379.00
Cost of drilling, per drill hour		1.105
Cost of drilling, per foot drilled		0.049
Average depth of drilling, per hour (ft)	2¼	
Depth of drilling (ft.)	0 to 11	

153. Résumé.—The Lobnitz rock cutter works most efficiently in shallow layers of stratified rock, which is easily broken up. This form of rock excavator has not been adopted in this country because it is rather slow and cumbersome in operation and does not meet the needs of rapid channel construction in the rivers and harbors.

The drill boat works most efficiently in hard rock of depths of 3 ft. and over. The type of boat to be used depends on local conditions and especially as to the range of tide. For inland waters of shallow depth and little trouble from storms, the floating pontoon is the cheapest and simplest form of boat. For greater depths of water and where the range of tide is not over 2 ft., the floating drill barge can be efficiently used. Where waves, strong currents, flood conditions and ice jams may occur in inland waters, the barge equipped with submarine drilling frames or an adjustable platform should be used.

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CHAPTER XVI

CAR AND WAGON LOADERS

155. Preliminary.—One of the more recent developments in excavating machinery is the excavator and loader. There has been a great demand, in recent years, for a machine which would eliminate hand labor in loading and unloading cars and wagons.

Fig. 125.—Excavator and loader. (*Courtesy of T. L. Smith Co.*)

The excavation of foundations, basements and pits as well as the universal use of sand, gravel and broken stone in construction work has created a demand for a machine which will not only serve as a loader, but as an excavator as well. Two types of excavators and loaders have come into general use at the present time; the scraper-bucket type and the endless-chain type.

156. General Description.—The scraper bucket or drag-line excavator and loader consists of triangular frame mounted on a truck which carries an engine for the operation of a scraper bucket and hopper. An inspection of Fig. 125 will clearly show the various working parts of the machine. The projecting ends of the upright triangular frame carry the drum for the hauling cable, while the drum for the back-haul cable is located on the side of the machine. The dumping hopper is attached to the rear ends of a pivoted frame, and in its lowered position rests upon the lower ends of the side frame, with its edge in contact with a steel apron. The motive power is furnished by a 10-h.p. gasoline engine, but the machine is moved from place to place by a team or traction engine. The machine weighs 3000 lb. and costs $1500 f.o.b. factory.

Fig. 126.—Endless chain type of loader. (*Courtesy of Geo. Hoiss Mfg. Co.*)

The endless-chain type of excavator and loader consists of a four-wheel truck which supports an endless-chain excavator. See Fig. 126. Over the rear axle of the steel frame truck is located a triangular frame of steel members to which is pivoted the chain frame. This method of support allows the excavation of material of from 1 to 12 in. above the ground surface. The chains are of the roller-pin type and carry 20 carbon-steel

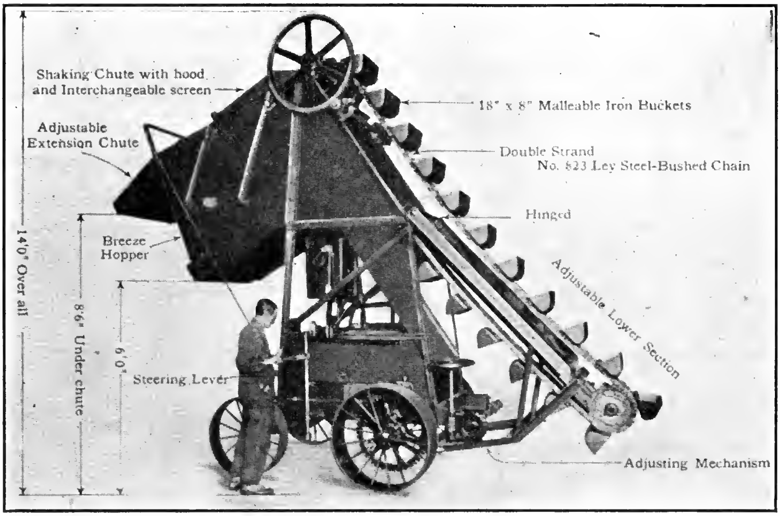

Fig. 127.—Self-propelling wagon loader.

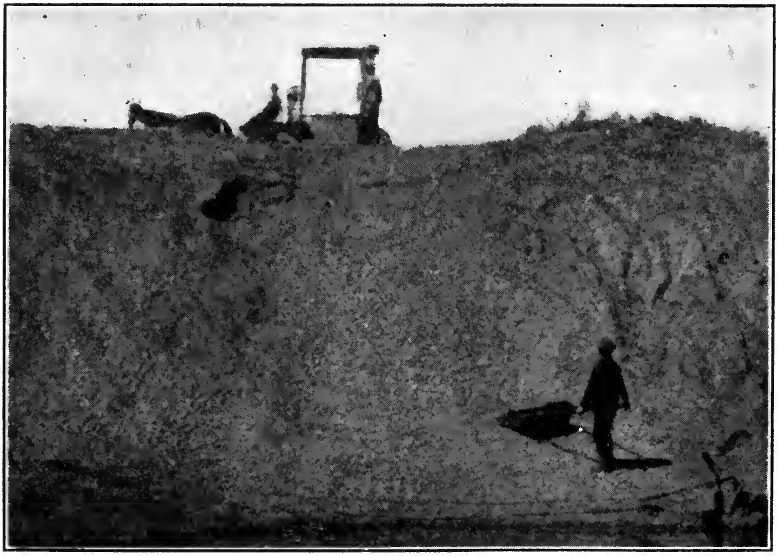

Fig. 128.—Scraper bucket excavator and loader excavating gravel pit.

buckets, each of which has a capacity of about ½ cubic foot. The motive power may be an electric motor or an internal combustion engine of 7½ horse power. The machine is equipped with a patent crowding device which pushes the elevator 30 in. into the material being excavated. The excavator weighs 5000 lb. and costs from $850 to $1100, depending on the kind of power used.

Another make of the endless-chain type of wagon loader is shown in Fig. 127. The loader shown is provided with a shaking chute and a hopper for the sifting and screening of coal, sand or gravel before dumping into cars or wagons. The special feature of this machine is a self-propelling device by means of which the loader may be moved forward or backward while the elevator is in operation. The loader may be adjusted by a worm-gear mechanism which operates a hinged frame. The wheels are all mounted on knuckles similar to the standard automobile practice. The entire operation of the machine is controlled by one man.

157. Method of Operation.—The initial step in the operation of the scraper-bucket loader is the lowering of the bucket or scoop to the place of excavation, where a man guides the bucket by the two handles, similar to the filling of a slip scraper. One of these machines being used for the excavation of a gravel pit is shown in Fig. 128. The loaded bucket is hauled by the hoisting line to the top of the slope, where the apron guides it into the hopper. The bucket releases a latch on the hopper which, with the continued pull on the hoisting line, is raised through a vertical arc until the contents are automatically discharged over an apron into a car or wagon. The engine is then reversed and the back-haul cable lowers the hopper to the loading position and pulls the scraper back to place of excavation. A chain can be attached to the outer or lower end of the cable and anchored to stakes or "deadmen." A pulley is attached to the chain near one end and a second pulley is placed at any other point along the chain. The back-haul cable is run through the fixed pulley and then through the movable pulley and then attached to the scraper. By shifting the position of the movable pulley along the chain, the scraper can excavate over a triangular-shaped area having the chain as its base and the machine as its apex. The dumping apron is attached to a pair of vibrating arms which raise it during the discharge of the hopper and thus prevents clogging. The machine can excavate to a distance of 80 ft. below or to its rear.

One man is required to operate the machine and one is needed to handle the scraper bucket. A two-horse team can haul the loader over ordinary roads.

The endless-chain loader for excavation work is operated in conjunction with a slip scraper which delivers the earth to the foot of the ladder chain and this lifts and discharges the material into the car or wagon under the spout. Where piles of sand, gravel, broken stone, earth or other materials are to be transported, the machine is backed up to the pile and the pivoted ladder placed so as to remove the material from the outside and bottom and thence working into the pile as the material is elevated. See Fig. 126. One man is required to operate the machine and a shoveler for loading from a pile of sand, stone, etc.

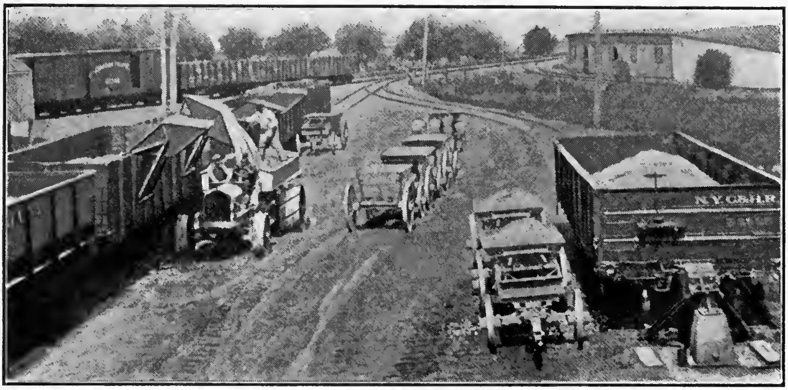

Fig. 129.—Loader used in loading trucks from cars.

A recent device has come into use for the loading of sand, gravel, crushed stone, coal and other similar material, into wagons, motor trucks and other vehicles, from railroad cars, gravel pits, sand bins, cinder piles, coal yards and other sources where the material can be shoveled by hand or elevated by mechanical means into the loader. As will be seen from an inspection of Fig. 129, it consists of a pivoted steel hopper which can be readily hung on the side of a car, wall or bin. It is easily tipped by the opening of a latch and when empty returns automatically to the loading position. The economy in its use comes from features of direct shoveling without waste and the saving of time usually lost by waiting for teams. The shovelers can be filling the loaders while the teams are away, and the dumping of the load requires only about a minute.

158. Cost of Operation.—The relative economy of loading a loose material such as sand, gravel, etc., with an endless-chain loader and by hand shoveling is given in the following statement which was furnished by the Efficiency Department of the Goodyear Tire and Rubber Company, Akron, Ohio:

Hand Labor:

Loading Wagons, 8 laborers, 3 yd., 13 min. @ $0.25 per hour	$0.435
Loading auto truck, 8 laborers, 2½ yd., 10 min. @ $0.25 per hour	0.415
Cost of auto truck @ $1.00 per hour	0.160
Cost per 5½ yards	$1.010
Cost per yard	0.184

Haiss "Digging" Wagon Loader:

Loading wagons, 2 laborers, 3 yd., 4.8 min. @ $0.25 per hour	$0.040
Loading auto truck, 2 laborers, 2½ yd., 4 min. @ $0.25 per hour	0.033
Cost of auto truck @ $1.00 per hour	0.066
Power @ ½¢. per cubic yard	0.028
Oil, grease, interest on investment	0.010
Cost per 5½ yards	0.177
Cost per yard	0.032
Cost per yard hand labor	$0.184
Cost per yard machine	0.032
Amount saved per yard	$0.152

This saving is entirely exclusive of supervision and overhead charges. Furthermore it was found that the men were forced to wait anywhere from 10 to 30 min. between loads; a loss of from $0.20 to $0.60 per load, amounting to from $3.00 to $9.00 per day. By using the proposed machine the cost of such unavoidable waits would be decreased approximately 75 per cent.

At an average of 100 yd. per day the saving due to this machine would amount to $15.00 per day and thus pay for itself in approximately two months.

159. Résumé.—The excavator and loader is a useful device which has been very recently developed to facilitate the handling of great quantities of loose material. The rapid development in the use of concrete for construction work has required the excavation and handling of large amounts of sand, gravel and broken stone and several forms of loading machines have been devised to meet this need. For direct loading from a pile or small pit, the endless belt or continuous bucket chain machine has proved to be very efficient, while for the excavation and loading of material from large pits, the scraper-bucket type is the most practicable.

The scraper-bucket excavator and loader is especially adapted for the removal of material from pits, cellars, basements, etc., where the working space is limited and the use of a power excavator would be impracticable. This form of excavation is generally done by hand shoveling at an excessive expenditure of time, labor and expense and the development of an efficient machine will meet a long-felt want.

The unloading of cars into motor trucks, dump wagons, etc. has always been caried on in a crude, expensive manner by hand shoveling. The use of automatic loaders is a great saving of time and expense, as 6 men with the loaders can ordinarily do the work of 8 men shoveling directly from the car into the wagons.

160. Bibliography.—For further information, consult the following:

Magazine Articles

1. Dragline Excavator with Wagon Loader. *Engineering News*, January 14, 1915. Illustrated, 600 words.

DIVISION II

A Discussion of the Efficient and Economic Use of Various Types of Excavators in Different Fields of Construction.

CHAPTER XVII

HIGHWAY CONSTRUCTION

161. Preliminary.—The great development in highway construction during recent years has emphasized the efficiency of light, portable and adaptable types of excavators for the varying needs of this kind of work. Generally it is true that each machine has its own special field of usefulness and its own economical method of operation. The blade and elevating graders have been used for a generation on road construction in the Middle West where they have proven their special adaptability for shallow excavation and grading. Recently, a large capacity wheel scraper has come into general use and has demonstrated much greater efficiency than its older prototype, the two-wheel scraper, for hauls greater than 300 feet. A special form of small, portable power shovel has been developed for the successful excavation of light cuts and the removal of shallow layers of hard material. A discussion of the various types of excavators used in highway and street construction will be given in the following paragraphs.

162. Scrapers.—The scraper is adapted to road construction where the topography requires the making of a number of small cuts and the handling of small quantities of earth on short hauls. See Art. 9, page 6. The drag or scoop scraper has been used to some extent on this type of construction work, but is not economical except for light excavation on steep grades, and for hauls of less than 200 feet. Three to twelve teams traveling in a circle or ellipse of about 200 ft. circumference can often be worked to advantage. The Fresno scraper is the form of drag scraper best adapted to highway construction on account of its long cutting edge and ease and rapidity of loading. See Art. 11, page 8. The depth of cut can be varied from 1 to 12 in., and the driver always has the scraper under complete control by the operation of the dumping lever. The snatch team and dumpman can often be dispensed with and if the earth is previously ploughed, the driver can load his own scraper. Generally the drag scraper of any type is only economical for the moving of earth which can be loaded without the use of a snatch team. The Fresno scraper can be used efficiently up to hauls of 300 feet.

The two-wheel scraper should be used with snatch teams and for work where the amount of excavation does not exceed 50,000 cubic yard. The two-wheel scraper can be efficiently used in gangs of from 5 to 7 on hauls of from 200 to 500 ft. for the excavation of average soils at a cost of from 17 to 25 cents per cubic yard. For stiff and heavy soils this cost would be increased from 50 to 100 per cent. See Art. 13, page 10.

The best form of wheel scraper to use on road construction is the four-wheel scraper made in two sizes, ½ and 1 yd. capacities. This machine has come into nearly universal use and for nearly all conditions of soil, haul, etc. has proved to be superior to any other type of scraper. For hauls of 300 ft. and over it is 50 to 100 per cent. more efficient than the two-wheel scraper and the efficiency increases with the length of the haul up to a possible maximum of 1000 feet. See Art. 15, page 12. The scraper under ordinary conditions has an average speed of 120 ft. per minute including time of loading and dumping. With a traction engine about 60 scrapers can be loaded per hour under average conditions of soil, haul, climate, etc. A 1-yd. scraper should average about 12 cu. yd. per hour or about 100 cu. yd. per 10-hr. working day. The cost of excavation, including overhead expenses, should average from 8 to 12 cents per cubic yard for a 200 ft. haul, and increase about 1 cent per cubic yard per 100 ft. increase in length of haul.

Scraper operation is very often uneconomically carried on because of a lack of proper planning and execution of the work. This is especially true of highway construction where the cuts are shallow and the hauls short. Care should be exercised to keep the scrapers moving and prevent "bunching" at the loading and dumping points. A few hours trial and time study will determine the proper number of scrapers to use in any case, a greater or less number of machines increasing the unit cost of the work. The loading foreman should see that each scraper is fully loaded and especially for two-wheel scrapers, a shoveler or the use of gates may be necessary. The work should be routed that the loaded teams may have the shorter haul and the empty teams the longer haul. All parts of the work, the loader, the scrapers and the dumpman should all be working uniformly and the teams kept continuously on the move, so that each part of the outfit will be properly coördinating to secure an economical performance of the job as a whole.

163. Use of Four-wheel Scrapers in Illinois.—The writer has observed the use of the four-wheel scraper on street and road work in Illinois during the years 1914 and 1915. The soil and topographic conditions were favorable; glacial clay and light grades. The width of cut varied from 18 to 25 ft. and the depth of excavation averaged about 12 inches. The average length of haul was about 350 feet. The scrapers were hauled by two-horse teams and loaded by a traction engine. A gang of about 7 scrapers was used for these conditions and an average statement of cost based on a 10-hr. day is given in the following table:

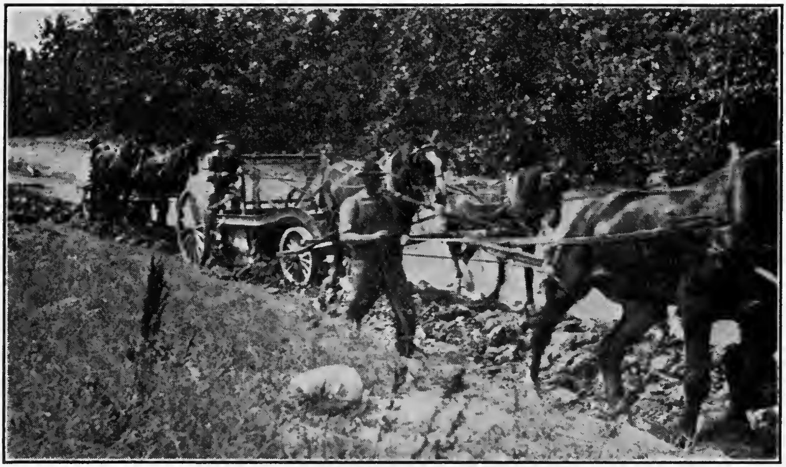

Fig. 130.—Four-wheel scrapers on highway construction.

Labor:		
2 fireman @ $4.00	$8.00	
1 cableman	2.50	
7 teams and drivers @ $5.00	35.00	
Total labor cost		$45.50
Loading Auxiliary:		
1 traction engine and operator		$16.00

General and Overhead Expenses:			
Supervision and general expenses	$5.00		
Interest on investment (7 per cent. of $2000)	0.70		
Depreciation, based on 5-year life	0.90		
Repairs, estimated	1.10		
Total overhead expenses		$7.70	
Total cost of excavation per 10-hr. day			$69.20
Total excavation			800 cu. yd.
Cost of excavation			$69.20 ÷ 800 = $0.0865

A view of a gang of four-wheel scrapers on highway construction is shown in Fig. 130.

164. Blade Graders.—The blade or scraping grader is a time-honored and much used and abused machine for the construction and maintenance of earth roads. The blade grader should be used for shaping up the cross-section after the grade reduction has been completed by the scraper or elevating grader.

Fig. 131.—Two-wheel grader shaping up a road. (*Courtesy of the Baker Mfg. Co.*)

The two-wheel grader is suitable for the grading up of old roads and the excavation of the side ditches. See Arts. 20 and 21, pages 19 and 20. The advantages of this form of machine are its lightness, ease of operation, requiring a two-horse team and a driver; and low cost of operation. Several townships in Iowa and Illinois have used two-wheel graders for the construction of side ditches and the shaping up of roads with an average output of 1 mile of ditch per 10-hr. day at a cost of about $10.00 including overhead expense. Figure 131 shows a two-wheel grader opening up a road ditch.

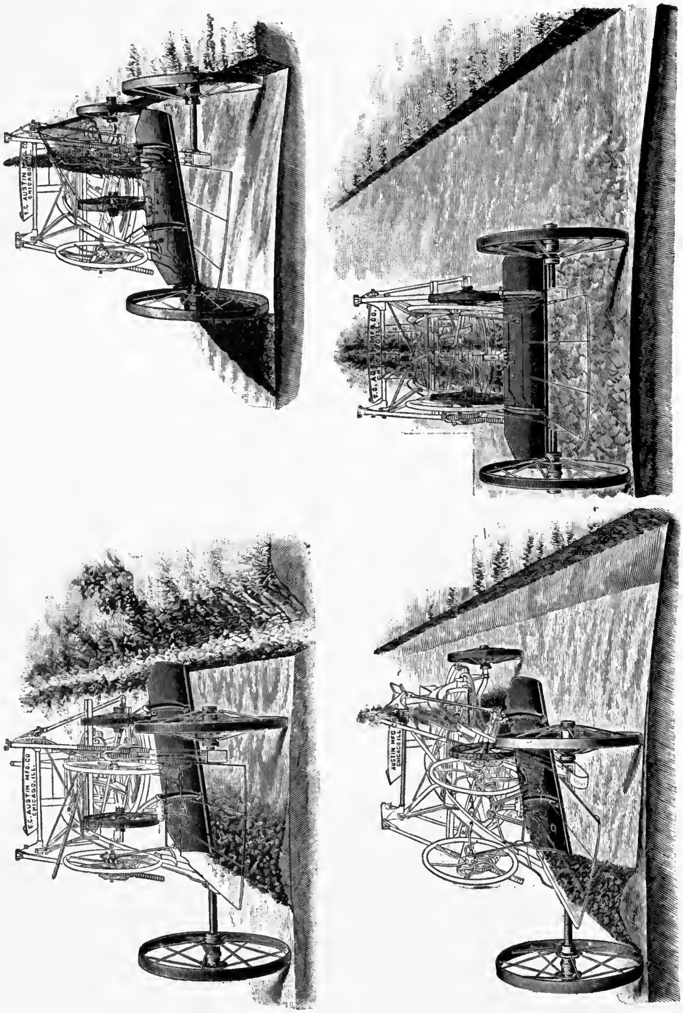

FIG. 132.—Diagram showing four stages of road construction. *(Courtesy of F. C. Austin Mfg. Co.)*

The four-wheel blade grader is a very serviceable machine for the shaping up of earth roads especially where the grades are light and the soil conditions are favorable. The ideal conditions for its use are in a prairie country where there are few rocks or stumps to hinder the work. See Art. 22, page 20.

The blade grader is operated so as to excavate a continuous slice of earth from one side of a cut and move it laterally and gradually by making several trips or rounds of the machine. The various steps are shown in Fig. 132. The grader begins at the side of the road with the blade elevated so that the point acts as a plow. On the second round, with the front and rear wheels in line along the edge of the road the blade is lowered and follows up the furrow made on the first trip. The third round is made with the rear wheels near the center of the road, the blade more nearly horizontal and swung around so as to push the earth toward the center of the road. The final round is made with the wheels in line and the blade nearly at right angles to the draft and so hung as to level off the material. A typical view of a large size grader shaping up an earth road is given in Fig. 133.

FIG. 133.—Blade grader shaping-up earth road. (*Photo by Author.*)

A great deal of difficulty has been experienced in the use of a road grader, especially in the excavation of stiff or dense clay soils, in preventing the displacement of the machine due to the lateral thrust of the material. Recently a type of grader, which was originally devised for ditch excavation on reclamation work, has been successfully adapted to road construction. This type of grader has pivoted axles so that the wheels can always be maintained in a vertical position. See Art. 23, page 22. This provides for the utilization of the weight of the machine to counteract the lateral pressure of the earth on the mold board and thus prevent side draft. Where work of considerable magnitude is included in one job or located in one locality, a traction engine can be used economically for the hauling of the grader. Two graders can be hauled by one engine and thus serve to move the earth from the side ditch to the center of the road in one operation.

165. Use of Blade Graders in Iowa.—In road construction in Van Buren County, Iowa, the tractor was a 60-h.p. gasoline engine and hauled two Reclamation graders as shown in Fig. 134. Sixty miles of earth road were built (1912) at a cost of $20.00 per mile. The road was 30 ft. in width, center to center of side ditches, which were 20 in. wide on bottom and had depths of 36 inches. The soil was the average loam and clay of the prairie country.

Fig. 134.—Reclamation graders on road construction.

166. Elevating Graders.—The elevating grader has been universally used on road construction in this country during the past generation. The ideal conditions for its use are in level country, and where there are few obstructions such as stones, roots, stumps, etc. However, under average working conditions of shallow cuts and ordinary soil, this type of machine is one of the most efficient in general use. It is more economical

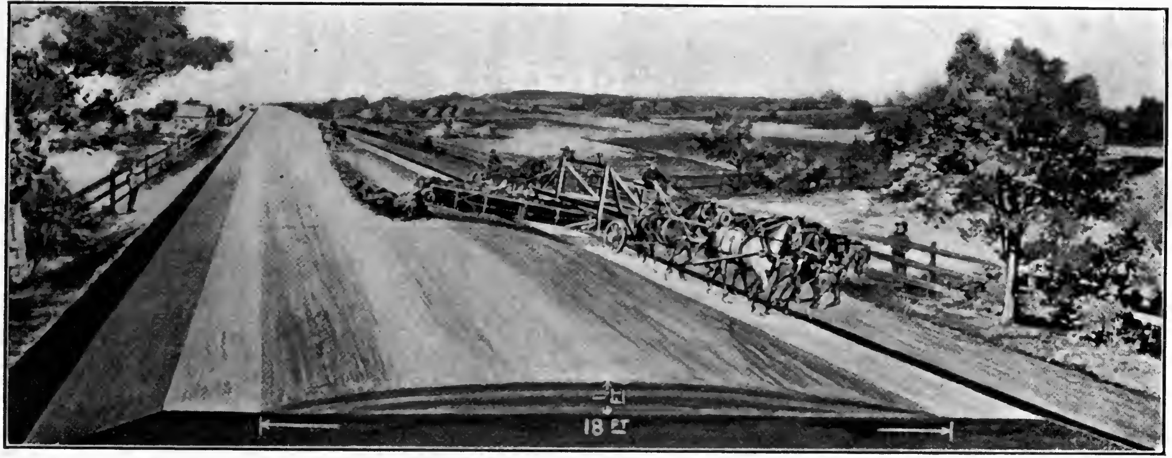

FIG. 135.—Diagrammatic view showing method of road construction with elevating grader. (*Courtesy of Western Wheeled Scraper Co.*)

than the blade grader on road construction, since the excavated material can be moved as cheaply 24 ft. as 10 ft. from the plow in one operation, while with the blade grader the distance to which the earth can be moved is limited to the length and set of the blade. In the shaping up of old roads where the side ditches are narrow and deep, the elevating grader is not serviceable and the blade grader should be used. As in the case of the four-wheel scraper, the elevating grader leaves the surface rough and uneven and a blade grader must be used to complete the work. See Chapter IV. In the use of the elevating grader on road construction, the method of operation and the character of the auxiliary machinery will depend upon the class of work to be performed. Ordinarily, three classes may be considered:

1. Nearly level country where the profile of the new grade is nearly parallel to the original surface.
2. Undulating or rolling country, where there are cuts and filling not over 3 ft. in depth.
3. Broken or rough country where the excavation is considerable.

In all classes of work, the grader should commence work at one side or edge of the road and make a furrow which is used as a guide in making the succeeding cut. As far as possible the work should be done in sections of considerable length so as to eliminate loss of time by frequent turning of the machine. Figure 135 gives a diagrammatic view of an elevating grader on road construction.

On roads of Class 1, the excavation is made continuous throughout the section and the material deposited uniformly along the center part of the road. The proper distribution of the material along the road should be done by drag or wheel scrapers, depending on the length of haul and the magnitude of the work.

On roads of Class 2, the excavated material is deposited on the road directly from the elevator only on the low sections. Where cuts are to be made, the material is deposited in dump wagons and hauled to the fills. Care should be taken to plan the work so as to eliminate loss of time waiting for wagons. The grader should be kept continuously in operation, with as few "waits" and delays as possible. A view of an elevating grader on road construction is shown in Fig. 136.

On roads of Class 3, the work must be carried on in relatively short sections, except when the cuts are of great magnitude and in this case some other type of excavator should probably be used. Under ordinary conditions, the revolving type of power shovel or scraper-bucket excavator is the more efficient form of machine to use in this class of road construction where the magnitude of the work exceeds 50,000 cubic yards.

Fig. 136.—Elevating grader on road construction. (*Courtesy of Western Wheeled Scraper Co.*)

167. Relative Cost of Use of Elevating Graders with Animal and Tractor Power.—The power tractor is the more economical form of power for the hauling of grading machines. The following statement has been prepared to show the relative cost of excavation with animal power and with the use of the power tractor. This is based on average working conditions and in fairly level country and for work under Class 1.

Animal Power

Labor:			
7 teams @ $3.00	$21.00		
2 drivers @ $3.50	7.00		
1 operator	4.00		
Total labor cost		$32.00	
General:			
Interest on investment @ 6 per cent	$1.20		
Depreciation, based on 10-year life	2.00		
Repairs and general expenses	1.30		
Total general expenses		$4.50	
Total cost per 10-hr. day			$36.50
Amount of excavation			800 cu. yd.
Cost per cubic yard, $36.50 ÷ 800 =			$0.045

GASOLINE TRACTOR

Labor:		
1 engineer	$5.00	
1 operator	4.00	
Total labor cost		$9.00
Power:		
Gasoline 30 gal. @ 25¢	$7.50	
Cylinder oil, 1½ gal. @ 50¢	0.75	
Grease, 2 lb.	0.25	
Repairs, waste, etc.	1.00	
Total power cost		$9.50
General:		
Interest on investment @ 6 per cent	$2.40	
Depreciation, based on 10-year life	4.00	
Repairs, and general expenses	1.60	
Total general expenses		$8.00
Total cost per 10-hr. day		$26.50
Amount of excavation		1000 cu. yd.
Cost per cubic yard, $26.50 ÷ 1000 =		$0.026

168. Power Shovels.—The steam shovel has become one of the best known and most generally used of power excavators. The advent of the light, portable type of revolving shovel has greatly enlarged the field of use of the power shovel and one of the new lines of operation is highway construction. See Art. 39, page 36. The revolving shovel is a machine of small capacity, light weight, rapid action and easy portability. The essential features of this type of excavator are the full-circle swing and separate hoisting, swinging and thrusting engines, the last of which provides for the pushing of the dipper forward into the earth and for the prying up of hard materials. See Fig. 137. During recent years, it has been successfully used in all types of road construction and maintenance; the excavation of all classes of earth and of cuts from 6 in. to 15 ft., of hard road surface and street pavements, the operation over steep grades, and its adaptability to side-hill work.

169. Use of Revolving Shovel in California.—A section of the Pacific Highway near Redding, California was completed in the Spring of 1915 and gives a clear idea of highway construction where heavy side-hill work is involved. Figure 138 shows the shovel in operation. The contract comprised the handing of 200,000 cu. yd. of excavation, 50 per cent. of which was earth, 25 per cent. loose rock and 25 per cent. solid rock requiring blasting. The work was done partly by overcasting and partly by the use of

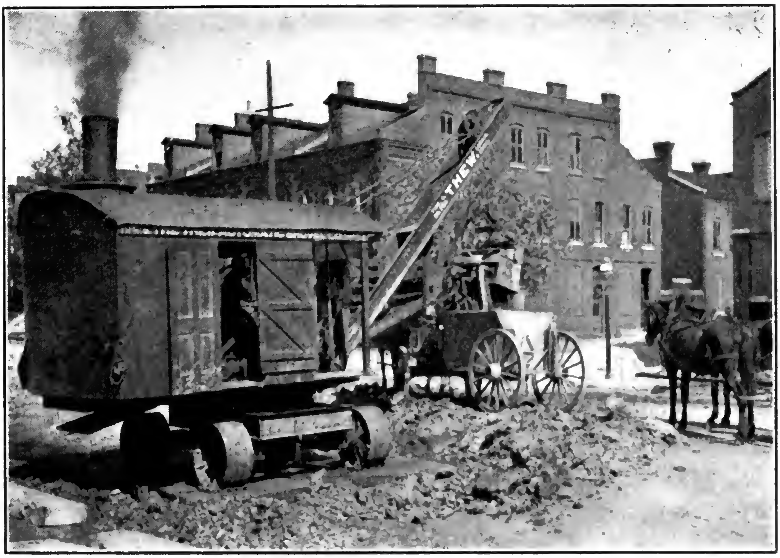

FIG. 137.—Steam shovel removing old street surface. (*Courtesy of Thew Automatic Shovel Co.*)

FIG. 138.—Revolving shovel on highway construction. (*Courtesy of the Excavating Engineer.*

1-yd. dump cars operated on narrow gage tracks. See Fig. 138. The length of the line graded was 16 miles and the road bed had a width of 10 ft. in cuts and 19 ft. in fills. The work was completed in about 300 days. The shovel was a Bucyrus revolving steam-operated shovel, equipped with a 25-ft. boom and a 1-yd. dipper.

170. Use of Revolving Shovel in Iowa.—An example of highway construction through typical rolling country is shown in Fig. 139. The contract comprised the reconstruction of the "Four Mile Hill" near Marshalltown, Iowa, as a section of the Lincoln Highway. The original road on a grade of from 12 to 15 per cent. was lowered to a grade of 7 per cent. and involved the excavation of 8200 cu. yd. of compact glacial clay at an average cost of 25 cents per cubic yard. The work required 32 days during April and May, 1914. The excavator was a 14-B Bucyrus revolving steam shovel equipped with a ⅝-yd. dipper. Ten dump wagons were used for the transportation of the excavated material. The average haul was 700 ft. and the maximum was 1200 feet. On April 18, 372 wagons were loaded in 7 hr., on April 19, 387 were loaded in 8 hr. and on April 30, 391 were loaded in 8 hours. The labor crew consisted of a foreman, an engineer and a fireman, in addition to a daily

Fig. 139.—Highway construction in rolling country. (*Courtesy of the Excavating Engineer.*)

supply of from 6 to 8 teams and drivers. The shovel consumed on an average a ton of coal per day.

171. Revolving Shovel in Shallow Excavation.—Up until very recently (1913), the power shovel has been economically used only for work of considerable magnitude and where the cuts were greater than 3 feet. However, later experience has demonstrated the adaptability of the revolving shovel to the work of shallow excavation, such as the removal of old street surfaces and pavements and the excavation for new street pavement foundations.

FIG. 140.—Steam shovel excavating for pavement. *(Courtesy of Thew Automatic Shovel Co.)*

See Fig. 140. Several cases which have come to the author's attention, during the past 3 years, have shown that for ordinary grading work in street pavement construction, the average cost varied from 8 to 10 cents per cubic yard when the depth of cut was about 12 inch. For the excavation of hard surface material such as old street pavements, the cost would be from 12 to 15 cents per cubic yard. These figures assume an average haul of 300 ft. for the dump wagons and the use of a ⅝-yd. or ¾-yd. revolving shovel. The following statement in Table XIII gives an approximate idea of the performance to be expected of a ⅝-yd. revolving power shovel under average working conditions for a 10-hr. day.

TABLE XIII.—CAPACITIES OF A REVOLVING SHOVEL IN SHALLOW EXCAVATIONS

Depth of cut, inches	Classification of material							
	Loose earth		Packed earth		Hard-pan		Pavements	
	Output, cu. yd.	No. of observations	Output, cu. yd.	No. of observations	Output, cu. yd.	No. of observations	Output, cu. yd.	No. of observations
18	360	12	280	9	225	3	300	2
12	300	5	240	7	175	4	250	4
9	250	3	200	4	150	1	200	2
6	200	1	150	3	100	1	150	1

In shallow excavation the proportion of time spent in "moving up" will be much greater than that of the fixed-platform type of power shovel used in work of average extent (see page 51) and would vary inversely as the cut. There would be a proportionate decrease in the actual loading time. Hence, it is clear that it would be uneconomical to use a power shovel when the total quantity of excavation is so small that the fixed charges of installation of the shovel on the job and its removal therefrom would bring the unit cost of operation above that obtained by the use of other methods and machinery.

172. Continuous Bucket Excavators.—During the past 2 years (1916 and 1917), several excavators of the continuous bucket type have been devised and used to a limited extent in street grading. These machines all embody the features of the endless-chain type of continuous bucket excavator for the purpose of making a shallow cut of a limited width and to a definite grade. See Art. 84, page 120.

A construction company of Illinois has devised an attachment for an ordinary continuous bucket trench machine. This consists of a cutter frame, 5 ft. 10 in. in diameter, rotated by the bucket chain, which travels on sprockets on the shaft of the cutter frame. The cutter is made up of 6 rows of 8 teeth each. Inclined plates are so located as to transfer the earth loosened by the teeth to the buckets, which elevate it to the cross conveyor delivering to the spoil bank or dump wagons. At the rear of the cutter frame is a scraper or templet plate which serves to catch the stray material and to trim the grade. See Fig. 141. This excavator can cut a strip having a width of 8½ ft. and a depth varying from 2 in. to 5½ feet. The cutter frame is pivoted to the rear of the main frame and its elevation is regulated by a screw device. The machine can be adapted to the preparation of the subgrade for a wide street pavement by making the side cuts first and to the proper pitch required by the crown of the street. The cutters are sufficiently rigid and strong to dig up old macadam paving.

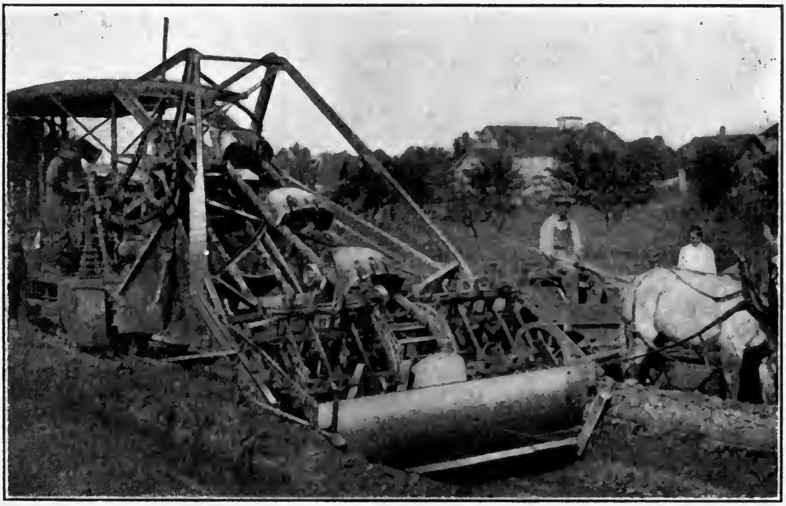

Fig. 141.—Continuous bucket excavator on street grading.

A continuous bucket or wheel grader has recently been used successfully on street grading in the Middle West. It is called the turbine traction grader and is manufactured by the Koehring Machine Company of Milwaukee, Wisconsin. An inspection of Fig. 142 will give an idea of the construction and method of operation of the machine.

A steel-framed platform carries the operating equipment at the front end and the excavating equipment at the rear end. The operating equipment consists of a 45-h.p., four-cylinder, four-cycle, vertical gas engine, or a 25-h.p., vertical, duplex steam engine and a 30-h.p. vertical, multi-tubular boiler. The engine operates the excavating equipment by a chain drive and the multiplane tractors by gear drive. The excavating equipment is composed of a rotating cylinder on which are mounted 12 buckets, on the cutting edges of which are rooters which excavate the material, dropping it back into the buckets which in turn elevate and dump it on the belt conveyor, extending at right angles from the side of the machine in position to discharge the material directly into wagons, cars, or trucks. The cutting wheel can be adjusted vertically to make a cut of from 1 in. to 2 ft. in depth, and the finished cut has a width of 5 ft. 7 inches.

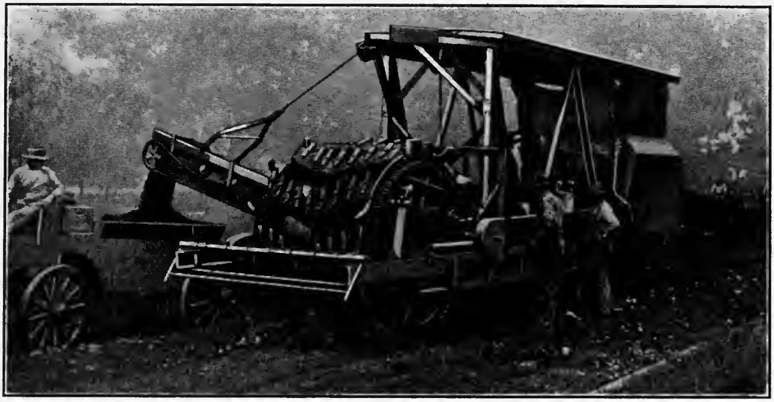

Fig. 142.—Turbine traction grader on street construction. (*Courtesy of Koehring Machine Co.*)

While in operation the machine may be moved ahead at any one of three speeds depending on the depth of cut and character of the material.

A grader was used during July, 1917, in Chicago on street grading. The material was clay, and the machine was operated by a 34-h.p. engine. The following is a statement of the cost of operation during a typical 9-hr. day:

Labor:		
1 foreman	$6.00	
1 operator	7.00	
1 helper	3.50	
2 laborers @ $3.00	6.00	
7 teams @ $7.00	119.00	
Total labor cost		$141.50

Fuel:		
Gasoline and oil	$12.50	
Total cost of operation		$154.00
Total excavation		624 cu. yd.
Cost per cubic yard, $154.00 ÷ 624 =		$0.247

The dump wagons were of 1 ¾ yd. capacity and were loaded in from 59 to 70 sec. and hauled about ½ mile to the dump.

173. Résumé.—In the selection of an excavator for highway construction, the essential considerations are lightness, portableness, ease and rapidity of operation and special adaptability to special kinds of work.

In the early days of road building, a generation ago, the scrapers and graders were used in a crude, unscientific way without much regard to their efficiency or adaptability to the particular work in hand. With the rennaissance in road construction during the past decade, these time-honored types of excavators have been studied as to their peculiar limitations of efficient use and new types have been introduced to meet the demands of modern construction work.

Slip or scoop scrapers are suitable for small work where the haul is about 100 ft. and especially in coöperation with an elevating grader for light cuts and fills. The Fresno scraper is efficient for hauls up to 250 ft. and where the wide cutting edge may be used to advantage in pushing earth over short distances.

The wheel scraper is more efficient than the scoop or Fresno scraper for hauls over 250 ft. and where the soil must be previously loosened. Under average conditions the four-wheel scraper is the best type of scraper to use in highway or road work and is efficient up to hauls of 1000 feet.

The blade grader is of especial service in road maintenance and the smoothing and leveling off of a surface previously prepared by a scraper or elevating grader. As the blade grader moves earth by pushing or sliding it along the surface, it is only adapted to shallow excavation.

The elevating grader can be used successfully in grade reduction in conjunction with scrapers for light cuts or with dump wagons for the heavier work. In nearly level country or where the grade reduction work is completed, the elevating grader is an efficient machine for the "shaping up" of the cross-section of the road.

In highway construction through rough country where the excavation is of considerable magnitude and side-hill work occurs, the revolving power shovel is the most efficient machine to use. The introduction of the crowding or thrusting device for the horizontal movement of the dipper arm has brought the small, portable revolving shovel into the field of shallow excavation for street pavement construction, where it is especially useful in the excavation of hard materials.

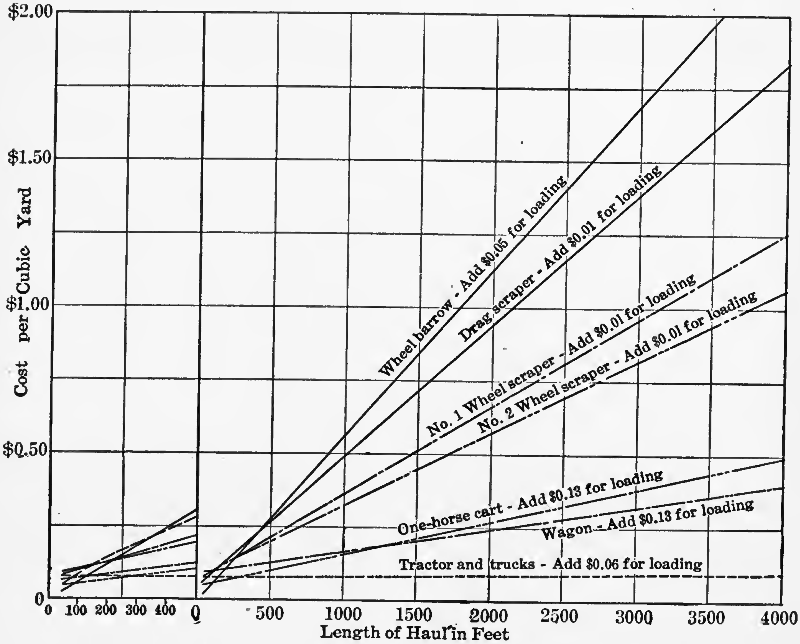

FIG. 143.—Cost of grading in highway construction.

The latest type of continuous bucket machine has proved its efficiency particularly in the excavation of roads and streets for pavements. The author believes that the greatest developments in machinery for road construction will be of this type in the future.

The cost of moving earth in highway construction varies greatly with local conditions of climate, soil, topography, labor, etc.[1] Figure 143 gives a graphic comparison of the cost of grading by various methods. The figures are based upon a wage scale of 15 cents per hour and capable supervision.

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[1] See *Engineering Record*, Vol. 70, page 570.

Table XIV[1] gives the cost of earthwork on four roads in New York State and represents easy, average and difficult work. The cost per cubic yard includes excavation and placing in fill, shaping the subgrade for the stone, and trimming the shoulders and ditches. For heavy fills with short hauls, wheel scrapers were used, but the larger part of the work was done by wagons.

TABLE XIV.—EARTH EXCAVATIONS—NEW YORK STATE ROADS

Road No.	Length, miles	Total excavation, cu. yd.	Wages per hour		Cost per cu. yd.	Kind of soil
			Men	Teams		
1	2.5	8,600	$0.175	$0.45	$0.452	Loam and gravel, easy work.
2	5.5	28,000	0.175	0.45	0.482	Largely clay, hard excavation.
3	6.0	18,000	0.150	0.45	0.460	Gravel, sand, clay, loam, etc., average work.
4	4.0	10,000	0.175	0.45	0.650	Small boulders, 25 per cent. excavation, difficult excavation.

174. Bibliography.—The reader is referred to the following for further information:

Books

1. "Construction of Roads and Pavements," by T. R. AGG, published in 1916 by McGraw-Hill Book Company, New York. 6 in. × 9 in., 432 pages, 116 figures. Cost, $3.00.

2. "Earthwork and Its Cost," by H. P. GILLETTE, published in 1912 by McGraw-Hill Book Company, New York. 5 in. × 8 in., 238 pages, 60 figures. Cost, $2.00.

3. "Elements of Highway Engineering," by A. H. BLANCHARD, published in 1915 by John Wiley & Sons, New York. 6 in. × 9 in., 497 pages, 202 figures. Cost, $3.00.

4. "Handbook of Cost Data," by H. P. GILLETTE, published by McGraw-Hill Book Company, New York. 4¾ in. × 7 in., 1900 pages. Cost, $5.00.

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[1] From Harger & Bonney's Highway Engineer's Handbook.

5. "Highway Engineers' Handbook," by HARGER and BONNEY, published in 1916 by McGraw-Hill Book Company, New York. 4 in. × 7 in., 609 pages, figures. Cost, $3.00.

6. "Roads and Pavements," by IRA O. BAKER, published in 1914 by John Wiley & Sons, New York. 6 in. × 9 in., 698 pages, 171 figures. Cost, $4.50.

7. "Textbook on Highway Engineering," by BLANCHARD and DROWNE, published in 1911 by John Wiley & Sons, New York. 6 in. × 9 in., 761 pages, 234 figures. Cost, $4.50.

Magazine Articles

1. Conditions Determining Maximum Grades and Methods and Cost of Road Grading in West Virginia. *Engineering & Contracting,* January 6, 1915. 2000 words.

2. Design and Construction of Earth Roads in Iowa. *Engineering News,* April 16, 1914. Illustrated, 2700 words.

3. Detailed Cost of Constructing a Sand-Gumbo Road in Mississippi County, Missouri. *Engineering-Contracting,* October 27, 1909. Illustrated, 600 words.

4. Earth Handled Cheaply in Grading Utah Roads. *Engineering News,* July 6, 1916. Illustrated, 1000 words.

5. Earth Road Construction in Murray County, Minnesota. *Engineering & Contracting,* August 2, 1916. Illustrated, 1500 words.

6. Efficient Plant Used in Excavating Gravel for Road Work. *Contractor,* July 1, 1916. Illustrated, 2500 words.

7. Gasoline Tractor for Southern Road Work. *Engineering News,* August 27, 1914. Illustrated, 1300 words.

8. Gravel Road Construction in Wisconsin. *Engineering News,* October 15, 1914. 2200 words.

9. Hydraulic Excavation Methods in Seattle. *Engineering Record,* May 4, 1912. Illustrated, 2500 words.

10. Industrial Railways in Road Construction. *Engineering & Contracting,* February 7, 1917. 1500 words.

11. Making a Highway in Two Days. *Engineering News,* October 10, 1912. Illustrated, 4000 words.

12. Methods and Cost of Gravel Road Construction in a Road Improvement District in Loundes County, Miss. *Engineering & Contracting,* September 23, 1914. Illustrated, 1800 words.

13. Methods of Handling Earth in Road Construction, C. R. THOMAS. *Engineering & Contracting,* February 7, 1917. 1500 words.

14. Operation Analysis of New Machines Which Cheapen the Moving of Earth on Road Work. *Engineering Record,* July 31, 1915. Illustrated, 3000 words.

15. Practical Road Building. *Municipal Engineering,* April, 1912. 1500 words.

16. Revolving Shovel Operation on the Mississippi River Power Company's Project, near Keokuk, Iowa. *Excavating Engineer,* December, 1913. Illustrated, 1500 words.

17. Road Construction Work by Grading Camp Maintained by County. *Engineering-Contracting*, September 30, 1908. 900 words.

18. Road Making in the United States. *Surveyor*, September 9, 1910. 4000 words.

19. Street Grading in Everett, Washington with Revolving Shovel. *Excavating Engineer*, February, 1914. Illustrated, 300 words.

20. Street Grading with a Revolving Shovel in Los Angeles. *Excavating Engineer*, June, 1914. Illustrated, 800 words.

CHAPTER XVIII

RAILROAD CONSTRUCTION

175. Preliminary.—Since the early days of railroad construction in this country, about 50 years ago, great progress has been made in the methods of earthwork. The original crude methods of hand labor have been largely superseded by large and efficient power machinery. During the past decade, the use of the steam shovel has been put on a much more efficient basis than formerly, and the introduction of the revolving shovel and the scraper-bucket excavator has been a great factor in recent realinement and grade reduction work.

During the past 5 years especially, considerable advance has been made in the economical and efficient handling of machinery. This progress has been coincident with the development of the science of management in the industries and the result of the introduction of the principles of efficiency engineering in the handling of earth. The most notable progress has been made in the operation of steam-shovel outfits in the construction of large cuts and fills. Labor-saving devices have been employed to great advantage in conjunction with new and more efficient methods. Thus the gradual adoption of new devices and efficient methods have replaced the former dependance upon manual labor and rule-of-thumb methods.

A discussion of the various types of excavators used in railroad construction and maintenance will be given in the following sections.

176. Scrapers.—The use of the drag and wheel scrapers has become a well-known factor in railroad construction. A quarter of a century ago during the period of great railroad development in this country, the scraper and the cart or wagon were universally used. Gradually, the fields of efficient employment of the various types became known and understood as the steam shovel came into prominence on work of considerable magnitude. At the present time, each type of excavator has its special function and scope of economic employment and this has become especially true with respect to the various forms of scrapers. See Art. 9, page 6 and Art. 162, page 250.

An excellent analysis of scraper work was made by Mr. A. C. Haskell for the Construction Service Company of New York.[1] The following statement is of interest and value to those who have estimates and studies to make in the use of scrapers for earthwork.

The general economic formula for transportation is as follows:

Symbol	Factor
C	The total expenses per day in cents.
w	The net load, for the average trip, in pounds, or other convenient unit.
S	The speed (average) when loaded, in feet per minute.
KS	The speed (average) when returning, in feet per minute.
D	The length of haul in feet.
l	The time lost in turning, resting, and wasted for an average round trip, in minutes.
Rt	The total cost in cents per ton for transportation.
W	The number of minutes in the working day.
	The following facts are deducible algebraically:
D/S	Time for a loaded trip, in minutes.
D/KS	Time for the empty haul.
$1 + D/KS$	Actual time not occupied in transporting material, in minutes.
$\frac{D}{S}\left(1 + \frac{1}{K}\right) + l$	Average time for one round trip, in minutes.
$\frac{W}{\frac{D}{S}\left(1 + \frac{1}{K}\right) + l}$	Average number of trips per day. This value must be an integral quantity, for the average work for any one day.
$\frac{Ww}{\frac{D}{S}\left(1 + \frac{1}{K}\right) + l}$	Average total amount transported per day.
$R = C\,\frac{\frac{D}{S}\left(1 + \frac{1}{K}\right) + 1}{Ww}$	Cost of transportation per pound, or other convenient unit.

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[1] See *Engineering and Contracting*, June 3, 1914, page 629.

The value of "*C*" will depend on the number of horses used to haul the scraper, the nature of the loading auxiliary, the organization and operation of the outfit and to a lesser extent upon the repairs, depreciation and other overhead expenses. The value of "*w*" will depend on the character and size of the equipment, the efficiency of operation and maintenance of the machines. The results of a large number of observations of the use of wheel and Fresno scrapers in the excavation of various kinds of soil are summarized in Fig. 144.

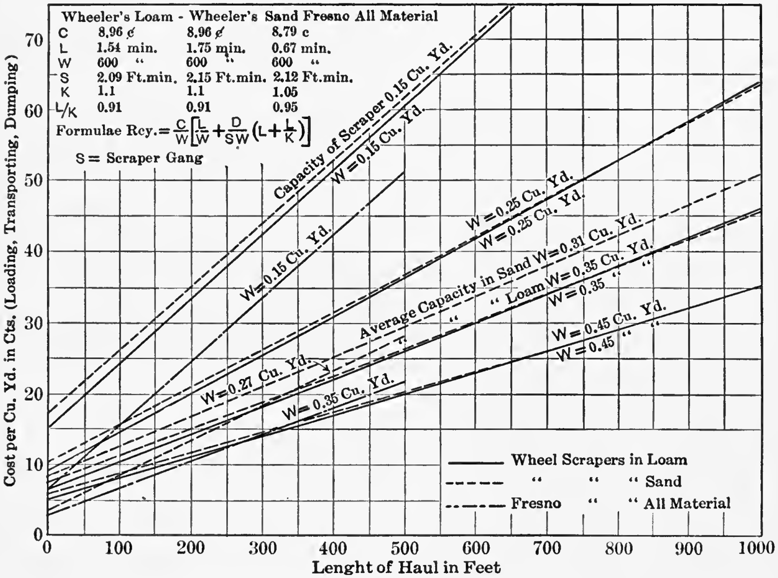

FIG. 144.—Cost of earthwork with Fresno and wheel scrapers. (*Courtesy of Engineering & Contracting.*)

177. Use of Wheel Scrapers.[1]—The following statement gives a comparative study of the use of the wheel scraper in the construction of railroad grades. The reader should note the relation between the cost of excavation and the length of lead or haul.

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[1] Abstracted from *Engineering-Contracting*, September 4 and 25, 1907.

The labor schedule for all of the work based on a 10-hr. working day, was as follows:

Foreman	$3.00
Extra foreman	2.50
Scraper team and driver	4.75
Four-horse plow team and two men	9.20
Three-horse snatch team and one man	6.00
Three-horse plow team and two men	7.50
Two-horse snatch team and one man	4.60
Loaders	1.60
Laborers	1.50
Water boy	1.00

A four-horse plow team was used to loosen the earth and in Case V, a three-horse team was used when sand was encountered. A three-horse snatch team was used in loading the scrapers and in Case V, a two-horse team was used in sandy soil. The wheel scrapers were all No. 2½ with a capacity of about ⅓ cu.yd., place measurement. Two men loaded and dumped each scraper, except in Case I. The work was done in the fall of the year when climatic conditions were favorable for grading work.

Case I.—The material moved in this case was a sandy loam, which was easily plowed and scraped up. The lead was 260 ft., making a round trip of 600 ft. for each team and a total distance per day for each scraper of about 12 miles. Five scrapers were worked together on this job. The average amount of earth moved per 10-hr. day was 34 cu. yd. for each scraper and 31 cu. yd. for each team employed.

The cost of excavation per cubic yard of earth method is given below:

Foreman	$0.017
Scrapers	0.138
Plowing	0.052
Snatching	0.034
Loaders	0.018
Dumping	0.008
Water boy	0.006
Total cost per cubic yard	$0.273

Case II.—The material excavated on this work was an average clay, fairly easy to handle. The lead was 300 ft., a round trip of 700 ft. for each team and a total distance per day for each scraper of about 12 miles were made. Five scrapers were used together. The average amount of earth moved during a 10-hr. day was 30 cu. yd. for each scraper and 19 cu. yd. for each team employed.

The cost of excavation per cubic yard of earth moved is given below:

Foreman	$0.019
Scrapers	0.158
Plowing	0.057
Snatching	0.037
Loaders	0.020
Dumping	0.016
Water boy	0.004
Total cost per cubic yard	$0.311

Case III.—The material on this work was a wet clay, saturated with water from recent rains and local springs. The lead was 400 ft., making a round trip of 1000 ft. for each team and a total distance traveled per day of 12½ miles. Five scrapers were used in a gang as in the previous cases. The embankment was made on marshy land and the services of an extra laborer were required to shovel earth ahead of the teams. The average amount of earth moved was 22 cu. yd. for each scraper and 13 cu. yd. for each team employed.

The cost of excavation per cubic yard of earth moved is given below:

Foreman	$0.026
Scrapers	0.216
Plowing	0.080
Snatching	0.052
Loaders	0.028
Dumping	0.039
Water boy	0.009
Total cost per cubic yard	$0.450

Case IV.—The material excavated on this work was a fine sand which retarded the work by allowing the wheels of the scrapers to sink below the surface until the bottoms of the bowls touched. The lead was 500 ft., making a round trip of 1000 ft. for each team and a total distance traveled per day of 12½ miles. Six scrapers were worked in a gang. The average amount of earth moved was 21½ cu. yd. for each scraper and 13 cu. yd. for each team employed.

The cost of excavation per cubic yard of earth moved is given below:

Foreman	$0.024
Scrapers	0.222
Plowing	0.073
Snatching	0.050
Loaders	0.026
Dumping	0.027
Water boy	0.008
Total cost per cubic yard	$0.430

Case V.—The material was a light red clay and sandy loam running into sand in the bottom of the cut. The cut required the excavation of 2000 cubic yards. The lead was 700 ft. and the total distance traveled per day by each team was 6 miles. The embankment was made over a tide-water marsh, and in many places the surface would not support a man. There brush was placed to form a matting. Four men were employed to shovel earth ahead of the wheelers.

On one side of the cut was a bluff 15 ft. high, where the scrapers could not be used. A gang of extra laborers with a foreman pulled this bank down with pick and shovel and it was removed by the scrapers. The average amount of earth moved was 23 cu. yd. for each scraper and 15½ cu. yd. for each team employed.

The cost of excavation per cubic yard of earth moved is as follows:

Foreman	$0.02
Scrapers	0.21
Plowing	0.053
Snatching	0.03
Loaders	0.02
Dumping	0.033
Water boy	0.001
Total cost of scraper work	$0.367

Tearing down bank:

Foreman	$0.006
Extra laborers	0.066
Total	$0.072
Total cost of excavation per cu. yd.	$0.439

The following table has been compiled from the above data to show the effect of the lead, soil conditions, etc., upon the efficiency of the work.

TABLE XV.—EFFECT OF LEAD AND SOIL UPON COST

Case	Lead, ft.	Average amount moved by scraper, cu. yd.	Average scraper cost per cu. yd.	Average total cost per cu. yd.	Scraper cost divided by total cost, per cent.	Soil excavated
I	260	34	$0.138	$0.273	50.5	Sandy loam
II	300	30	0.158	0.311	50.8	Clay.
III	400	22	0.216	0.450	48.0	Wet clay
IV	500	21½	0.222	0.430	51.6	Fine sand
V	700	23	0.210	0.367	57.2	Red clay, loam and sand

The plow teams in the five cases loosened during each 10-hr. day the following average amounts:

Case I, 170 cu. yd.; Case II, 150 cu. yd.; Case III, 115 cu. yd.; Case IV, 125 cu. yd.; Case V, 164 cubic yards.

It will be noted that these amounts are all about one-half of what they should have been, considering the soil and climatic conditions. The dumping cost is also high in the last four cases. One man for each scraper would have been sufficient. It is evident that under the conditions existing on this work, that far more efficient work would have been done if about 8 to 10 scrapers had been used in a gang. The same foreman, loaders and dumpers could have taken care of the larger number of scrapers.

The figures in the fifth column of the above table do not include the expense of superintendence, inspection, repairs, depreciation, etc. Note that the cost of the scraper work was about 50 per cent. of the total cost.

The most efficient and economical type of scraper for hauls of from 200 to 1000 ft. is the four-wheel scraper. For a haul of from 200 to 400 ft. this type of scraper is about 100 per cent. more efficient than the two-wheel scraper and the efficiency increases with the length of haul. See Art. 15, page 12. For railroad construction in prairie or slightly rolling country where a series of small cuts occur with short hauls, the scraper can be used to advantage. The reader is referred to Art. 162, page 250, for a discussion of proper methods of scraper operation. Figure 145 shows Maney scrapers on railroad construction in California.

178. Graders.—The use of the blade grader in railroad construction is limited to the leveling off and smoothing up of the subgrade, following the rough excavation work of the scraper or elevating grader. In the making of cuts and fills the road grader is not adapted and can be efficiently used only in coöperation with other forms of excavators.

Fig. 145.—Maney scrapers on railroad construction. (*Courtesy of Baker Mfg. Co.*)

The elevating grader has been successfully used in railroad construction during the last 30 years. See Chapter IV. Its field of use is in the construction of light cuts and fills in prairie or slightly rolling country. See Art. 166, page 256. In nearly level country, the grader overcasts the excavated material from the sides to form the central embankment. The various forms of embankment made in this way are given in Fig. 146. In rolling country, where the cuts are light, the grader is used as an excavator and a loader, operating in conjunction with dump wagons.

The number of wagons necessary to provide for the efficient operation of an elevating grader depends largely upon the length of haul. The following table gives a rough estimate of this service.

TABLE XVI.—NUMBER OF WAGONS REQUIRED TO SERVE ONE ELEVATING GRADER AT VARIOUS LENGTHS OF HAUL

Length of haul, ft.	Number of wagons	Length of haul, ft.	Number of wagons	Length of haul, ft.	Number of wagons	Length of haul, ft.	Number of wagons
100–300	5	600	8	1000	12	2000	25
400	6	700	9	1200	15	2500	30
500	7	900	10	1700	20	3000	35

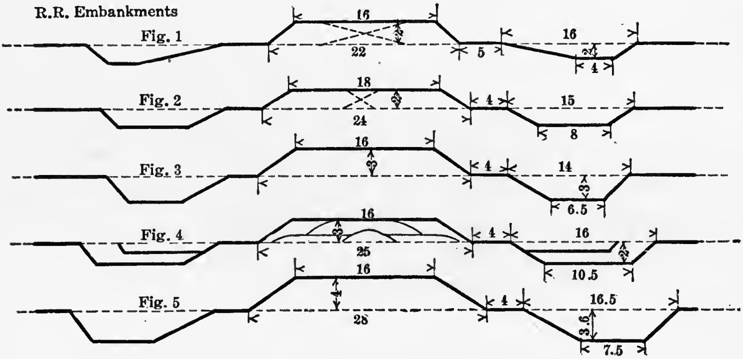

FIG. 146.—Types of railroad embankments built by elevating grader. (*Courtesy of Austin Mfg. Co.*)

Figure 147 shows an elevating grader constructing a deep cut in Iowa.

179. Use of Elevating Grader in Colorado.—The cost of moving earth with elevating graders in the construction of embankments is well illustrated by the following statement giving the analysis of the cost of construction of the Stanley Lake Dam, near Denver, Colorado. Elevating graders were used to excavate material from borrow pits for the construction of dikes along the toe of both slopes of the main embankment. The excavated material was moved from the borrow pit to the site of the dikes about 1000 ft. over nearly level ground, in 1½-yd. two-horse dump wagons. The material handled was largely loam and clay, underlaid by a thin stratum of sand and gravel. The material was laid in uniform layers until embankments having a top width of 30 ft. and a height of 30 ft. at the lowest point of the valley were constructed.

The work was carried on from July to November, 1908 and few delays were experienced from climatic conditions. No blasting was required, but a plow was occasionally used to loosen the soil.

The excavating outfit consisted of three elevating graders, except during November when only two machines were used. One grader was hauled by a traction engine, one by 12 horses and the other by 12 mules. The traction engine did not operate efficiently due to bad water for the boiler and slippery ground for traction during part of the working period. In computing the labor cost, the wages paid were increased 50 cents per day per man for board, including Sundays. Feed for the horses and mules was estimated at 82 cents per head per day, including Sundays. The regular working day was 10 hours.

FIG. 147.—Elevating grader on railroad construction.

The regular force account as distributed over the entire job was as follows:

	Cost per day
One walking boss @ $125.00 per month, plus board..	$5.31
One foreman @ $100.00, plus board...............	4.34
One foreman @ $75.00, plus board................	3.38
One timekeeper @ $75.00, plus board..............	3.38
One blacksmith @ $60.00, plus board..............	2.81
One blacksmith's helper @ $1.75 per day...........	1.75
Two corral men at $45.00 per man.................	4.46
One water boy at $1.75 per day....................	1.75
Total per day of 10 hours..................	$27.18

The actual average working time per hour was about 45 min. for the graders. For a lead of 500 ft. the greatest efficiency was secured by the use of 7 dump wagons to each grader. For each 100 ft. increase in lead, one extra wagon load was about 1¼ cu. yd., place measurement.

The average cost of operating a grader with the 12-horse team was $21.34 per 10-hr. day, and with a traction engine was $26.11. During August, 1908, the average cost of excavation with the use of the traction engine was 13.3 cents per cubic yard, the average haul 962 ft. and the wagon-hours per cubic yard about 0.598. For the horse-drawn graders, the average cost per cubic yard was 13.5 cents, the average haul 965 ft., and the average wagon-hours per cubic yard about 0.6.

180. Use of Elevating Grader in New York.[1]—The use of an elevating grader in the excavation of a railroad cut is rather unusual and the following statement is valuable on account of its completeness and accuracy.

During the latter part of 1911 and 1912, an Austin elevating grader hauled by a 20-ton steam tractor was used in the excavation of 20,000 cu. yd. (place measurement) from a series of cuts for the construction of the Halite and Northern R.R., Livingston Co., N. Y.

The grader was supplemented with a light grading equipment, consisting of Fresno, drag and wheel scrapers, which were used in places inaccessible to the grader. The transportation of material was done in 1½-yd. bottom-dump wagons, hauled by three-mule teams.

The material was a stiff clay, hard and brittle when dry, but plastic, slippery and rather unworkable when wet. Considerable time was lost during the winter of 1911 on account of unfavorable climatic conditions.

The method of excavation had to be adpated to conditions, which required a cross-section with a bottom width of 20 ft. and side slopes of 1½ to 1. For a depth of 3 ft., the wagons were able to load alongside the grader by "straddling" the top edge of the slopes. Below this depth, the grader had to excavate a base of 30 ft. width to an elevation 5 in. above subgrade. Material was borrowed from shallow trenches in addition to the 5 in. depth of base to replace the triangular-shaped sections exca-

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[1] Abstracted from *Engineering News*, September 10, 1914.

vated from the lower sections of the side slopes. Even a 30 ft. width cut did not provide sufficient space for loading all the material directly into the wagons. In excavating the material along the middle third of the section, the material was first deposited from the belt conveyor along the slopes where it could be raked down and again raised by the grader for deposition in the wagons. This rehandling of material involved considerable loss of time and motion.

The elevating grader worked 119 days or allowing for loss of time due to wet soil conditions, 76 actual working days. About 20,000 cu. yd. or a daily average of about 260 cu. yd. of earth was excavated. This is about one-half of the output which might be expected from the machine, working in an unrestricted area.

The following is a statement of the cost of operation per working day of 10 hours:

Labor:			
1 foreman	$6.00		
1 tractor engineer	4.00		
1 tractor steersman	2.00		
1 grader operator	3.00		
1 tank-wagon driver	2.00		
1 extra tank-wagon driver	5.50		
4 dump wagon drivers @ $2.00	12.00		
2 dump men @ $2.25	4.50		
1 blacksmith	3.00		
1 barnman @ $40.00 per month	2.00		
1 cook @ $40.00 per month	2.00		
Total		$46.00	
Fuel:			
Fuel, oil, etc.		$5.00	
Miscellaneous:			
Corral expenses for 25 animals	$20.00		
Insurance, interest, depreciation, etc. @ 12½ per cent	9.00		
Total		$29.00	
Total daily cost			$80.00
Average daily excavation			260 cu. yd.

Average unit cost, $80.00 ÷ 260 = $0.307 per cu. yd.

181. Power Shovels.—The steam shovel has been in use on railroad construction during the past 50 years and is doubtless the best known and most generally used type of excavator on this class of work. The earlier forms of shovel were of the fixed-platform class and operated on railroad trucks. Later the same class of shovel was mounted on broad-tired wheels for transportation over roads. Since 1900, the revolving shovel has come into general use and is especially adapted for light work, shallow cuts and where the cuts are scattered.

With the recent development of the electric railroad and cheap electric power, the electrically operated shovel has come into use. Electric power has definite advantages over steam as to simplicity and ease of operation, cleanliness, etc., and where the power is available at a low unit cost, it is the most satisfactory and economical form of power, especially in the operation of the lighter shovels of the fixed-platform class and of the revolving class. See Chapter VI.

The following statement is abstracted from the Handbook of Steam Shovel Work published by the Bucyrus Company, South Milwaukee, Wisconsin, 1911, and gives an analysis of the cost of steam-shovel work. This Handbook quoted contains the record of time studies and reports made on the operation of 45 steam shovels operating under various conditions of material, management, depth and magnitude of excavation, disposal of material, etc.

The following formula gives the cost of shovel operation, in cents per cubic yard on cars (place measurement).

$$R = \frac{27C}{M}\left(d + \frac{f}{c} + \frac{e}{nc} + \frac{g}{LA}\right) \text{ where}$$

d = time in minutes to load 1 cu. ft. (place measurement).
c = capacity of one car in cu. ft. (place measurement).
f = time shovel is interrupted in spotting one car.
e = time shovel is interrupted to change trains.
g = time required to move shovel.
L = distance of one shovel move in feet.
M = minutes per working day less loss for accidental delays.
A = area of excavated section in square feet.
R = cost per cubic yard on cars, in cents (place measurement).
n = number of cars in train.
C = shovel expense in cents per working day, not including the overhead and superintendence charges.

Graphic charts may be prepared by assuming values of "*C*" and "*A*" and by taking the following average or estimated values for the other quantities, except "*M*" and "*d*." From these curves, the relation between "*R*" and "*d*" for various values of "*M*" may be obtained.

To determine "*C*," the following estimate is made for a shovel valued at $14,000.

	Per year
Depreciation, $4\frac{2}{3}$ per cent	$653.34
Interest @ 6 per cent	840.00
Repairs, when working one shift	2000.00
Total	$3493.34

	Per day
Per year of 150 working days	$23.29
Shovel runner	5.00
Cranesman	3.60
Fireman	2.40
Half-time of watchman @ $50 per month	1.00
6 pit men @ $1.50	9.00
1 team hauling coal, etc. @ $5.00	2.50
$2\frac{1}{2}$ tons coal @ $3.50	8.75
Oil, waste, etc.	1.50
Cost per day or $\frac{C}{100}$	$57.04

The depreciation is estimated by assuming the difference between the initial cost at $150.00 a ton and the scrap value at $10.00 per ton as distributed over a working life period of 20 years.

The interest is assumed at the uniform rate of 6 per cent.

The cost of repairs is based largely on the character of the work and has relatively little bearing on the age of the shovel. Thus the amount of repairs will be more for rock than for earth excavation and be greater for badly broken rock than for well-blasted material.

The assumption of 150 working days a year is based on the allowance for climatic conditions, transportation of plant, repairs, etc. Local conditions will modify this value considerably.

The average shovel move was taken as 6 feet. The values of "*LA*" were assumed as 1500, 3000 and 6000 cubic feet. The values of "*L*" and the width of cut are determined by the limitations of each shovel. The maximum and minimum limits of depth of cut are dependent on the material and its physical condition. Great depths are apt to incur slides while slight depths will greatly increase the cost of filling the dipper.

The time "*d*," required to load 1 cu. ft. will depend on the character of the material, the depth of cut, the size of the machine and the capacity of its dipper, the efficiency of operation of the shovel, etc.

The results of the tests give the average time to load 1 cu. yd., place measurement, as 10.5 sec. for iron ore, 12.1 sec. for sand, 18.34 sec. for clay, 18.4 sec. for earth and 30.7 sec. for rock. The average dipper capacities, place measurement, were 2⅓ cu. yd. for iron ore, 1¼ cu. yd. for sand and earth, 1½ cu. yd. for clay and 1 cu. yd. for rock.

The value of "*f*," time for spotting cars, may be taken as zero, as is generally the case when the train is alongside the shovel, and the moving up of cars is done during the swinging of the dipper.

The value of "*e*," time between trains, was found to average 4 minutes.

The capacity of one car in cubic feet (place measurement), "*c*," was assumed as 67.5 cu. ft., based on a contractor's side dump car of a capacity of 4 cu. yd. (water measurement), or 2.5 cu. yd. (place measurement).

The average number of cars per train, "*n*," was 10.

The average time required to move the shovel, "*g*," was about 8 minutes. The various steps in moving a shovel should be systematized so as to secure efficiency and eliminate lost time. A very good discussion of the subject is given on pages 364 and 365 of the Handbook.

The actual working time of the shovel, "*M*," was determined by allowing for accidental delays, the following average amounts: 7.25 per cent. for brick clay, 8.4 per cent. for sand and gravel, 8.6 per cent. for iron ore, 17.15 per cent. for clay and loam, 17.75 per cent. for crushed stone from quarries, and 19.87 per cent. for rock cuts. The maximum values are about 20 per cent. for sand, gravel, iron ore, and glacial drift, 28 per cent. for crushed stone from quarries, 40 per cent. for clay and loam and 56 per cent. for rock cuts.

Delays may be due to the character and condition of the material to be handled, to breakdowns of the shovel or transportation equipment and to accidents. Wet sticky clay or gumbo soil necessitates further breaking up by "mud capping," block holing or some other suitable method. The following observances will reduce accidental delays to a minimum.

1. Proper spacing and charging of drill holes.
2. Smooth and efficient operation of shovel and transportation equipment.
3. Regular daily inspection of shovel and transportation equipment.
4. Reserve supply of duplicate parts for shovel and transportation equipment.
5. Efficient supervision of work.

The average values stated above are used to develop so-called standard cost curves which may be used for estimating the cost of proposed work and checking up the cost of work in progress.

The principal benefit to be derived from a study of the data obtained from the actual use of this formula is the determination of the factors producing inefficient operation. From an inspection of the formula,

$$R = \frac{27C}{M}\left(d + \frac{f}{c} + \frac{e}{nc} + \frac{g}{LA}\right),$$

it will be seen that the cost, R, is directly proportioned to the factors, d, f, e and g, and hence it is important on any job to reduce these to a minimum. This *desideratum* can be affected by the use of a suitable plan of operations, proper equipment, efficient operation and careful supervision.

The following table gives a statement of the cost of shovel work, R for the 45 cases considered.

TABLE XVII.—COST OF SHOVEL WORK

Material	Cost in cents per cubic yard		
	Maximum	Minimum	Average
Iron ore	2.2	0.8	1.60
Sand and gravel	3.2	0.5	1.85
Clay	3.6	1.1	2.20
Earth and glacial drift	3.8	1.8	2.60
Rock	12.7	1.5	4.70

In making a cut for a railroad, the shovel makes a through cut working along one side and dumping into wagons or cars on a higher level. A typical arrangement would be as shown in Fig.

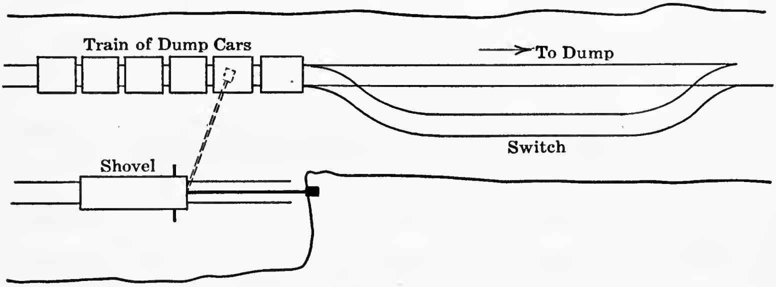

FIG. 148.—Diagram of shovel operation.

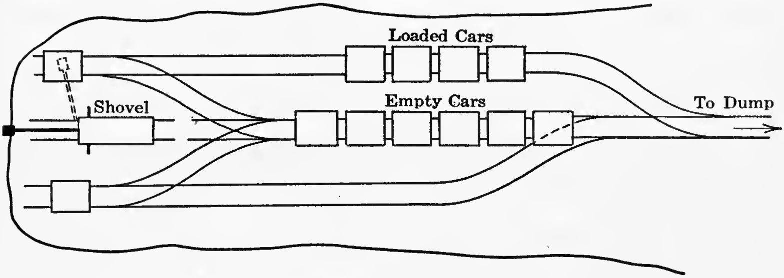

FIG. 149.—Diagram of shovel operation.

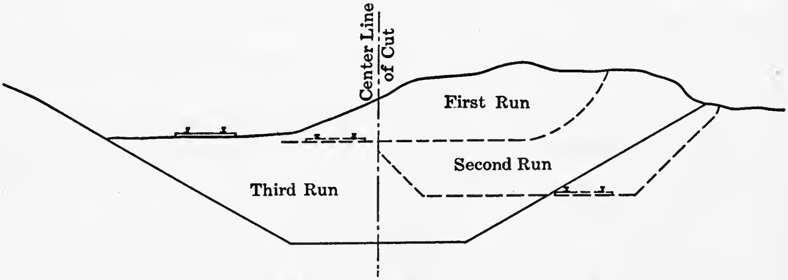

FIG. 150.—Diagram showing method of making cut.

148. In a wide cut, where the shovel is cutting on both sides, loading tracks can be provided on both sides of the shovel track and one car can be "spotted" on one track, while the shovel is loading a car on the opposite side. See Fig. 149. The procedure

in making a deep through cut is to start excavation just inside the side slope stakes along one side, undercutting the side slope slightly. The return cut is taken next to the first cut and the process continued until the other side of the section is reached. For each new cut the loading track is moved into the preceding shovel cut. See Fig. 150.

182. Use of Steam Shovel near Newcomb, Montana.[1]—The extension of the Chicago, Milwaukee and St. Paul Railway to Seattle on the Pacific Coast was made in many places by the construction of large trestles across valleys. These trestles were later filled in and a permanent embankment made. The Basin Creek bridge required 162,000 cu. yd. of material, which was excavated by a steam shovel in the Newcomb pit and hauled in dump-car trains to the site of the fill.

The following tabulated statement gives a detailed account of this work for the month of March, 1909.

Shovel—Bucyrus No. 453, 2½-yd. dipper, weight of machine 65 tons.
Engines—Prairie type, three in use, tractive power, 33,000 pounds.
Cars—Western dump, average load 12.6 cubic yards.
Trains—One engine hauling 13 cars, and a caboose.
Yardage—68,000 cu. yd. handled in 27 working days of 10 hr. each.
Yard miles—308,780.
Average haul—4.54 miles. Rate of ascending grade against loads, 88 ft. per mile.

Total Cost, Labor:			
Steam shovel pay-roll	$1815.64		
Section labor	99.94		
Total			$1915.58
Work Train Service, Labor:			
Conductors, 95.8 @ $3.68	$352.54		
Brakemen, 191.6 @ $2.53	484.75		
Engineers, 95.8 @ $4.40	421.52		
Firemen, 95.8 @ $2.95	282.61		
Total labor		$1541.42	
Fuel and Supplies:			
Supplies, 95.8 days @ $0.32	$30.66		
768 tons of coal @ $4.00	3072.00		
1,916,000 gal. of water	178.83		
Total cost of fuel and supplies		$3281.49	

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[1] Abstracted from the *Railway and Engineering Review*, July 10, 1909.

General:			
Depreciation, 81 days @ $2.03	$164.43		
Interest, 81 days @ $2.03	164.43		
Repairs, 81 days @ $3.00	243.00		
Total general cost		$571.86	
Total cost of work train service			$5394.77
Fuel for Steam Shovel:			
172.8 tons of coal @ $4.00			$691.20
Camp Maintenance:			
Boarding camp	$174.27		
Commissary	15.74		
Total			$190.01
Total cost of work for March, 1909			$8191.56
Excavation			68,000 cu. yd.

Cost of excavation $8191.56 ÷ 68,000 = $0.1205 per cu. yd.

183. Use of Steam Shovel in Illinois.[1]—The Burlington System of railroads in 1906 made two improvements in location on the Beardstown-Centralia Division in Illinois. They are known as the Big Shoal cut-off and the Little Shoal cut-off.

The Big Shoal cut-off was a change in alinement and grade between Sorento and Reno, Illinois. The total amount of excavation in the improvement was 318,711 cu. yd., of which 251,711 cu. yd. were steam-shovel work. Two temporary trestles were used, having a total length of 2961 ft. and an average height of 40 feet. The average haul for the embankment was 1½ miles and the average depth of cut 15 feet. The material handled was a wet clay. The stickiness of the excavated material made its handling difficult and delayed the work to some extent. The trestle was designed to carry a loaded train of 5-yd. dump cars before being filled and the engine in service after being filled. Each bent consisted of two soft wood piles with cap and cross-bracing. For each 13-ft. span, two 8 × 16-in. stringers were used. The stringers were removed and the remainder of the trestle left in the embankment.

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[1] Abstracted from *Bulletin* No. 81, American Railway and Maintenance of Way Association.

The Little Shoal cut-off was a change in alinement and grades between Ayers and Durley, Illinois. This work comprised the handling of 188,240 cu. yd. of material. This was about 40 per cent. hard-pan, which was as hard as the shovel could dig without blasting. A temporary trestle was used, having a total length of 2142 ft. and an average height of 35 feet. The average haul was ½ mile. On the work the shovel and trains moved over 6 per cent. grades and 16-degree curves without difficulty.

The work was all done by the railroad company and the table below shows the saving made over contract work. This was done in spite of the disadvantages under which the company worked, such as working under the regular schedules and the lack of freedom in the handling of labor, supplies and commissary.

The equipment consisted of a 65-ton Bucyrus steam shovel, two 30-ton switch engines, 43 dump cars of 5 cu. yd. capacity and a Jordan spreader. The shovel worked 228 shifts of 10 hr. each, two per day. The average output was 1104 cu. yd. per shift or 3.35 cu. yd. per car. The labor employed incuded 70 men during the day shift and 28 during the night shift.

The following table gives a résumé of the cost of the work and the comparative cost by contract.

Table XVIII.—Comparative Cost of Company and Contract Work

Character of work	Big Shoal cut-off		Little Shoal cut-off	
	Total	Per cubic yard, cents	Total	Per cubic yard, cents
Equipment	$2,733	1.0	$2,911	1.5
Steam shovel (labor and supplies)	23,351	8.9	18,136	9.6
Temporary trestle	9,008	3.6	5,853	3.1
Track-work	12,438	5.0	7,817	4.2
Engineering and supervision	610	0.2	487	0.3
Total	$48,140	18.7	$35,204	18.7
Total by contract, at 26 cents per cubic yard	$65,445	26.0	$48,942	26.0
Saving by company work	17,305	7.3	13,738	7.3

184. Drag-line Excavators.—Drag-line or scraper-bucket excavators have been in general use during the last 15 years. A decade ago this type of machine was largely used in canal excavation but recently it has been successfully adapted to other forms of earthwork and notably railroad construction. The revolving upper platform containing the operating and excavating equipments, and the long boom with a drag bucket provide for a wide latitude of operation which is impossible with the power shovel. See Chapter VII.

In building fills, the drag-line excavator has the following definite advantages:

(*a*) The excavation and deposition of material at any point within a complete circle of operation.

(*b*) The operation of the machine while located on the ground surface so that it will not be affected by low, wet, soil conditions.

(*c*) The long boom and drag-line bucket provide for the removal of material from wide, shallow borrow pits and its use in the construction of high and wide fills. The radius of action is about twice the length of the boom of the machine.

In the excavation of cuts, the excavator has about the same advantages as stated above. The machine moves over the ground surface and backs away from the excavation. The excavated material is deposited in spoil banks away from the cut or in wagons or cars for transportation to place of adjacent fill.

The complete control which the operator has over the action of the bucket enables him to secure smooth and uniform side slopes in the excavation of cuts.

The drag-line excavator can be used for driving and pulling piles in the construction of trestles in crossing marshes, bogs, etc. The recent use of caterpillar tractors enables even the largest machines to move over soft soils that will not support a team. The machine can easily and quickly be adapted to the work of a derrick or crane, and thus can handle its own track in short sections.

The larger machines can efficiently excavate loose rock and hard-pan, and can handle large masses of blasted rock.

185. Use of Drag-line Excavator in South Dakota.—Two drag-line excavators were employed during the summer of 1912 in the construction of fills for the Puget Sound extension of the Chicago, Milwaukee and St. Paul Railway near Andover, South Dakota. The machines were Bucyrus Class 20 equipped with an 85-ft. boom and a 2½-yd. bucket and Bucyrus Class 24 with a 100-ft. boom and a 3½-yd. bucket. Figure 151 shows the Class 20 machine at work.

The material excavated was largely black loam and hard glacial clay, although blue shale rock was encountered occasionally. The material was borrowed from shallow pits along the right of way and dumped directly into the fill. The Class 20 machine commenced work on May 16, 1912 and the Class 24 machine on May 29, 1912. The total excavation was 11,700 cu. yd. for May; 98,900 cu. yd. for June; 156,400 cu. yd. for July and 151,000 cu. yd. for August.

The embankments were leveled off with a team and Marmon scraper. The final leveling was done by dragging a 90-lb. rail over the surface. The shoulders were trimmed by hand labor.

Fig. 151.—Drag-line excavator on railroad construction. (*Courtesy of The Excavating Engineer.*)

186. Use of Drag-line Excavator in Ohio.—A Class 14 Bucyrus drag-line excavator was used in the construction of a difficult railroad cut for the Lorain, Ashland and Southern Railroad, near Wellington, Ohio.

The excavator was operated by steam, and was equipped with a 60-ft. steel latticed boom and a 2-yd. bucket.

The cut was on a curve, 2800 ft. in length and varied in depth from 7 ft. to 20 feet. The material was largely a glacial clay with hard-pan in the lower section of the cut. Figure 152 clearly shows the nature of the work done by the machine.

187. Railway Ditching Trains.—One of the more important features of railroad maintenance of way work is the maintenance of side ditches and cuts. The time-honored custom for the repair of cuts and the cleaning of side or roadway ditches is by hand labor, with the regular section gang. However, railroad officials are coming to realize that the traditional methods are slow, laborious and uneconomical and are adapting machinery to replace hand labor. This change has become imperative in very recent years on account of the scarcity and high cost of labor.

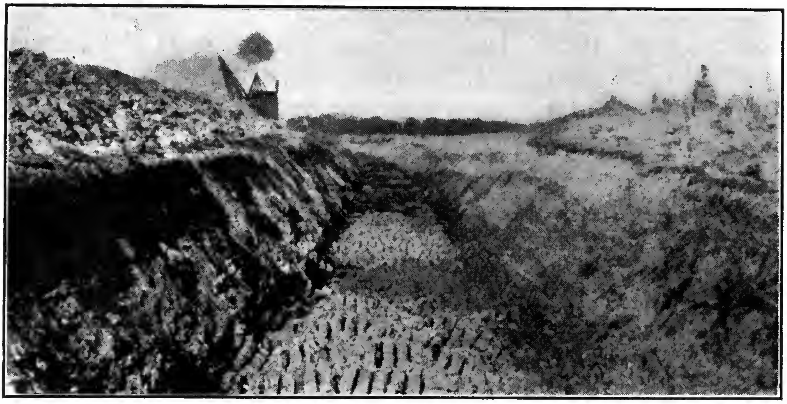


Fig. 152.—Railroad cut made by drag-line excavator. (*Courtesy of The Excavating Engineer.*)

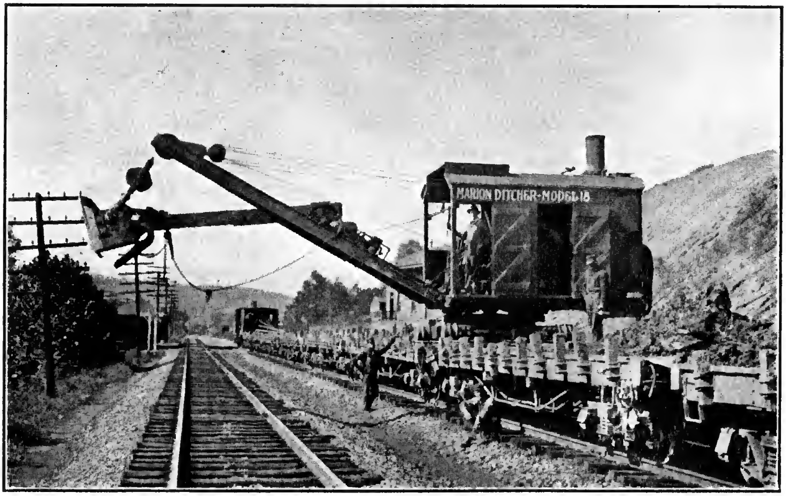
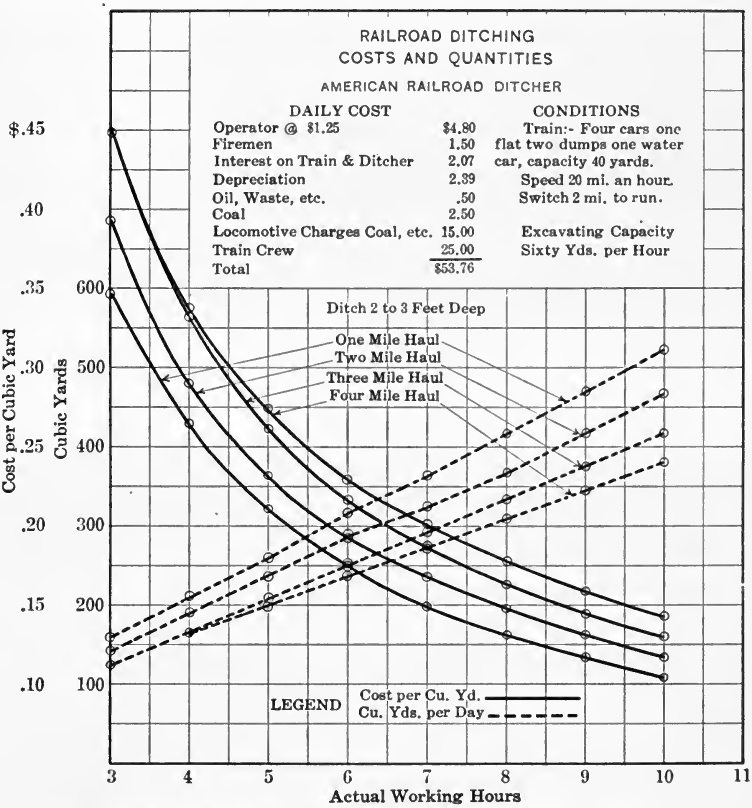


Fig. 153.—Railway ditcher and train. (*Courtesy of Marion Steam Shovel Co.*)

The two classes of machinery in present use for the widening of cuts and cleaning of side ditches are:

1. A power ditcher with a train of flat cars and an unloader plow.
2. A power ditcher and a train composed of air-operated dump cars.


RAILROAD DITCHING
COSTS AND QUANTITIES
AMERICAN RAILROAD DITCHER

DAILY COST	
Operator @ $1.25	$4.80
Firemen	1.50
Interest on Train & Ditcher	2.07
Depreciation	2.39
Oil, Waste, etc.	.50
Coal	2.50
Locomotive Charges Coal, etc.	15.00
Train Crew	25.00
Total	$53.76

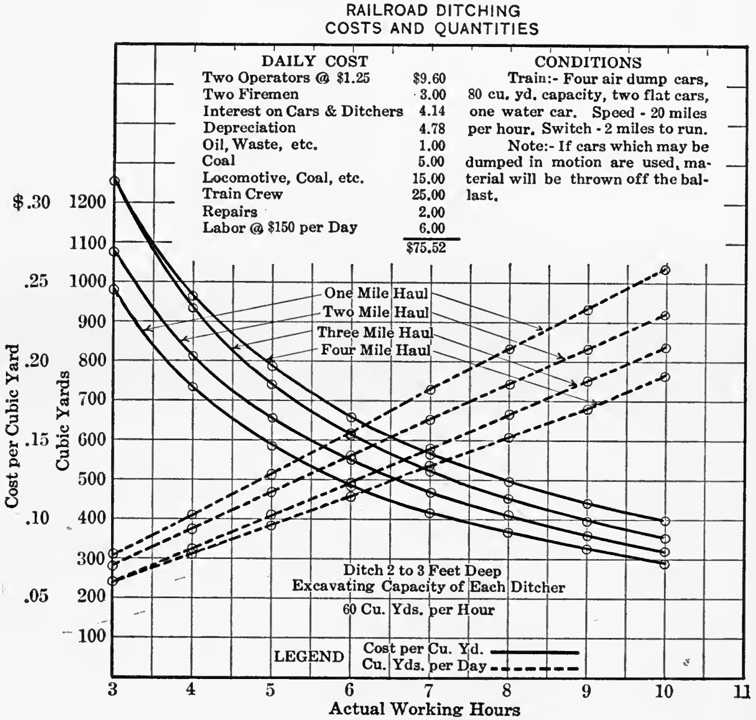
CONDITIONS
Train:- Four cars one flat two dumps one water car, capacity 40 yards.
Speed 20 mi. an hour.
Switch 2 mi. to run.
Excavating Capacity Sixty Yds. per Hour

Ditch 2 to 3 Feet Deep

Fig. 154.—Diagram showing excavating cost with single railroad ditcher. (*Courtesy of American Hoist & Derrick Co.*)

The first class of ditcher consists of a locomotive crane or a small revolving steam shovel mounted on a flat car near the center of a long train of flat cars. An unloading plow is placed near one end of the train and is operated by means of a cable attached to the drum of a hoisting engine. Figure 153 clearly illustrates the method of operation of such a train. The crane or shovel may be fixed on a car and the cars of the train shifted as they are loaded, or the ditcher may be mounted on rollers which move along a section of rails loading each car in turn as it comes to it.

The second class of ditcher consists of a specially designed revolving steam shovel which is usually mounted on a flat car placed between two air-operated dump cars. The complete train consists of a locomotive, two 20-yd. dump cars, a ditcher, a spreader car, a caboose and usually a water tank car. The shovel


RAILROAD DITCHING
COSTS AND QUANTITIES

DAILY COST	
Two Operators @ $1.25	$9.60
Two Firemen	3.00
Interest on Cars & Ditchers	4.14
Depreciation	4.78
Oil, Waste, etc.	1.00
Coal	5.00
Locomotive, Coal, etc.	15.00
Train Crew	25.00
Repairs	2.00
Labor @ $150 per Day	6.00
	$75.52

CONDITIONS

Train:- Four air dump cars, 80 cu. yd. capacity, two flat cars, one water car. Speed - 20 miles per hour. Switch - 2 miles to run.

Note:- If cars which may be dumped in motion are used, material will be thrown off the ballast.

Ditch 2 to 3 Feet Deep
Excavating Capacity of Each Ditcher
60 Cu. Yds. per Hour

FIG. 155.—Diagram showing excavating cost with double railroad ditcher. (*Courtesy of American Hoist & Derrick Co.*)

or ditcher is connected to the tank car so that water may be pumped during its operation.

The manufacturers[1] of the American Railroad Ditcher have prepared diagrams to show the capacity and cost of operating single and double ditching trains. The double train consists of a locomotive, four 20-yd. dump cars, two ditchers and flat cars, a spreader car, a caboose and usually a water car.

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[1] American Hoist and Derrick Co., St. Paul, Minn.

Figure 154 shows the cost and performance of a single ditcher train. The curves are based on a daily expense of $53.76, and for the excavation of ditches 2 to 3 ft. in depth. The excavating capacity is 60 yd. per hour; speed of train is 20 miles per hour working and distance to switch of 2 miles. Assuming 5 hr. time, the train can remove and dump about 240 cu. yd. at a cost of about 17 cents per cubic yard.

Figure 155 gives the performance and cost of operation of a double ditcher train. The curves are based on a daily expense of $75.52, and for the excavation of ditches 2 to 3 ft. in depth. The excavating capacity of each ditcher is 60 cu. yd. per hour; speed of train 20 miles per hour and length of haul to switch of 2 miles. With a working time of 5 hr., the double train can excavate and dispose of 460 cu. yd. at a cost of 12 cents per cubic yard. Figure. 156 shows a double ditcher train in operation.

Fig. 156.—Double ditcher railway train. (*Courtesy of American Hoist & Derrick Co.*)

During the Spring of 1911, a double train ditcher was used near Thebes, Illinois in the cleaning out and widening of a railroad cut. The material was clay with about 75 per cent. of boulders and 24,000 cu.yd. of material was handled in 1000 days of 11 to 12 hr. at an operating cost of $15.00. The operating expense per day was as follows:

Engineer	$5.00
Fireman	2.50
Watchman	1.60
3 laborers @ $1.75	5.25
Total	$14.36

188. Special Ditching Machine.—Several forms of ditching and grading machines have recently been devised for the maintenance of the roadbed of a railroad. These excavators are generally rather complicated, elaborate, and involve a high initial expense.

One of the best known of these graders is the Bowman ditcher and grader, which has been used successfully for clearing roadbed ditches, widening fills and trimming the slopes of cuts. An inspection of Fig. 157 shows the general form and construction of the machine. Two steel gallows-frames are mounted on a 50-ft. steel flat-car. At each side of the gallows-frames is mounted a jib crane carrying a 4-yd. steel scraper bucket which is operated by two vertical air cylinders, the larger, 24 × 60 in., operates the hoisting chain and the smaller, 12 × 60 in., operates the dumping chain attached to the rear of the bucket.

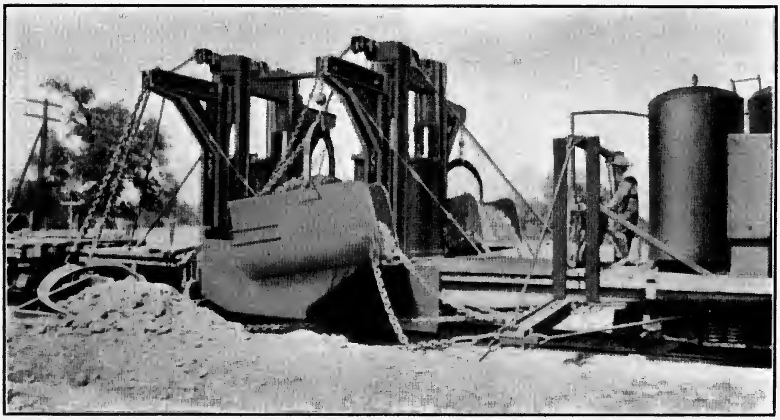

Fig. 157.—Bowman ditcher on railroad maintenance.

On the forward section of the car is placed the air plant consisting of several large air reservoirs and three brake pumps which are operated by steam from the locomotive.

The method of excavation consists in lowering the two front buckets which are filled by the forward motion of the car. When these buckets are filled they are raised, and the rear buckets are lowered and filled. The car is then hauled to the fill or dump where the buckets are dumped and returned for another load.

A scraper blade is attached to each side near the rear end of the car (see Fig. 157), and is used for spreading material dumped along the track on fills or in yards. A heavy plow can be readily attached to a frame projecting from either side of the car and used to excavate material too hard for the buckets or beyond their reach. For dressing slopes, widening cuts or trimming ballast, a scraper is attached to a pair of telescopic struts and extends from the side of the car.

The Bowman ditcher and grader has been used by several railroads for roadbed maintenance. A machine in recent years used on the Southern Pacific R.R. handled 22,320 cu. yd. of earth from 8650 lin. ft. of ditch at a cost of about 6½ cents per cubic yard. The average output for this grader was 8720 cu. yd. per month at an average cost of 15 cents per cubic yard.

189. Résumé.—Where the magnitude of the work is under 50,000 cu. yd., some form of scraper or grader can be economically used, especially where the cuts are light and the material is loose earth that can be readily excavated.

The scarcity and high cost of labor have in very recent years developed the use of power machinery. The older types such as the steam shovel and drag-line excavator have been modified and adapted to light work and unfavorable soil conditions and many highly specialized types have been introduced. The revolving shovel has been used efficiently in the excavation of small cuts as occurs in railroad construction in gently rolling country. In rough country and for the excavation of hard materials such as hard-pan, gravel and rock, the larger and heavier types of steam shovels are required.

The drag-line excavator has established itself as an efficient type of power excavator in railroad construction. In locations where the material is borrowed from the side of the right of way for the construction of cuts, and where the excavation from cuts may be disposed of by overcasting, the drag-line machine may be used without any equipment for hauling the material at a considerable saving of operating cost. In wet and soft soil conditions, the use of the caterpillar tractors, enables the machine to work through swamp and marsh lands and to handle material within a wide range vertically and through a complete circle horizontally.

The ditching train is especially adapted to the maintenance of long sections of roadbed, the cleaning out of side ditches and the widening of cuts. The use of a well-designed ditcher and dump cars is to be recommended over the older form of ditching train. The operation of the unloader is often attended with difficulties especially in the removal of heavy soils and where large rock occur. The displacement or "jumping" of the unloading plow may sometimes result in a serious delay in handling material.

The especially designed ditcher and grader has been used to a limited extent on railroad roadbed maintenance and has proved to be a very economical machine for the cleaning out of side ditches, the smoothing up of side slopes and the trimming of the ballast and shoulders of fills. The initial cost of such a machine is large but the cost of operation and excavation is sufficiently low to justify its use on lines where there is enough work to keep it in use a larger part of the time.

190. Bibliography.—For further information consult the following:

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3. "Earthwork and Its Cost," by H. P. Gillette, published in 1912 by McGraw-Hill Book Company, New York. 5 in. × 8 in., 238 pages, figures. Cost, $2.00.
4. "Handbook of Cost Data," by H. P. Gillette, published by McGraw-Hill Book Company, New York. 4¾ in. × 7 in., 1900 pages. Cost, $5.00.
5. "Handbook of Construction Plant," published in 1914 by McGraw-Hill Book Company, New York. 4¾ in. × 7 in., 702 pages, figures. Cost, $5.00.
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8. Dragline Excavators in Railroad Construction. *Railway Age Gazette*, June 19, 1914. Illustrated, 1200 words.

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18. Methods and Cost of Moving Earth with Fresno Scrapers in Arizona, and the Cost of Trimming Slopes. *Engineering-Contracting*, October 2, 1907. 1500 words.

19. Methods of Constructing a 96-ft. Fill Across Papio Valley on the Union Pacific Ry. *Engineering-Contracting*, May 17, 1911. Illustrated, 3500 words.

20. Methods of Excavating Rock in Large Masses. *Engineering & Mining Journal*, August 3, 1907. 2500 words.

21. Methods of Handling Light Earthwork. *Railway Age Gazette*, August 15, 1913. Illustrated, 2000 words.

22. Methods of Making Deep Fills by Suspending Tracks from Cableway. *Engineering-Contracting*, July 20, 1910. 3000 words.

23. Railway Steam Shovel of New Design. *Engineering News*, August 4, 1904. Illustrated, 2800 words.

24. The Rainy Lake Fill. *Scientific American Supplement*, April 4, 1914. Illustrated, 2000 words.

25. Record of Steam Shovel Work, Ann Arbor Railroad. *Engineering News*, July 23, 1896. 800 words.

26. Steam Shovels and Steam Shovel Work in Railway Construction. *Engineering News*, April 11, 1907. 2000 words.

27. Suction Dredges in Railroad Construction. *Western Engineering*, January, 1916. Illustrated, 900 words.

28. Two Methods of Constructing Railway Embankment Over Soft Grounds. *Engineering & Contracting*, June 12, 1912, Illustrated, 700 words.

CHAPTER XIX

RECLAMATION WORK

191. Preliminary.—Reclamation work includes the construction of ditches, canals, the foundations for masonry structures, earth dams, levees, etc., for irrigation and drainage projects, and flood prevention and flood protection works.

The type of machinery to be used in any case depends on the character, magnitude and distribution of the work. This is especially true in reclamation work where the construction of the smaller ditches, canals or levees usually requires some form of light, portable excavator which entails small initial cost of plant and adaptability of light excavation extending over considerable areas. Light, inexpensive outfits should be used where practicable even if less efficient than heavier equipment in order to secure low unit costs. The recent and more universal use of the power tractor in place of teams has been a great factor in the development of the economic use of scrapers and graders in earth-work.

Irrigation structures are largely built in the arid zone where dry soil conditions favor the use of the dry-land types of excavators; scrapers, graders, drag-line excavators, power shovels, templet excavators, etc.

Drainage structures usually consist of ditches and canals built through low, wet lands and require the use of some type of floating excavator, although soil conditions occasionally permit the use of some form of dry-land excavator such as the drag-line machine.

Flood prevention and flood protection works consist largely in the construction of reservoirs, levees and canals and the work may require either the dry-land or floating type of excavator. Each case or each particular job should be studied independently, and occasionally on a large project in connection with other parts of the work, to determine from the governing factors of soil conditions, magnitude and extent of the work, length of haul, labor and fuel condition, etc., the proper equipment to be used.

The discussion of the various types of excavators used in reclamation work will be considered in three general divisions; irrigation works, drainage works, and flood prevention and flood protection works.

I. IRRIGATION WORKS

192. Scrapers.—The Fresno scraper, drawn by four horses, has been found to be very efficient in the excavation of canals. The long cutting edge is especially adapted to the pushing ahead of large quantities of material. The economic limit of haul is about 250 ft. and beyond this distance the wheel scraper should be used. See Art. 11, page 8.

The best form of wheel scraper to use for hauls of from 250 ft. to 1000 ft. is the four-wheel scraper. See Art. 15, page 12. It is from 50 to 100 per cent. more efficient than the two-wheel scraper for hauls of 300 ft. and over. A traction engine should be used wherever practicable for the loading of the scrapers as this method of loading is cheaper and quicker than with the use of animals for a snatch team. See Art. 162, page 250.

193. Use of Scrapers in Idaho.—The excavation of the main canal of the Payette-Boise project of the U. S. Reclamation Service near Nampa, Idaho, comprised the excavation of about 654,000 cubic yards. The work was started in February, 1906, and completed in March, 1908.

The following detailed statement gives the unit cost of excavation of the various classes of material. During the early part of the work, a 10-hr. working day was used, but most of the work was done with an 8-hr. working day. The following rate of wages was paid on the basis of an 8-hr. day:

Superintendent, $125.00 per month; timekeeper, $100.00 per month; foreman, $3.00 to $4.00 per day; powder man, $3.00 per day; drivers, $2.50 per day; laborers, $2.25 per day; stable boss, $67.00 per month. Coal cost $9.00 per ton on the job; black powder $2.00 per keg and giant powder $0.15 per pound.

Class 1 excavation consisted largely of a stiff loam containing a large percentage of clay, and loose rock of various sizes scattered through the material. The excavation was made almost entirely from the canal section and about one-half was handled with Fresno scrapers and the remainder with slip and two-wheel scrapers.

Table XIX.—Unit Costs of Canal Excavation

Item	Class 1 467,785 cu. yd.	Class 2 69,009 cu. yd.	Class 3 20,303 cu. yd.	Class 4 10,933 cu. yd.	Class 5 85,828 cu. yd.	Class 6 207,074 cu. yd.
Interest	$0.002	$0.005	$0.008	$0.009	$0.017	
Preparation	0.001	0.002	0.004	0.004	0.008	
Depreciation	0.003	0.006	0.008	0.009	0.020	
Repairs	0.006	0.011	0.014	0.017	0.042	$0.001
General supplies	0.001	0.002	0.004	0.003	0.007	
Superintendence	0.014	0.025	0.031	0.033	0.092	0.001
Grubbing	0.001	0.001	0.002	0.001	0.002	
Plowing	0.019	0.056	0.058	0.085		
Drilling, hand	....	....	0.057	0.021	0.209	
Explosives and drills	....	....	0.098	0.029	0.225	
Loading, hauling and spreading	0.089	0.164	0.255	0.294	0.507	0.021
Finishing	0.006	0.016	0.021	0.032		
Water and hauling	0.001	0.003	0.001	0.001	0.004	
Contractor's total cost	$0.143	$0.291	$0.561	$0.538	$1.133	$0.023
Engineering	0.007	0.016	0.022	0.035	0.046	0.001
Total cost	$0.150	$0.307	$0.583	$0.573	$1.179	$0.024

Class 2 excavation consisted of an indurated clay and gravel which could be plowed by a 10-horse team. The material was usually found below the Class 1 material and was handled by means of Fresno and two-wheel scrapers.

Class 3 excavation consisted of indurated clay and gravel which required blasting. It occurred near the surface of the canal in spots. After being broken up, the material was removed by two-wheel scrapers.

Class 4 excavation consisted of boulders less than ½ cu. yd. in volume, scattered through the Class 1 material. The material was removed with stone boats used in conjunction with two-wheel and Fresno scrapers.

Class 5 excavation consisted of boulders exceeding ½ cu. yd. in volume and solid rock requiring blasting. This material was drilled by hand and blasted largely by black powder. About two-thirds of the material occurred in three heavy cuts, the remainder being scattered along the canal. The fractured material was removed by stone boats and horse-power derricks.

194. Use of Drag and Fresno Scrapers in Colorado.—In the excavation of a ditch in eastern Colorado, having a 6-ft. bottom width, average depth of 7 ft., and side slopes of 1½ to 1, a No. 1 drag scraper or "slip" moved by a team excavated from 30 to 75 yd., or an average of 50 cu. yd. of earth (sandy loam), in a working day of 10 hours. A No. 1 "Fresno" scraper, moved by four horses under the same conditions and on the same work, excavated from 50 to 175 cu. yd. or an average of 110 cu. yd. in the same time. The excavation cost 10 cents per cubic yard. This example shows the superiority and greater capacity of the Fresno scraper in this class of earthwork.

195. Use of Fresno Scrapers in Nevada.[1]—The Reclamation Service used the Fresno scraper in the construction of an irrigation canal near Fallon, Nevada, during April, May and June, 1906. The soil excavated was principally a compact sand, with some gravel, loam and sub-soil of hard clay in places. The ditch had an average bottom width of 20 ft. and side slopes of 2 to 1. The spoil bank was made 6 to 12 ft. wide on top and with an average height above grade of 7½ feet. The canal was generally located along a comparatively even side hill, although in places material from cuts as deep as 20 ft., was wasted beyond a 50-ft. berm or hauled 200 ft. to 300 ft. to reinforce the banks along adjacent depressions.

The berms were first plowed and the entire right-of-way cleared of brush before the excavation of the canal was begun. It was excavated truly to grade and the side slopes carefully trimmed. The length of the working day was 8 hours.

A very good illustration of the efficiency of Fresno scrapers in the excavation of ditches is given in the following example.

The ditch was for irrigation, having an average depth of 6 ft. to 7½ ft. and side slopes 2 to 1. The excavated material generally formed the banks. The soil excavated was a sandy loam.

The working force was made up of 10 to 12 Fresno scrapers and a two-horse plow which loosened up the earth for the scrapers. Each scraper worked continuously back and forth, down one bank and up the other. Each driver loaded and dumped his own scraper. One finishing scraper was used to trim up the sides and bottom of the ditch. The men were paid $2.25 for an 8-hr. working day.

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[1] Abstracted from *Engineering-Contracting*, November 3, 1909.

The following table gives the working cost per scraper per day:

Labor:	
Four horses, Fresno and driver	$5.30
One-tenth of two-horse plow and driver @ $3.95	0.395
One-tenth of loader	0.225
One-tenth of foreman @ $4.00	0.40
Total	$6.32
Average excavation per scraper per day	125 cu. yd.
Cost of excavation per cu. yd., $6.32 ÷ 125 =	5.06 cents.

196. Use of Four-wheel Scrapers in Oregon.—The Maney four-wheel scraper was used in the construction of the South Branch Canal on the Klamath Project near Klamath Falls, Oregon. This canal is unique in its being built in an elevated enbankment above the general level of the original surface of the land. The top of the dike is 14 ft. and the bottom of the finished canal is 8 ft. above the original ground surface. The material was placed in 6 in. layers, sprinkled, and rolled only by the tractive action of the wheels of the scrapers. The average haul from borrow pit to dike was 400 feet. The material excavated from the borrow pit was sandy loam for the first 18 in. and underlying this 3½ ft. of hard-pan. This latter material required 8 to 10 head to move the plow through it. The total amount of material handled was 170,000 cu. yd. and the average cost of handling per cubic yard was 14 cents.

197. Use of Four-wheel Scrapers in Colorado.—The use of this four-wheel scraper for 3 years in the construction of reservoir dikes and irrigation ditches in Colorado, where a friction drum and cable attached to a traction engine were used for extra power in loading, gave good results. Two sizes of this machine were used, a three-horse holding 1 yd. and a four-horse holding 1½ yards. The material averaged from a loose sand to a very stiff clay. A loading average was made of 100 loads per hour with each loading engine. The cost of excavating and moving the dirt was from 5 to 8 cents per cubic yard on short hauls of 100 to 200 ft; for longer hauls the cost was 1 cent per cubic yard per 100 ft. increase of length of haul. The large size of scraper can be economically used up to a 2000-ft. haul.

Figure 158 shows a gang of scrapers using a traction engine in the place of snatch teams.

198. Use of Four-wheel Scrapers in Illinois.[1]—The excavation of a site for a large artificial lake at Libertyville, Illinois, was recently accomplished with Maney scrapers.

The area of the pit excavated was oval in shape with a diameter of about 400 feet. The material was a very hard brick clay.

The scrapers were loaded, at first, with snatch teams but later a 10-h.p. double-drum engine was used. The engine was placed on the bank of the pit and a ½ in. diameter steel cable run from each drum through a two-sheave steel pulley block anchored to a "deadman" about 50 ft. away. The outer end of each cable was fastened to a hook, attached to the tongue of a scraper. The operation of each drum of the engine wound up the cable and pulled the scraper through the plowed ground toward the bank of the pit. Either one or two scrapers could be loaded at one time. Generally one scraper proceeded to the dump, while the other one drew the cables back to the loading point. The average haul was about 500 ft., varying from 200 to 1200 feet.

FIG. 158.—Maney scrapers on irrigation work. *(Courtesy of Baker Mfg. Co.)*

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[1] Abstracted from *Engineering-Contracting*, September 18, 1912.

Each scraper required the services of only one man who rode, drove the team and operated the levers for loading and dumping the scoop. The operation of the engine was controlled by one man.

The following is a statement of the work for July, 1912.

6338 loads of about 29 cu. ft. equal 5106 cu. yd. (place meas.)

Average number of cu. yd. excavated per team-hour	3.01
Average number of cu. yd. excavated per scraper-hour	3.92
Average number of cu. yd. excavated per scraper per day	35.3
Average number of cu. yd. excavated per day	255.3

The labor cost for this work is given as follows:

1 foreman	$3.00
1 dumpman	2.25
2 pitmen @ $2.25	4.50
1 engineer	2.75
9 teams and men with 7 scrapers @ $5.00	45.00
Total labor cost per day	$57.50
Average excavation per day	255.3 cu. yd.

Labor cost of excavation, $57.50 ÷ 255.3 = $0.225 per cu. yd.

199. Graders.—The two-wheel grader can be used to advantage for construction of the smaller lateral and distribution ditches of an irrigation system. See Arts. 20 and 21, page 20. The machine will construct V-shaped laterals from 12 to 36 in. deep, and from 24 to 60 in. wide at the top, at a cost of from 2 to 8 cents per rod.

The ordinary road or blade grader is not well adapted to the excavation of ditches and canals. However, a special form of blade grader, the Reclamation grader, has been successfully used in the construction of irrigation ditches in Colorado, Idaho and Montana. The machine has a much greater latitude in the vertical adjustment of blade and the lateral or oblique motion of the wheels of both trucks than the ordinary road grader. It can excavate ditches to a depth of 3 ft. below the original surface, to a bottom width of 10 ft., and with side slopes as steep as 2 to 1. The cost of construction of irrigation ditches has run from 1 cent to 8 cents per cubic yard, depending on the cross-section of the ditch and the character of the soil.

The elevating grader can be used for the excavation of ditches and canals, especially where the soil conditions allow for uninterrupted operation and the material can be deposited directly in the spoil banks. The diagrams of Fig. 159 show the range of size of ditches which can be excavated by an elevating grader, without using dump wagons. The method of excavation of a ditch or canal depends on the width and depth. The smaller ditches are generally excavated by starting at one side and throwing the material to the spoil bank on the opposite side. As the ditch becomes wider, it is necessary to work from the center of the section, moving the material to each side and doing the work in sections. The elevating grader is not an efficient machine for the excavation of a canal having a bottom width of less than 10 ft., as the machine does not have room in which to operate freely. It is necessary to follow up the grader with a scraper or blade grader in order to secure a uniform grade and smooth side slopes. Figure 160 shows an elevating grader constructing an irrigation canal in the Middle West.

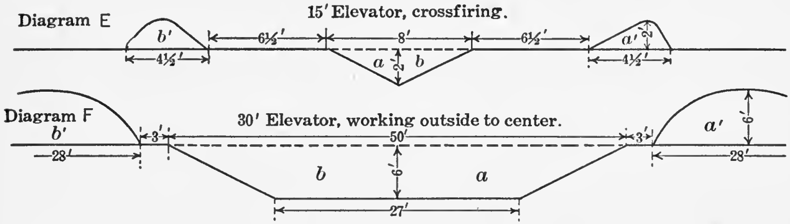

Fig. 159.—Cross-sections of ditches and canals. (*Courtesy of Western Wheeled Scraper Co.*)

Fig. 160.—Elevating grader on canal construction.

200. Use of Elevating Grader in Montana.—On the Blackfeet Project of the U. S. Reclamation Service, near Blackfeet, Montana, a New Era Reversible Elevating Grader was used in the construction of an irrigation ditch having a bottom width varying from 10 to 15 feet. Eighteen heavy mules were used to draw the grader, the elevator belt of which was run by a 9-h.p. gasoline engine. The ditch was excavated principally on flat country and on hillside with slight slopes. The material excavated was principally clear loam and loam mixed with a small amount of gravel. Four men were required to operate the machine and the average excavation was 110 cu.yd. per hour, at a cost of 6 cents per yard for actual operation (not including administration and camp expense). The experience of the engineers on this project in the use of elevating graders in the excavation of ditches or canals, showed that although animals as motive power gave good satisfaction, the greatest efficiency and economy are secured by the use of a traction engine. This type of excavator cannot be used to advantage on a ditch having a bottom width of less than 10 feet.

A Western Standard elevating grader was used in Montana, in the construction of irrigation ditches. The material excavated was a heavy sandy loam and was wasted on both sides of the ditch. On the basis of a 10-hr. day, an average excavation of 900 cu. yd. was made at a cost for power and labor of 7 cents per cubic yard. Experience on this work showed that the grader was useful only in the excavation of large ditch prisms and that it was generally necessary to use some other machinery to finish the ditches and make smooth side slopes and bottoms.

201. Power Shovels.—The larger sizes of the fixed-platform type of power shovel are generally not adapted to ordinary canal excavation, except for channels of large cross-section and through hard-pan or rock. These machines are efficient in the excavation of the foundations of dams, power houses and other structures.

The revolving shovel has been successfully used in canal excavation where the cross-section is of sufficient width to permit of its free operation; the minimum bottom width of channel being about 15 feet. However, unless the material to be excavated is hard-pan or rock, some other form of excavator can generally be used to better advantage.

The use of power shovels in the construction of earth dams and reservoirs will be discussed in the following division, "Flood Prevention and Flood Protection Works."

202. Use of Steam Shovel in Texas.—An irrigation project in the Rio Grande Valley, Texas, including the construction of a ditch or canal about 21 miles long. This canal had a bottom width of 16 ft., an average depth of 4½ ft., and side slopes, in earth. 2 to 1, in rock 1 to 5, and for embankments 1½ to 1. The grade of the canal was about 6 in. in 1000 feet. The country through which the canal passes was very rough and necessitated many heavy cuts and fills, a 34-ft. cut in solid rock being made in one place.

The work included the excavation of 90,000 cu. yd. of solid rock, 120,000 cu. yd. of loose rock, and 1,750,000 cu. yd. of earth. Steam shovels of a standard make were used in the entire work.

The daily operating cost of each shovel is given as follows:

1 engineer	$5.00
1 assistant engineer	5.00
1 fireman	2.00
1 coal hauler	2.00
1 water hauler	2.00
1 assistant	2.00
2 tons of coal @ $3.50	7.00
Total operating cost	$25.00

Each shovel excavated on an average of 1000 cu. yd. of earth or 500 cu. yd. of rock during a 10-hr. working day. The size of the dippers used was 1 cubic yard. The total estimated cost of handling the earth was 25 cents per cubic yard and for rock, was 50 cents per cubic yard.

203. Use of Steam Shovel in Utah.—A self-traction steam shovel weighing about 22 tons and equipped with a ¾-cu. yd. dipper was used (1911–12) in the construction of an irrigation ditch on a project in Grand Valley, near Agate, Utah. The ditch was 10 ft. wide on the bottom, 14 ft. wide on top and 2½ ft. deep in level country. There were several deeper cuts through hills, the maximum depth of which was 10 feet. The shovel was run along the bottom of the ditch on 4-in. × 12-in. timbers which served as a track.

The work involved the excavation of 50,000 cu. yd. of shale and 300,000 cu. yd. of sandy loam and clay. Up to March, 1912, the material excavated was loose and solid shale. The crew on the shovel consisted of an engineer, a cranesman, a fireman, and four laborers. The average excavation was 200 cu. yd. per day of 10 hr. and the average cost of excavation was 16 to 17 cents per cubic yard (not including overhead expenses). In the excavation of loose shale about 1 ton of coal per 10-hr. day was consumed and 2 tons of coal in the excavation of solid shale.

The trench was 5 ft. wide and 14 ft. deep and had to be braced. The material excavated was hard blue clay.

204. Use of Atlantic Steam Shovel in Idaho.—During 1912 and 1913, the preparation of the foundation of the Arrowrock Dam near Boise, Idaho, involved the excavation of about 230,000 cu. yd. of loose boulders, earth and rock. About 57,700 cu. yd. of this material was removed in the fall of 1912 with an Atlantic steam shovel, Class 45, equipped with a 2½-yd. dipper. Working in conjunction with the shovel were two Vulcan 16-ton and one American 16-ton locomotives, and twenty-five 4-yd. Western dump cars. Figure 161 shows the Atlantic steam shovel in operation.

Fig. 161.—Atlantic steam shovel excavating foundation of Arrowrock Dam. (*Courtesy of the Bucyrus Co.*)

The material in places was composed of boulders of various sizes up to 150 cu. yd. and were nested together solidly with finer material in the interstices. Occasionally blasting was necessary to break up this material for the shovel. This required considerable delay and hard usage for the shovel. The engineer's estimate gave 27,300 cu. yd. of solid rock and 30,400 cu. yd. of other material.

The following is a statement of the cost of operation of the shovel from February 27, 1912 to October 10, 1912:

Shovel:		
Labor	$6,935.49	
Fuel	2,122.75	
Supplies	1,732.79	
Miscellaneous	5.65	
Repairs	2,496.99	
Depreciation	905.48	
Total		$14,199.15

Cost of shovel operation per cu. yd., $14,199.15 ÷ 57,000 = $0.246

Dinkey Trains:		
Labor	$5,498.11	
Fuel	1,710.99	
Supplies	696.22	
Track maintenance	2,852.63	
Repairs	1,773.98	
Depreciation	1,214.80	
Total		$13,746.73

Cost of transportation per cu. yd., $13,746.73 ÷ 57,000 = $0.238

Preliminary expenses	$1,099.89
Grand total	$20,045.77

Total unit cost of excavation, $20,045.77 ÷ 57,700 = $0.503

205. Scraper-bucket Excavators.—The scraper bucket or drag-line excavator has developed into one of the most efficient machines for the excavation of ditches, canals and foundations where the soil is free from large rock, stumps and other obstructions and not too dense and hard. The ease of portability and the great latitude of operation of the drag-line machine adapt it especially for the excavation of canals; the smaller ditches being built by one machine working from the center or one side only, while the larger canals can be excavated by two machines working coördinately along both sides. See Art. 59, page 80.

206. Use of Drag-line Excavator in Nevada.—The Reclamation Service used (1912) a drag-line excavator in the construction of canals and embankments of the Truckee-Carson project, near Fallon, Nevada. The excavator was equipped with a 14-ft. roller circle, a 60-ft. structural steel boom and a 1½-cu. yd. three-line, scraper bucket. The machine was equipped with electric motors throughout, using alternating current at 440 volts. The current was generated at a hydro-electric plant located on the main canal of the project. The cost of this electric power would be equivalent to coal at about $2.00 per ton. Steam-coal at this place would cast $9.00 per ton, delivered on the excavator.

The average capacity of the machine, excavating gravel, clay and loam under ordinary conditions, was about 500 cu. yd. per 10-hr. day. It required the service of one operator on the machine and two trackmen and laborers on the ground to operate the excavator.

207. Use of Drag-line Excavators in Idaho.—From 1910 to 1914, drag-line excavators were used in the construction of deep drainage channels on the North Side Mindoka irrigation project of the U. S. Reclamation Service in Idaho. These drains were about 10 ft. deep and a mile to a mile and one-half apart. The material excavated was a sandy loam from a depth of from 3 ft. to 7 ft., underlaid by sand and gravel to a depth of from 20 ft. to 30 feet.

The drag-line excavators consisted of two steam-operated machines and two electric-operated machines. The steam-operated machines were of the ordinary type and were built on the job. They had revolving frames, rope swing, 1-yd. buckets, 58-ft. booms and cost about $5000.00. The electric-operated machines were of the Class 9½ Bucyrus type. They were equipped with gear swing, caterpillar tractors, 1¼-yd. buckets, 54-ft. booms and cost about $13,800.00. The caterpillar tractor feature of these machines was found to be very efficient in providing for the movement of the excavator over very soft or rough ground and in the saving of time and the services of one laborer, required for the roller and plank operation of the steam machines.

The two steam machines excavated 675,000 cu. yd. of material from two channels at an average cost of 13.22 cents. The following is a detailed statement of this work:

	Cost per cubic yard
Labor excavation	$0.0434
Hauling and pumping water	0.0123
Hauling and handling coal	0.0066
Coal, including freight	0.0252
Repairs, labor	0.0017
Repairs, material	0.0051
Cables	0.0034
Carbide	0.0013
Miscellaneous supplies	0.0049
Depreciation in machinery	0.0111
Engineering and administration (15 per cent.)	0.0172
Total	$0.1322

The following statement gives the detailed cost of operation of the two electric machines during a period two months:

	Cost per cubic yard
Labor excavation	$0.0204
Electricity at $0.01 per kilowatt	0.0045
Repairs, labor	0.0001
Repairs, material	0.0004
Steel rope	0.0011
Transmission line @ $0.06 per foot	0.0078
Miscellaneous supplies	0.0035
Depreciation on machinery	0.0240
Engineering and administration (15 per cent.)	0.0092
Total	$0.0710

208. Use of Electrically Operated Drag-line Excavators in Montana.[1]—Electrically operated drag-line excavators were used for canal construction during 1914 on the Sun River project of the U. S. Reclamation Service near Great Falls, Montana. The essential part of the work consisted of the building of a 45 mile canal, largely side-hill work and through heavy material. Two electrically actuated drag-line machines were used and power was furnished to three points along the canal line by a transmission line 75 miles long. The following is a description of the excavators and a detailed statement of the operating costs:

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[1] Prepared from data furnished by U. S. Reclamation Service.

THE CLASS 20 BUCYRUS DRAG LINE

This machine is an electrically actuated drag line equipped with 85-ft. boom, 2½-cu. yd. Bucyrus bucket (old type with cast-steel swinging bale); the main motor is 135 h.p. and the swinging motor 75 horse power. There is also a 2-h.p. motor direct connected with the air compressor for operating brakes and frictions. The machine weighs 90 tons when ready for work. The crew employed on each shift during the period covered by these costs consisted of a runner at $175.00 to $225.00 per month who acted as shift foreman; an oiler and four trackmen at from $2.00 to $2.50 per day; an electrician who served for all shifts at $150.00 per month; and a team and driver at $5.00 per day, which hauled supplies, moved transformer wagon and did odd trucking. The machine was operated two shifts most of the period but at the end was running three shifts. Electric energy was delivered to contractors' transformers at 16,500 volts. It was transformed by one set to 2200 volts and stepped down on the machine to 440 volts. The cost of the electricity includes cost of lights for the night shifts. The electricity cost the contractor 1 cent per kilowatt-hour measured at the substation. The preliminary expense given on the list attached hereto consisted of unloading the machine from the cars, hauling to the work, erecting, camp expense and other incidental expenses. Excavating expense includes supervision, time-keeping and clerical.

THE CLASS 24 BUCYRUS DRAG LINE

This machine is owned by Yale & Reagan, is electrically actuated, equipped with one 100-ft boom and 3½-cu. yd. heavy service Page bucket. The main motor is 200 h.p. and the swinging motor 115 horse power. There is also a 2-h.p. motor direct connected to the air compressor for operating the brakes and frictions. The machine weighs about 120 tons when ready for work. The crew employed during the period covered by these costs for each shift consisted of a runner at $175.00 to $200.00 per month; an oiler and four trackmen at from $2.00 to $2.50 per day; an electrician who acted as foreman for both shifts at $175.00 per month; and one or two teams with drivers at $5.00 per day, who moved the transformers and brought supplies to the machine. The machine was operated one shift the first part of the period when 1½-cu. yd. wagons were loaded on construction of a large rolled embankment, and two shifts a large part of the period when the machine was excavating for a concrete lined section on heavy side-hill work, the upper end being as great as 80 feet. Electrical energy was delivered to the contractor at 16,500 volts to transformer wagons, where it was stepped down to 2200 volts and then stepped down on the machine to 440 volts. The cost of electrical energy included cost of lights for night shift. The electrical energy was charged to the contractor at 1 cent per kilowatt hour at the substation.

COST OF OPERATING ELECTRICALLY ACTUATED DRAG LINES

Class 20 Drag Line owned by Buchanan & Co.

Machine operated April 11 to September 15, 1914.

Total amount of material moved (all classes)		222,580 cu. yd.
Class 1	218,272 cu. yd.	
Class 2	1,544 cu. yd.	
Class 3	2,764 cu. yd.	
Total value of plant		$20,957.13

Cost of Entire Excavation, Including Overhaul

Item	Total cost	Unit cost
Interest on investment @ 6 per cent	$903.18	$0.004
Preparatory expense	4,762.27	0.021
Plant depreciation, 2 per cent. mo	2,219.11	0.010
Repairs	1,592.39	0.007
Executive	1,350.63	0.006
Labor	8,685.40	0.039
Supplies	2,213.43	0.010
Electric energy	1,657.08	0.008
Total cost to contractor	$23,383.49	$0.105

Cost of Class 1, Including 3860 cu. yd. Sta. Overhaul

Item	Total cost	Unit cost
Interest on investment @ 6 per cent	$851.49	$0.004
Preparatory expense	4,489.00	0.021
Plant depreciation, 2 per cent. mo	2,093.00	0.009
Repairs	1,500.45	0.007
Executive	1,287.30	0.006
Labor	8,162.76	0.0374
Supplies	2,163.93	0.010
Electrical energy	1,581.43	0.007
Total cost to contractor	$22,129.36	$0.1014

(This material was largely a fine sandy clay with some water in the bottom, and some coarse loose gravel.)

Cost of Class 2 Excavation, 1544 cubic yards

Item	Total cost	Unit cost
Interest on investment @ 6 per cent	$8.89	$0.006
Preparatory expense	47.15	0.031
Plant depreciation, 2 per cent. mo	21.80	0.014
Repairs	15.75	0.010
Executive	2.73	0.002
Labor	117.63	0.076
Electric energy	17.40	0.011
Total cost to contractor	$231.35	$0.150

(This material was partly coarse tight gravel and the remainder loose soft sandstone.)

Cost of Class 3 Excavation, 2764 cubic yards

Interest on investment @ 6 per cent	$42.80	$0.015
Preparatory expense	226.12	0.082
Plant depreciation, 2 per cent. mo	104.31	0.038
Repairs	76.19	0.027
Executive	60.60	0.022
Labor	492.01	0.178
Supplies	49.50	0.018
Electric energy	58.25	0.021
Total cost to contractor	$1109.78	$0.401

(This material was largely seamy sandstone in ledges about three quarters of which was removed without the use of powder.)

COST OF OPERATING ELECTRICALLY ACTUATED DRAG LINES

Class 24 drag-line owned by Yale & Reagan

Machine in operation from March 20 to December 1, 1914

Total amount of material moved (all classes)	281,748 cu. yd.
Class 1	253,174 cu. yd.
Class 2	19,163 cu. yd.
Class 3	9,413 cu. yd.
Overhaul	145,000 cu. yd. sta.

(Cost of overhaul not included in cost of excavation. Cost of contractor 4 cents per cu. yd. sta.)

Total value of plant	$36,326.63

Cost of Entire Excavation, Excluding Overhaul

Item	Total cost	Unit cost
Interest on Investment @ 6 per cent.	$2,492.47	$0.0089
Preparatory expense	6,363.47	0.0224
Plant depreciation @ 2 per cent. mo.	6,382.68	0.0227
Repairs	6,082.10	0.0216
Executive	2,437.37	0.0084
Labor	12,996.89	0.0461
Supplies	4,400.14	0.0156
Electric energy	2,417.67	0.0084
Miscellaneous	536.32	0.0014
Total cost to contractor	$44,109.11	$0.1565

Cost of Class 1 Excavation, Excluding Overhaul

Interest on investment @ 6 per cent.	$1,995.35	$0.0079
Preparatory expense	5,100.00	0.0205
Plant depreciation @ 2 per cent. mo.	5,105.58	0.0202
Repairs	4,865.60	0.0192
Executive	2,035.54	0.008
Labor	10,412.55	0.0413
Supplies	3,069.86	0.0122
Electric energy	2,035.54	0.008
Miscellaneous	485.77	0.0015
Total cost of contractor	$35,105.79	$0.1388

Cost of Class 2 Excavation, 19,163 cubic yards

Item	Total cost	Unit cost
Interest on investment @ 6 per cent.	$194.00	$0.0101
Preparatory expense	767.63	0.0400
Plant depreciation, 2 per. cent mo.	497.10	0.0259
Repairs	475.90	0.0248
Executive	200.78	0.0105
Labor	1,018.44	0.0531
Supplies	332.73	0.0174
Electric energy	197.72	0.0103
Miscellaneous	30.11	0.0016
Total cost to contractor	$3,714.41	$0.1937

Cost of Class 3 Excavation, 9413 cubic yards

Interest on investment @ 6 per cent	$303.12	$0.0322
Preparatory expense	486.00	0.0516
Plant depreciation, 2 per cent. mo	780.00	0.0828
Repairs	740.60	0.0786
Executive	201.05	0.0213
Labor	1565.90	0.1662
Supplies	997.55	0.1060
Electric energy	184.41	0.0196
Miscellaneous	20.44	0.0022
Total cost to contractor	$5279.07	$0.5605

(The Class 2 and Class 3 material in this work consisted of heavy tight gravel with some cemented gravel, and seamy sandstone in ledges, some of which was excavated without use of powder and the remainder drilled with a Fort Wayne Electric Drill and blasted with black powder.)

Depreciation on the plants was taken at 2 per cent. per month continuous, whether the machine was running or not. It might perhaps better have been taken at 3 per cent. per month when the machine was running, which would give the same results in the end, *i.e.*, a four season life for the machine. Preparatory expense has to be prorated over the work done and as more work is accomplished this item will decrease in amount. There will be of course the cost of dismantling the machines when the work is done and transporting them back to the railroad.

209. Use of Drag-line Excavator in Idaho.—The use of an Atlantic type of steam shovel in the preparation of the foundation for the Arrowrock Dam was described in Art. 204. In this article will be given a brief description of the use of a drag-line excavator on the same work.

The machine was of the regular type, equipped with a 70-ft. boom and a 2-yd. bucket. It was steam operated from a 70-h.p. vertical boiler, and mounted on skids and rollers. The body and boom were built of timber.

The drag-line excavator moved back and forth across the bed of the foundation over a zone lying underneath two nearly parallel cableways, which were used to elevate and transport the skips filled by the excavators. The skips were placed in rows of 6 or 8 under each cableway and were filled successively by the drag-line machine which worked from either side so as to be out of danger from work falling from the skips as they were raised;

A view of the drag-line excavator in operation is shown in Fig. 162.

FIG. 162.—Excavation of foundation for Arrowrock Dam. *(Courtesy of U. S. Reclamation Service.)*

The material handled consisted of 12,000 cu. yd. of solid rock previously blasted and 111,000 cu. yd. of gravel and sand with 5 to 10 per cent. of boulders about two-man size. The following statement gives the cost of operation:

Labor	$9411.95
Fuel	2357.40
Supplies	3092.26
Repairs	1801.81
Depreciation	2025.26
Preliminary expenses	1012.63

Total cost	$19,701.31
Total excavation	113,000 cu. yd.

Unit cost of excavation, $19,701.31 ÷ 113,000 = $0.174.

FIG. 163.—Templet excavator constructing irrigation ditch. (*Courtesy of F. C. Austin Co.*)

210. Templet Excavators.—The efficiency of an open channel is largely dependent on the uniformity of grade and smoothness of the sides and bottom. Finished cuts cannot be made with the power shovel or drag-line machine and usually these must be followed up by scrapers or blade graders in order to secure uniform and smooth surfaces. As the construction of irrigation channels is generally in the softer and looser soils such as sand, sandy loam, sandy clay, gravel, etc., a templet machine can be used to advantage, as this type of excavator gives finished channels with the desired cross-section and side slopes. Experience shows that banks cut to the finished slope in this way maintain their original condition much longer than when unevenly excavated by other types of excavator. The construction of finished surfaces is a great advantage in cases where the channels are to be lined with concrete. See Chapter VIII. A typical irrigation channel built by a templet excavator is shown in Fig. 163. This ditch had a bottom width of 4 ft., an average depth of 9 ft. and side slopes of 1½ to 1.

211. Use of Templet Excavators in Colorado.—Two templet machines were used during the season of 1911 for the excavation of irrigation ditches in the San Luis Valley in Colorado.

The ditches excavated had 6 ft. and 8 ft. bottom widths, an average depth of 6 ft. and side slopes of 1½ to 1. The material varied from a sandy loam to a gravel stratum filled with silt. In the former material the average excavation was 750 cu. yd. for a 12-hr. shift, while in the latter material the digging was hard and did not average over 500 cu. yd. per shift.

The following table gives the average cost of operation for a 12-hr. shift:

1 operator	$4.00	
1 fireman	3.00	
1 trackman	1.50	
1 man and team on track	4.25	
1 man and team on water wagon	4.25	
1 cook	1.00	
Coal @ $4.50 per ton on cars	6.00	
Boarding supplies	2.00	
Oil	1.00	
Repairs, cable, chain, waste, etc	1.00	
Total		$28.00

At 750 cu. yd. for each 12-hr. shift, the cost of operation would be 3.73 cents per cubic yard.

Recently (1915–1917), three templet machines have been used in the San Luis Valley, Colorado, for the construction of a large number of irrigation and drainage channels. The material excavated has been largely a loose sandy loam, underlaid by gravel. The ditches were built with a bottom width of 8 ft., depths varying from 6 ft. to 8 ft. and side slopes of 1½ to 1. The excavated material was deposited on both sides of the channel with an 8-ft. berm on each side. The work was carried on in two 10-hr. shifts, five men in the day crew and four men in the night crew (engineer, fireman, trackmen and teamster). The average excavation for a 10-hr. shift varied from 800 to 1000 cubic yards. Each machine was equipped with a 1-yd. bucket, cutting in both directions, transversely. The machines were supported on track stringers, one on each side of the channel and consisting of a heavy timber bolted between a pair of channels.

212. Floating Excavators.—The maintenance of irrigation systems involves the periodic cleaning out of ditches and canals. Some form of floating dredge can be efficiently used for this cleaning-out work. The reader is referred to Division II, Drainage Works for a discussion of this class of work and the use of floating dredges.

II. DRAINAGE WORKS

213. Scrapers.—The various forms of scrapers are not well adapted to the excavation of drainage ditches, especially under wet, heavy soil conditions. The author has known of instances where the slip and the two-wheel scraper have been used in the construction of small lateral ditches of a drainage system. But the results were very unsatisfactory and uneconomical, and the author would not recommend the use of scrapers except where especially favorable soil conditions or availability of other equipment require their employment. For a general discussion of the use of scrapers in ditch and canal construction see Art. 192, page 304.

214. Graders.—The two-wheel grader can be efficiently used for the construction of small lateral ditches where the soil is loose and soft enough to be easily excavated. The presence of roots, stumps or boulders in a soil would make the use of such a machine impracticable.

The four-wheel grader is not adapted to ditch construction and should be used for the smoothing and grading of the bottom and side slopes of a canal. The Reclamation grader with pivoted axles is the best type of machine for this class of work. However, in heavy, wet or soft soils the blade or scraping grader cannot be efficiently used in ditch construction.

The elevating grader can be efficiently used in the construction of the upper sections of canals and lateral ditches with a bottom width of not less than 10 feet. However, soil conditions largely govern the satisfactory use of this machine, as wet, heavy soils or soil where roots and boulders abound are not suitable for grader work.

215. Use of Two-wheel Grader in Mississippi.—The Twentieth Century Grader made by the Baker Manufacturing Company, Chicago, Illinois, has been used extensively in Mississippi, Louisiana, and Texas, in the excavation of small lateral ditches. On large plantations near Greenville and Yazoo City, Mississippi, drainage ditches, having a bottom width of 2 ft., average depth of 2 ft. and average top width of 6 ft., have been constructed with this grader. The machine was pulled by four mules and the services of two men were required, one to drive the mules and the other to operate the grader. In cases where the excavation was made in soft soil and the cut was uniform, one man furnished all the labor required. The average day's work resulted in the construction of ½ mile of ditch, having the cross-section noted above. The cost of construction was $4.00 per day or about 3 cents per rod.

Another form of two-wheel machine has the axles pivoted so that the wheels, either one or both may be inclined to prevent the lateral motion of the machine on an inclined surface or as a result of the side thrust of the blade.

216. Use of Elevating Grader in South Dakota.—From August, 1910 to December, 1911, three lines of lateral ditches, having an average length of 6 miles each, were constructed tributary to the Clay Creek Ditch in Clay County, South Dakota. The contract required the excavation of ditches having bottom widths of 3 ft., side slopes of 1 to 1 and depths, varying from 3 ft. to 7 feet. The contract price was 10 cents per cubic yard for excavated ditch section and the excavated material formed into a suitably graded-up road. The upper section of the ditches was entirely excavated by elevating graders drawn by traction engines. The graders used were the New Era Senior and the Standard Western. Hart-Parr gasoline engines having a capacity of 45–25 tractive horse power were used. An average of 800 cu. yd. of rather stiff loam and clay were excavated in a 14-hr. day. About 60 gal. of kerosene per day was used as fuel for each engine and the cost of labor was as follows:

1 engineer for engine, $3.50 per day and board
1 operator for elevating grader, $3.00 per day and board

217. Use of Elevating Grader in Minnesota.—The following description of the use of an elevating grader in the construction of a drainage ditch is taken from Bulletin No. 110 of the Northwest Experiment Farm of the University of Minnesota.

The machinery of the grader was operated by a 12-h.p. gasoline engine. A disc plow with a diameter of 24 in. and set at an angle of about 5 in. was used to elevate the earth on a 30-in. belt. The elevator had a length of 22 ft. with a maximum extension to 30 feet. The elevator and plow are supported from a steel frame, which is mounted on two trucks, the front truck having a wheel width of 6 ft. and the rear truck a wheel width of 9½ feet. The rear wheel on the elevator side had a tire width of 20 in. and the other three wheels a tire width of 10 inches.

The machine was drawn by 16 horses, 4 in the lead team and 6 in each of the front and rear teams. A driver was used for each team and one man operated the elevating machinery. The time of turning the grader averaged 1 minute. The average speed of the machine was 1.3 miles per hour for a working day of 10 hours. The average fuel consumption was 12 gal. of gasoline per 10-hr. day.

It was found that the minimum cross-section of ditch, which could be excavated with the elevating grader was one having a bottom width of 8 ft., a depth of 2.5 ft. and side slopes of 1 to 1. The greater the bottom width, the deeper the machine can excavate, but the narrower the berm becomes. It required 25 ft. clear space along each side of the ditch for operation and a length of 100 ft. at the end of the ditch for turning.

On a level stretch with a length of three-fourths of a mile and where the earth was dry and free from obstruction, an average daily excavation of 1200 cu. yd. was made. Of this amount 200 cu. yd. was outside of the required cross-section of the ditch, leaving 1000 cu. yd. of pay excavation.

218. Templet Excavators.—The templet excavator can be efficiently used for the excavation of drainage ditches when the soil conditions are favorable. It is not suited to the excavation of very wet soil or where trees, stumps, and large stones abound. Some recent machines have been equipped with caterpillar tractors and can operate on wet soils by commencing at the outlet and working upstream. See Art. 73, page 114. See Fig. 163.

219. Use of Templet Excavator in Illinois.—One of these templet excavators was used in the construction of a drainage ditch in southern Illinois. The ditch had a bottom width of 4 ft., side slopes of 1½ to 1, an average depth of 6 ft., and a length of 10,600 feet. The total excavation was 29,704 cu. yd. and required 45 working days. The machine was dismantled, hauled 6 miles, and erected for this job, and the cost for this complete removal was $499.56. Following is a table of the operating expenses for this work, based on a cubic yard of material excavated.

OPERATING EXPENSES PER CUBIC YARD

Superintendent	$0.00250
Engineer and fireman	0.01434
Moving track	0.01575
Coal	0.00880
Repairs	0.00602
Board for entire crew	0.00710
Explosives for stump removal	0.00440
Total	$0.05891

The excavator was dismantled, hauled 4 miles and set up for the next job at a cost of $756.00.

The soil excavated was a sandy loam underlaid by a clay subsoil. The soil was heavy and wet but not swampy.

220. Use of Templet Excavator in North Dakota.—During the summer of 1906, an excavator, very similar in construction and method of operation to the Austin excavator, was used in Pembina County, North Dakota. This machine is known as the Junkin Ditcher, and consists of a steel-framed car, thoroughly braced and trussed. The sides of the car are supported on two trucks, each of which has four flanged steel wheels which run on a portable track laid on each side of and parallel to the ditch line. The car thus straddles the ditch and moves ahead parallel to it. On the car floor is placed the locomotive type boiler and the machinery, which consists of a double engine of 70 h.p. for operating the excavating machinery and a double engine of 30 h.p., for operating the cutting frame.

At the rear end of the car is placed a large triangular-shaped framework, the lower end of which is made like a templet to conform to the sides and bottom of the completed ditch. Around the perimeter of each half of this frame moves a bucket belt, composed of two chains 30 in. apart and carrying 14 steel buckets spaced at equal distances. These buckets have cutting edges which are bolted to the sides and can be easily removed for sharpening. The chains are driven toward each other and in opposite directions by means of cog gearing and move over large sheaves placed at the vertices of the frame. The frame is fed downward by a screw gearing. As the bucket chains revolve, the buckets follow each other along the bottom of the excavation and then up the slopes, each one removing a thin slice of earth, which is carried to the top and outer end of the frame, where as the bucket turns about the sheave and starts on its return course, the earth falls out and the bucket is automatically cleaned by a stationary scraper. As the earth is excavated the frame is gradually lowered until the required depth is reached. This is shown by a graduated scale on the frame. Thus a strip of earth 30 in. wide is excavated to the finished grade line of the proposed ditch and the machine then moves ahead 30 in. and another strip 30 in. wide is excavated and so on until a section 30 ft. long has been dug. Then the machine is run back to the beginning of the section and the car is moved slowly ahead and the buckets remove the loose dirt and give the cross-section a final smoothing-up. As the two bucket chains do not come together at the center of the bottom, a ridge is left in the completed ditch about 18 in. wide at the base, and 12 in. high, but this does not present a serious objection, as the flow of water in the ditch soon levels it. If desired, the ridge can be removed by moving the earth to one side by hand as the excavator proceeds on its first trip and this surplus material would be removed during the second passage of the excavator.

The track is made in 30-ft. sections which are moved ahead of the machine by a team of horses, as fast as the sections of excavation are completed. The excavator starts at the outlet of a ditch and works upstream, the excavating being done on the downstream side of the car.

The labor required to operate a Junkin ditcher consists of one operator, who controls the operation of the excavator; one fireman and one oiler to feed the boiler and care for the machinery; a man and team for hauling water for the boiler and four men and a team to move the track.

An average amount of fuel of 2 tons of coal is required to run the machine during a 14-hr. working day.

The average excavation made by this machine during a 33 days' run of 14-hr. per day, was 1449 cu. yd. or about 100 cu. yd. per hour. The ditch excavated had a 10-ft. bottom, side slopes of 1½ to 1 and a depth varying from 6 to 12 feet.

A 5-ft. berm is left on either side of the ditch and the spoil banks have a triangular section and excavated material is deposited in them in a finely divided condition.

The excavator has a total weight of 60 tons and is made in sections so that it can be easily and readily assembled or dismantled. The boiler is the only part of the machine which cannot be loaded on to an ordinary wagon. It is said that the dismantling and loading upon wagons can be accomplished by 8 men in 2½ days and set up by the same crew in 5 days.

221. Wheel Excavators.—The wheel excavator is the most practical machine for the construction of small open ditches, especially in reclamation work, where a true grade and smooth side slopes are necessary. The small laterals of drainage and irrigation systems run full during a small part of the year, and they tend to fill up with silt, débris and vegetation. These obstructions greatly impair the efficiency of the channel, and hence the desirability, especially in small waterways to secure a true cross-section.

222. Use of Wheel Excavator in Florida.[1]—A wheel excavator was used during December, 1913 and January, 1914 in the excavation of drainage ditches in the Everglades. The machine weighed 37 tons and was operated by a 45-h.p. gasoline engine. Caterpillar tractors were used to support the rear of the machine containing the excavating equipment, and a bearing on the ground of about 350 lb. per square foot was obtained. The front part of the machine was extended and elevated to support a cabin which furnished the living quarters for 8 men. An independent electrical equipment furnished light for the living quarters and for a searchlight, which made night work possible.

The machine cut a ditch 2½ ft. wide on bottom, 9 ft. wide on top and 5 ft. deep at an average speed of 8 ft. per minute or 480 cu. yd. per hour. The maximum record was 1 mile of ditch in 10 hr. or 528 cu. yd. per hour. The average soil was sand and muck.

During December, 1913, about 43,630 cu. yd. of material was excavated at a cost of $0.0287 per cubic yard, including overhead expense, fixed charges and cost of clearing. During the first 23 days of January, 1914, the records showed an output of 58,630 cu. yd. of sand and muck at an average cost of $0.0240 per cubic yard.

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[1] Abstracted from *Engineering Record*, February 7, 1914.

223. Dry-land Dredge.—One of the most useful of the smaller power machines is the dry-land dredge which operates on the shovel principle and is built to span the channel and work upstream. The dredges are built in sizes varying from 14 ft. to 30 ft. gage, and are equipped with ½-yd. to 1-yd. dippers and kerosene engines of 25 h.p. to 40 h.p. capacity.

The machine travels on grooved wheels under each corner of the platform, moving along a track consisting of a single rail along each berm. The operations are governed by four cables; the hoisting cable, attached to the bail of the dipper; the backing cable, attached to the rear of the dipper; the swing cable, and the hauling cable. Three men are required to operate the machine; the engineer, and two laborers for moving the track and general work around the machine.

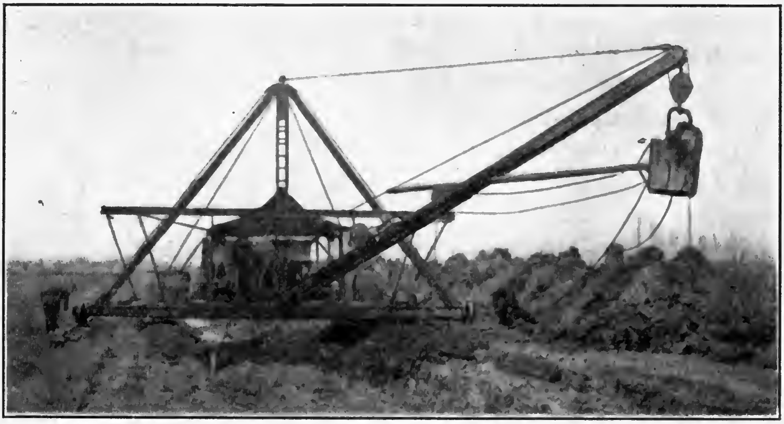

Fig. 164.—Land dredge excavating small drainage ditch. (*Bay City Dredge Works.*)

The cost of operation varies from $10.00 to $15.00 per 10-hr. working day. One machine, operating during the summer of 1913 in Tuscola County, Michigan, averaged from 600 cu. yd. to 900 cu. yd. of loam and clay per 10-hr. day, in the excavation of a drainage ditch. See. Fig. 164. The machine had a 32-ft. gage, a 39-ft. boom and a 25-h.p. engine, which consumed about 25 gal. of gasoline per day.

224. Scraper-bucket Excavators.—The scraper-bucket excavator has been recently adapted to the various phases of drainage reclamation with considerable success. The use of caterpillar tractors and the wide latitude of operations afforded by the revolving platform and drag-line principle allow the machine to excavate low, wet soils to a considerable depth. The drag-line excavator can handle almost any kind of soil except solid rock but is not efficient in the removal of silt and soft soils which wash easily. The operation of the machine is also greatly retarded in the excavation of soils where obstructions such as stumps, roots and large boulders occur in quantity. See Chapter VII.

225. Use of Drag-line Excavator in South Dakota.—During the latter part of the year 1911, a 2¼-cu. yd. bucket, drag-line excavator was used in the excavation of a section of ditch in the lower Vermilion River Valley, Clay County, South Dakota. The cross-section excavated had a bottom width of 20 ft., average depth of 8 ft., and side slopes of 1 to 1. The material excavated was loam and clay, there being an alluvial deposit of about 6 ft. of loam underlaid with yellow clay.

The total working time was 148 days of 22 hr. each; there being two shifts of about 11 hr. each. The total amount of excavation was 222,494 cu. yd., or an average daily rate of 1503 cu. yd. and an average hourly rate of 68 cubic yard.

A tabulated list of operating expenses is given below:

Labor:

Operator	$125.00 per month	
2 cranesmen @ $100.00	200.00 per month	
4 laborers @ $50.00	200.00 per month	
1 teamster	50.00 per month	
1 cook	35.00 per month	
Total cost of labor	$3060.00	
Cost of labor per cubic yard excavated		1.38 cents

Fuel:

15,444.8 gal. of gasoline @ 12.4 cents	$1915.15	
Cost of fuel per cubic yard excavated		0.86 cent

Cable:

First quality steel wire rope, ⅞ in., for hoisting and swinging cables, and 1¼ in., for drag-line cable.		
Total cost of wire rope	$978.87	
Cost of wire rope per cubic yard excavated		0.44 cent

Repairs and Renewals:		
Bucket bailers, friction blocks, sheaves, etc.		
Total cost of repairs and renewals	$845.93	
Cost of repairs and renewals per cubic yard excavated		0.38 cent
Board and Lodging:		
Total cost of board and lodging of 9 men for full time of 148 days	$561.81	
Cost of board and lodging per cubic yard excavated		0.25 cent
Miscellaneous:		
Livery, horse keep, hardware, lumber, oil, grease, waste, freight, express, etc., etc. (not including general office expenses, depreciation, insurance and interest on investment).		
Total cost of miscellaneous	$2,078.72	
Cost of miscellaneous per cubic yard excavated		0.93 cent
Total amount of operating expenses	$9,440.48	
Cost of operating excavator per working day.		$63.79
Cost of operating excavator per cubic yard excavated		4.24 cents
Initial cost of excavator, moving, setting up, taking down, etc	$10,500.00	
Contract price for work, per cubic yard		7 cents

The drag-line excavator was made by the Monighan Machine Co. of Chicago, Ill., and used a 50-h.p. Otto gasoline engine for power. The boom has a length of 60 ft. and the 2¼-cu. yd. scraper bucket was of the Martinson type.

226. Use of Drag-line Excavators in Florida.—During the years 1911, 1912 and 1913, a large outlet canal was excavated by four drag-line excavators. The work was locted near Sebastian on the east coast of Florida and the material excavated was sand and shell marl. The ditch or canal was 4½ miles long, had a bottom of 50 ft., depth varying from 10 to 18 ft. and side slopes of 2 to 1. Berms of 20 ft. were left along the sides of the ditch.

The four excavators each had a bucket capacity of 1½ cu. yd. and a boom length of 70 feet. The excavators were of standard make and used complete steam equipments. The machines worked in pairs on opposite sides of the canal and excavated to a fairly uniform grade and even side slopes.

During the five months from May to November, 1911 (inclusive), the four excavators together excavated on the average, 111,210 cu. yd. per month of 27,800 cu. yd. for each excavator per month. Two shifts, of 10 hr. each per day, were worked, and the average excavation per machine for each shift was 620 cubic yards. The total yardage excavated during the year 1911 was 1,023,662 cu. yd., one machine working 12 months, two machines working 11 months, three machines working 10 months and four machines working 9 months.

The entire labor organization when the four machines were working together was as follows:

1 Superintendent of works,
1 Master mechanic,
9 Operators,
4 Roller gang foremen,
32 Laborers in roller gangs (negroes),
8 Firemen (negroes),
1 Oiler,
1 Blacksmith,
1 Assistant blacksmith,
2 Pump men,
3 Teamsters (6 mules) (1 horse),
2 Cooks,
1 Yard man,
2 Dynamite men,
7 General laborers (negroes).

The fuel used was pine wood, which had been partially seasoned. About two cords of wood were used for each excavator per shift.

The following table gives a brief statement of the cost of operation:

Operating costs	$67,645.19
Board and lodging	6,137.85
Repairs and renewals	7,231.02
Stable unkeep	1,527.94
Total	$82,542.00

Average cost of excavation, (based on a total excavation of 1,023,662 cu. yd.)... 8.05 cents per cu. yd.

The above estimate does not include depreciation or overhead charges.

227. Floating-dipper Dredges.—The floating-dipper dredge is the most universally used type of excavator for drainage reclamation work. In the heavily timbered and swamp lands of the south and middle west, the dipper dredge has proved to be the only successful machine for ditch and canal excavation. The direct prying action of the dipper is necessary for the removal of roots and stumps, and the power of a dredge is very often governed by the character and magnitude of this class of work rather than by the purely excavation requirements. Experience has proved that the smaller lateral drainage ditches can be dug more economically by a small floating-dipper dredge even when it is necessary to excavate a channel 50 to 100 per cent. larger than required in order to float the machine. The unit cost of excavation with a dipper dredge decreases with the increase in the size of the machine and the channel, up to a cross-sectional area of about 700 square feet. The limiting size of channel, which a floating-dipper dredge can construct is one having about 1200 square feet. See Chapter XII.

228. Use of Floating-dipper Dredge in Colorado.—A standard make of floating-dipper dredge was used during the year 1911 in the cleaning out and enlarging of a large supply canal on an irrigation project in eastern Colorado.

The material excavated was a sandy loam and an average of 373.5 cu. yd. were excavated in each 100-ft. length of canal. A total excavation of 394,387 cu. yd. was made in a total canal length of 20 miles and during 187 actual operating days. The dredge crews were on duty 268 days. The dredge was operated in two shifts of 10 hr. each, and 1 hour per day was spent in oiling and cleaning the machinery.

Screened pea coal from New Mexico was used as fuel and water for the boiler was pumped directly from the canal. The deposition of mud and the formation of scale resulting from the use of this water caused considerable boiler trouble. A feed water heater was not used, although the purification of the water before feeding it to the boiler would doubtless have saved time and expense.

The dredge had a wooden hull, 75 ft. long and 24 ft. wide. The boom had a length of 50 ft. and the dipper had a capacity of 1½ cu. yd. Marion anchors or bank spuds were used.

The cost of operation for the year is as follows:

Labor:

1 head engineer or runner	$120.00 per month
1 runner	110.00 per month
2 cranesmen	55.00 per month
2 firemen	45.00 per month
2 deck hands	40.00 per month
1 teamster	40.00 per month
1 cook	50.00 per month
Total cost of labor for operating dredge..	$6243.70
Cost of labor per cubic yard excavated	0.0157 cent

Fuel:

1,276.65 tons coal @ $3.175 per ton	$4053.36	
Cost per fuel per cubic yard excavated		0.0103 cent

Repairs and Maintenance of Machinery:

Total cost of cables, repairs and renewals, of machinery	$3894.67	
Cost of repairs and renewals per cubic yard excavated		0.0098 cent

Miscellaneous:

Total cost of miscellaneous supplies, oil, waste grease, etc.	$692.81	
Cost of miscellaneous supplies per cubic yard excavated		0.0012 cent

Expense of Floating Dredge:[1]

Cost of retaining water in canal to keep the dredge afloat	$369.24	
Cost of floating dredge per cubic yard		0.0009 cent
Total cost of operating dredge for 187 days	$15,253.78	
Cost of operation per day	81.57	
Cost of operation per cubic yard excavated		0.0372 cent
Cost of dredge and house boat	$16500.00	

The following general and overhead expenses were included in this work.

Engineering, supervision and office work	$1859.10	
Team work in building up spoil bank and constructing road on the top for 20 miles @ $236.08	$4721.75	
Removing and replacing 10 highway and 1 railroad bridges	$837.78	
Right of way and legal expenses	$190.42	
Interest on investment (8 per cent. of $16,500)	$1320.00	
Depreciation (20 per cent. of $16,500)	$3300.00	
Total amount of general expenses		$12,229.05
Amount of general expenses per cubic yard excavated		0.0310
Total cost of work per cubic yard excavated		0.0682

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[1] In cleaning out a canal it is often necessary to maintain a dam of excavated material in front of the dredge to provide a sufficient depth of water to float the dredge. In crossing another and existing stream, channel or waterway, a dam or dike must be constructed on the down-stream side to prevent the loss of water through the original channel.

229. Use of Floating-dipper Dredge in Florida.—Two floating-dipper dredges have been used recently in the construction of the large outlet canal located near Sebastian, Florida. The dredges were used (1911–13) to excavate the sections of the main canal with dense clay sub-soil, and the larger lateral ditches.

The larger dredge had an all steel hull 100 ft. long and 33 ft. wide, a 70-ft. boom and a 2½-cu. yd. dipper. The smaller dredge had a wooden hull 70 ft. long and 18-ft. wide, bank spuds, a 50-ft. boom and a 1½-cu. yd. dipper.

The average monthly excavation for the two dredges was about 100,000 cubic yards. The cost of excavation (not including overhead charges and depreciation) averaged 4¾ cents per cubic yard. Partially seasoned pine was used for fuel and an average of two cords per shift of 10 hr., or 103 cords per month of 26 days, were consumed.

230. Use of Floating-dipper Dredge in South Dakota.—In the construction of the Clay Creek Ditch in Clay and Yankton Counties, South Dakota, during the years 1908, 1909 and 1910, one of the two floating-dipper dredges used made such uniform progress that an accurate cost record was kept of its operation.

This dredge has a wooden hull, 87 ft. long, 30 ft. wide, and 6 ft. deep. The framework of the hull was composed of 54 keelsons, 8 in. × 10 in. × 30 ft. long and spaced about 3 ft. 3 in. on centers. The side and end verticals or posts were 6-in. × 6-in. Douglas fir timbers, 6 ft. long and spaced 6 ft. in the clear. The sides, ends and bottom were formed of 3-in. yellow pine planking. The deck was made of 2-in. yellow pine planking. All main timbers were strongly bolted together and the planking was spiked to the framework. The joints of the sides, ends and bottom were well calked with three strings of oakum, and then hot tar was applied until the joints were filled flush with the outer surface.

Marion anchors or bank spuds, attached to the head block of the A-frame were used. These anchors were made of 14-in. × 14-in. oak timbers sliding in steel boxings, whose lower ends supported heavy platforms about 6 ft. square. The A-frame had a height of 44 ft. and was built of two 14-in. × 16-in. timbers of Douglas fir. The rear spud was single-oak timber 10 in. square. The boom had a length of 66 ft., was 5 ft. deep in the center, had 8-in. × 8-in. fir flanges and a web of 5-in. yellow pine. It was made in two equal sections. The dipper handle was made of two oak timbers, 10-in. × 14-in. and having a length of 38 feet. Steam was furnished by a 60-h.p. boiler of the locomotive type. The main engine was built by the Marion Steam Shovel Company, and was equipped with two 9-in. × 11-in. cylinders. The hoisting drum had a diameter of 30 in. and the backing drum 18 inches. The diameter of the frictions was twice that of the drums. A separate swinging engine was used, and was equipped with two drums having a diameter of 18 inches. A 3-in. chain connected the drums with a steel swinging circle having a diameter of 17 ft. 4 inches. A small dynamo was belt connected to the swinging engine and furnished light for the night operation of the dredge. Water was at first pumped directly into the boiler from the ditch, but as the water contained so much scale-forming impurities, it was found necessary to install a feed water heater and purifier, to purify the water before it was used in the boiler.

The following table gives the amount of excavation made by this dredge during the months when operation was uniform and uninterrupted by climatic conditions, floods, etc.

Month	Progress, ft.	Estimated excavation, cu. yd.	Actual excavation, cu. yd.	Surplus excavation, cu. yd.
August, 1908	5750	54,227	58,708	4481
September, 1908	4600	54,395	60,443	6048
October, 1908	6350	65,383	74,753	9370
November, 1908	6250	62,108	67,279	5171
December, 1908	5750	60,805	63,894	3089
April, 1909	6700	74,287	79,310	5023
May, 1909	4800	69,536	75,401	5865

The "surplus excavation" shows that the dredge excavated outside of the side slopes of 1 to 1 and the bottom grade, which were required by the specification and established by the side slope and grade stakes. This "surplus excavation" is necessitated by the fact that the dredge cannot excavate a true 1 to 1 side slope or uniformly to grade. The contractor is not paid for this extra work, but only for the excavation within the boundaries established by the stakes and the specification. During the seven months, as recorded in the table above, the average actual monthly excavation was 68,541 cu. yd., the average estimated monthly excavation was 62,963 cu. yd., making an average monthly surplus of 5578 cu. yd. or about 9 per cent. During

August, 1908, the dredge was working in the upper section of the ditch, whose cross-section was a base of 20 ft., average depth of 9½ ft. and side slopes of 1 to 1. From September, 1908, to December, 1908, inclusive, the dredge was excavating a ditch the cross-section of which was a base of 25 ft., an average depth of 10 ft. and side slopes of 1 to 1. During April and May, 1909, the dredge worked in the ditch where the bottom width was 30 ft., average depth of 10¼ ft. and side slopes of 1 to 1. The material excavated was loam to a depth of from 3 to 6 ft. and the remainder yellow clay.

The work was carried on in two shifts of 10 hr. each for 6 days a week. Sunday was spent in making small repairs, cleaning and oiling the machinery, rolling and replacing boiler tubes, etc.

The following schedule gives the cost of labor employed in the operation of the dredge:

Labor:

2 engineers or runners @ $100.00 per month	$200.00	
2 cranesmen @ $75.00 per month	150.00	
2 firemen @ $60.00 per month	120.00	
4 laborers @ $50.00 per month	200.00	
1 cook @ $35.00 per month	35.00	
Total monthly labor cost	$705.00	
Total cost of labor for operating dredge	$5641.29	
Cost of labor per cubic yard excavated		0.0123 cent

Fuel:

730 tons of coal @ $6.50 per ton	$4748.52	
Cost of fuel per cubic yard excavated		0.0103 cent

Repairs and Maintenance:

Total cost of cables, bolts, pins, blocks, sheaves, oil, waste, grease, etc.	$2535.44	
Cost of repairs, and maintenance per cubic yard excavated		0.0055 cent

Board and Lodging:

Total cost of board and lodgings for 10 men and 1 woman cook for 200 days	$1417.03	
Cost of board and lodging per cubic yard excavated		0.0038 cent
Total cost of operating dredge for 200 days	$14,342.28	
Cost of operation per day	71.71	
Cost of operation per cubic yard excavated		0.0312 cent
Initial cost of dredge (moving, erection and dismantling) and of house boat[1]	$8830.16	

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[1] The cost of boiler and engines was $6000.00.

The following allowance was made for general and overhead expenses.

Supervision and general office expenses	$2000.00	
Interest on investment (8 per cent. of $8830.16)	$706.41	
Depreciation (20 per cent. of $8830.16)	$1776.03	
Total amount of general expenses	$4482.44	
Amount of general expenses per cubic yard excavated		0.0097 cent
Total cost of work per cubic yard excavated		0.0409 cent
Contract price for excavation		0.0800 cent

231. Ladder Dredges.—The ladder dredge is not adapted to the excavation of narrow channels, and thus is not an efficient type of excavator to use in general reclamation work. Ordinarily a dipper dredge is much more efficient for this class of work. In the excavation of drainage channels, the wet, sticky material clogs the buckets and the spoil conveyors, and occasionally is so soft and fluid as to render its handling and disposition in the spoil banks a difficult matter. Most drainage channels require the construction and maintenance of side slopes of at least 1 to 1 and these are difficult to construct with a ladder dredge; requiring the gradual swinging of the dredge to the side and the raising of the bucket chain. See Chapter XIII.

232. Use of Ladder Dredge in Washington.—The U. S. Reclamation Service has used a Bucyrus ladder dredge on the enlargement of the Main Canal of the Sunnyside Project near Sunnyside, Washington. The excavation extended from mile 0.228 to mile 20.67—making a total length of canal dredged of 20.342 miles. The average distance of the work from the railroad station was 2 miles.

The work was carried on in two shifts from December 1, 1909, to June 19, 1910, and in three shifts per day from June 19, 1910, to October 1, 1911. The character of the material excavated varied from loose gravel to hard-pan. At about mile 1, the material was so hard that explosives were necessary to assist the hydraulic giant in breaking down the high banks. Blasting was carried on from this point to the end of the work. From mile 13 to mile 20.67, teams were employed to excavate the high banks above the water line. Difficulty was experienced in disposing of the excavated material where the banks were high. On fills and shallow cuts bulkheads were built along the right-of-way on the lower bank to keep the wet material from flowing into adjoining fields. In winter, ice hindered the progress of the work to a considerable extent.

The dredge used was a Bucyrus ladder dredge equipped with steam power and a 3½-cu. ft. continuous bucket chain. The hull was built of timber with a length of 82 ft., a width of 30 ft., a depth of 6 ft. 6 in. and drew 5 ft. of water. Steam was furnished by two locomotive type boilers, 44 in. in diameter and 18 ft. long and having a rated capacity of 80 horse power. The main drive and ladder hoist were driven by an 8-in. × 12-in. double horizontal engine of 70 horse power. The winch machinery for operating the spuds and swinging the dredge was driven by a two-cylinder 6-in. × 6 in. double horizontal engine of 20 horse power. The belt conveyors were operated by two 7-in. × 10-in. single-cylinder, center-crank, horizontal engines of 18 horse power. A No. 1 Hendy hydraulic giant was mounted on the bow of the dredge and water was forced through it by a two-stage, 6-in. centrifugal pump belted to a 10-in. × 12-in. single-cylinder upright engine of 80 horse power. This giant or monitor was used to remove banks above the water level and beyond the reach of the buckets. Two belt conveyors, one on each side of the dredge, were used for the disposal of the excavated material. Each conveyor was 72 ft. long and consisted of a steel framework supporting a 7-ply 32-in. rubber conveying belt. Figure 165 shows the dredge in operation.

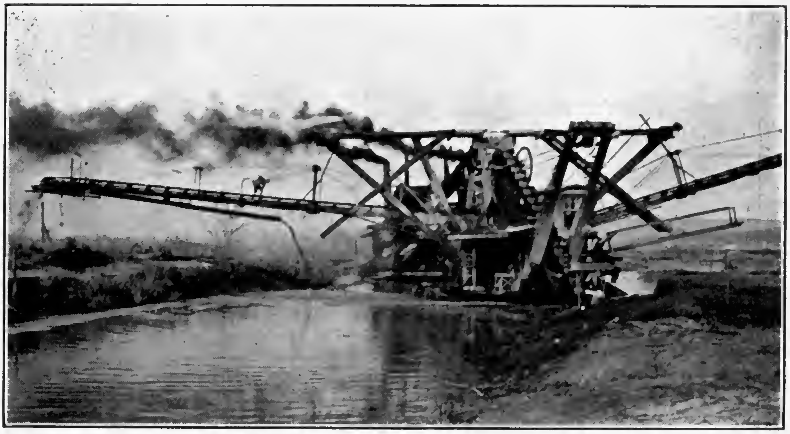

FIG. 165.—Ladder dredge excavating irrigation canal. (*Courtesy of U. S. Reclamation Service.*)

The operating force consisted of 8 men and 4 horses. The following scale of wages was paid:

Superintendent	$7.50 per day
Operator	5.00 per day
Engineer	4.67 per day
Spudman	3.83 per day
Fireman	3.33 per day
Oiler	3.00 per day
Deckman	2.50 per day
Man and team	4.50 per day

Table XX.—Cost of Canal Excavation with Ladder Dredge

Item	Total excavation, cu. yd.	Total cost	Cost per cu. yd.
Excavation	929,723		
Labor, dredge		$26,960.63	$0.029
Labor, spoil banks		31,159.06	0.034
Fuel		33,043.07	0.036
Plant maintenance		52,327.40	0.057
Plant depreciation		41,432.53	0.045
Total		$184,922.69	$0.201
Engineering and administration		28,154.41	0.031
Grand total		$213,077.10	$0.232

The maximum excavation per 8-hr. shift was 1429 cubic yards.

The average excavation per 8-hr. shift was 557.9 cubic yards.

The maximum excavation per week was 17,644 cu. yd. for the week ending June 28, 1911, working three 8-hr. shifts.

The average excavation per actual working hour was 128.7 cubic yards. The per cent. of lost time was 49, made up of moving as 10 per cent. and of repairs and miscellaneous as 39 per cent.

233. Hydraulic Dredges.—The hydraulic dredge is efficient in the excavation of soft material such as sand, silt and loose clay. However, the use of special forms of cutters permit of the efficient excavation of hard materials. Until recently the hydraulic dredge has not been successfully used on reclamation work on account of the difficulty of depositing the excavated material in restricted spoil bank areas, the clogging of the suction pipes and pumps with grass, roots and other débris, and the limitations of operation as to the excavation of relatively narrow channels with sloping banks. See Chapter XIV.

Hydraulic dredges for canal excavation should be provided with a discharge pipe which extends laterally either side of the canal to a point 50 ft. from the side of the dredge. Valves should be placed so that the discharges may be temporarily closed to pass obstructions or intersecting canals, and the use of joints, open at the bottom near the end of the discharge pipes, provide for the escape of heavy material which forms a ridge along each side of the canal. See Fig. 166. The use of large suction pumps, with suction pipes not less than 12 in. in diameter will largely overcome the difficulty from clogging.

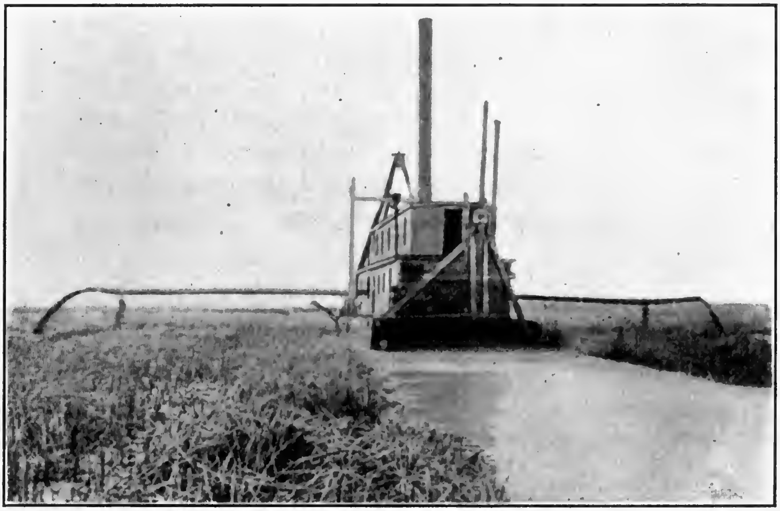

Fig. 166.—Hydraulic dredge excavating a drainage canal.

The hydraulic dredge can be used most efficiently in coöperation with a dipper dredge, the latter being used to form along each side of the canal, a barrier behind which the former machine may deposit its fluid discharge.

Examples of the methods and cost of operation of the hydraulic dredge will be given under Division III, Flood Prevention and Flood Protection Works.

234. Grab-bucket Dredges.—The gravity swing grab-bucket dredge equipped with vertical spuds and a long boom is a very economical type of excavator to use in canal excavation through loose and soft soils where stumps and roots are not prevalent. The orange-peel bucket should be used in muck, soft clay and for the pulling of stumps and roots. The clam-shell bucket is best adapted to the handling of dense sand and gravel. By careful manipulation of the bucket so that it shall be carefully loaded and tightly closed before raising, the orange-peel bucket may be used very successfully for the excavation of muck and silt.

235. Use of Grab-bucket Dredge in Louisiana.[1]—During 1913 and 1914, a 1½-yd. orange-peel dredge was used in the excavation of drainage channels in St. Bernard and Plaquemines parishes, Louisiana. The dredge had a hull of yellow pine 34 ft. × 79 ft., carrying a 80-h.p. boiler, a Worthington condenser and 10-in. × 12-in. dredge engines. The boom was of steel and had a length of 75 feet. The material excavated was light muck overlying a soft clay, with occasional pockets of sand. The following statement is based on an operating period of 15¼ months. The fuel used was oil until the cost reached $1.25 per barrel and then coal at $4.00 per ton.

Operating Expenses:		
Labor (double shift)	$6,458.64	
Fuel	4,776.09	
Main hoisting cables	1,011.04	
Repairs and renewals	2,184.19	
Lubricating oil	280.08	
Miscellaneous supplies	357.36	
General (including board of crew, operation of gasoline tenders, etc.)	2,175.41	
Supplies (estimated from vouchers)	1,200.00	
Total		$18,442.81
Miscellaneous and Overhead Expenses:		
Office and engineering expenses	$3,050.00	
Interest (estimated at 5 per cent.)	1,080.00	
Depreciation (estimated at 6 per cent.)	1,300.00	
Interest and depreciation (house boat, fuel, barges, etc.)	600.00	
Insurance	528.00	
Total		$6,558.00
Grand total		$25,000.81
Total excavation		924,204 cu. yd.
Unit cost		$25,000.81 ÷ 924,204 = $0.026

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[1] *Engineering News*, April 30, 1914.

III. FLOOD PREVENTION AND FLOOD PROTECTION WORKS

The construction of flood prevention and flood protection works consists in the dredging out of natural channels, the excavation of artificial channels and the building of levees, reservoirs, dams, etc. The use of various types of excavators in the construction of these works will be discussed in the following articles.

236. Scrapers.—The various types of scrapers have been used in levee building especially along the great streams of the Middle West; the Mississippi, the Missouri and their tributaries. The scraper is especially efficient in the construction of earthen levees and dams on account of the securing of a uniform distribution of the material and the compacting of the layers by the continuous movement of the teams. Experience with levees under flood conditions, has clearly demonstrated the superior density and stability of the scraper-built structure over that built by a large power machine. However, the use of the power excavator is clearly more efficient and economical in work exceeding the movement of more than 50,000 cu. yd. of material and the distribution and compacting may be secured by the use of drags and grooved rollers.

237. Use of Fresno Scrapers in Arizona.—The construction of the levee below the Colorado River break, in 1907, was made with four-horse Fresno scrapers. Muck ditches were constructed with 6-ft. to 10-ft. bases and with 2½ to 1 slopes, and then levees with 10-ft. top width and 3 to 1 slopes were built. The material which was an adobe or dark clay and loam, was taken from the borrow pits on the land side. These pits were made with a 40-ft. embankment berm, a depth of 4 ft. on the inside and a slope of 1 in 50 to the outside. At intervals of 400 or 500 ft. were left checks 17½ ft. wide, across the pits. About 150 Fresno scrapers and 600 head of stock were employed continuously on this work. During the month of February, 1907, 270,000 cu. yd. were moved and an average of 7000 cu. yd. were moved per day.

238. Use of Wheel Scrapers in Missouri.—A levee was constructed in 1916, in the St. John Levee and Drainage District near New Madrid, Missouri with two-wheel scrapers. The levee was about 10 miles long, had a crown width of 8 ft., a maximum height of 18 ft. and side slopes of 1 to 3. An allowance of 15 per cent. was made for shrinkage. From 19 to 28 scrapers of ½ yd. capacity were hauled by two-mule teams, and a three-mile snatch team was used in loading. Two plows hauled by two-mule teams were used for the loosening of the soil. The labor crew was composed of a foreman and dumpman at the dump, a loader for each three scrapers at the borrow pit, and a driver for each scraper and plow. About 30,000 to 40,000 cu. yd. of material were handled per month, based on a 12-hr. working day.

239. Use of Fresno and Wheel Scrapers in Wyoming.[1]—The Whalen dike of the North Platte project of the U. S. Reclamation Service was built in 1907 and 1908 to divert the flow of the North Platte River into the Interstate Canal, Wyoming. The dike is about 1600 ft. in length, 11 ft. wide on top, with an average height of 10 ft. and side slopes of 2½ to 1. The construction of the embankment involved the movement of about 35,000 cu. yd. of earth from a borrow pit on the upstream side, a minimum distance varying from 100 ft. to 500 feet. The excavated material was placed in layers varying from 6 in. to 12 in. in thickness and was transported by two-wheel scrapers.

The whole embankment was faced with gravel, the thickness on the top and downstream slopes being 1 ft. and on the upstream slope 2 feet. About 6,040 cu. yd. of gravel were moved for a total average haul of about 2620 feet. The gravel was loaded into four-horse wagons with slat bottoms, from two-wheel scrapers dumping through a trap. The material was dumped from the wagons onto the embankment and spread by a Fresno scraper and a hand shovel.

Table XXI gives the cost of the work based on the following labor schedule:

Foreman, 35 to 40 cents per hour.
Laborers, 22½ to 25 cents per hour.
Teams, 10 cents per hour.
Two-horse teams on gravel, 40 to 45 cents per hour.
Three-horse teams and drivers, 50 to 55 cents per hour.
Four-horse teams and drivers, 60 to 65 cents per hour.

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[1] Abstracted from Reclamation Record.

TABLE XXI.—COST OF CONSTRUCTION OF WHALEN DIKE

Distribution	35,000 cu. yd. earth		6,040 cu. yd. gravel		Total
	Total cost	Unit cost	Total cost	Unit cost	
Labor	$7695	$0.219	$5281	$0.874	$12,976
Plant depreciation	400	0.001	135	0.022	535
Superintendence	150	0.004	120	0.020	270
Total	$8245	$0.224	$5536	$0.916	$13,781

240. Graders.—The blade or scraping grader is used in conjunction with other forms of excavators in the construction of canals and embankments for the smoothing and grading of the surface slopes. In the construction of earth embankments, the blade-grader is generally used to distribute and spread the material.

The elevating grader has been often used and especially with other forms of machinery in the excavation of material for levees and embankments. The grader excavated the material from shallow borrow pits, and dumps it into wagons, which haul it to the site where it is dumped, spread and rolled in layers of from 6 in. to 12 in. in depth. About 20 per cent. shrinkage should be allowed for ordinary loam and clay or sand and clay soils.

241. Use of Elevating Graders in South Dakota.—A large earthen dam was constructed across Owl Creek near Belle Fourche, South Dakota, to form the reservoir for the Belle Fourche Project of the Reclamation Service. During the early stages of this work, elevating graders were used to excavate the material from the borrow pits, which were located on each side of the valley near the ends of the dam and the excavated material was hauled by means of 1½-cu. yd. dump wagons. They were drawn by either two-horse or three-horse teams and the average load was ½ cubic yard.

The graders were Western Elevating Graders of standard size. One grader was drawn by a 32-h.p., 20-ton, steam traction engine and the other by 12 or 14 horses.

The following report of hauling was submitted by Mr. F. C. Magruder, Project Engineer, and is given entire, as being of especial interest in this matter.

Wages paid were $1.75 per 10-hr. day for teamsters and $1.00 per day for horses. The dirt from Anderson's pit was brought up a 5 per cent. grade making a lift of 60 feet. C. Wilson had a lift of 45 feet. Pits 95–97, 56–96, and 332–372 were all at a higher elevation than the dam and the haul was all down grade. Part of the wagons were drawn by three horses and part by two horses. J. Lamoro used two horses and A. Lamoro used three horses; the other outfits used part twos and part threes.

TABLE XXII.—COST OF HAULING DIRT WITH 1½-YD. DUMP WAGONS

Pit No.	Foreman	Yardage	Cu. yd. per wagon day	Cost per wagon day	Length of haul	Cost per cu. yd.	Cost per cu. yd. per 100
290–291	J. Lamoro	7,250	76.0	4.39	600	$0.058	$0.0097
230–231	Anderson	5,070	48.3	5.34	1,200	0.111	0.0092
110–112	A. Lamoro	20,710	78.0	5.20	1,300	0.074	0.0057
231	C. Wilson	6,730	49.2	4.91	1,000	0.100	0.0100
332–372	J. Lamoro	4,550	51.4	4.48	1,500	0.087	0.0058
110	Cotter	2,270	28.4	4.91	2,000	0.173	0.0086
95–97	Cotter	25,900	25.7	4.91	2,600	0.194	0.0075
56–96	Cotter	4,550	30.1	4.91	3,000	0.163	0.0055

The material excavated was a gravel and a stiff clay which was easily removed by the grader plows and would stand in a vertical face several feet high without caving or sliding.

The following table gives an itemized statement of the cost of excavation and hauling for the season of 1908.

The labor cost includes the cost of superintendence, office expenses and all other general expense. Wages for common labor were $1.75 and $2.00 per day of 10 hours.

The repair charges include cost of all repair parts and labor expense involved in making repairs.

Depreciation charges are based on the amount of work to be done by each piece of machinery, and the estimated salvage at the end of the job.

Supplies include oil, waste, coal, boiler compound, packing and hose. Coal cost, delivered at the dam, from $7.50 to $10.50 per ton, according to the quality.

TABLE XXIII.—COST OF EXCAVATION AND HAULING

Classification	Hayes Bros. grader		Sub-contractor's grader		Total	
	Yardage 39,450 cu. yd. Daily average 391 cu. yd. Average haul 2400 ft.		Yardage 37,580 cu. yd. Daily average 572 cu. yd. Average haul 1200 ft.		Yardage 77,030 cu. yd. Daily average 406 cu. yd. Average haul 1800 ft.	
	Total	Unit	Total	Unit	Total	Unit
Excavation:						
Labor	$1583.40	$0.0402	$1737.21	$0.4620	$3320.61	$0.0431
Depreciation	599.87	0.0152	91.70	0.0024	691.57	0.0090
Repairs	1406.00	0.0356	171.50	0.0046	1577.50	0.0205
Supplies	1307.46	0.0332	....	....	1307.46	0.0170
Total	4896.73	0.1242	2000.41	0.4690	6897.14	0.0896
Hauling:						
Labor	6760.00	0.1715	2902.47	0.0772	9662.47	0.1264
Depreciation	7.00	0.0002	8.00	0.0002	15.00	0.0002
Total	6767.00	0.1717	2910.47	0.0774	9677.47	0.1266

242. Use of Elevating Graders in Idaho.[1]—The Lower Deer Feet Embankment was completed in January, 1908 and was built as a part of the Payette-Boisé project of the U. S. Reclamation Service in Idaho. The embankment is 7350 ft. long, 20 ft. wide on top, with a maximum height of 43 ft., and an upstream slope of 3 to 1 and a downstream slope of 1½ to 1. The body of the dam was built of earth removed by four elevating graders from borrow pits within the reservoir. The excavated material was hauled in 48 dump wagons to the site where two road or blade graders spread it in uniform layers. The average cost of handling the material was 21 cents per cubic yard.

243. Power Shovels.—The power shovel is efficient in the excavation of large quantities of all classes of material for the construction of earth embankments, dikes or dams. Also in the excavation of the foundation for masonry dams, the power shovel is used when the magnitude of the work justifies its installation.

In the construction of earth embankments or dams for reservoirs, the material may often be removed economically from pits near the ends of the structure and transported by trains of dump cars to the site. For small work (where the amount of material may be less than 100,000 cu. yd.) the revolving shovel and dump wagons may be efficiently used.

When the shovel is working at low levels, such as in foundation work, the use of skips operated by derrick or cableway is desirable for the hoisting and transportation of the excavated material.

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[1] Abstracted from the *Engineering Record*, May 16, 1908.

The use of electrically operated shovels is advised where the low cost of power justifies their use. This governing cost will, of course, depend on the relative cost of coal and electric current in any particular case. See Art. 48, page 60.

244. Use of Steam Shovel in South Dakota.—The construction of the large earthen dam to form the reservoir of the Belle Fourche Project of the Reclamation Service involved the excavation of a large amount of gravel and clay and its transportation to the site.

The dam was built across the valley of Owl Creek near Belle Fourche, South Dakota. It has a length of about 200 ft., height at center about 90 ft. and top width of 20 feet. A steam shovel was used to excavate the material from a hill near each end of the dam. The excavated material was hauled in trains of dump cars upon the site, dumped, spread out with scrapers into layers from 6 to 9 in. deep, sprinkled and then rolled with steam rollers. The layers were not carried clear through the width of the dam, but were made in varying widths and thicknesses so as to break joints.

Mr. F. C. Magruder, Project Engineer, has kindly furnished the following information as to the methods and costs of this work.

Two 75-ton Vulcan steam shovels with 2½-cu. yd. dippers were used during the season of 1908, loading trains made up of 4-cu. yd. side dump cars hauled by 18-ton Davenport dinkeys. At the beginning of the season one shovel was moved from pit at north end of dam to a pit at south end, a distance of 7500 ft. and at the end of season was moved back to north pit again. The cost of moving shovel, dinkeys and cars, amounting to $1290.00 or one cent per cubic yard excavated, has been charged in the south side shovel costs.

North side shovel had an average cut of 22 ft. and haul of 4800 ft. using four 10-car trains for hauling. South side shovel had an average cut of 6.5 ft., haul of 3700 ft. and used three 8-car trains. On account of shallow pit, south side shovel made 15 cuts during the season, while north side shovel made only four cuts. Cost of moving shovel back in pit was $0.011 per cubic yard and $0.002 per cubic yard respectively.

Switches were placed more advantageously in North Pit than in South Pit, causing a minimum amount of lost time in the former waiting for trains to pass.

Spreading was done by four-horse Fresno scrapers hauling the dirt about 50 ft. each way from the track, and after watering with

2-in. hose, was leveled by four-horse road leveler and rolled with a 21-ton traction engine. Track was shifted 13 ft. every third layer.

The labor cost includes all cost of superintendence, office expenses, telegraph and telephone bills and other general expenses. Wages for common labor were $1.75 per day, working 10 hr. until October 26 and 8 hr. for the balance of the season.

The repair charge is made up of the cost of all repair parts as taken from Hayes Bros. invoices, together with the labor cost of putting in those repairs.

Depreciation charges are based on amount of work to be done by each piece of machinery, and estimated salvage at the end of the job.

Supplies include coal, oil, waste, boiler compound, packing, hose, powder, etc. Coal costs, delivered on the job, from $7.50 to $10.50 per ton.

The following statement gives the cost per cubic yard and includes labor, depreciation, repairs, supplies, etc.:

	North side shovel	South side shovel	Average
Excavation	$0.0873	$0.1250	$0.1027
Hauling	0.0978	0.1020	0.0994
Main track	0.0076	0.0045	0.0064
Temporary track	0.0215	0.0240	0.0225
Spreading	0.0547	0.0564	0.0555
Rolling	0.0276	0.0298	0.0285
Watering	0.0194	0.0211	0.0201
Total	0.3159	0.3628	0.3351

245. Use of Steam Shovel in Maine.[1]—An Otis-Chapman shovel has recently (1910–12) been used for the excavation of earth to supply material for the embankments which form the southerly and northerly ends of the Aziscohos storage dam near Colebrook, New Hampshire.

The shovel borrow pit was located on a hillside about 500 ft. from the site of the embankment, and the slope to the embankment permitted gravity transportation, by carts, of the excavated material. The shovel worked most efficiently with a heading face of from 6 ft. to 10 feet.

The material was very compact and hard to work, being a glacial deposit of a clayey nature, locally called rock flour, with

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[1] From report of Seth A. Moulton, Portland, Maine.

about 5 to 6 per cent. of large boulders and a low percentage of small stone.

The total amount of earth excavated by the shovel was 23,614 cubic yards. A little over 5000 cu. yd. were placed by hand with derricks and skips, double shoveling at a cost of $1.15 per cubic yard, including superintendence and overhead charges.

The following is a statement of the cost per cubic yard of the work:

Shovel and pitmen	$0.115 per cubic yard
Dumpmen and puddlers	0.105 per cubic yard
Hauling (cars)	0.039 per cubic yard
Grubbing and clearing pit	0.030 per cubic yard
Move shovel and repair shovel	0.022 per cubic yard
Move railroad tracks and repair cars	0.027 per cubic yard
Total	$0.338 per cubic yard
Supt., insurance, general and overhead charges	0.081 per cubic yard
Total labor	$0.419 per cubic yard
Fuel (wood)	0.014 per cubic yard
Plant[1]	0.206 per cubic yard
Total cost of bank	$0.639 per cubic yard

The best day's run was 408 cu. yd. in 11 hr. on September 17, 1912. The detail costs for that day were:

	Total	Unit
Steam-shovel men	$11.25	$0.0275
Pitmen	15.95	0.0391
Man splitting fuel for shovel	2.20	0.0054
Dumpmen and spreaders	18.55	0.0454
Hauling	11.80	0.0289
Grubbing and clearing pit	6.60	0.0162
Repairing cars and track	2.50	0.0061
Total	$68.85	$0.1686
Supt., general and overhead charges 24 per cent. (average)		$0.0404
Total labor charge		$0.2090
Fuel	$3.40	$0.0083
Total without plant		$0.2173

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[1] Plant charge would have been much less with larger quantity to move.

246. Use of Power Shovels in New York.[1]—The construction of the Hill View Reservoir of the Catskill Water-supply system of New York City involved the excavation of about 3,000,000 cu. yd. of material, which was placed around the edge of the site to form a continuous earth embankment. The average cut was 25 ft. and the maximum cut 44 feet. The material was a dense, stiff, glacial drift containing many stones and boulders.

All the material was excavated by steam shovels and about 70 per cent. transported on trains of dump cars, consisting of ten 4-yd. side dump cars hauled by 10- to 15-ton locomotives running on 3-ft. gage tracks of 65- to 75-lb. rails. Five shovels of about 70 ton capacity were used in the heavy cuts and four 30-ton shovels in the lighter ones. The deep cuts up to 40 ft. in depth were shot down with black powder and handled by the shovels in one operation.

The distribution of output for the 9 shovels over the 5 years' service from 1910 to 1914 inclusive is as follows:

Years of service	Tons rating	Total excavation, cu. yd.
1	60	21,600
5	60	600,300
5	70	694,000
4	70	409,900
3	65	249,600
4½	30	277,500
4½	30	176,200
2	30	122,300
4½	30	289,400
		Total....2,840,800

247. Scraper-bucket Excavators.—The scraper-bucket excavator is being used generally and very successfully in recent years for the excavation of foundations for dams, the construction of earth embankments and of canals. The wide latitude of operation provided by the complete circle swing and the drag-line method of excavation make the scraper-bucket excavator especially efficient in the construction of earth embankments, dams and levees. Several machines can often be operated coördinately on large work. During the last few years (1915–

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[1] Abstracted from *Engineering News*, September 9, 1915.

1918), in the building of large levees along the Mississippi River, one machine has been used to strip the levee base and dig the muck ditch, while one or two other machines follow along, and excavate, from borrow pits, the material for the body of the embankment.

The caterpillar tractor has been the principal factor which has made possible the universal use of the drag-line excavator for the excavation of soft, wet soils. The low unit pressure over the extensive area of the moving platforms and the great flexibility of the latter provide for the movement of the heaviest machines over swampy and rough ground.

248. Use of Drag-line Excavator in Louisiana.[1]—During 1913 and 1914, 1500 ft. of new levee and 8400 ft. of old levee enlargement were built along the east bank of the Mississippi River below Baton Rouge, Louisiana. The new levee had a 10-ft. top width, an average height of 17½ ft., a bottom width of 110 ft., a downstream slope of 3 to 1 and a slope on the land side of 4 to 1. The enlargement of the old levee comprised the placing of material on the river side so as to raise the grade about 6 ft. with a shift of the center of the levee, 25 ft. toward the river.

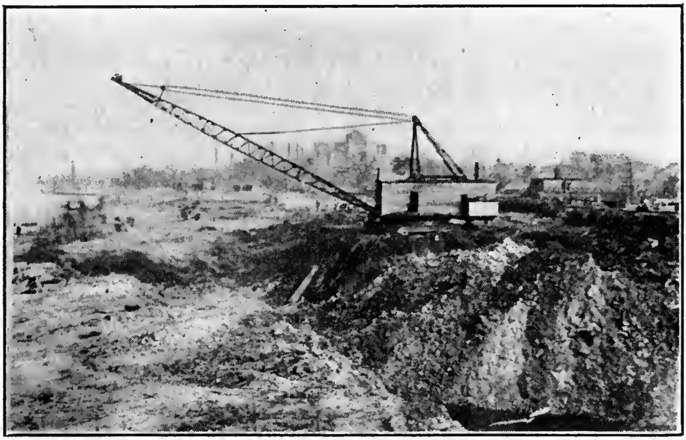

FIG. 167.—Drag-line excavator constructing a levee.

A Class 24, Bucyrus drag-line excavator was used. The machine was equipped with a 100-ft. boom and a 3½-yd. bucket. Special sectional platforms were used for the support of the excavator;

[1] Abstracted from *Excavating Engineer*, August, 1916.

five under each side, forming a track of about 100 ft. in length. Each section consisted of three 3-in. × 16-in. × 20-ft. stringers laid side by side forming a roller bed 4 ft. wide. Under these stringers were placed ten 6-in. × 8-in. × 8-ft. standard railroad ties, spaced 2 ft. on centers. Under these were placed three 2½-in. × 16-in. × 20-ft. planks, forming a lower floor for the section. The three sets of timbers were fastened together by thirty ¾-in. × 13-in. machine bolts, with heads countersunk below the top surface of the timbers. Figure 167 shows the excavator in operation.

The total contract involved the handling of about 375,000 cu. yd. of material. The following statement gives the estimated output of the machine.

Month	Number of shifts	Output, cu. yd.	Output per shift, cu. yd.
December, 1913	19	37,800	1900
January, 1914	42	87,000	2071
April, 1914	34	66,000	1942
May, 1914	19	39,000	2053

The greatest output during a single 11-hr. shift was 2660 cu. yd., and during two consecutive 11-hr. shifts was 5480 cubic yards.

249. Use of Drag-line Excavator in Missouri.[1]—The construction of the headwater diverision works of the Little River Drainage District of Missouri, during 1914 to 1916 included the construction of flood channels, having bottom widths of from 50 ft. to 112 ft., a maximum depth of 17 ft., side slopes of 2 to 1 and ¾ to 1 and a total length of 34 miles. Spoil was deposited in banks with 3 to 1 slopes, an 8-ft. crown and a 40-ft. berm on the channel side. The East Basin levee had an 8-ft. crown, side slopes of 2 to 1, and a central muck ditch 8 ft. deep and 6 ft. wide, similar to the one under the main embankment. The construction of the levees involved the handling of 8,600,00 cu. yd. of material.

The method of procedure in the construction of the great levees is interesting and worthy of the study of the reader. A reference to Fig. 168 will clearly indicate the various steps which were as follows.

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[1] Abstracted from *Engineering Record*, June 24, 1916.

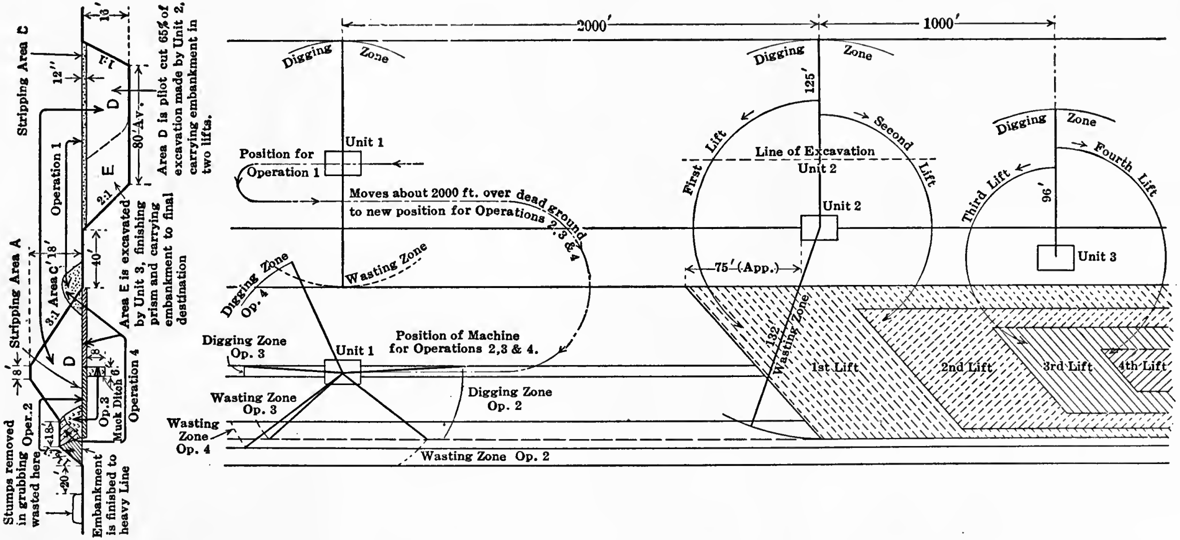

FIG. 168.—Diagram of operation of drag-line excavators in levee construction. (*Courtesy of Engineering News-record.*)

A Clyde stump puller followed the timber-clearing gang and deposited the stumps, roots, etc., in a continuous pile 20 ft. outside of the limits of the flooded area. This débris was later burned.

The next operation consisted in the stripping of the diversion channel area to a depth of about 6 in. with a Bucyrus steam-operated drag-line excavator, equipped with a 70-ft. boom and a 1½-yd. bucket. An inspection of Fig. 168 will show the movement of "Unit 1" in this work. Operations 1 and 2 consist of stripping. Operation 3 consists of the excavation of a muck ditch having a width of 6 ft. and a depth of 8 feet. The fourth operation comprised the stripping of the remainder of the levee area and the rehandling of the stripping taken from the channel area. The wasting zone for operation 4 was between that for operations 2 and 3 and on top of the material placed in operation 2. The material was leveled off to form a banquette with a top width of about 18 ft. and an outside slope of 1½ to 1.

The next step was the building up of the levee over its whole base area by means of a Bucyrus electrically operated drag-line excavator equipped with a 125-ft. boom and a 3½-yd. bucket. The machine, "Unit 2" in Fig. 168, moved along the berm line and excavated material within a zone having a width of 125 ft. and deposited the same over a zone with a width of 132 feet. The material was placed in two layers; the first having a depth of about 6 ft. and the second so as to bring the embankment to a height of about 10 feet. It will be noted that the far bank was cut to a 1 to 1 slope. This machine worked about 2000 ft. behind the stripping machine, and placed about 65 per cent. of the prism.

The last step consisted in the excavation of the remainder of the channel and the completion of the levee prism. This was done with "Unit 3," see Fig. 168, a Bucyrus electrically operated drag-line excavator mounted on trucks and equipped with a 100-ft. boom and a 4½-yd. bucket. The third and fourth lifts or layers of the levee had thicknesses of about 6 ft. and 4 feet. The near side of the channel was built with a slope of about 2 to 1. Where the channel excavation was insufficient to complete the levee, the depth of the waterway was increased. The slopes of the prism were maintained and the base width narrowed as the depth of excavation increased.

The current was furnished from a pole line erected along the line of the channel. The transformers were placed on barges which moved along the channel and reduced the line voltage of 13,200 to 440.

The excavators were operated in three shifts of 8 hr. each for the operators or runners; the rest of each crew, a foreman, three laborers, one helper and a spotter worked in two 12-hr. shifts. The rate of progress averaged about 60,000 cu. yd. per month for the 3½-yd. machine and 70,000 cu. yd. per month for the 4½-yd. machine. Maximum records gave as high as from 80,000 to 90,000 cu. yd per month and a single day's record of 5600 cubic yards. The equipment was shut down only about 5 per cent. of the time.

250. Grab-bucket Dredges.—Grab-bucket dredges have been used to a considerable extent, especially in the South, for the construction of levees in muck and soft soil. They may be equipped with either orange-peel or clam-shell buckets; the former is preferable for muck and silt and the latter for sandy soils. When the banks are dry and firm, the machine is generally mounted on skids and rollers, but may be placed on a barge under high-water conditions.

251. Use of Grab-bucket Dredge in Louisiana.[1]—The following table gives the cost of operation of a traction dredge, equipped with a 2½-cu.yd. orange-peel bucket. These figures are for a typical piece of levee construction in alluvial soil and where clearing is not required.

Labor:		
1 engineer @ $120.00 per month	$120.00	
1 fireman @ $50.00 per month	50.00	
1 track foreman @ $2.00 per day	52.00	
4 trackmen @ $1.75 per day each	182.00	
1 pumpman	39.00	
Total labor cost		$443.00
The above is the labor schedule for one 11-hr. shift.		
The night shift cost would be the same		$443.00
General Supplies:		
1 team and driver for hauling coal	$91.00	
1040 barrels of Pittsburgh coal @ $0.37	384.80	
Oil and waste	10.40	
Repairs and breakage	78.00	
Total cost of supplies		$564.20
Total operating expenses for 1 month		$1450.20
Average amount of excavation for 1 month		38,000 cu. yd.
Average cost of excavation per cubic yard		$0.038

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[1] Abstracted from Circular 74, U. S. Department of Agriculture.

The construction of the Myrtle Grove levee in 1913, was done by an orange-peel excavator, equipped with a 75-ft. boom and a 2-yd. bucket. The work was done during high water, making it necessary to operate the machine from a barge and to rehandle about 30 per cent. of the material.

The following statement gives detailed information concerning the character, scope and cost of the work.

Character of work: Enlargement and new levee.
Length of work: 2726 ft. of enlargement, 2411 ft. of new levee.
Net height of levee: 10.1 ft. to 12.6 ft.
Total cu. yd. in levee: 53,794.29.
Total time consumed on levee: 84 calendar days.
Total time lost in the 84 calendar days: 1 day towing, 12 Sundays, 3 half-day Saturdays, or 14½ days; also one holiday.

Analysis of Cost

		Equivalent cost per cu. yd.
For services, machine crew	$1772.30	$0.0329
For services, day labor	1517.33	0.0282
For towing services	96.73	0.0018
For team hire, plowing base and hauling coal	68.96	0.0013
For levee dressing	346.25	0.0064
For laundry	23.25	0.0004
For coal, 1098.5 bbl. @ 34½ ¢	378.98	0.0070
For subsistence	375.33	0.0070
For ice	81.70	0.0015
For gasoline	12.45	0.0002
For lubricants	45.90	0.0009
For headlight oil	9.20	0.0002
For miscellaneous supplies	188.55	0.0035
For repairs (ordinary)	116.75	0.0022
Construction cost	5033.68	0.0935
For interest on investment, 84 days, 6 per cent. per annum, $30,000.00	415.12	
For depreciation, 4 per cent. per annum	276.75	
Total	$5725.55	$0.1074
Estimated cost of work if let by contract		$0.25

About 30 per cent. of the material was handled twice. It was first dredged out of the river and placed on the land and afterward moved into the levee.

252. Use of Grab-bucket Dredge in California.[1]—The delta lands at the junction of the Sacramento and San Joaquin Rivers were reclaimed by the construction of levees.

The dredge had a hull whose length was 140 ft., width 50 ft., and depth 10 feet. It was made with two longitudinal and two cross bulkheads, extending from keels to deck. The hull was built of 12-in. square timbers. There were two side and one rear stationary spuds, and one fleeting spud. All the spuds were built of single timbers, each 30 in. square and 70 ft. long. The boom was made up of 24-in. square timbers spliced in the center and forming a structure 150 ft. long. The bucket had a spread of 14 ft. and was capable of lifting 14 cu. yd. of material weighing 25 tons at one time.

Power was furnished by a double-cylinder, high-pressure engine of about 500 horse power. The engine was equipped with two 14-in high-pressure cylinders, working into one 41-in. low-pressure cylinder. Steam was furnished by boilers of Scotch marine type, having lengths of 13½ ft. and heights of 7 feet. Crude petroleum oil was used for fuel.

The soils were sand and clay, and were efficiently excavated with this dredge. When working uniformly, the bucket made a round trip in about 1 minute. The work was carried on in two 11-hr. shifts for each working day and the average excavation was about 8000 cubic yards. The maximum excavation made in a day was about 10,500 cubic yards.

253. Templet Levee Builder.—The Austin Levee Builder is a templet excavator, built on the same general principles as those described in Chapter VIII. These excavators can be adapted to levee construction by making a few simple modifications.

The levee builder consists of a moving platform, which supports an excavator frame at one end and a levee runway at the other end.

The platform is generally built of timber and has a length of 22 ft. and a width of 20 ft. It carries the power equipment, which is generally housed in. Figure 169 shows one of the machines at work.

The platform moves on a track made up of 12-in. by 12-in. timbers, 200 ft. in length. On the tops of these are spiked T-

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[1] From information furnished by Capt. C. O. Sherrill, U. S. Corps of Engineers.

rails which take the flanged wheels of the plaftorm trucks. For soft ground, roller platform traction is used.

The power equipment consists of a steam-boiler and engine. The boiler is a 50-h.p. fire-box locomotive type weighing 10,500 pounds. The engine is a 40-h.p. reversible, double-cylinder, double-friction drum, hoisting engine, provided with steel gearing. The engine weighs about 12,000 pounds. The makers will furnish a gasoline engine instead of the regular steam equipment if desired.

A four-legged A-frame, made up of structural steel members is supported on the platform. From the top of this frame, cables pass over steel sheaves to the outer ends of the excavator frame and the levee runway. These cables are connected to the drums of the hoisting engine and thus control the raising and lowering of these two frames.

Fig. 169.—Austin templet machine constructing a levee. (*Courtesy of F. C. Austin Co.*)

On the outer or borrow pit end of the platform is hinged a steel frame or guideway, which has the general shape of a ditch cross-section, and can be raised and lowered by the operator by means of steel wire cables passing over a sheave at the outer end of the frame, thence to a sheave at the top of the A-frame and thence to the engine. This frame forms a track over which a bucket passes. The bucket commences at the farther outside bearing of the runway and is drawn by a wire cable attached to the engine drum toward the machine, passing along the guideway and then across the berm and up the levee runway and dumped. Thus the bucket in its path moves over a continuous guideway or steel track which extends from the outer point of the borrow pit, in front of the platform and to the center of the levee. The bucket after dumping, is pulled back along its track to the outer point of the cutting frame, where it commences the excavation of another slice of earth. The frame is gradually lowered as the bucket excavates, until the bottom of the frame is horizontal. Then the frame is raised and the whole machine moves ahead about 3 ft. and another section of the pit is excavated.

The bucket used is made of steel plate with heavy manganese steel cutting edge. Its length is 48 in., depth 36 in. and width 43 inches. Buckets having capacities of from 1⅓ cu. yd. to 2½ cu. yd. each, can be used on this machine. The approximate weight of a 2-cu. yd. bucket is 3000 pounds.

This levee builder is made to excavate borrow pits with 1½ to 1 or with 1 to 1 side slopes. With 1½ to 1 side slopes, the machine can excavate a pit having a maximum depth of 20 ft. and bottom width of 20 ft., and a minimum bottom width of 5 feet. With 1 to 1 side slopes, the maximum depth would be 30 ft. and corresponding maximum bottom width of 30 ft. and a minimum bottom width of 6 feet. The width of berm varies from 20 ft. to 40 ft. depending on the amount of material to be placed in the levee and local conditions.

Under favorable conditions, this machine will excavate and dump abut 1000 cu. yd. of earth per 10-hr. day. The labor required is an operator, a fireman, a track gang composed of two men and a team of horses and a man and team for hauling supplies, fuel, etc. When roller platform traction is used, the track gang is not necessary, except when the soil is very soft and one or two extra laborers are required for planking. About 2 tons of coal are used in a 10-hr. shift. The operating cost for a 10-hr. day would vary from $25.00 to $30.00, when the soil conditions were favorable.

The F. C. Austin Drainage Excavator Company have also designed a multiple bucket excavator for levee work. This machine consists of two moving platforms, each carrying its operating machine and excavator. The excavator consists of a triangular-shaped steel-truss frame supported at its inner end on the platform and also near its center by a cable from a crane, extending from the platform out over the excavator frame. The latter carries a continuous chain equipped with steel buckets, which cut out the soil as the frame is gradually lowered. At the platform end of the bucker chain, the buckets dump their loads as they turn over. The excavated material is dropped on a moving belt conveyor, which carries the material to the levee. The excavator frame and belt conveyor can be raised and lowered by the operator.

This excavator can be duplicated on the other side and a double levee constructed as is often necessary in straightening out and enlarging a natural water course. Each machine is designed to dig a pit having a bottom width of 40 ft., depth of 20 ft., and side slope of 2 to 1. The berm would vary from 40 ft. to 60 feet.

254. Cableways.—During the past 6 years (1912–18), the cableway has been greatly developed and adapted to earthwork. This has been especially true with regard to the excavation of large channels and the construction of levees. See Chapter XI.

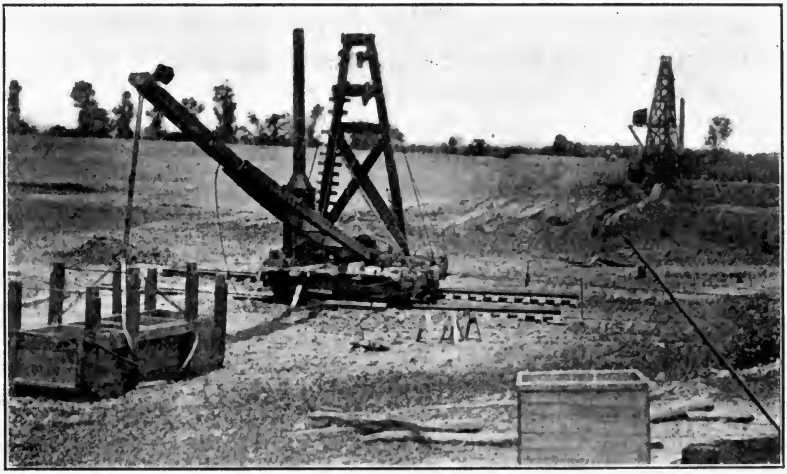

FIG. 170.—Drag-line cableway on levee construction. (*Courtesy of G. A. & R. A. McWilliams.*)

The tower excavator, the early type of slack-line cableway, has recently been used successfully in levee construction, but its field of use is largely limited to the construction of banquettes behind existing levees or the enlargement of existing banquettes. The borrow pits excavated by this machine are often irregular in section due to the difficulty of control of the bucket while being loaded.

The latest development in the cableway excavator is the taut-line machine. Its general features are shown in Fig. 170. The towers may be built of steel or timber and vary in height from 30 ft. to 90 feet. A heavy cable, 2 in. to 3 in. is stretched between them and supports a carriage carrying a drag-line bucket. The carriage is moved back and forth by means of an endless line, operated by one of the drums of the hoisting engine. The bucket is loaded by means of a cable operated by another drum of the hoisting engine, and is lifted by a fall line attached to the bail of the bucket and thence passing over a sheave on the carriage to a sheave at the top of the head tower and down to a third drum of the engine. The bucket is dumped by means of a haul-down cable operated from a special engine on the head tower. The tail tower is moved by a friction drum operated by the conveying line.

255. Use of Single-tower Excavator in Louisiana.[1]—Previous to the letting of the contract for a section of the work of reclamation of the Bogne Phalia Drainage District, the engineers, the Morgan Engineering Company of Memphis, Tenn., made a test of a single-tower excavator.

The ditch had a bottom width of 80 ft., an average depth of 17 ft., with 2 to 1 side slopes and berms of 30 feet.

The machine worked for 216 hr. between June 19, 1913 and August 4, 1913, by one shift and excavated 25,819 cu. yd. or at an average rate of 117 cu. yd. per hour. The following is a statement of the cost of operation:

Item	Total cost	Unit cost
Labor and board	$722.25	$0.0280
Livery and horse hire	85.00	0.0037
Coal, 85 tons @ $3.45	293.25	0.0113
Gasoline and oil	37.06	0.0014
Repairs	341.42	0.0132
Miscellaneous	1.50	0.0000
Total	$1480.48	$0.0576

Total excavation .... 25,819 cu. yd.

Unit cost, $1480.48 ÷ 25,819 = $0.0576

256. Use of Cableway Excavators in Mississippi.[2]—A taut-line or double-tower cableway was used in 1915 in the repair and

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[1] Abstracted from *Engineering News*, May 25, 1916.

[2] Compiled from *Professional Memoirs*, U. S. Corps of Engineers, May-June, 1916.

enlargement of levees near Greenville, Miss. The work required the excavation of about 2150 cu. yd. per station of 100 feet. In order to secure this material it was found necessary to go 63 ft. beyond the previous river-side pit and make a pit whose outer edge would be 428 ft. from the center line of the crown of the original levee.

The cableway consisted of two steel towers; the head tower 85 ft. high and the tail tower, 45 ft. high, supporting a 2½ in. steel cable. The carriage which traveled on this cable supported a 3-yd. drag-line bucket. A derrick was used on the tail tower to move the track sections, and on the head tower, the track sections were moved by the hoisting engine. The frictions and brakes were all operated by compressed air.

The labor used in the operation of this machine was as follows: one foreman rigger, one operator, one rigger's helper, one engineman, one fireman, one signalman, eleven laborers, three trackmen for tail tower, five trackmen for head tower and three laborers for dressing the levee, and three teamsters for ploughing, dressing levee and hauling supplies.

The following statement gives the cost of operation during the working season of 1915.

Month—1915	Monthly excavation, cu. yd.	Cost per cu. yd.	Total excavation to date, cu. yd.	Average cost per. cu. yd.
April	5,211	$0.185	5,211	$0.185
May	13,239	0.139	18,450	0.152
June	20,050	0.155	38,500	0.153
July	23,850	0.113	62,350	0.138
August	19,050	0.149	81,400	0.140
September	2,600	0.705	84,000	0.158
October	22,800	0.104	106,800	0.146
November	28,500	0.111	135,300	0.139
December	18,600	0.225	153,900	0.149

The very high costs of September were due to delays from high water, wet pits and repairs. The high costs of December were caused by delays from high water, a coal shortage and the holiday season. The average distance the excavated material was hauled was 412 ft., and the average amount of slope dressing was 17,200 sq. ft. per 100 ft. station.

257. Floating-dipper Dredge.—The floating-dipper dredge has been used to some extent in the South for the construction of levees, where the latter are of small cross-section. As this type of excavator must remove all the material from a channel and in front of itself, it is not a practical machine for the construction of large levees. The latter would require the excavation of deep channels, which would lie too near the toe of the levee for safety. The dipper dredge has a comparatively short boom and reach and hence is generally not adapted to the construction of levees where the prism has a volume of over 1000 cu. yd. per 100 ft. station.

The floating-dipper dredge has been successfully used in coördination with a hydraulic dredge in levee construction along natural streams. The dipper dredge builds a small embankment along the toe of the proposed levee and thus furnishes a dam behind which the hydraulic dredge discharges its fluid material.

258. Hydraulic Dredge.—The hydraulic dredge has generally been considered rather an uneconomical and inefficient type of excavator to use in the construction of levees on account of the difficulty and expense of retaining the fluid dredged material within the limits of the desired prism. The early method of retaining the fluid material consisted in the initial construction of two ridges of dry material at the toe of the two slopes, and then filling in between with the material from the discharge pipe of the hydraulic dredge, up to the top of the ridges. After the wet filling dries out and solidifies, two more ridges are built and filled in. This process is continued until the levee is carried to the proper elevation and completed. This process is satisfactory as to final results, but slow and expensive.

Since 1910, two methods have been successfully used in the construction of hydraulic fill embankments. The first is the use of "shutter pipes" and the second is with baffle or slope boards.

The "shutter pipes" are 14 ft. to 20 ft. lengths of discharge pipe of from No. 10 to No. 14 sheet steel and provided with openings in the bottom. These openings are controlled by steel plates or shutters and may be closed or opened to any extent. The pipes are generally laid on a timber trestle over the site of the embankment and connected to the discharge pipe of the dredge. The surplus water is carried away through a length of discharge pipe beyond the "shutter pipes." This method operates on the principle that the material flowing in the discharge pipe moves in strata with the heavier material at the bottom and the sand and silt in the upper section of the pipe. The velocity of the material is inversely proportional to its density. The motion is not uniform and occurs like wave action with a series of crests and troughs.

Baffle or slope boards are wooden or steel boards from 12 in. to 20 in. wide and 8 ft. to 20 ft. long. The wooden boards are generally of 1-in. material, and held in place by 2 in. by 4 in. studding. The steel boards are of from No. 10 to No. 16 gage steel with angle iron tips for lateral stiffness. These slope boards are placed at the intersection of the side slope with the natural slope of the end of the fill under construction. These boards serve to restrain the flow of the fluid material until the top is reached, when they are pulled out and moved further up the slope.

The two methods described above are often used together and recently some remarkably efficient and economical results have been obtained. Considerable care must be exercised to keep a uniform flow of material in the discharge pipe. Judgment is necessary to ensure the proper operation of the shutters; opening them up to discharge more water to secure a flatter slope and closing some if the percentage of solid material decreases. The handling and placing of the slope boards is important and requires considerable experience to secure an embankment with proper slopes.

259. Use of Hydraulic Dredges in California.[1]—Two large and powerful hydraulic dredges were used during several seasons for the construction of levees along the Sacramento River. The two dredges had steel hulls, 104 ft. long, 35 ft. wide and 9 ft. deep and were equipped with suction pipes 50 ft. long and rotary cutters. One dredge had a steam equipment consisting of a triple-expansion engine of about 600 h.p. supplied with steam at 160 lb. pressure from two water tube boilers, for the operation of the 74-in. runner at 190 r.p.m.; a double-cylinder, 10-in. by 12-in. engine for driving the cutter; and a double-cylinder, 8-in. by 8-in. engine for the operation of the winding machinery which handles the spuds and ladder and swings the dredge. A surface condenser received the exhaust from all the engines. The dredge cost $105,000.00 including pontoon line and shore pipe.

The electrically operated dredge was provided with a 20-in. centrifugal pump with a 50-in. runner, and was driven by a

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[1] Abstracted from *Engineering News*, October 29, 1914.

750-h.p. motor whose speed varied from 300 to 350 r.p.m., winding machinery actuated by a 35-h.p. motor and the cutter by a 150-h.p. motor. Three-phase, 60-cycle, alternating current, at 11,000 volts, was brought to the dredge by a submarine cable and stepped down to 2200 volts. This dredge cost $85,000.00.

The steam-operated dredge has deposited several million cubic yards of material at an average cost of 6.6 cents per cubic yard. The average output has been about 200,000 cu. yd. per month; the dredge operating 24 hr. a day and 6 days per week. The record for one month was 248,000 cubic yards. The labor required for the operation of the dredge consisted of 6 men per shift and about 16 extra laborers to handle the pipe line.

260. Use of Hydraulic Dredge on Mississippi River.[1]—The following is a typical example of the cost of operation of a 15-in. hydraulic dredge on levee construction on the lower Mississippi River.

The dredge should be equipped with a cross-compound engine of the horizontal type, direct connected to the 15-in. centrifugal pump. Steam should be supplied from water tube boilers with a minimum heating surface of 2500 sq. ft. and a capacity of about 300 horse power. A double-cylinder single-drum engine of about 20 h.p. is used to operate the suction pipe. A deck capstan with independent engines is desirable for handling the hull, which should be about 110 ft. long, 30 ft. wide and 5 ft. deep. The complete dredge will cost from $30,000 to $50,000 depending on local conditions, market prices, etc.

The following statement gives typical operating costs for a 15-in. hydraulic dredge on levee construction on the Mississippi River. The labor costs are for two 12-hr. shifts per day and do not include subsistence.

Labor:	*Per month*	
1 foreman	$150.00	
1 engineman	125.00	
1 engineman	100.00	
2 suction operators @ $100.00	200.00	
2 oilers, @ $60.00	120.00	
2 firemen @ $70.00	140.00	
2 coal passers @ $60.00	120.00	
3 deck hands @ $60.00	180.00	
1 levee foreman (day shift)	90.00	
1 levee foreman (night shift)	70.00	
10 levee laborers @ $60.00	600.00	
Total monthly labor cost		$1895.00

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[1] Abstracted from *Engineering News,* October 29, 1914.

Fuel and Supplies:

Coal, 300 tons @ $4.00	$1200.00	
Supplies, rope, oil, packing, etc	150.00	
Total cost of fuel and supplies		$1350.00

Overhead and Miscellaneous:

Repairs and renewals	$200.00	
Office and overhead expenses	200.00	
Insurance, fire and liability	100.00	
Interest and depreciation (2 per cent. of $35,000)	700.00	
Total miscellaneous expenses		$1200.00
Total monthly operating cost		$4445.00
Total monthly output of dredge		75,000 cu. yd.

Cost of operation, $4445.00 ÷ 75,000 = $0.059

261. Use of Hydraulic-fill Method in Washington.[1]—The hydraulic-fill method of earth dam construction was used in 1908, 1909 and 1910 in the construction of the Conconcully Dam, which forms a part of the Okanogan Project of the U. S. Reclamation Service in northern Washington.

The dam has a crest length of 1010 ft., a crest width of 20 ft., a maximum height of 66 ft., slopes of 3 to 1 on the downstream face and of 2 to 1 on the upstream face, and a volume of 351,500 cubic yards.

The material used in the construction of the dam consisted of sand and silt from the disintegration of granite. The borrow pits were located on the mountain side above the dam and adjacent to one end. The material contained considerable silt and also coarser material of rock fragments up to a cubic yard in size.

The sluicing of the borrow pits was affected by giants with 2-in. to 3½-in. nozzles and supplies with feed water brought down the mountain side through 14-in. No. 16 steel slip-joint pipes. Each giant consumed from 1½ to 5½ cu. ft. of water. The supply pressure on the main flume varied from 114 ft. to 170 feet. The main supply flume was a ditch which ran along the lower edge of the borrow pits and then proceeded on a high trestle to the site of the dam. Here the flume connected with lateral flumes which were located along the edges of the slopes and parallel to

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[1] Compiled from *Transactions of American Society of Civil Engineers* December, 1911, Vol. LXXIV.

the longitudinal axis of the structure. These flumes had 4 per cent. grades, and the material was discharged at several delivery points in rows of cone-shaped piles, forming ridges. Deflecting screens, spouts, etc., were used to direct the coarser material toward the outside slopes. The material carried toward the pond in the center of the embankment was the fine sand and silt, the coarser material settling out along the inner slopes of the ridges. As the dam built up and the upper surface narrowed, the coarse material extended to a great extent across the section and it became necessary to break up the material by the use of paddles and finally to introduce an artificial core composed of fine, loamy sand. This core was started at an elevation of 14 ft. above the general base of the dam and carried to a point 39 ft. above high-water line. The material was hauled in scrapers up to a platform, from which it was sluiced through an 8-in. pipe to its place in the dam. In this manner, about 16,600 cu. yd. of material were placed between diaphragms of 1-in boards.

The dam was built to a super-elevation of 1 ft. across the valley, and the final settlement amounted to about 15,500 cu. yd., the greatest settlement at any point being 3.9 ft.

The segregating effect of the water resulted in an increase of dam over borrow pit measurement, the swell in volume during the first season being about 12 per cent. but decreasing in magnitude for the completed work, as follows:

Material from borrow pits	349,455 cu. yd.
Loss of silt from pits in waste water	20,000 cu. yd.
Net volume in dam, pit measurement	329,455 cu. yd.
Volume of dam above original surface	336,000 cu. yd.
Volume of dam below original surface	15,500 cu. yd.
Total volume of dam	351,500 cu. yd.
Material from valley pits	11,600 cu. yd.
Material from side-hill pits, bank measurement	339,900 cu. yd.
Swell, 3.2 per cent	10,455 cu. yd.

The cost of construction of the dam is given in detail in the following statement. The labor schedule, based on an 8-hr. working day was as follows:

	per day
Common labor	$2.25 to $2.50
Pitmen	2.75 to 3.00
Monitor operators	3.00
Powder men	3.00
Carpenters	4.00 to 4.50
Foremen	5.00

Hydraulicking:

Plant	$69,099.00	
Supplies	11,783.00	
Labor	74,755.00	
Total cost of sluicing		$155,637.00

Dam Construction:

Puddle core	$22,885.00	
Slopes	8,465.00	
Miscellaneous	1,382.00	
Total cost of dam construction		$32,732.00
Total cost of earthwork		188,369.00
Total material handled		351,500 cu. yd.

Unit cost of excavation, $\$188{,}369.00 \div 351{,}500 = \$0.533$.

262. Résumé.—The field of earthwork operations in reclamation work is broad and varied, and offers opportunities for the use of many types of excavators. The proper method and machine to use in any case depends on several factors; magnitude of the job, area over which the work extends, nature of soil to be removed, length of haul, cost and availability of fuel, labor, etc., location of job with respect to transportation facilities, etc.

On a small job, the initial cost of the earth-handling plant may be a large proportion of the total cost of the work, and hence it is necessary to use an inexpensive equipment. In the case of a large job, however, the cost of a large and expensive equipment can be distributed over a large output and thus only slightly affect the unit cost. Where the amount of earthwork at any section is small but extends over a considerable area, as is the case of small canal and levee work, the work can generally be most efficiently executed with scrapers, graders, or some type of small, portable excavator. Where the work is of considerable magnitude at any section, as in the construction of large open channels, levees, earth dams, etc., some form of dry-land or floating excavator should be used. When the job is a long distance from a line of transportation, the cost of hauling, and the scarcity and high cost of labor and fuel, may require the use of the small, portable types of machinery.

The smaller ditches and canals should be made wherever possible with a wheel or templet excavator to secure a true grade and smooth and uniform side slopes. These machines can be efficiently used on the excavation of irrigation and drainage channels when the soil is fairly dry, softer than hard-pan or indurated gravel and free from stumps, large stone and other obstructions. Where the soil conditions are unfavorable, one of the lighter, portable forms of scraper-bucket excavator or traction shovel should be used. In wet, swampy lands and where timber abounds, the small floating-dipper dredge is the most efficient form of machine, even when the size of the hull necessitates the excavation of a channel considerably larger than the required section.

The larger ditches and canals can be most efficiently excavated with the scraper-bucket or drag-line excavator, the floating dipper or ladder dredge and the cableway excavator. The drag-line excavator has proved its efficiency and adaptability over a wide range of soil conditions, and can handle stumps, large stone and other obstructions with facility by means of the direct pull and power afforded by the drag-line cable. The wide range of operation and flexibility of this machine adapt it to a great variety of soil and topographic conditions. The floating-dipper dredge is the most satisfactory excavator in the construction of open channels through low, wet, swampy land. The disadvantages of the use of this machine lie largely in the difficulty of securing a prism with a true grade and smooth uniform side slopes, and in leaving clear, clean berms. Great skill and care are necessary on the part of the operator to ensure even a fairly true and smooth channel. The ladder and hydraulic dredges are principally useful in the excavation of very large wide channels where there is ample space for the swinging of the dredge and the excavation of a true and uniform prism is not necessary.

The various forms of cableway excavator are being successfully adapted to the excavation of wide channels in dry soils. The original form of single-tower excavator, used 20 years ago on the Chicago Drainage Canal has been developed recently (1913–18) into a two-tower machine which moves along the axis of the channel and operates a drag-line bucket on the principle of the taut line or the slack line. The relative efficiency of these two methods of operating a cableway excavator has not been sufficiently well-established to make a definite statement. However, these machines of both types are being continually improved and later developments in the smoothness of operation and control of the bucket will doubtless greatly increase their usefulness and efficiency.

The excavation of dense, hard material in the preparation of the foundations of dams and other structures can be most efficiently handled by power shovels. The scraper-bucket excavator can also be used to advantage where the material is sufficiently loose or well-broken up to be handled directly. In work of this class, the cableway is a very efficient tool to use for the raising and transporting of skips or buckets, which are loaded by the excavators working on the lower levels of the excavation.

The construction of small levees and earth embankments can be economically done with the wheel scraper and the grader. The constant compacting given an embankment during construction by the movement of the teams is an important factor in securing density and imperviousness. For work of any considerable magnitude, the large power excavator should be employed; the proper type of machine for any case depending on local conditions of topography, soil, fuel and transportation conditions, etc. The power shovel has been most universally used for the excavation of hard soil such as hard-pan and rock. The material is taken from borrow pits, loaded into wagons or trains of dump cars and hauled to the site of the embankment. The drag-line excavator can often be used to great advantage in levee construction by one handling of the material from borrow pit to embankment, doing away with the use of transportation equipment.

The construction of levees involves capacity, the ability to rapidly transport material over wide areas and the proper compacting of the material. In the early days of flood protection work, along the Mississippi River the scraper and wheelbarrow were universally used. In the former days of plentiful and cheap labor these tools were efficient and fairly economical, but present-day conditions of scarce and high-priced labor and work of great magnitude have developed the use of large, power-operated machines of great capacity. The floating-dipper dredge is suitable for the building of small levees along the smaller streams. However, when the embankment contains over 1000 cu. yd. per station of 100 ft., the "reach" of the machine is not sufficient to properly excavate the borrow pit and place the levee. In such cases, even in low, wet soils, the drag-line excavator can be used to great advantage. When the soil conditions are such as to require the use of a floating excavator, the grab-bucket machine with a long boom and mounted on a barge is the most efficient type. These machines are built with booms up to 125 ft. in length and with a capacity of 3000 cu. yd. per 11-hr. shift. The templet excavator can be successfully used where the soil is not too hard and is fairly free from stumps, large stone and other obstructions. The machine excavates a borrow pit of smooth and uniform cross-section and deposits the material in even layers on the embankment.

The principal objection to the use of any large power excavator is the difficulty of securing a uniform distribution of the material and a dense embankment. Although the material drops from the bucket of a machine excavator with considerable force, yet the resulting consolidation in the bank is generally "spotty" and uneven. The only satisfactory method to use in order to overcome this difficulty is to deposit the material in uniform and shallow layers, which are successively spread and rolled.

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39. Levee Building with Bucket Excavator Dredge Equipment with Stern Delivery Stacker. *Mining and Science Press*, April 18, 1914. Illustrated, 700 words.

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50. Moving $500,000 Worth of Dirt on Vincennes, Ind., Levee Job, S. E. BATES. *Contractor*, November 1, 1916. Illustrated, 2500 words.

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53. Progress of Excavation on the Winnipeg Aqueduct. *Excavating Engineer*, January, 1917. Illustrated, 2000 words.

54. The Pumping Dredge used in Reclaiming Land. *Engineering Record*, February 13, 1892.

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56. Reducing the Cost of Drainage Excavation. *Engineering Record*, December 26, 1914. 1200 words.

57. River Diversion and Flood Control in Missouri. *Engineering News*, August 24, 1916. Illustrated, 3000 words.

58. Scraper Dragged from Extension Boom Cleans Berm of Ditch. *Engineering Record*, June 5, 1915. 300 words.

59. Small Dragline Succeeds in Tough Ditching in Peat Bog Near Bridgeport, Conn. *Excavating Engineer*, April, 1917. Illustrated, 1800 words.

60. Some Records of Steam Shovel Ditch Excavation. *Engineering & Contracting*, February 26, 1913. 2500 words.

61. Steam Shovel Operation on the East St. Louis Levee Project. *Excavating Engineer*, March, 1917. Illustrated, 1200 words.

62. Steam Shovel Work at Ashokan Reservoir. *Engineering Record*, October 3, 1914. Illustrated, 2000 words.

CHAPTER XX

RIVERS, HARBORS AND CANALS

264. Preliminary.—The construction and improvements of rivers, harbors and canals is largely a matter of the efficient use of the larger types of power excavators. The three branches of the subject are distinctive and involve so many special elements that they will be treated separately in the following discussion of the use of excavating machinery in the regulation of rivers, the construction and maintenance of channels in lakes and harbors, and the construction of barge and ship canals.

I. RIVERS

265. General.—The regulation of rivers has become a very important matter in the Middle West, where the maintenance of channels and the construction of flood prevention and protection works are increasingly necessary for the purpose of inland navigation and public safety. The three best known methods of river improvement are; by the regulation of the river, by canalization, and by dredging. The latter may be considered as a special form of regulation and is often employed in connection with artificial works of regulation. However, in recent years, experience has shown that periodic dredging is often more efficacious and economical than the construction of permanent works such as deflectors, training walls, dikes, spurs, etc. This method avoids the large initial expense of permanent regulation works, which establish a fixed form of improvement that may be later unsuited for growing and developing commercial conditions. This is especially true as regards the maintenance of channels in the large alluvial rivers of the middle western section of this country.

The dredging of a river channel should be done so as to assist the stream in the construction and the later maintenance of the new channel. The excavation should proceed downstream, this method being more effective because it removes the entire prism, produces a less strain on the anchorages, and facilitates the formation of a strong current which assists in the work by its erosive action. The location and direction of the new channel should be such that the prevailing river currents will follow the new channel and serve to keep it flushed out and open. This matter requires a careful study of the physics of a river, and the lines of probable maximum current energy should be determined before dredging operations begin.

Ordinarily the excavated material should be deposited at a sufficient distance from the channel to preclude any possibility of its being washed back. However, in many cases, this material may be effectively utilized in the filling-in of adjacent pools or the construction of dikes to deflect and confine the water within the new channel.

Alluvial rivers of unstable regimen require frequent dredging to maintain the channels, although only a portion of the cuts require renewal if their location has been properly determined. In the case of rivers of more stable regimen, and dense, firm bed material, the dredged channels will remain nearly permanent and require very little if any maintenance.

The type of excavator to be used in dredging depends on the size and character of the stream, the kind of material to be excavated, the disposition of the spoil, the magnitude of the work, etc. The various types in general use will be discussed in the following articles.

266. Floating-dipper Dredges.—The dipper dredge has certain special qualities of simple action, positive control and definite application of power in digging. These factors make this machine especially useful in the excavation of dense, hard material at moderate depths. Dipper dredges are of little value in the dredging of alluvial rivers except near their mouths, or for the removal of bars of stiff, tenacious material. They are especially adapted to the maintenance of channels in improved rivers, where the regimen is stable and slight.

267. Use of Dipper Dredges on Ohio River.[1]—The U. S. Government during the fiscal year ending June 30, 1911, used two dipper dredges on channel improvement on the Ohio River below Pittsburgh.

The dredges were the "Ohio" and "Oswego" and were equipped with buckets of 2.7 cu. yd. capacity.

The "Oswego" excavated during the year, 122,967 cu. yd. of sand, gravel, clay, boulders and cemented gravel, 93.67 tons of rock, and 18.7 tons of snags. The cost of excavating the sand, gravel, clay, etc., was 16.85 cents per cubic yard, and for removing rock and snags was $3.79 per ton. The dredge operated 189.4

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[1] Abstracted from Report of Chief of Engineers, U. S. Army.

days, the effective working time being 103.67 days and the time lost by bad weather, repairs, Sundays, holidays, etc., was 89.72 days.

The following statement gives the cost of excavation for the two dredges for the fiscal year. The high cost was due to the difficulty of removing the cemented gravel at Five Mile Bar, during a low stage of water, and also due to long distance hauling of the excavated material.

	Dredge "Oswego"	Dredge "Ohio"
General supplies and expenses	$1,824.31	$1,789.40
Towing and fuel	8,308.47	9,256.64
Repairs	2,373.71	2,211.22
Salaries	7,906.59	8,126.01
Subsistence	312.90	320.25
Launch	312.90	398.43
Total	$21,038.88	$22,101.95

268. Use of Clam-shell Dredges in North Carolina.—The Corps of Engineers of the U. S. Army used two clam-shell dredges in the clearing of the channel of the Cape Fear River, at and below Wilmington, North Carolina, during the fiscal year ending June 30, 1911. The dredges were used in clearing out the full channel to a depth of 10 ft. and in removing shoals. The material excavated was silt and sand.

The following is a statement of the cost of operation of the dredge "Hercules," equipped with a 7-yd. clam-shell bucket.

Operation	$20,566.06
Tug for towing	13,551.12
Superintendence and surveys	2,642.00
Office expenses	837.00
One-half re-handling of 215,560 cu. yd. material by dredge "Jacksonville"	8,622.42
Total cost	$46,218.60
Unit cost of excavation	$0.082 per cu. yd.

The dredge "Ajax," equipped with a 5-yd. clam-shell bucket made the following record:

Operation	$17,968.82
Tugs for towing	10,507.14
Superintendence and surveys	2,176.00
Office expenses	689.00
One-half re-handling of 215,516 cu. yd. material by dredge "Jacksonville"	8,622.42
Total cost	$39,963.38
Unit cost of excavation	$0.074 per cu. yd.

Fig. 171 shows an orange-peel dredge on river improvement.

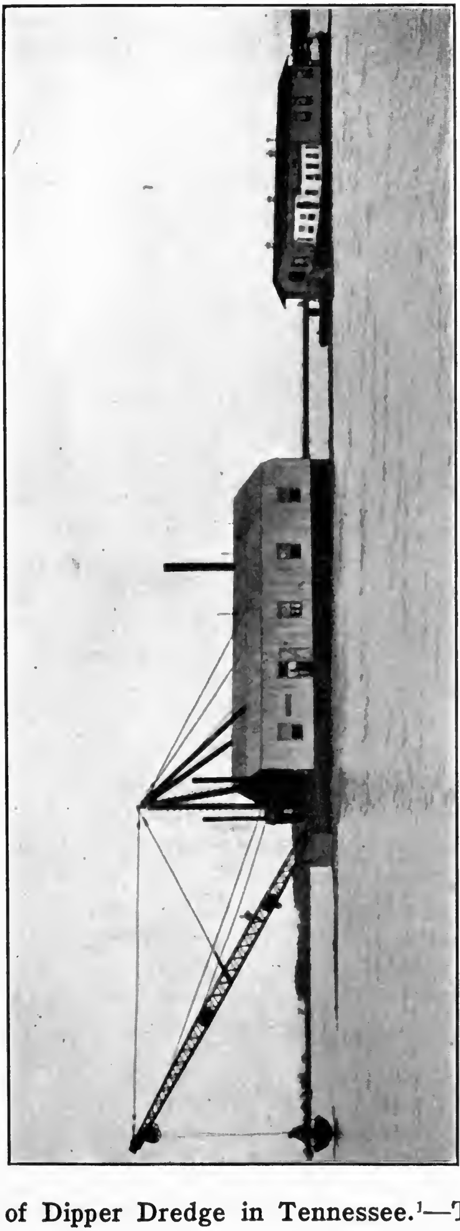

Fig. 171.—Orange-peel dredge constructing river channel.

269. Use of Dipper Dredge in Tennessee.[1]—The Corps of

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[1] Abstracted from Report of Chief of Engineers, U. S. Army.

Engineers of the U. S. Army used a dipper dredge, during the fiscal year ending June 30, 1912 in the clearing out of the channel of the Tennessee River. The operations consisted in the removal of 112,500 cu. yd. of silt and 5700 cu. yd. of rock from a low water depth of 2.5 ft. to a depth of 6 feet.

The dredge used was the "Kentucky" and consisted of a steel hull 100 ft. long, 34 ft. wide and 6 ft. 10 in. deep, equipped with a 45-ft. boom and two dippers, one of 2 yd. capacity and one of 4 yd. capacity. The machine was built in 1900 at a cost of $36,300.00 and re-built by the government in 1908.

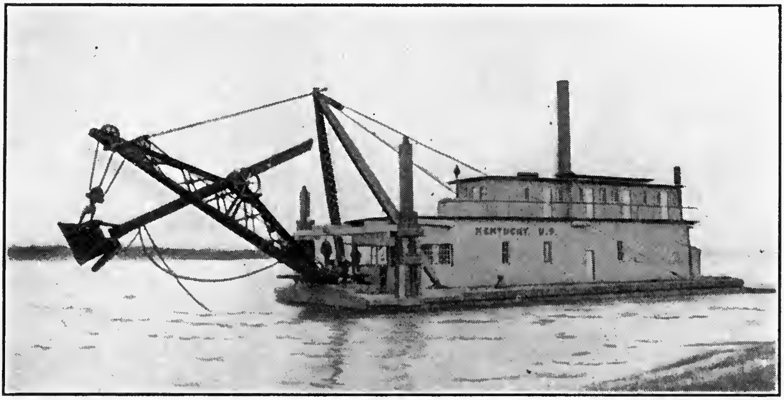

Fig. 172.—U. S. dipper dredge on river improvement.

The hourly output of the dredge averaged about 200 cu. yd. of silt and sand and 15 cu. yd. of rock. A view of the dredge in operation is given in Fig. 172.

The following is the operating record of the dredge for the year:

Days in operation		165	
Hours in operation per day		8	
Distance to dump, miles		0.5	
Number of scows loaded per day		25	
Average scow load, cu. yd		60	
Loading time of scow, hours:	Rock	2	
	Gravel	0.5	
Maximum output per hour, cu. yd		200	
Maximum output per day, cu. yd		1750	
Time lost, days:	Repairs, hull	60	days
	Repairs, machinery	16	days
	Weather	75	days
	Shifting	3	days
Total time lost		154	days

The following statement gives the cost of operation of the dredge during the year.

Labor	$7,900
Coal	1,600
Kerosene	36
Lubricating oil	65
Supplies: Food	2,000
Machinery	1,000
Laundry, ice, etc.	144
Miscellaneous	125
Total dredge cost	$12,870
Towboat operations	8,374
Scow and barge repairs	200
Total field cost	$21,444
Office expenses, superintendence, survey, etc.	1,800
Grand total	$23,244
Unit cost of excavation (estimated): Silt and sand	$0.15 per cu. yd
Rock	1.00 per cu. yd

270. Ladder Excavators.—The ladder dredge is a machine of rather a restricted field of use as compared with the dipper dredge which has always been the popular form of floating excavator in the United States. Hence, the ladder dredge has never come into popular favor with contractors and has been little used in this country. However, with a better understanding of the limitations of this type of dredge, its use will doubtless become more extended in the near future.

The high cost of construction and of operation require that the dredge be in use a large proportion of the available working period in order to justify its investment and secure low dredging costs. The requirements for successful operation are work of great magnitude and ample space for manipulation and these are seldom met with on river improvement work. There are a few noteworthy examples of the successful use of ladder dredges in river channel maintenance and these cases will be described in the two following articles.

271. Use of Ladder Dredges in Canada.—The Canadian Government for several years has used ladder dredges for the maintenance of the channel of the St. Lawrence River from Quebec to Montreal. This work comprised the annual removal of from 1,500,000 cu. yd. to 2,500,000 cu. yd. of material over a length of about 60 miles of river. The original depth of water was about 11 ft., and the present channel has a depth of 30 ft. at low water and a minimum width of 450 feet.

Six dredges with 1-yd. buckets and an average daily output of about 5000 cu. yd. are employed on this work. The record output for one of these dredges is 5740 cu. yd. per day for a period of 21 days.

The ordinary channel width of 450 ft. is made in one cut feeding laterally. The width of channel at the bends is from 600 ft. to 750 ft. and this cut is made the full size at one time by lateral feeding. The dredge is manipulated by wire cables carried about 2000 ft. ahead and supported on floats.

272. Use of Ladder Dredge in Wisconsin.[1]—A ladder dredge, built by the Bucyrus Company of South Milwaukee, Wis., was used by the U. S. Government for dredging of the channel of the Fox River in Wisconsin. The plant consisted of a dredge with two intermediate and one delivery scow, which were operated either in line or without the use of one or both of the intermediate scows. Figure 173 gives a general view of the plant in operation.

The dredge was a regular elevator dredge, equipped with a chain of 39 buckets of 5 ft. capacity each. The buckets were provided with steel teeth, and excavated hard material up to a depth of 10 feet. One stern spud provided a pivot about which the dredge could swing through a radius of 80 ft. and covering a channel width of 145 feet.

The bucket chain was driven by a 9-in. × 12-in. double reversing engine, by gearing, which also operated the ladder hoist. A 6-drum winch, driven by a 6-in. × 6-in. double-cylinder engine, was used to operate the anchor, spud lines, etc. A walking spud operated by a steam cylinder was used to move the dredge. The belt conveyors on the dredge and the scows were operated by electric motors supplied with current from a 35-k.w. electric generator, driven by a 10-in. × 10-in. engine on the dredge. This generator also supplied current for lighting the plant and power to a 6-in. spray pump for cleaning the belts. Steam was furnished by a Scotch-marine boiler 9 ft. in diameter and 10 ft. in length, waterback type and equipped with two Adamson furnaces 35 in. in diameter. The delivery scow was provided

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[1] Abstracted from *Engineering News*, October 25, 1906.

with a winch operated by an electric motor and used for operating the anchor lines, gantry and spud.

FIG. 173.—Ladder dredge operating on Fox River, Wisconsin. (Courtesy of The Bucyrus Co.)

The hulls were built of Oregon fir and strongly braced and bolted together. The dredge was 75 ft. long, 31 ft. wide and 6 ft. deep. Quarters for the crew were provided on the upper deck, where the pilot house was also located, whence the operator had complete control of the operation of the plant and from which a view of the whole work was afforded.

The intermediate scows were 40 ft. long, 16 ft. wide and 3 ft. deep, each carrying a belt conveyor 65 ft. long. The delivery scow was trapezoidal in shape, having a length of 31 ft. 4 in., 16 ft. 4 in. wide and 2 ft. deep at the receiving end and 33 ft. 4 in. wide and 4 ft. deep at the delivery end. The hull was given this shape so as to support the overhanging load of the delivery conveyor and to secure a greater angle of gyration when the scow is attached to the dredge.

The capacity of the dredge averaged 200 cu. yd. per hour in tough clay and hard-pan under adverse conditions. The preliminary test showed a capacity of 400 cu. yd. per hour in ordinary soil under favorable conditions. Most of the water raised by the buckets was lost on the conveyors and the excavated material was deposited along the banks in a nearly solid condition. The crew of the plant consisted of 9 men and the cost of operation averaged about $30.00 per day.

273. Hydraulic Dredges.—The hydraulic dredge has undergone a great development during the last 25 years to supply the increasing demand for an excavator for the maintenance of the channels of the navigable rivers of this country. The requirements for this class of earthwork are for an excavator of great capacity, power and high economy in the removal of great quantities of rather loose, soft material. As a result of many years of investigation and trial, the Corps of Engineers of the U. S. Army has adopted the hydraulic dredge as the type of excavator best adapted for this class of work. The Mississippi River Commission has been using a fleet of hydraulic dredges (about 10 in number) during the past 14 years (since 1904) in the maintenance of a channel in the lower Mississippi.

Originally the suction dredge was used largely for silt and sand excavation, but recent experience with new types of cutters and the use of the water jet for loosening the material has demonstrated the practicability of its efficient use in the excavation of the more tenacious materials such as clay.

274. Use of Hydraulic Dredge in Washington.—As a recent example of the use of electric power in the operation of a hydraulic dredge, the following description of the dredge "Washington" will be given.

This dredge was built by the Tacoma Dredging Company of Tacoma, Washington, for the dredging out of the Puyallup River in Tacoma harbor.[1]

The dredge was operated by electric power taken from one of the 60,000-volt, 60-cycle, three-phase transmission lines of the Seattle Tacoma Power Company. This voltage was stepped down to 2300 volts at a temporary substation, located near the scene of the work. From the substation the distributing circuit was carried on a temporary pole line along the water's edge. The switchboard panel in the pilot house of the dredge was connected to the distributing circuit by a three-phase flexible cable, of sufficient capacity to transmit electric power equivalent to a total of 1500 horse power. This cable was carried along the

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[1] Quoted from the *Electric Journal,* March, 1910.

discharge pipe, from which it extended to the shore line at convenient points.

The electrical equipment of the dredge provided for the operation of the cutter, the spuds, the pump and the several auxiliaries.

The cutter was operated by a wound-rotor type, 150-h.p., 2300-volt, 690-r.p.m., semi-enclosed motor. A drum type reversing controller, with gird resistance, was used to operate the motor from the pilot house. The motor was equipped with a special bearing and was connected to the cutter by double reduction gearing. The whole equipment was designed to operate at the angle at which the cutter was operating, the normal position of operation being at an angle of about 45 degrees with the horizontal.

The cutter was raised and lowered by a direct-connected hoist, which was driven by a 30-h.p., 220-volt, two-phase, 850-r.p.m., wound-rotor type motor. This motor was also controlled from the pilot house by a drum type reversing controller with gird resistance.

Two large timber, iron-shod spuds were located in the stern of the dredge. They served to brace the dredge as the cutter moved forward into the bed of the stream. By raising and lowering these spuds alternately, the dredge could be swung in an arc and allow the cutting of a channel 40 ft. to 50 ft. wide and from 10 ft. to 15 ft. deep. The spuds were operated by a 60-h.p., 220-volt, wound-rotor type motor.

The main suction pump was of the single-runner centrifugal type, operating at a speed of 460 r.p.m. It was located about amidships and connected by a rope drive to two 500-h.p., 2300-volt, self-contained wound-rotor type motors. The two motors were operated in multiple on a single shaft.

The discharge pipe was a 26 in. diameter, wooden-stave pipe and took care of a discharge of 21,000 gal. per minute.

Several smaller motors of the squirrel-cage type were used for the operation of small auxiliaries, such as a lathe, an air pump, etc.

This dredge was in operation a little over a year and worked very satisfactorily. The power equipment furnished a continuous load of from 900 to 1250 h.p. for 24 hr. a day and 7 days a week. The dredge handled 30,000,000 gal. of a heavy solution of mud and water per 24-hr. day.

TABLE XXIV.—COST OF HYDRAULIC DREDGES ON MISSISSIPPI RIVER

Name of dredge	Size of pump, in.	Date built	Length of pipe line		Diameter of pipe line		Initial cost of dredge and pipe line	Output, cu. yd.	Cost of operation[1]	Cost per cu. yd.
			Suction, ft.	Discharge, ft.	Suction, ft.	Discharge, ft.				
Geyser	10	1893	65	520	12	12	$ 5,450	67,922	$7,880.84	$0.116
Hecla	15	1901	65	500	18	15	27,380	190,120	9,850.19	0.051
Pelee	15	1909	65	600	18	17	36,130	303,365	18,601.23	0.061
Vesuvius	15	1909	65	600	18	17	33,375	427,956	15,026.48	0.030
Etna	18	1909	80	500	18	18	29,415	422,024	17,514.48	0.041
Mayon	18	1912	80	500	18	18	38,500	158,737	6,031.05	0.038
Taal	18	1912	80	500	18	18	38,500	202,221	7,384.14	0.036
Apo	18	1912	80	500	18	18	38,500	73,123	9,225.82	0.126

[1] Costs do not include care, repair or use of plant.

275. Use of Hydraulic Dredges on Upper Mississippi River.[1]—Since 1912, extensive dredging operations have been carried on to construct a 6-ft., low-water channel in the Mississippi River from St. Paul, Minnesota to the mouth of the Missouri River. The width of the channel varies from 300 ft. at St. Paul to 1400 ft. at the mouth of the Missouri River and is narrow in comparison with the width of the river at these points.

The accompanying table gives a statement of the size, capacity, cost and excavation costs of 8 suction dredges in operation during the working season of 1912.

The accompanying table shows a total excavation of 1,845,486 cu. yd. at a cost of $91,514.23 during an actual working period of 8848 hours. This gives an average output of 208.58 cu. yd. per pump hour per dredge at a unit operating cost of $0.0495 per cubic yard, not including plant up-keep or rental.

276. Use of Suction Dredge on Lower Mississippi River.[2]—During 1912 and 1913, the U. S. Government has used a large sea-going suction dredge of the Fruhling type, the "New Orleans," in the

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[1] Abstracted from *Engineering News*, July 24, 1913.

[2] Astracted from *Professional Memoirs*, Corps of Engineers, U. S. Army.

excavation of the Southwest Pass at the mouth of the Mississippi River.

The dredge is 315 ft. long, 50 ft. wide and 26 ft. deep. The hull is of steel and is provided with a stern well in which the dredge arm operates. The dredge is of the suction-hopper type, and is propelled by twin screws and controlled by twin-rudders. The cutter can excavate to a depth of 50 ft. below light-water line. The hopper has a length of 93¾ ft. and a capacity of 3000 cubic yards.

The operating equipment consists of four sets of triple expansion marine engines, having cylinders 12 in., 19 in. and 32 in. in diameter with a common stroke of 24 inches. The total capacity of the engines is 2500 i.h.p. The two forward sets of engines are direct connected to two 26-in. centrifugal dredging pumps, equipped with runners of small diameter, chambers lined with manganese steel, and removable wearing pieces of the impellers. Three vertical duplex pumps are used for supplying water under pressure to the head jets and hopper pipes. Steam is supplied by four water-tube boilers, having a heating area of 12,664 sq. ft. and a grate area of 317 square feet.

The excavating equipment consists of a suction head of the Fruhling type, attached to the end of the drag arm, which is hinged and suspended from the stern of the vessel. Water at 200 lb. pressure can be used as jets on the cutting edge to loosen hard material or as mixing water to loosen up material adhering to the inside of the head.

The following table gives a statement of the operations of the dredge in Southwest Pass, during the fiscal years, 1912 and 1913.

Item	1912	1913
Character of material	Sand and mud	Sand, mud and silt
Average distance to dump	2 miles	3 miles
Quantity dredged	186,515 cu. yd.[1]	1,280,054 cu. yd.
Total number of loads	187	934
Number of loads per working day	3.9	4.28
Average quantity per day	3,885.7 cu. yd.	5,871 cu. yd.
Average quantity per load	997.4 cu. yd.	1,371 cu. yd.
Average quantity per hour	399.7 cu. yd.	786.75 cu. yd.
Percentage of time pumping	29.50	18.58

[1] Dredge began operations, April 12, 1912.

Item	1912	1913
Percentage of time going to and from dump	14.30	8.23
Percentage of time lost from other causes, including night	56.20	77.19[1]
Total service hours	1,056	8,760
Operating cost	$21,009.06	$82,085.49
Average cost per working hour	$29.51	$23.35
Number of days when dredging	48	218
Average number of working hours per day	14 hr. 40 min.	16 hr. 7 min.
Average time to dredge one load	1 hr. 39 min.	1 hr. 45 min.
Average dumping time	13 min.	12 min.
Average time going to and returning from dump	48 min.	46 min.
Total operating cost	$23,199.06	$92,730.22
Cost per cu. yd. without repairs	$0.111	$0.0685
Cost per cu. yd. with ordinary repairs	$0.124	$0.0688
Total cost per cu. yd. with extraordinary repairs	$0.124	$0.0724
Fuel, tons	1,411.74	6,753.64
Cost per ton	$4.00	$3.95
Fuel, per cu. yd. dredged	15.12 lb.	10.55 lb.
Total mileage of dredge	1,152	4,813
Total cost per yard-mile	$0.062	$0.0241

During the fiscal year 1914, up to April 1st, 1,060,969 cu. yd. were removed at a cost of $0.0607 per cubic yard.

II. HARBORS

277. General.—The excavation of channels in harbors involves the use of some type of floating dredge; the selection depending upon the local conditions regarding location of work, tidal range, material, etc.

In well-protected, land-locked harbors, the non-propelling, spud-operated type of dredge can be used to advantage. But in large exposed harbors, the sea-going ship type of dredge must be used.

The nature of the material to be removed from the channel bed is an important factor in the selection of the most efficient type of dredge. Silt and loose sand in large quantities can be most economically excavated by a suction or hydraulic dredge and harder materials by a dipper dredge, when the latter can be used.

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[1] Includes night work when a single crew worked.

Rock must be previously broken up by a rock breaker or by a drill boat.

The removal of large quantities of material from the channels of harbors, ocean bars, etc., requires the use of large capacity, self-propelling, self-contained dredges which are built of sufficient strength to withstand rough weather conditions. However, as a general rule, it may be stated that more economical results are secured by the use of dredges of about 500 h.p. capacity rather than the machine of very large power. This is especially true as to ladder dredges, while suction dredges of great capacity have been successfully used.

FIG. 174.—Dipper dredge constructing harbor channel.

278. Floating-dipper Dredges.—The floating-dipper dredge is especially adapted to the excavation of hard material, the removal of old piers, cribs, etc., in protected or land-locked harbors. The universal scope of operation of this type of dredge; its power to excavate all classes of soil, pull stumps, remove large boulders, bridges, piles, cribs, etc., drive piling, etc., make it of especial value in the construction of harbor structures such as docks, piers, ship-yards, dry-docks, etc.

279. Use of Dipper Dredge in New York.[1]—The Corps of Engineers of the U. S. Army used the dipper dredge "Sodus," during

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[1] Abstracted from Report of Chief of Engineers, U. S. Army.

the fiscal year ending June 30, 1912, in the dredging of a channel in Oswego Harbor, New York. The dredge operated in from 7 ft. to 14 ft. of water, excavated to a maximum depth of 15 ft. and removed 42,500 cu. yd. of silt and sand from April 29, 1912 to June 30, 1912.

The dredge had a wooden hull 100 ft. long, 35 ft. wide and 9 ft. 8 in. deep, and was operated by a horizontal, 14-in. × 16-in. engine. It was equipped with two dippers, one of 3.22 yd. capacity and one of 4½ yd. capacity. The dredge was built in 1910–12 and cost $36,000.00. The average working capacity of the excavator was 250 cu. yd. per hour. Figure 174 shows the dredge in operation.

The operating record of the dredge from April 29, 1912 to June 30, 1912 is as follows:

Days in operation	42
Hours in operation per day	8
Distance to dump, miles	0.75
Number of scows loaded per day	4.5
Average scow load, cu. yd	230
Time to load scow, hours	1.4
Maximum output per hour, cu. yd	250
Maximum output per day, cu. yd	1610
Time lost, days,	
Repairs, hull	1.5
Repairs, machinery	11.25
Weather	2.5
Total time lost	15.25

The operating cost of the dredge is as follows:

Labor	$1428.00
Coal	307.00
Kerosene	2.00
Lubricating oil	14.00
Supplies,	
Food	344.00
Miscellaneous	100.00
Repairs, hull	57.00
Repairs, machinery	269.00
Laundries, ice, etc	23.00
Total dredge cost	$2544.00
Tow-boat operations	973.00
Barge and scow repairs	55.00
Barge and scow, miscellaneous	82.00
Total field cost	$3654.00
Office, superintendence, survey, etc	178.00
Grand total	$3832.00

Based on an output of 42,500 cu. yd. of excavation, the unit costs would be as follows:

Dredge operation	$0.059 per cu. yd.
Transportation of spoil	0.026 per cu. yd.
Office, superintendence, etc	0.004 per cu. yd.

280. Use of Dipper Dredges in British Columbia.—The Department of Public Works of Canada has used two dipper dredges in the excavation of channels in Vancouver Sound.

The "Mudlark" was built in 1888 and is constructed of wood throughout. The hull has a length, including the boom, of 122 ft., a width of 30 ft. and a draft of 5 ft. 6 inches. The operating equipment consists of a double-cylinder engine for dredging, and moving the forward spuds, an independent engine for the operation of the rear spuds, and a pair of steam cylinders on the upper deck for swinging the boom. The excavating equipment consists of a 2½-yd. dipper which can excavate to a depth of 40 feet.

Following is a statement of the operation costs for the fiscal year 1911–12:

Operation cost of dredge	$20,632.27
Operation cost of two tugs	5,247.52
Repair cost of dredge	7,649.25
Repair cost of scows	3,628.64
Repair cost of tugs	1,801.09
Total cost	$38,958.77
Total excavation	90,675 cu. yd.

Cost of excavation, $38,958.77 ÷ 90,675 = $0.429 per cu. yd.

The "Ajax" was built in 1908, and with the exception of the superstructure, is constructed entirely of steel. The length of hull, including boom, is 159 ft., the width is 38 ft. and the draft 9 feet. The operating equipment is of the standard type and steam operated. The dredge is provided with two dippers, one of 3 cu. yd. and the other of 5 cu. yd. capacity, and the efficient excavating depth varies from 15 ft. to 40 feet.

The following statement gives the operating costs for the fiscal year 1911–12:

Cost of operation of dredge	$27,951.48
Cost of operation of tug	6,098.18
Repair cost of dredge	10,993.63
Repair cost of scows	1,574.79
Repair cost of tug	689.37
Total cost	$47,307.45
Total excavation	154,190 cu. yd.

Cost of excavation, $47,307.45 ÷ 154,190 = $0.307 per cu. yd.

The cost of excavation with the two dipper dredges is very high on account of the great amount of time consumed in making heavy repairs.

281. Ladder Dredges.—Ladder dredges for harbor work may be of two classes, depending on the conditions and location of the proposed service. In protected and land-locked harbors, the larger sizes of river dredge may be used but in exposed harbors and open sea work, the sea-going type of dredge is necessary. The latter class consists of a self-contained, self-propelled vessel built of steel and of great strength to withstand the storms and the strain of the work. The hull is divided into several compartments separated by water-tight bulkheads for safety against submersion.

Sea-going ladder dredges are made of two types; the single and the hopper dredge. The former consists of a vessel carrying all the necessary operating and excavating equipment. The tower is located amidship, and the material is discharged into scows through a central chute terminating on either side of the vessel. The latter or hopper dredge, is built larger to contain hoppers into which the material is discharged. The hopper bottoms are provided with trap doors controlled by chains and so arranged that they can be operated freely. When the hoppers are filled with the excavated material, dredging operations are suspended and the vessel moves to deep water or the dumping ground, where the hoppers are discharged.

Sea-going ladder dredges have a central longitudinal well in which the ladder operates. The tower is generally located amidship to secure stability. For deep water excavation, the ladder is often placed in a well, located in the bow of the vessel both for navigation and dredging. For excavation at varying depths, the well is open and located in the stern, the operating machinery being placed in the forward section of the vessel.

In semi-sea-going ladder dredges, more attention is given to securing rigidity and stability of the excavating equipment than in providing for sea-worthy qualities. The hull is generally open to offer great latitude for the use of the ladder at various depths. The ladder well is located either at the stern or bow of the vessel, the operating equipment being placed at the other end in either case. Some dredges of this class are not self-propelling and must be towed from place to place, but most vessels are equipped with propelling machinery consisting of a single screw. Sometimes a single paddle wheel located in the ladder pit furnishes the means of propulsion.

282. Use of Ladder Dredge in British Columbia.—The Department of Public Works of Canada has been using a ladder dredge in the widening of the First Narrows at Vancouver.

The dredge is built of steel, has an overall length of 206 ft., a beam or width of 36 ft. 6 in., and a maximum draft with ladder raised of 12 feet.

The operating equipment consists of two compound, surface-condensing engines for either the operation of the bucket line or the propulsion of the ship. The engines are so arranged that either one can be used for either purpose and each develops about 600 i.h.p.

The excavating equipment consists of a ladder of sufficient length to dredge to a depth of 50 ft. and a bucket line of 48 buckets. Each bucket has a capacity of 24 cu. ft. and is provided with manganese-steel replaceable lips.

The following table gives the output and cost of operation for the fiscal year 1911–12:

Cost of operation of dredge	$53,445.65
Cost of operation of four tugs	9,412.16
Rent of three tugs	27,450.91
Repairs to dredge	8,036.67
Repairs to scows	4,136.87
Repairs to tugs	937.66
Total cost	$103,419.92
Total excavation	621,310 cu. yd.

Cost of excavation, $103,419.92 ÷ 621,310 = $0.166 per cu. yd.

283. Use of Ladder Dredge in Massachusetts[1].—In 1910, a large ladder dredge was used in clearing out a channel at the entrance of Boston Harbor. Dipper dredges had previously proved unsatisfactory on account of rough weather conditions.

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[1] Abstracted from *Engineering News*, January 27, 1910.

The work required the removal of hard-pan, clay, stone and gravel at a maximum high-tide depth of 50 feet.

The dredge "Denver" was a heavily built wooden vessel, 242 ft. long, 36 ft. beam and a depth of 21½ feet. The vessel was self-propelling and operated by steam engines of 700 horse power.

The excavating equipment consisted of a steel ladder frame of sufficient length to allow excavation to a depth of 51 feet. The buckets had a capacity of 1¼ cu. yd. and the chain was ordinarily driven at a speed of 14 buckets per minute.

The dredged material was discharged through a hopper and chute into scows of 1800 cu. yd. capacity. The dredge was maintained in position by two bow and two stern lines attached to anchors set out at suitable distances from the vessel. A continuous feed over the bottom was secured by steam winches acting on the mooring lines. A 700 ft. width of channel was thus secured at one time.

The average daily output was 8000 cu. yd. and the maximum was 10,500 cubic yards. In a run of 55 min., 1475 cu. yd. were removed. The loss of time and cost of repairs during a year's run were about the same as for a dipper dredge of about the same class.

284. Hydraulic Dredges.—The so-called sea-going, hydraulic dredge is generally used in harbor improvement work. This class of dredge is built in two types; the single excavating machine, and the hopper dredge. The former is simply an excavating machine requiring barges or scows for the removal of the excavated material while the latter is both an excavating and transporting machine. The former type is generally employed for relatively shallow work in protected harbors while the hopper dredge is especially useful for deep water work in locations subject to rough weather conditions. The hopper dredge is a self-contained, self-propelling vessel for heavy, strong construction and provided with a carrying capacity of from 2000 cu. yd. to 3000 cubic yards. The vessel transports the excavated material to deep water, where tidal action will not affect the dump.

The hopper of a hopper dredge consists of two rows of bins located amidship and usually separated by the pit or well in which the suction ladder operates. In some cases the hoppers are located fore and aft in the hull, the operating machinery being placed amidship. The hoppers are generally made with sloping sides and provided with bottom hinged doors for the free discharge of the material. Recently, a few dredges have been equipped with pumps and discharge pipes for the removal of the material in the hoppers by pumping.

The ordinary method of channel excavation is as follows. The suction pipes are lowered to the bottom when the dredge is at the site, and the vessel moves ahead slowly while the dredging pumps are operated. In this manner, one or more furrows are made, depending on the number of cutters, drags and suction pipes. When the hoppers are filled, the vessel proceeds to the deep water dumping ground where the material is discharged. The vessel's course in dredging should be so arranged that the channel will be closely followed and a full load obtained in the shortest run.

Fig. 175.—Scraper of the hydraulic dredge "Fruhling."

285. Use of Hydraulic Dredges in British Columbia.[1]—The Department of Public Works of Canada has used two different types of hydraulic dredge for channel improvement in British Columbia.

The "Fruhling" was built in 1906 and was especially designed for dredging sand bars to a maximum depth of 45 feet.

The dredge is of the hopper type, self-contained and self-propelling and is of steel throughout. The hull has a length of 187 ft., a beam of 34 ft. 6 in. and a draft of 14 ft. 10 inches. The operating equipment consists of twin-screw, surface-condensing engines. The dredging pumps are equipped with open runners 54 in. in diameter and 16 in. suction pipes. They operate at

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[1] Abstracted from *Engineering Record*, August 23, 1913.

200 r.p.m. and are arranged so as to draw from the header, the hoppers or the channel, and to discharge into the hoppers or directly into barges. The excavating equipment consists of a great steel scraper head which is hinged to the ladder at the end of the suction pipe. See Fig. 175. The hoppers have a capacity of about 800 cubic yards.

The following statement gives the operating cost for the fiscal year 1911–12, while excavating sand bars at the mouth of the Fraser River.

Operation cost of dredge	$35,055.30
Repair cost of dredge	10,713.35
Total cost	$45,768.65
Total excavation	669,100 cu. yd.

Cost of excavation, $45,768.65 ÷ 669,100 = $0.068 per cu. yd.

The other hydraulic dredge used on this work is the agitator suction dredge "King Edward." This excavator was built in 1901, and is of the stern-wheel steamboat type. The excavating equipment consists of a 20-in. centrifugal pump operated by triple-expansion, direct-connected engines at a speed of 170 r.p.m. The dredging depth varies from 6 ft. to 45 feet.

The following table gives the operating costs for the fiscal. year 1911–12, while excavating channels near the mouths of the Fraser River and False Creek, Vancouver.

Operation cost of dredge	$32,531.34
Tug rental	2,740.00
Operation cost of tug (5 months)	2,028.54
Repair cost of dredge	6,320.92
Repair cost of scows and pontoons	1,523.93
Repair cost of tug	408.76
Total cost	$45,553.49
Total excavation	379,520 cu. yd.

Cost of excavation, $45,553.49 ÷ 379,520 = $0.121 per cu. yd.

286. Use of Electrically Operated Hydraulic Dredge in Minnesota.—During the working season of 1915, an electrically operated hydraulic dredge was used in extensive excavation and filling-in work around Lake Nakomis, Minneapolis, Minnesota.

The hull was of timber, 80 ft. long, 24 ft. wide and 7 ft. deep and drew 40 in. of water. Figure 176 shows the dredge in operation.

The excavating equipment consisted of a centrifugal pump equipped with a 54-in. runner and operated at speeds of 250 r.p.m. and 300 r.p.m. by a 500-h.p. synchronous motor running at 720 r.p.m. Speed reduction and change were affected through two sets of cut helical gears running fully enclosed, and lubricated with oil. A lever on top of the gear box connected with a rigid clutch, controls and locks the gears in position for the required speed. The loss of efficiency in transmission through the reduction gears is less than 2 per cent., and results over a period of 2 months' operation gave a power consumption of from ½ k.w. to ¾ k.w. per cubic yard of excavated material discharged through a pipe line varying in length from 500 ft. to 2000 feet.

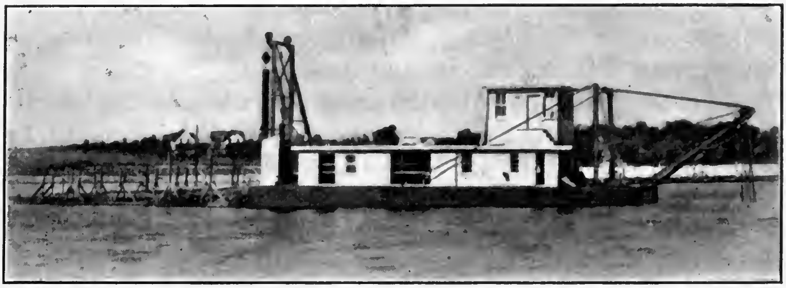

Fig. 176.—Electrically operated hydraulic dredge on lake improvement. (*Courtesy of Norbom Engineering Co.*)

The runner speed of 250 r.p.m. was used in pumping through pipe lines of from 1200 ft. to 1500 ft. in length and under a head of 12 feet. The higher speed of 300 r.p.m. was used in pumping against higher resistances.

The cutter was operated by a 50-h.p. slip-ring motor and the main hoisting engine by a 30-h.p. motor of the same type. The hoist comprised five drums and two winches. A water-jet exhauster, operated from an auxiliary pump, was used for priming the main pump.

The current used was 2300-volt, alternating, three-phase 50-cycle and was used without stepping down on the three motors. The current was reduced to a lower voltage for the service motor, and a motor generator set was used for furnishing direct current for lighting. The lighting equipment consisted of a 6000 candlepower searchlight, several arc and incandescent lamps.

The output of the dredge under average conditions was 5000 cu. yd. per day, place measurement. The maximum output was about 7000 cu. yd. in 24 hours.

287. Subaqueous Rock Breaking.—When solid rock forms the bed of a river or harbor channel, the material must be broken up into small fragments before it can be removed. The breaking up of the rock may be accomplished in two differnt ways:

1. By hammering, using a Lobnitz Rock Cutter.
2. By drilling and blasting with a drill boat.

The operation of a rock cutter consists in the raising and dropping of a heavy ram, either by gravity or by compressed air. The ram drops upon the rock surface and gradually pulverizes and shatters the material. The impact of the ram should be repeated on the same spot, a slight deviation causing a considerable reduction of efficiency. The blows should be directed at spots about 3 ft. on centers, and the rock shattered to a depth of from 3 ft. to 5 ft., the thickness depending on the character of the material. The broken rock is then removed by a dredge, and the process repeated until the desired depth is reached.

The drill boat has been developed to an efficient condition and some one of several types is generally used in this country at the present time. See Chapter XV. By using a barge with several drills, large quantities of rock may be drilled and blasted in a short time. The holes are thus simultaneously made in rows, the holes in each row being from 5 ft. to 8 ft. apart and the spacing of the rows depending on the character of the rock to be handled. The holes are charged with dynamite cartridges and the latter exploded by an electric machine from the drill boat.

288. Use of Rock Cutters and Drill Boat in England.[1]—The two methods of subaqueous rock excavation were used in 1906 at Blyth, England in the breaking up of 500,000 cu.yd. of sandstone, and shale. Two Lobnitz rock cutters, and one drill boat were employed on this work. Two 700-ton clam-shell dredges of the hopper type were used for the removal of the fractured material.

Each rock cutter consisted of a steel barge carrying shear-legs which supported a steam ram, 17 in. to 19 in. in diameter, 40 ft. to 50 ft. long and weighing 15 tons. The ram was operated by a friction-clutch drum and was allowed to fall through an average

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[1] Abstracted from *Engineering*, London, June 28, 1907.

height of 8 feet. Eight to nine blows of the ram were required to break up the rock to a depth of 3 feet. The boat was anchored in position by chains attached to steam winches. The working positions were from 3 ft. to 4 ft. 6 in. on centers, depending on the character of the rock.

The following statement gives the average output and cost of operation of one cutter per working day of about 22 hr., based on 6 months' operation.

Labor	$11.18
Coal, stores, and water	4.54
Repairs	15.30
Insurance	1.35
Interest @ (4 per cent. of $33,110)	3.64
Depreciation @ (2½ per cent. of $33,110)	2.27
Total daily cost	$38.28
Total excavation	129.71 cu. yd.

Cost of excavation, $38.28 ÷ 129.71 = $0.29 per cu. yd.

The drill barge was equipped with 6 drills operated by steam power. The drill holes were spaced 5 ft. on centers in each row and 6 ft. 2 in. between rows. Bellite was used as blasting material and was placed in the holes through drilling tubes, and fired by fuses and detonators. The average amount of rock blasted was about 70 cu. yd. per working day and the average cost of drilling and blasting was about $0.06 per cubic yard.

The broken up rock was excavated by the hopper dredges, which were equipped with two sets of buckets, one set for rock dredging and the other for sand, clay or gravel and having 50 per cent. greater capacity. The bucket lips were of cast steel and the pins and bushings of the bucket chain of manganese steel. The lips of the buckets for rock dredging were set at an angle of about 27 degrees to the backs, and those for sand, etc., at an angle of about 55 degrees.

The rock was elevated and deposited in the hoppers, and carried to sea and discharged in deep water, or occasionally dumped into barges having grilled hoppers, thus providing for the screening and segregation of the rock.

The average amount of blasted rock removed by one dredge during a working day of 22 hr. was 158 cu. yd. and the average cost was $0.76 per cubic yard. The average output of one dredge per day for rock broken up by the rock cutter was 182 cu. yd., and the average cost of excavation was $0.66. The quantity of rock removed by the dredges was 15 per cent. greater for the material broken up by the rock cutter than that drilled and blasted on account of the smaller size of the fragments.

The following is a comparative cost statement of the complete operation by the two methods of breaking.

		Per cubic yard
Drilling and blasting		$0.72
Dredging		0.76
Total cost		$1.48
Breaking by rock cutter	$0.29	
Dredging	0.66	
Total cost		$0.95
Saving in cost by using rock cutter		$0.53

289. Use of Rock Cutter and Drill Boat in British Columbia.—A Lobnitz rock breaker and a drill boat form part of the dredging fleet operating in British Columbia waters under the supervision of the Department of Public Works of Canada.

The rock breaker consisted of a barge equipped with two cutters, one weighing 20 tons and suitable for working depths up to 40 feet. Each cutter had a detachable projectile steel tip with a hard center core. The following is a statement of the cost of operation for the fiscal year 1911–12, while working in channel improvement in Victoria Harbor.

Operation cost of cutter	$7869.21
Tug rental	373.57
Repair cost of cutter	784.21
Total cost	$9026.99
Total amount of rock broken	1000 cu. yd.

Cost of rock broken, $9026.99 ÷ 1000 = $9.026 per cu. yd.

The drill boat comprised a scow upon which is mounted a 5-in. drill which is carriage operated and can be moved to work through wells spaced on 18-in. centers. The scow was raised above high-water level and supported on the four corner spuds before drilling commenced. The maximum depth of drilling was 35 ft. below the scow floor. The steam and all auxiliary equipment were placed on a small scow floating alongside the drill barge. The cost of operation during the fiscal year 1911–12 is given in the following statement. The work was done in channel improvement in Victoria Harbor.

Operation cost of drill-boat	$9,978.12
Repair cost of drill boat	414.26
Total cost	$10,392.38
Number of 2½-in. holes drilled	992
Total depth of holes	4442.6 ft.
Total amount of rock broken	1690 cu. yd.

Cost of breaking up, $10,392.38 ÷ 1690 = $6.13

290. Use of Drill in Shallow Water in British Columbia.[1]—During the Spring of 1916, a drill was used for the breaking up of rock at the dry dock of the Grand Trunk Ry., Prince Rupert, British Columbia. The water was shallow but the tidal variation was about 20 ft. and precluded the use of any of the usual types of drill barges or platforms. So a temporary platform was built over the site, there being sufficient mud overlying the rock to hold the lower ends of the piles in place.

The material was a hard schist weighing about 168 lb. per cubic foot. The holes were 3 in. in diameter and spaced 5 ft. on centers. The drill used was an Ingersoll-Rand, K64 with a 6½-in. bore and a 9-in. stroke. The drilling was carried on during 54 days of 24 hr. each. The average rate of drilling was 5 ft. to 6 ft. per hour while the actual return was about 8 ft. per hour. The maximum record was 120 ft. in 20 hours. The total length of hole drilled was 4269 ft. with a loss of 299 ft., leaving a net result of 3970 feet.

The blasting was done with 60 per cent. dynamite, made up in special sticks 15 in. long and 2 in. in diameter. The broken up rock could be easily handled with an orange-peel bucket.

III. CANALS

291. Preliminary.—This division will discuss the various types of machines used in the construction of artificial waterways such as the Chicago Drainage Canal, the New York State Barge Canal, the Welland Canal, the Panama Canal, etc.

Many sections of large canals and artificial waterways are constructed through dry material and hence a much greater diversity of excavators may be used in this class of work, than is possible

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[1] Abstracted from *Engineering News*, July 27, 1916.

in the construction of channels in lakes, rivers and harbors. For example, in the building of the Chicago Drainage Canal, about a quarter of a century ago, almost every well-known type of excavator was used, especially of the dry-land class, from a slip scraper to drag-line excavator. Several new types of machines such as the tower excavator and two forms of templet excavator were devised especially for this work. Hence in the following statement a discussion of the use of rather a wide range of types of excavating machines will be given, and a number of examples of costs quoted to show the *comparative* cost of excavation with the different machines.

292. Scrapers.—Slip and wheeled scrapers have been used in the past on the construction of large artificial waterways, but their use has been largely discontinued in recent years since the introduction of the large power machines, which are generally more economical for work of this magnitude. Thus the scraper-bucket machine or the tower excavator would under ordinary conditions be more efficient than a scraper for a canal in dry earth, which would be of a cross-section required for navigation.

293. Use of Wheeled Scrapers on the Chicago Drainage Canal.—The following data give the cost of excavation work on the Chicago Drainage Canal, referring to those sections where wheeled scrapers were used.

"The soil moved by wheelers was a 'fairly soft clayey loam' and the average haul was about 400 ft., the material being deposited in spoil banks.

"On the Brighton Division, Section K, 68,300 cu. yd. were moved in 62 days, the average force being 23.8 men and 36.8 teams with drivers. There were two plows and 24 No. 3 wheelers in use, hence each plow loosened 550 cu. yd., and each wheeler moved 46.1 cu. yd. per 10-hr. day, while the average output, including snatch teams of which there appear to have been one for every three wheelers, and including plow teams, was about 30 cu. yd. per day per team.

"For Summit Division, Section E, the haul was 400 feet. The number of men engaged is not given, but we have assumed two-thirds man per team, which is not far from right.

"The table shows that there were about five wheelers to each plow, hence each plow must have loosened about 200 cu. yd. in 10 hr. the hardest section being from Sta. 480 to Sta. 490, where 168 cu. yd. were the average per plow team per day. Doubtless two teams were worked on each plow. One snatch team to every 4.4 wheelers appears to have been the average, or each snatch team loaded about 175 cu. yd. a day at a cost of two cents per cubic yard."[1]

TABLE XXV.—AMOUNTS AND COST OF WHEEL SCRAPER WORK

Stations	Average		Total excavation, cu. yd.	Daily average, cu. yd.		Ratio of teams		Cost, cents per cu. yd.	(1)
	Fill ft.	ut, ft.		Per team	Per wheeler	Wheelers to plows	Wheelers to team		
460–470	12	8.0	94,879	29.8	42.2	$5\frac{1}{3}$ –1	$4\frac{4}{10}$–1	15.1	(2)
470–480	12	8.3	98,515	27.1	39.3	$4\frac{9}{10}$ 1	$4\frac{4}{10}$–1	16.6	(2)
480–490	11	7.0	85,761	24.4	35.2	$4\frac{8}{10}$–1	$4\frac{3}{10}$–1	18.4	(2)
490–500	7	3.4	33,185	35.0	50.1	$4\frac{9}{10}$–1	$4\frac{4}{10}$–1	12.9	(3)
500–507	7	4.3	29,678	28.3	42.1	$4\frac{6}{10}$–1	$3\frac{7}{10}$–1	15.9	(4)

(1) Assuming two-thirds man per team.
Material: (2) Very stiff blue and yellow clay with a few large boulders.
(3) Loamy clay.
(4) Stiff clay.

294. Graders.—The elevating grader like the scraper is a machine of rather small and limited capacity to use on the excavation of large channels. However, the grader may be often employed to advantage in coöperation with the large power excavators. For example, during the construction of the New York State Barge Canal, elevating graders were used to form levees, behind which the material from hydraulic dredges could be discharged.

295. Use of Elevating Graders on Chicago Drainage Canal.—During the latter part of the year 1894, while waiting for the completion of the bridge conveyors which were to be used in the excavation of sections K and I of the Chicago Drainage Canal, and to keep up with the contract requirements as regards monthly progress, the earth to a depth of about 5 ft. over the entire area of the two sections was excavated and removed with elevating graders and dump wagons.

There were five New Era graders and 35 Austin Dump Wagons used on this work. Each grader was operated by 12 horses and three men and served by 7 dump wagons with three horses and a driver to each.

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[1] From "Earthwork and Its Cost," by H. P. Gillette.

The soil excavated was a soft clayey loam and the average haul was about 500 feet.

The average excavation[1] for each grader was 500 cu. yd. for a 10-hr. working day. Records kept on Section K during August and September, 1894, gave the average output as 490 cu. yd. and 515 cu. yd. per 10-hr. day, respectively. On Section I the average output for each grader for September, 1894, was 485 cu. yd. per 10 hours. The total time consumed on both sections was 123 10-hr. days, and the average daily force was 50.4 men, 41.9 teams, 22.3 wagons and 3.1 New Era graders. The average output per day worked for each quarter was 508 cubic yards. The use of these graders on the top-soil excavation of these two sections was very satisfactory.

296. Power Shovels.—The power shovel has been an important factor in canal construction during the last 25 years. The special province of this type of excavator is in the handling of the harder materials such as hard-pan and rock. The larger sizes of shovels of the first-class mounted on trucks of standard gage, and used in conjunction with trains of dump cars, are the most efficient for work of this character and scope. The reader should make a study of the methods of handling material on such work as the excavation of the Culebra Cut of the Panama Canal. Shovels up to 110-ton in size and equipped with 5 yd. dippers have come into general use. Recently the 40-ft. steel cars of 100,000 lb. capacity have been utilized for the removal of spoil. However, the most efficient size of power shovel to be used in any case must depend on the local conditions of material, haul, size of cross-sections, etc. In many cases which have come under the author's observation, it has been evident that the greater power and capacity of the largest size shovels did not compensate for the loss in speed of operation, the increased number of delays for shifts, and the difficulty of providing material cars of suitable strength and capacity.

297. Use of Steam Shovel in Ontaria, Canada.[2]—The work done was the excavation of a section of the Trent Canal near Trenton, Canada. The average cut was 10½ ft. and was side cutting. The material was gravel and was loaded into cars as high as the machine would reach. The shovel handled 16,000 cu. yd. from June 1 to 12, 1908, the average haul being 1200

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[1] "The Chicago Main Drainage Channel," by C. S. Hill.

[2] From *Engineering-Contracting*, October 14, 1908.

feet. From June 15 to 30, 20,000 cu. yd. were excavated and moved at an average haul of 1400 feet. The total excavation was 36,000 cu. yd. with an average haul of 1300 feet.

The outfit used consisted of a 65-ton Bucyrus steam shovel with a 2½-yd. dipper, two 12-ton Porter dinkeys, 22 dump cars of 4 cu. yd. capacity and about ⅛ mile of track. The cost of this outfit was approximately as follows:

1 65-ton shovel	$9,000.00
2 12-ton dinkey engines	5,000.00
22 4-ton dump cars @ $230.00	5,060.00
16 tons 20-lb. rails @ $32.00	512.00
1000 ties @ 10 cents	100.00
Total	$19,672.00

On this investment of $19,672.00, 2 per cent. was allowed for interest, depreciation and repairs, per month, making a monthly charge of $393.44.

The following statement is based on the fact that 26 days were worked during the month. The shovel worked 12 hr. per day and the track gang and water wagon 10 hr. per day.

Loading:		
1 shovel runner	$125.00	
1 cranesman	90.00	
1 fireman	60.00	
4 pitmen	156.00	
1 team hauling water	180.00	
50 tons coal @ $5.00	250.00	
Oil, waste, etc	10.00	
Total		$871.00
Hauling:		
2 dinkey runners @ $3.00 per day	$156.00	
2 brakemen @ $2.00 per day	104.00	
1 oiler @ $1.75 per day	45.50	
1 trackman @ $1.50 per day	39.00	
60 tons coal @ $5.00	300.00	
Oil, waste, etc	16.00	
Total		$660.50
Dumping:		
1 foreman @ $3.00 per day	$ 78.00	
16 laborers @ $1.50 per day	624.00	
1 water boy @ $1.00 per day	26.00	
Total		$728.00

Miscellaneous:

1 superintendent	$150.00	
1 timekeeper	65.00	
1 watchman	40.00	
Total		$255.00

Track Gang:

1 foreman @ $3.00 per day	$ 78.00	
5 laborers @ $1.50 per day	195.00	
Interest depreciation and repairs	390.00	
Total		$663.00
Grand total		$3177.50

Total amount of excavated material.......... 36,000 cu. yd.
Cost of excavation, $3177.50 ÷ 36,000 = 8.7 cents per cu. yd.

The cost of excavation may be divided up as follows:

Superintendence	$0.007
Loading	0.024
Hauling	0.018
Dumping	0.020
Track work	0.008
Interest, depreciation and repairs	0.010
Total	$0.087

298. Use of Power Shovels on Panama Canal.—The following notes of steam-shovel work have been taken from the Canal Record and several engineering periodicals.

Records for April, 1908 in four construction districts of the Culebra Division are given in table below.

Shovel number	Location	Excavated material, cu. yd.	Kind of material
216	Empire	2780	Rock and earth
124	Empire	1608	Rock
215	Bas Obispo	2904	Earth
127	Bas Obispo	2076	Rock and earth
202	Pedro Miguel	2600	Earth
123	Pedro Miguel	1469	Earth
222	Culebra	2612	Rock and earth
152	Culebra	1704	Rock and earth

Shovels in the "100" class are 70-ton shovels with buckets of 2½ cu. yd. capacity. Shovels in the "200" class are 95-ton shovels with dippers of 5 cubic yards. The shovels operate during an 8-hr. day.

On March 2, 1909, shovel No. 220 removed 3941 cu. yd. of earth and rock in an 8-hr. working day. The shovel was actually operating during 6 hr. and 50 min., the remaining period of 1 hr. and 10 min. being spent in waiting for cars.

During June, 1909, the following records were made:

Shovel No. 204, working in the Culebra District excavated 49,767 cu. yd. of earth in 25 working days or an average of 1990.7 cu. yd. per day.

Shovel No. 132, working in the Tabernilla District, excavated 30,021 cu. yd. of earth in 25 working days or an average of 1200.8 cu. yd. per day.

Shovel No. 223, working in the Culebra District, excavated 3268 cu. yd. of rock on June 24.

Shovel No. 132, working in the Tabernilla District, excavated 2060 cu. yd. of earth on June 26.

During August, 1909, the following records were made:

Shovel No. 223, working in the Culebra District, excavated 45,694 cu. yd. of earth in 26 working days, or an avergae of 1757.5 cu. yd. per day.

Shovel No. 204, working 8 days in the Culebra District, excavated 16,755 cu. yd. of earth or an average of 2094.4 cu. yd. per day; working 18 days in the Empire District, excavated 26,518 cu. yd. of earth, or an average of 1473.2 cu. yd. per day.

Shovel No. 217, working in the Culebra District, excavated 2549 cu. yd. of earth and rock on August 31.

Shovel No. 108, working in the Bas Obispo District, excavated 31,299 cu. yd. of earth in 26 working days, or an average of 1203.8 cu. yd. per day.

Shovel No. 127, working in the Tabernilla District, excavated 1750 cu. yd. of earth on August 14.

During May, 1909, the following records were made:

Shovel number	District	Excavation, earth, cu. yd.	Excavation, rock, cu. yd.	Total excavation, cu. yd.	Working days, cu. yd.
127	Chagres	34,894	....	34,894	25
114	Chagres	31,303	....	31,303	24
211	Empire	....	44,500	44,500	25
210	Empire	....	37,144	37,144	25
224	Culebra	....	41,672	41,672	25
208	Culebra	....	40,539	40,539	24

The following daily records were made during May, 1910:

Shovel number	District	Date	Character of excavated material	Excavation, cu. yd.
111	Chagres	May 6	Earth	1500
209	Chagres	May 3	Earth	1490
111	Chagres	May 7	Earth	1450
211	Empire	May 12	Rock	2432
211	Empire	May 11	Rock	2391
210	Empire	May 23	Rock	2165
217	Culebra	May 5	Rock and earth	3477
217	Culebra	May 6	Rock and earth	3249
208	Culebra	May 23	Rock	3059
231	Pedro Miguel	May 26	Rock	2850

The monthly records were based on place measurement and the daily records on car measurement.

The following table gives the record of excavation made by several 70-ton shovels during 8 months of 1910 on the relocation of the Panama railroad. This record is remarkably good considering that the work was done during a very rainy season.

Month, 1910	Output, cu. yd.	Average number of shovels	Number of working days	Output per shovel	
				Per day, cu. yd.	Per month, cu. yd.
January	206,334	8.24	25	1,002	25,040
February	214,411	7.91	23	1,179	27,106
March	234,571	7.31	26	1,234	32,089
April	212,097	7.15	26	1,140	29,648
May	212,135	7.88	25	1,077	26,921
June	236,689	8.00	26	1,138	29,586
July	197,069	7.44	25	1,060	26,488
August	250,341	7.04	27	1,318	35,575

During January, 1910, the following record of excavation was made:

Shovel No. 223, working in the Culebra District, excavated 50, 933 cu. yd. of rock in 25 working days, or an average of 2037.3 cu. yd. per day.

Shovel No. 219, working in the Culebra District, excavated 50,270 cu. yd. of rock in 25 working days or an average of 2010.8 cu. yd. per day.

Shovel No. 111, working in the Bas Obispo District, excavated 27,688 cu. yd. of earth in 23 working days, or an average of 1203.8 cu. yd. per day.

Shovel No. 218, working in the Empire District, excavated 3009 cu. yd. of rock on January 8.

The steam shovel No. 213, working in the Culebra District, on March 22, 1910, excavated 4823 cu. yd. of earth and rock, place measurement. The material was loaded on 235 Lidgerwood cars and the division of time was as follows:

Time loading cars	320 minutes
Moving up 20 times @ 5 minutes	100 minutes
Waiting for cars	55 minutes
Coaling shovel	5 minutes
Total time	480 minutes or 8 hours

The expense for labor and supplies is given below:

Labor:		
1 engineer, 1 day @ $7.56	$7.56	
1 cranesman, 1 day @ $6.48	6.48	
1 foreman, 1 day @ $2.83	2.83	
2 firemen, 1 day @ $1.67	3.34	
1 laborer, 8 hours @ $0.13	1.04	
7 laborers, 8 hours @ $0.16	8.96	
Total labor		$30.21
Supplies:		
5¼ tons of coal @ $4.41	$23.15	
3 gal. of car oil @ $0.18	0.54	
2 gal. of valve oil @ $0.31	0.62	
2 lb. of cup grease @ $0.10	0.20	
1 lb. of gear grease @ $0.08	0.08	
Total supplies		$24.59
Grand total		$54.80
Total excavation		4832 cu. yd.

Cost of excavation, $54.80 ÷ 4832 = $0.0114 per cu. yd.

299. Use of Power Shovels on Cape Cod Canal.[1]—During the period 1910–14, three steam shovels were used on a dry-earth section of the Cape Cod Canal in Massachusetts. The equipment

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[1] Abstracted from the *Excavating Engineer*, September, 1913.

consisted of two Bucyrus 70-ton shovels, one Marion model 60, two Baldwin and six Vulcan locomotives and seventy 4-yd. Western dump cars.

The material handled was sand, glacial drift and boulders, which was difficult to handle on account of surface conditions.

One of the 70-ton shovels worked 281 days and achieved an average daily output of 1456 cu. yd. and a monthly record of 44,301 cubic yards. From March 1, 1913 to February 28, 1914, the output was 909,010 cu yd. or an average of 34,084 cu. yd. per month. The average haul for the excavated material was about one-half mile.

300. Scraper-bucket Excavators.—The scraper-bucket or drag-line excavator is one of the most efficient of the larger power machines for canal excavation in the softer and looser materials, where the magnitude of the work will be greater than 50,000 cu. yd. for one set-up of the machine. The portability and adaptability of the machine make it especially serviceable for this class of work. The excavator may, in the case of large channels, work along the berm and dispose of the material directly in spoil banks without the use of a transportation system. Thus several machines may operate coördinately on one job and greatly facilitate the progress of the work.

301. Use of Drag-line Excavators on New York State Barge Canal.[1]—Three drag-line excavators were used in earth excavation on Contract No. 42 of the New York State Barge Canal, during April, 1910. The material excavated was principally a heavy gumbo soil.

Two of the excavators were electrically driven Lidgerwood-Crawford drag-line machines, equipped with 100-ft. booms and 2½-yd. Page buckets. The engines were driven by a 25-h.p. motor for swinging and a 125-h.p. motor for hoisting. City current was used and cost about 1 cent per cubic yard of material excavated. These machines moved about during the month and most of their excavation was superficial. Excavator No.1 worked 13 days and Excavator No. 2 worked 10 days during the month.

The other machine was a Heyworth-Newman drag-line excavator operated by steam power and equipped with a 100-ft boom and a 2½-cu. yd. bucket. All excavators worked in three shifts of 8 hr. each.

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[1] *Engineering-Contracting*, September 28, 1910.

Following is a tabulated statement of the cost of labor and excavation for these three machines.

HEYWORTH-NEWMAN EXCAVATOR

1 operator	$4.00
1 fireman	2.00
5 laborers @ $1.50	7.50
1 foreman, average $85.00 per month	2.83
1 pumpman	1.50
1 oiler	2.00
1 team for 1 shift per day	4.50
Total cost of labor per day	$24.33
Total cost of excavation per month	$1983.84
Total cubic yards excavated per month	23,192
Cost of excavation per cubic yard	$0.085

TWO LIDGERWOOD-CRAWFORD EXCAVATORS
(Labor for Each Machine)

1 operator	$4.00
1 oiler	2.00
5 laborers @ $1.50	7.50
1 sloper	2.25
1 foreman @ $85.00 per month	2.83
1 electrician @ $125.00 per month	4.17
Total cost of labor per day for each machine	$22.75

Excavator No. 1

Total cost of excavation per month	$1.667.80
Total cubic yards excavated per month	2271
Cost of excavation per cubic yard	$0.735

Excavator No. 2

Total cost of excavation per month	$992.30
Total cubic yards excavated per month	2583
Cost of excavation per cubic yard	$0.384

302. Use of Drag-line Excavators on Calumet-Sag Canal.[1]—Several drag-line machines were used from 1912 to 1915 on the construction of the Calumet-Sag Canal, which is a drainage channel connecting the Little Calumet River (and Lake Michigan) with the Chicago Main Drainage Canal.

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[1] Abstracted from *Engineering News*, January 23, 1913.

A drag-line excavator equipped with an 85-ft. steel boom and a 2½-yd. bucket was used in the excavation of the glacial drift forming the upper section of the main canal prism. The machine moved along the berms and deposited the excavated material in the spoil areas on each side of the channel. The loam was stored separately and later removed for use in the Chicago parks. The length of this section was 6754 ft. and the amount of glacial drift removed was 221,000 cubic yards. The cut averaged 8 ft. and the output about 50,000 cu. yd. per month, working during a daily 10-hr. shift. The contract price for the work was $0.22 per cubic yard.

On Section No. 3, a drag-line excavator with a 100-ft. boom and a 2½-yd. Page bucket was used to remove the glacial drift from the channel. The machine operated along one berm and then returned in the opposite direction along the other berm, depositing the excavated material in spoil banks along the right of way. The material comprised about 335,000 cu. yd. in a length of 5397 feet. The lower 5 ft. to 6 ft. directly overlying the stratified limestone rock was hard, cemented gravel and rock, and required blasting. The contract price for this work was $0.29 per cubic yard.

The work on Section No. 4 comprised the removal of 780,000 cu. yd. of glacial drift over a length of 5377 feet. A self-propelling steam drag-line excavator, equipped with a 100-ft. steel boom and 3½-yd. and 6-yd. buckets was used. The smaller size bucket was used for the excavation of the clay, and the larger size bucket for the removal of the peat and light surface material. The output of the machine averaged 60,000 cu. yd. per month, working two 10-hr. shifts per day and employing 12 men per shift. The contract price for the work was $0.25 per cubic yard.

Two drag-line excavators, equipped with 100-ft. steel boom and 2½-yd. Page buckets were used on Section No. 5. The total excavation amounted to 1,070,000 cu. yd. of glacial drift over a length of 8127 feet. The machines were electrically operated and the contract price for the work was $0.24 per cubic yard.

303. Tower Cableway Excavators.—The tower or some type of cableway excavator is especially adapted to the construction of channels with relatively wide and shallow prisms. See Chapter XI and Art. 254, Chapter XIX. The machine moves along the channel and digs, conveys, elevates and dumps in one positive, continuous operation. The arrangement of the towers provides for the disposal of the excavated material at either or both sides of the channel. The relative advantages of slack and taut-line machines depend on the character and scope of the work, and must be determined for each case. See Art. 26, page 372.

304. Use of Tower Excavator on New York State Barge Canal.[1]—The following is a detailed estimate of the cost of a tower excavator, which has recently (1910–12) been used on the New York State Barge Canal.

5080 ft. B. M. lumber @ $38.00 per M	$193.04
360 ft. B. M. white oak @ $45.00 per M	16.20
540 lb. iron bolts and nuts @ 6 cents	32.40
120 ft. 5/8-in. wire rope backstays	13.20
2 5/8-in. turnbuckles	0.80
1 headblock sheave and bearing	10.00
1 hauling sheave and bearing	4.00
1 8¼ × 10-in. Lidgerwood double-drum hoisting engine	1089.00
1 scraper bucket complete with cutting edge, sheaves, etc.	300.00
Labor erection (carpenters @ $2.50 for 8-hr. day)	200.00
Total	$1858.64

At a cost of operation for a two-shift day of $60.00 and with an average daily excavation of 2000 cu. yd., the cost of operation per cubic yard would be 3 cents.

During April, 1910, a tower excavator[2] was used on Contract No. 42 of the New York State Barge Canal. The material excavated consisted mostly of a heavy gumbo soil. The tower was 85 ft. high and the bucket used had a capacity of 1⅞ cubic yards. The excavator was operated by a 10-in. × 12-in. hoisting engine, which was furnished steam from a 40-h.p. boiler. Following is a tabulated statement of the cost of labor and excavation.

1 operator, per day	$4.00
1 fireman @ $75.00 per month, per day	2.50
1 foreman @ $200.00 per month, per day	6.67
1 pumpman, per day	1.50
6 laborers @ $1.50 per day	9.00
Total cost of labor per day	$23.67
Total cost	$1,455.81
Total cubic yards excavated	15,065
Cost per cubic yard	$0.096

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[1] *Engineering-Contracting*, October 26, 1910.

[2] *Engineering-Contracting*, September 28, 1910.

Although this type of excavator has been rarely used and is little known and understood by contractors, its use in the past has clearly demonstrated its efficiency and economy of operation, especially in the excavation of large ditches.

During the early part of the year 1910, a tower excavator was at work on a section of the New York State Barge Canal. The following statement of the cost of operation has been furnished by the contractors.

Labor:

1 fireman @ 37½ cents per hour	$3.00	
1 engineer @ 37½ cents per hour	3.00	
1 fireman @ 22 cents per hour	1.76	
1 signalman @ 25 cents per hour	2.00	
9 laborers @ 20 cents per hour	14.40	
Total cost of labor per shift	$24.16	
Total cost of labor per month (52 shifts)		$1256.32

Material:

Wire cable	$160.00	
Fuel, 20 tons of coal @ $4.00	80.00	
Oil, waste and repairs	15.00	
Total cost per month		$255.00
Interest on investment ½ per cent. per month		9.30
Total cost of operation (not including office expenses)		$1520.62
Total excavation @ 700 cu. yd. per day		18,200

Cost of excavation per cubic yard, $1520.62 ÷ 18,200 = $0.084

305. Use of Double-tower Excavator on Chicago Main Drainage Canal.—A double-tower drag-line excavator was used with very satisfactory results in the excavation of two sections of the Chicago Drainage Canal. The canal prism, which this excavator made was unusually true to the theoretical cross-section, there being less than 1½ cu. yd. of excavation per lineal foot outside of the required lines.

The canal excavated had a bottom width of 26 ft. and side slopes of 2 to 1. The average depth was 27½ feet. The canal lay in nearly a level plain and the material excavated was clay.

This excavator was designed by the late J. T. Fanning of Chicago, and consisted principally of two towers and two buckets.

Figure 83 is a diagram illustrating the principles of construction and operation. It will be seen by the plan that the two inclined booms are so constructed that a straight line from the apex of either tower to the point of the opposite boom, clears the side of the tower. This allows the bucket to clear the tower and empty directly on the adjacent spoil bank. As will be seen from Fig. 177, there are two buckets, working in opposite directions and each excavating its half of the canal prism.

A double-drum hoisting engine was placed on the side of the platform of each tower. Each bucket was operated by a drag or digging line and a load line. The drag line was run from the smaller drum of the engine to the bucket, which dug in a downward direction on the side of the canal opposite to its tower. The load line, which is slack during the filling of the bucket, extends from the larger drum of the engine, upward through the tower, over a sheave near the apex of the tower, then out to a stationary sheave, which is suspended between the two towers, then down to a sheave attached to the bail of the bucket and then out to the end of the boom on the opposite tower. As soon as the bucket is filled the load line is wound up with the drag line kept taut. This raises the bucket up above the surface of the ground and to an elevation slightly higher than the point of the boom. Then the drag line is released and the bucket allowed to run down the load line by gravity to the dump pile or spoil bank near the end of the boom. By changing the location of the

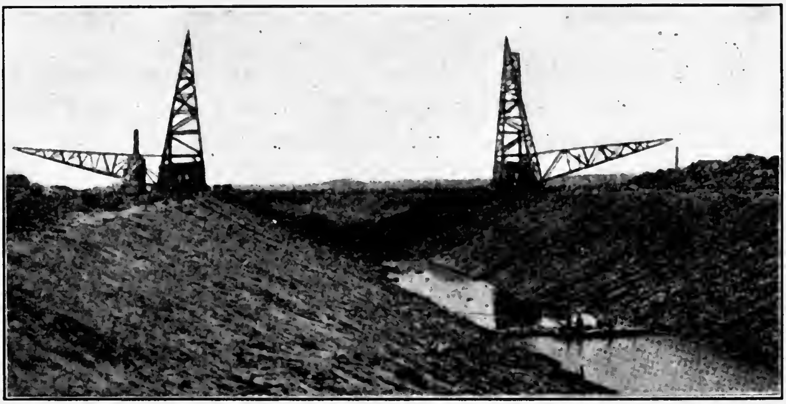

Fig. 177.—Double tower excavator. (*Courtesy of Engineering & Contracting.*)

suspended sheaves, the position of the bucket in digging can be altered so as to reach the entire half width of the canal prism.

The buckets used had a capacity of ¾ cu. yd. and a tripping device near the end of each boom, caused the bottom of each bucket to swing loose and drop the load on the spoil bank.

The excavator was used for a period of 2 years on daily shifts of 10 hours. The labor employed consisted of an engineer, a fireman and a track gang of five men. An average gang of 12 men, including a superintendent, a watchman and the operating laborers, were used. The average daily excavation was 500 cu. yd. to 600 cubic yards. The maximum monthly excavation was 19,000 cu. yd. in June, 1910, while the minimum monthly excavation was 4750 cu. yd. in December, 1908. A record of two trips per minute for each bucket was made but the average speed of excavation was one trip per minute.

306. Floating-dipper Dredges.—The floating-dipper dredge is probably the best known and most widely used type of excavator on canal construction. Its universal adaptability to a wide range of operating conditions and its great, concentrated power make it very efficient in the excavation of material of all kinds and the handling of obstructions, both natural and artificial.

Recently, dredges of large capacity have been built and operated successfully. The most notable example of large dredge operation is the use of the two 15-yd. dipper dredges on the Panama Canal, as described in a subsequent article.

The special field of work of the dipper dredge is in the excavation of hard material up to a depth of 50 feet. The use of steel wire rope and the proper proportioning of the parts to ensure an efficient angle of lead and operating speed, are factors tending toward the satisfactory use of dredges of great power and capacity in large canal excavation and maintenance.

307. Use of Dipper Dredges on Panama Canal.—From 1913 to date (1918), two 15-yd. dipper dredges, the Gamboa and the Paraiso, have been used in the removal of the slides in the Culebra cut and for general maintenance work.

The dredges are equipped with 10-yd. rock dippers and are designed to dig to a depth of 50 ft. below the surface of the water. These dredges are equipped with main hoisting engines consisting of horizontal, twin-tandem, compound-condensing engines, compound geared to heavy spur gears mounted on the main hoisting shaft which carries the drums.

The dredges commenced work early in the Spring of 1914 and had difficult and heavy digging to contend with. The material was largely a hard trap rock and many boulders weighing from 10 to 30 tons apiece were encountered. The early output per day of 16 hr. was from 3000 to 5000 cu. yd. and was later increased to an average of from 9000 to 10,000 cubic yards. The Paraiso made the following record for June to November, 1914. June, 72,700 cu. yd.; July, 84,700 cu. yd.; August, 96,400 cu. yd.; September, 109,800 cu. yd.; October, 125,000 cu. yd.; and and November, 140,000 cubic yards.

The following statement gives the cost of dipper dredging on the Panama Canal for the years 1915 and 1916.[1]

TABLE XXVI.—COSTS OF DIPPER DREDGE OPERATIONS ON PANAMA CANAL —1915 AND 1916

Dredge	Output, cu. yd.			Cost	Unit cost per cu. yd.
	Earth	Rock	Total		
			1915		
Gamboa	....	1,825,122	1,825,122	$628,901.11	$0.3446
Paraiso	....	1,739,228	1,739,228	611,444.02	0.3516
Cardenas	2,869	462,505	465,374	210,660.61	0.4527
Chagres	....	353,619	353,619	166,485.61	0.4708
Mindi	1,416	400,294	401,710	180,585.96	0.4495
			1916		
Gamboa	....	3,097,226	3,097,226	$762,904.83	$0.2463
Paraiso	....	3,004,104	3,004,104	750,103.25	0.2497
Cardenas	....	171,203	171,203	59,763.10	0.3491
Chagres	....	234,131	234,131	76,459.46	0.3266
Mindi	....	228,442	228,442	90,329.81	0.3954

The Cardenas, Chagres and Mindi are 5-yd. dipper dredges.

308. Use of Dipper Dredges on New York State Barge Canal.—From 1906 to 1911 inclusive, two dipper dredges were used in the excavation of the Hudson River between Waterford and Fort Edward, New York to form a section of the New York State

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[1] Abstracted from Annual Reports of Governor of the Panama Canal, 1915 and 1916.

Barge Canal for a distance of about 7 miles. The original estimated excavation was 913,500 cu. yd. and the contract price was 57¾ cents per cubic yard, without classification.

The excavators were two floating-dipper dredges, 97 ft. long, 18 ft. wide and 6 ft. draft. Pontoons were provided for the sides of the hulls to give stability during operation. The dippers had a capacity of 3⅓ cubic yards.

The material was generally of a silt and clay character but three rock reefs were encountered. The rock was broken up by a Lobnitz rock breaker. The excavated material was loaded in dump scows and hauled by tugs to the dumping grounds, where it was deposited.

The total excavation for the two dredges for the year ending September 30, 1906 was 47,261 cubic yards. During the fiscal year ending September 30, 1907, 384,810 cu. yd. was removed, 25,480 cu. yd. of which was rock. During this year the working day was of 24 hr. duration except during the winter months of December, January, February and March. During the year ending September 30, 1908, the two dredges removed 215,225 cu. yd. of material; working 24 hr. per day except during the four winter months. During the next fiscal year, ending September 30, 1909, the output was 25,924 cu. yd., 10,000 cu. yd. of which was rock. The dredge "Pontiac" worked only during the months of September and October, 1908. During the next two years the other dredge, the "Peconic," excavated 15,986 cu. yd. of Hudson River shale, working generally on the basis of an 8-hr. day.

The output for 1907 averaged about 1,000 cu. yd. per 24-hr. working day per dredge, representing an income of about $560.00 per day.

309. Ladder Dredges.—The ladder dredge has been universally used on large canal construction, especially on the Suez Canal and the Panama Canal with the French régimé. In this country, this type of dredge has not come into general use on account of the large initial cost of the plant. The American contractor has been prejudiced against the use of the ladder dredge on account of its heavy initial expense and maintenance, large crew and limited field of work. However, in canals with plenty of room for manipulation and where the soil conditions are favorable, the ladder dredge has, in recent years, proved to be more efficient than any other type. In coarse sand, gravel and stiff clay free from large boulders, this machine has achieved remarkable results.

The disposition of the excavated material on canal work may be by conveyors, by discharge through a hopper into barges or into hoppers and later carried to the dumping ground. Difficulties are often encountered in the use of conveyors on account of the clogging of the conveyor, and the proper disposition of the fluid material in suitable spoil banks. Hence one of the latter methods of handling the material should be used.

310. Use of Steel Pontoon Ladder Dredge on New York State Barge Canal.[1]—During the four months from August 1, 1909 to December 1, 1909, a ladder dredge of standard design was operated on a section of the New York State Barge Canal, near Adams Basin. Figure 178 shows the front view of this dredge.

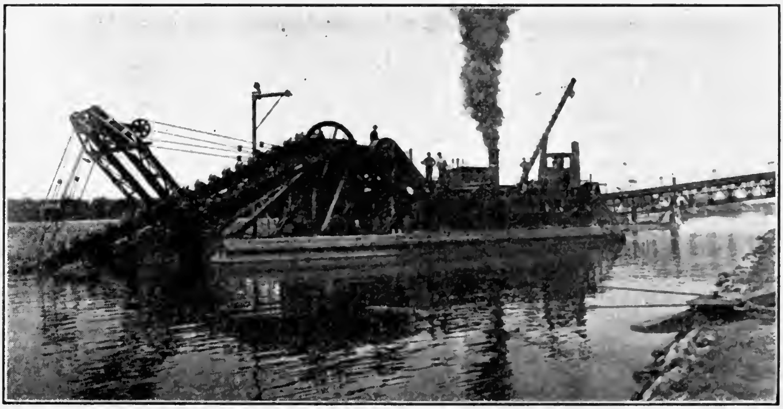

Fig. 178.—Ladder dredge on New York State barge canal. *(Courtesy of The Bucyrus Co.)*

The hull was made up of two steel pontoons, which were braced together by a rigid steel framework. The buckets were each of 5 cu. ft. capacity. The excavated meterial was discharged into a hopper at the top of the ladder and then on to a belt, which in turn discharged into a second hopper and on to a second belt. These belt conveyors were carried by pontoons or scows, placed at the rear of the dredge. A third belt conveyor carried the material 40 ft. to 50 ft. on to the bank of the channel. The third pontoon was pivoted to the stern of the second pontoon. The belt conveyors were each operated by a small electric motor.

The total cost of the entire dredge plant was $70,000.00.

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[1] Abstracted from *Engineering-Contracting*, September 7, 1910.

Considerable difficulty was experienced in keeping the soft excavated material in place on the spoil banks. At first heavy wooden fences were built to hold the embankment to full height. But these proved to be very expensive and inefficient and were replaced by dikes of earth and sod having a height of 4 ft. and placed along the outside edge of the embankment.

Following is given the cost of the work for the months of August, September and October, 1909:

August, 1909

Coal and oil	$1,984.50
15 tons coal for hoisting engine @ $2.85	42.75
Miscellaneous supplies for hoisting engine	5.25
Miscellaneous supplies for hoisting engine and derrick	6.48
Hauling supplies	54.00
Crew of dredge	2,296.68
Total cost	$4,389.66
Total excavation	18,638 cu. yd.

Cost of excavation, $4,389.66 ÷ 18,638 = 23.6 cents per cu. yd.

Cost of moving 6,244 cu. yd. of earth by use of scrapers (supplementing work of dredge)	$1,280.50
Cost of scraper work	20.5 cents per cu. yd.
Cost of wooden forms and compacting and spreading 10,015 cu. yd. of excavated material	$1,193.25
Cost of forms, spreading, etc	11.9 cents per cu. yd.

September, 1909

Interest, depreciation and repairs	$2,205.00
180 tons of coal (2 tons per shift)	513.00
150 gal. gasoline @ 12 cents	48.00
Oil (80 gal. @ 19 cents, 60 gal. @ 35 cents)	36.20
1200 lb. grease @ 8 cents	96.00
200 lb. waste @ 8 cents	16.00
Teams	245.00
Labor	2,827.00
Total cost	$5,986.20
Total excavation	32,000 cu. yd.

Cost of excavation, $5,986.20 ÷ 32,000 = 18.6 cents per cu. yd.

Total working time was 90 eight-hour shifts.

The cost of embankment was as follows:

Labor, spreading and compacting	$3,151.50
Hauling lumber for forms	177.16
Cost of lumber for forms	1,125.00
General	290.00
Labor on forms	828.32
Hauling supplies	55.00
Total cost	$5,626.98
Total amount of excavated material worked	11,000 cu. yd.

Cost of embankment, $5,626.98 ÷ 11,000 = 51.1 cents per cu. yd.

October, 1909

Interest and depreciation	$2,351.66
186 tons coal @ $2.85	530.10
Labor	3,145.58
Teams	5.00
Oil, Grease and waste	153.09
Gasoline	18.60
Repairs	18.90
Total cost	$6,222.93
Total excavation	25,500 cu. yd.

Cost of excavation, $6,222.93 ÷ 25,500 = 24.4 cents per cu. yd.

Total working time was 93 eight-hour shifts.

The cost of embankment was as follows:

Labor, spreading and compacting	$2,898.25
Forms	567.50
Erection	108.50
Hauling	95.00
Total cost	$3,669.25
Total amount of excavated material worked	21,800 cu. yd.

Cost of embankment, $3,669.25 ÷ 21,800 = 16.9 cents per cu. yd.

311. Use of Ladder Dredge on Panama Canal.[1]—One of the largest and most efficient ladder dredges in existence is the Corozal which has been in operation on the Panama Canal since 1911. This dredge was built primarily to excavate a submerged plateau composed of hard and soft rock, stiff boulder clay and conglomerates of all kinds. The surface of the material varied from 18 ft. to 40 ft. below mean tide datum and about 4,000,000 cu. yd. have been handled.

The dredge is a self-contained, self-propelling, twin-screw hopper vessel, which has a dredging capacity at a 50-ft. depth of about 1300 cu. yd. of soft material per hour and about 500 cu. yd. of boulder clay per hour.

The operating equipment consists of two steel cylindrical multitubular boilers, supplying steam at 180 lb. and equipped with Morrison corrugated furnaces, and two sets of triple-expansion engines, equipped with independent surface condensers, circulating air and feed pumps, and auxiliary engines for winches, dynamos, pumps, etc. Each main engine is of about 700 i.h.p., has a piston speed of 600 ft. per minute, and is provided with friction and toothed gearing for working at three speeds when dredging, and arranged to throw out of gear when propelling

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[1] Abstracted from *Engineering News*, January 25, 1912.

the vessel. The dredge is provided with a complete electrical equipment for furnishing light, an ice machine, and all the necessary outfit of water and oil tanks, boats, ropes, lifebuoys, etc.

The excavation equipment consists of a steel ladder with buckets of 54 cu. ft. capacity for soft material and 34 cu. ft. capacity for hard material. The ladder is supported at its upper end on a tower amidship and passes through a well in the bow of the vessel. The dredging speed is about 18 buckets per minute in soft material and 14 per minute in hard material. The buckets are made of pressed steel plates, cast-steel backs and manganese steel forged lips. The hopper capacity is 27,500 cu. yd. including coamings. The speed of the vessel with a full hopper load is about 10 miles per hour.

The following is a statement of the output and cost of operation of the Corozal for the years 1915 and 1916.

Date	Output, cu. yd.			Cost	Unit cost per cu. yd.
	Earth	Rock	Total		
1915..	224,833	821,191	1,046,024	$459,204.61	$0.4390
1916..	....	1,459,312	1,459,312	494,134.53	0.3386

312. Hydraulic Dredges.—The hydraulic dredge has developed greatly during the last 25 years in efficiency and scope of field of usefulness. The increase in efficiency has come largely through the use of more efficient pumps and engines. The use of special forms of cutters and greater power has made it practicable for the hydraulic dredge to satisfactorily excavate hard materials. For many years, the cutter served merely as an agitator to stir up and mix the loose material with water but recently it has become an excavator and works very efficiently in dense clay and hard gravel.

The hydraulic dredge although wasteful of power and relatively inefficient as compared with some types of dredges, is the most economical type of excavator to use in canal work where there are large quantities of sand, gravel, silt and clay. This machine cannot operate successfully in hard pan, rock or in material where large quantities of boulders abound.

313. Use of Hydraulic Dredges on New York State Barge Canal.—During 1907 and 1908 two hydraulic dredges were in operation near Oneida Lake, New York, in the construction of a section of the New York State Barge Canal. These dredges were the "Oneida" and the "Geyser" and each will be described separately as each contained many individual and peculiar details, although they were both very similar in general design.

The "Geyser" was provided with a hull having a length of 96 ft., width of 29 ft., and drew 9 ft. of water. The dredge was so constructed as to excavate material to a depth of 19 ft. below the water surface and discharge the excavated material through the pontoon pipes, at a distance of 1500 ft. and to a shore elevation of 25 ft. above water.

At the bow of the boat a steel frame of trapezoidal shape supported the suction pipe and cutter head, the driving shaft and gearing. The steel girder was 33 ft. long and was pivoted at the inner end on one side of the elbow of the suction pipe and on the other side by a hollow pivot through which the cutter-shaft is driven by a counter shaft geared to a 65 h.p. engine with double 10-in. × 12-in. cylinders.

The pump used was a 20-in. centrifugal, direct-connected to a triple expansion engine of 450 nominal horse power, which developed on occasions 550 h.p. on overload. The pump and engine were placed near the center of the hull. The steel discharge pipe was 20 in. in diameter and passed back on the port side to the stern of the boat, where a valve was placed to prevent backing up of the material. The pipe was in 32-ft. sections and was supported on pontoons, which were heavy water-tight casks. Heavy rubber sleeves were used to connect the ends of the sections of pipe.

The boiler plant consisted of two B. & W. water-tube boilers, having a rated horse power of 230, and used at about 160-lb. pressure. One duplex pump furnished water under pressure to the pump stuffing box and cutter-head bearing. Two other duplex pumps were used to supply the boilers directly or through a 400-h.p. feed-water heater. The pumps were arranged to take suction either from cold water or the hot well, as did the injectors, one of which was used with each boiler.

Electric current was supplied by a 6 k.w. electric generator and furnished light for night work.

The hoisting engine was provided with five drums and was operated by a double-cylinder engine of 45 horse power. Upon the forward shaft, the drums on each side swung the dredge and the center drum raised or lowered the suction ladder or boom. The two rear drums operated the two spuds at the stern of the hull. A winch head was placed at each side of the deck for mooring purposes. The pilot or operating house was placed directly over the engine and the operator by means of 12 levers had complete control of the hoisting and lowering of the ladder and the spuds, the swinging of the dredge and the speed of the cutter.

The "Oneida" excavated that section of the New York State Barge Canal commencing at the junction of Fish Creek and Oneida Lake and following the creek valley for a distance of about 5 miles.

The material excavated was a loose sandy loam and in many places large quantities of quicksand were encountered. The depth of excavation at Oneida Lake was about 15 ft. and gradually increased to 25 ft. at the eastern end of the section.

The dredge was one of two constructed by the New York Shipbuilding Company of Camden, N. J., for the Empire Engineering Corporation, which executed two contracts on the canal with these two excavators.

The hull of the dredge was constructed of steel and had an overall length of 97 ft., beam width of 17.5 ft., molded depth to deck of 10 ft. and draft of 5.5 feet. The general shape of the hull was that of a huge rectangular box with the bilges rounded off. The frames were of 3-in. × 3-in. × 5/16-in. angles, in one piece from keel to deck and spaced 21 in. c. to c. The reverse frames were of 2¼-in. × 2¼-in. × ¼-in. angles and followed the tops of the 10-in. × 3/8-in. floor plates, every alternate one extending to the deck and the intermediate one extending to the lower stringers. The deck beams were 4½-in. × 3-in. × 3/8-in. angles; one attached to each frame and crowned 3 in. in the center of the vessel. The center keelson extended the full length of the hull and intercostal keelsons were used at the main engine foundations, where the hull was very strongly braced. The covering of the hull was steel plates 5/8 in. thick.

The suction pipes were two in number and were made of steel plates and angles having a bearing on their upper sides for the cutter shafts. The interior diameter of these pipes was 19¼ in., thus giving an area of 291 square inches. The suction pipes extended from the centrifugal pump to the cutters at the outer ends. The steel plate, intermediate lengths of suction pipes, were connected to the pump by cast-iron breech pipes bolted to the pump and joined the pipes by heavy steel angle flanges. The breech pipes were connected at their forward ends to two Bates curved telescopic joints, the movable interior portions of which were bolted to the upper end of the ladders. These ladders were suspended by means of heavy brackets from trunnions, the axes of which were those of the telescopic joints. The cutter heads were mounted around and concentrically with the ends of the suction pipes and were 5.5 ft. in diameter and 3⅔ ft. in height. Each cutter was composed of 12 knives of manganese steel, ⅞ in. thick. The cutters and ladders were raised and lowered by two sets of blocks having five sheaves in each block and using ⅜-in. wire rope. The power to operate the ladders was furnished by two independent, compound, vertical, reversing engines of 100 h.p. each. These engines were located back to back in the forward engine room. In the same engine room were located a service pump, electric light plant and blower engine. The service pump was used as an auxiliary feed pump and discharged to the boilers, ladder and cutter-head bearings, fire service pipes and over board. On the supply of suction heads, it was connected to the hot well, canal, bilges and settling tank.

The centrifugal pump was located in the after engine room and was provided with two suctions having a diameter of 19¼ in. and a discharge of 26 in. diameter. The casing of the pump was made in five pieces; a throat piece containing a steel knife, two upper and two lower segments. The runner was of cast steel and had a diameter of 6½ feet.

The pump was direct connected to a triple-expansion engine which developed 750 h.p. at a speed of 165 r.p.m., cutting off steam in the H.P. cylinder at about six-tenths of the stroke. The H.P. cylinder has a diameter of 17 in., the I.P. cylinder a diameter of 25 in.; and the L.P. cylinder a diameter of 42 inches. The average stroke was 24 inches.

A separate engine was used to operate the two spuds at the stern of the hull. This engine was of the horizontal type with two cylinders 6½ inches × 8 inches.

Steam was supplied from two standard water-tube boilers, working at 200-lb. pressure and having a combined heating surface of 3750 sq. ft. and a grate area of 95 square feet. The engine was compound geared and provided with reverse link motion. The drums were 18 in. in diameter and were controlled by a friction hand brake. Flat cables, 3 in. × 3/8 in. were used and these were run at a speed of 40 ft. per minute.

On the forward deck of the dredge was placed a two-cylinder steam winch with 8¼ in. × 10 in. cylinders. There were two drums, each having a diameter of 18 in. and face width of 38 in. to hold 1000 ft. of 3/8-in. wire rope in four layers; and also two drums, each 24 in. in diameter and having a face width of 16 in., to hold 400 ft. of ¾-in. wire rope in three layers.

The discharge pipe was supported on 16 intermediate and one terminal pontoon. It was also found necessary at times to use two pontoons, each 6 ft. wide, one on each side of the dredge, to secure necessary stability while in operation.

The excavation began October 1, 1906, and was worked one 8-hr. shift daily, during the early part of this month. Later, two 8-hr. shifts were used and from November, 1906 on, three 8-hr. shifts were used. The work of the dredge was in charge of a chief engineer and a chief operator. Following is the labor schedule for each 9-hr. shift.

1 operator	@	$100.00 per month
1 engineer	@	100.00 per month
1 engineer	@	80.00 per month
3 firemen	@	70.00 per month each
1 spudman	@	60.00 per month
1 oiler	@	50.00 per month
4 deckhands	@	50.00 per month each

Besides the above force was a gang which moved the discharge pipe and repaired the levees along the canal and behind which the spoil was deposited. An engineer or operator for the gasoline launch, which towed the fuel scow, and a night watchman were also constantly employed.

The following table gives the labor costs of excavation for this hydraulic dredge during the month of November, 1906.

The "laborers" were those in the gang employed in moving the discharge pipe and repairing the levees.

Table XXVII.—Cost of Labor for Hydraulic Dredge

Description	No. of days	Rate	Amount
1 chief engineer	30	$150.00	$150.00
1 chief operator	30	135.00	135.00
3 engineers	86	100.00	286.67
3 engineers	86	80.00	229.33
3 operators	86	100.00	286.67
9 firemen	258	70.00	602.00
3 spudmen	86	60.00	172.00
3 oilers	86	50.00	143.33
12 deckhands	344	50.00	573.33
1 night watchman	30	1.60	48.00
1 foreman	34¼	3.00	102.75
1 foreman	37¾	2.00	75.50
Laborers	1056½	1.60	1690.40
1 engineer, tug	30	80.00	80.00
			$4574.98

Amount of excavated material .... 144,882 cu. yd.
Cost of excavation, $4,574.98 ÷ 144,882 = $0.0316 per cu. yd.

314. Use of Hydraulic Dredges on Panama Canal.—The following is a statement of the output and cost of operation of the fleet of six suction dredges operating on the Panama Canal during the years 1915 and 1916.

Table XXVIII.—Costs of Hydraulic Dredge Operations on Panama Canal, 1915 and 1916

Dredge	Output, cu. yd.			Cost	Unit cost per cu. yd.
	Earth	Rock	Total		
1915					
No. 4, 18 in.	317,254	6,650	323,904	$134,667.71	$0.4158
No. 82, 20 in.	603,696	50	603,746	151,057.31	0.2999
No. 83, 20 in.	589,680	64,954	654,634	145,015.31	0.2215
No. 84, 20 in.	790,807	26,846	817,653	139,448.31	0.1705
No. 85, 20 in.	1,374,379	....	1,374,379	239,002.31	0.1739
No. 86, 20 in.	1,053,177	92,853	1,146,030	281,156.79	0.2453
1916					
No. 4, 18 in.	204,520	265,005	469,525	$186,264.04	$0.3967
No. 82, 20 in.	117,023	....	117,023	72,224.84	0.6172
No. 83, 20 in.	221,188	161,726	382,914	148,762.86	0.3885
No. 84, 20 in.	180,784	173,711	354,495	142,399.30	0.4017
No. 85, 20 in.	827,342	4,187	831,529	162,588.79	0.1995
No. 86, 20 in.	763,374	24,374	787,748	260,318.24	0.3304

315. Résumé.—The improvement of rivers, harbors and canals consists principally in the construction of artificial channels by some form of excavator. The river and harbor work is, of course, largely subaqueous and requires the use of some type of floating dredge. Considerable canal work is done in dry-earth sections where some form of dry-land machine can be efficiently used.

Work of this character is of considerable magnitude and extent, and justifies the use of an extensive and expensive equipment. The initial cost of the plant can be distributed over a large amount of work, and thus only slightly affect the unit cost.

The type of excavator to use for subaqueous work depends largely upon the size of the job, depth of digging and character of material. The dipper dredge is undoubtedly the most universally adaptable machine for all kinds of material, and the use of machines of large capacity and power have made it an economical machine for work of great magnitude. Where obstructions such as stone and large boulders abound, the dipper dredge is the most practicable machine.

The ladder dredge must have plenty of room for manipulation and operation. It is especially efficient in the excavation of material of a uniform, dense character, such as clay and gravel. The hopper type of dredge is generally used for deep-water work and when built of steel and strongly braced has proved to be seaworthy and satisfactory.

The hydraulic dredge is a very inefficient machine in its use of power, but with a pump efficiency of 60 per cent. to 70 per cent. and careful regulation as to feeding of the material into the suction pipe, it may be used very economically in the excavation of large quantities of soft material such as sand, gravel and clay. The style and operation of the cutter is a very important factor in the excavation of the harder materials.

The following is a brief statement[1] of the comparative use of the various types of excavators on Contract 66 of the New York State Barge Canal from 1909 to 1912.

The contract comprised the removal of about 650,000 cu. yd. from a prism having a bottom width of 50 ft. and 3 ft. deep, the side slopes on the berm sides being 25 ft. wide and 12 ft. deep.

The following table gives a summary of the output. The steam shovel only operated during the winter season, when the

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[1] Abstracted from *Engineering and Contracting*, May 21, 1913.

canal was dry and Koppel car outfits were used to transport the excavated material. The cranes handled scale buckets set on portable transverse tracks in the bed of the canal, and were loaded by hand and pushed to the crane, which dumped the buckets upon the spoil banks. For the wet excavation, derrick boats equipped with orange-peel and clam-shell buckets were used for a minor part, and the ladder dredge "Mineola" for the major part of the work.

Method of Operation	Output (cu. yd.)					Total cost	Unit cost per cu. yd.
	1909	1910	1911	1912	Total		
Teams, scrapers....	33,923	49,507	15,799	5,000	104,229	$51,688	$0.499
Steam shovel.......	69,743	34,945	43,850	16,300	164,868	82,005	0.497
Cranes............	....	....	36,072	20,000	56,072	27,832	0.494
Clam-shells, orange-peels.............	....	27,014	40,071	19,879	86,964	43,239	0.497
Ladder dredges.....	56,137	115,344	45,469	23,050	240,000	119,280	0.493
Totals...........	159,903	226,810	181,261	84,259	652,133	$324,044	....

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CHAPTER XXI

MUNICIPAL IMPROVEMENTS

317. Preliminary.—This chapter will take up the discussion of the various excavating machines used in the various phases of municipal improvement, with the exception of street and pavement construction which is described in Chapter XVII, on Highway Construction. The excavation of open ditches, canals and reservoirs is fully discussed in Chapter XIX on Reclamation Work. The reader is referred to these chapters for information on these subjects. Hence, this chapter will deal with the methods and costs of digging trenches for water and sewer pipes, cellars and basements for buildings, foundations for power houses, pumping plants, sewage disposal plants, etc. The subject will be presented under the two divisions; I, Trench Excavation and II, Foundation and Basement Excavation. The division of Trench Excavation will be considered in two parts; A—Pipe-trench Excavation and B—Tile-trench Excavation.

I. TRENCH EXCAVATION

A—Pipe-trench Excavation

318. General.—The advantages of machinery in the excavation of trenches depend on the depth, character of material, and local conditions of labor supply, transportation facilities, etc. For trenches under 3 ft. in width the minimum depth justifying the use of excavators is about 6 ft., while for trenches 3 ft. and over in width, the economical, governing depth is about 10 feet. The direct advantages from the use of machinery in trenching are; increased output, less liability of bank caving, less obstruction to street traffic, and the availability of hoisting apparatus (with some type of excavators) for the raising of boulders and other obstructions, and the lowering of pipes. At the present time (1918), the scarcity and high cost of hand labor (40 cents per hour), make the use of machinery necessary whenever the economic conditions justify it. For shallow trenches and work of small magnitude, it is clearly evident that the cost of transportation and erection, dismantling and re-loading on car, together with the freight charges would result in a loss to the contractor.

319. Scrapers.—Drag and wheel scrapers have been used to some extent, for the removal of the top section of wide trenches. However, this method has been almost entirely superseded by some form of power excavator or trench machine, which can ordinarily handle the material more efficiently and economically.

320. Power Shovels.—The power shovel, in recent times, has been adapted to t ench excavation by the use of a long dipper handle or a high boom or a combination of the two. The revolving shovel has been used for making the first cut of deep sewers of large dimensions, without any special changes or modifications in the machine. The great weight of the machine is carried near the sides of the trench and necessitates extra heavy bracing to prevent undue settlement and cave-ins. It is difficult to sheet and brace a trench for power-shovel operation, so that the bracing will not be in the way of the dipper. The excavation, under such conditions, is apt to be too wide or too narrow, as close and accurate trimming of the banks is impossible.

The author does not recommend the use of a power shovel for trench excavation, unless the trench is large and the material hard. The delays incident to this class of work result in the uneconomical use of the machine.

321. Use of Steam Shovel in New York.—By the use of a specially rigged boom, called a "trench boom," the revolving type of shovel may be very efficiently used in the construction of large trenches for sewer and water pipe. During the latter part of the year 1910, in Buffalo, N. Y., a 1-yd. steam shovel having a working weight of 30 tons, excavated 100 lineal feet of sewer trench per day. The trench was 60 in. wide, 15 ft. to 18 ft. in depth, and the material excavated was very hard clay. On this contract, the steam shovel was more efficient than the regular trench excavators, as the former was not delayed by the breakdowns and repairs which the latter required.

At Batavia, N. Y., a ¾-yd. dipper, revolving steam shovel excavated 85 lineal feet of sewer trench per day.

Figure 179 shows a Seventy C Bucyrus sewer excavator at work.

In 1910,[1] an investigation was made of the use of a steam-op-

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[1] Abstracted from *Engineering Record*, May 23, 1914.

erated revolving shovel in the excavation of pipe trenches through sandy soil. The shovel was of 25-ton capacity, mounted on traction wheels and equipped with a 1-yd. dipper and dipper arm specially designed for the work. The supporting platform, upon which the shovel worked, consisted of twelve 12 in. × 12 in. timbers spaced 4 in. apart and bolted together in sections of three. These timbers rested upon planks laid upon the ground and supported planks upon which the traction wheels moved.

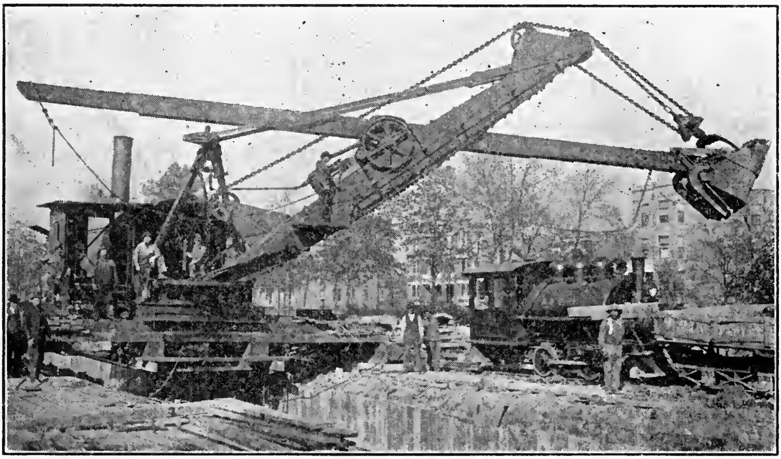

FIG. 179.—Steam shovel excavating large sewer trench. (*Courtesy of The Bucyrus Co.*)

Considerable difficulty was experienced in keeping the trench properly braced, and many delays resulted from cave-ins and "waits" for sheeting to be installed.

The following is an analysis of the work of the shovel for 1 day's operation

Kind of shovel	25-ton
Capacity of dipper	1 yd.
Length of move	4 ft.
Number of moves	20
Average time to sheet trench	92 min.
Average time to move up	4.5 min.
Time worked by shovel	565 min.
Depth of cut	9 ft.
Width of cut	36 in.
Output	80 cu. yd.
Unit cost per cu. yd	22.6 cents

Daily Cost of Operation

1 runner	$5.00
1 fireman	2.31
1 laborer	1.75
1 laborer	1.65
Supplies	4.50
Interest and depreciation, 17½ per cent. on $4500 (based on 200 working days per year)	4.00
Total	$19.21

Unit cost, $\$19.21 \times \frac{565}{600} = \$18.10$; $\$18.10 \div 80 = \$0.226$ per cu. yd.

Process Analysis

	Time, minutes	Per cent.	Cost—cents per cu. yd.
Actual digging	202	35.8	8.10
Delays: A—Sheeting trench	184	32.6	7.35
B—Moving up	90	15.9	3.60
C—Due to curve	89	15.7	3.55
Totals	565	100.0	22.60

322. Use of Steam Shovel in Chicago, Ill.[1]—A 70-ton steam shovel was used in 1909, for the excavation of a sewer trench on Western Avenue, Chicago, Ill. The shovel was a 70-ton Bucyrus mounted on a 38 ft. × 24 ft. platform resting on wooden rollers. The machine was moved by a cable with block and fall, attached to a "deadman" and operated by the shovel engine.

The trench was 16 ft. wide and 28 ft. deep; the cut being made in two benches, the first 10 ft. and the second 16 feet. Sheeting was required to a depth of 10 ft. only. The material was loam to a depth of 10 ft., and underlaid by glacial clay. Trimmers followed the shovel and prepared the sides of the trench for the sheeting. The shovel excavated a section of the 10 ft. bench and then backed up and cut the second bench. The machine while operating on the second bench, was supported by I-beams, braced every 20 ft. by jacks. The I-beams held the sheeting in place until the shovel had passed, when the regular bracing was

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[1] Abstracted from Handbook of Steam Shovel Work, The Bucyrus Company.

installed. The excavated material was transported by trains of 4-yd. and 6-yd. dump cars hauled by 18-ton dinkeys.

The following is an analytical statement of 1 day's operation of the shovel.

Kind of shovel	70-ton
Capacity of dipper	2 yd.
Average length of move	15 ft.
Number of moves	4
Average time to move up	33¾ sec.
Working time	602 min.
Depth of cut	26 ft.
Width of cut	16 ft.
Output	569 cu. yd.
Unit cost per cu. yd.	6.7 cents

Cost of Operation

1 runner	$5.00	
1 craneman	3.60	
1 fireman	2.00	
7 rollermen	10.50	
Supplies	9.00	
Interest and depreciation at 17½ per cent. on $9000 (based on 200 working days)	8.00	
Total		$38.10
Unit cost:		$38.10 ÷ 569 = $0.067 per cu. yd.

PROCESS ANALYSIS

	Time, minutes	Per cent.	Cost, cents per cu. yd.
Actual digging	270.5	44.9	3.01
Delays: A—Waiting on sheeters	50.0	8.4	0.56
B—Moving up	135.0	22.4	1.51
C—Waiting on cars	139.5	23.2	1.55
D—Miscellaneous	7.0	1.1	0.07
Total	602.0	100.0	6.70

323. Use of Steam Shovel for Backfilling in Minneapolis, Minn.—During 1914, a steam shovel was used for the backfilling of large water main trenches in the streets of Minneapolis, Minn. Figure 180 shows the shovel in operation.

The shovel was equipped with a ¾-yd. dipper and the following is a statement of the cost of operation during an 8-hr. working day.

Labor:		
1 engineer	$6.00	
1 fireman	2.50	
2 laborers @ $2.50	5.00	
Total labor cost		$13.50

Fig. 180.—Revolving steam shovel backfilling large trench. (*Courtesy of City Engineer, Minneapolis, Minn.*)

Miscellaneous:		
Coal, ½ ton @ $6.00	$3.00	
Oil, grease and waste	0.15	
Repairs and overhead charges	1.05	
Total miscellaneous		$4.20
Total cost of excavating 354 cu. yd		$17.70
Cost of excavation of 1 cu. yd		$17.70 ÷ 354 = $0.05.

324. Grab Bucket Excavators.—Various types of dry-land excavators have been successfully used in trench excavation. The drag-line machine is not so well adapted to this class of work on account of the limitations of space for the operation of a scraper bucket, but this form of machine is very efficient in trench excavation through the softer soils when equipped with some form of grab bucket.

325. Use of Locomotive Crane in Indiana.[1]—A simple form of locomotive crane was used during the season of 1908 for the excavation of a sewer trench in Gary, Indiana. The excavator consisted of a ¾-cu. yd. Hayward orange-peel bucket operated by a 25 h.p. hoisting engine and a separate swinging engine. The whole machine was mounted on a heavy platform supported on rollers and moved ahead by means of a wire cable attached to a "deadman" ahead.

The trench had a rectangular cross-section of 30 ft. width and a depth of 12 ft., and in the bottom was a secondary rectangular channel, 10 ft. wide and 4 ft. deep. The material excavated was a fine lake sand and the last 3 to 4 ft. of excavation was in water.

The labor schedule was as follows:

1 engineer @ $6.00 per day
1 foreman @ $3.50 per day
5 laborers @ $1.50 per day

The work was commenced on April 2, 1908, and the first 1830 ft. were completed May 31, 1908. The machine was shut down 5 days for repairs and a night crew worked 13 extra shifts, so that a total of 51 shifts or working days were used for this work.

The following table will give the cost of the work.

Labor:		
1 engineer @ $6.00	$306.00	
1 foreman @ $3.50	178.50	
5 laborers @ $1.50	382.50	
Extra labor of engineer and fireman for 5 days making repairs	47.50	
Total labor expense		$914.50
Fuel and Supplies:		
Coal	$255.00	
Oil, waste and repairs	65.00	
Total		$320.00
Grand total expense		$1234.50
Total amount of excavation		21,250 cu. yd.
Cost of excavation, $1234.50 ÷ 21,250 = $0.058 per cu. yd.		

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[1] Abstracted from *Engineering-Contracting*, July 15, 1908.

326. Use of Locomotive Cranes in Kentucky.[1]—Three Browning locomotive cranes were used during the season of 1910 in the excavation of a large sewer trench in Louisville, Kentucky.

The trench was 2723 ft. long, the average depth of excavation was 22.4 ft., and the average amount of excavation per linear foot of trench was 12.25 cubic yards. The material excavated consisted of blue and yellow clay to a depth of 6 ft., yellow clay and loam for the next 6 ft. to 12 ft. and this was underlaid with fine and coarse sand.

The excavators were 10-ton Browning locomotive cranes, one of which was equipped with an automobile orange-peel bucket of 1 cu. yd. capacity and one with an automobile clam-shell bucket of ½ cu. yd. capacity. The cranes ran on a standard gage track of 60-lb. and 65-lb. rails. The cranes operated as follows: Crane No. 1, equipped with an Owens clam-shell bucket, moved along the trench and excavated the first 10 feet. to 12 feet. The sheeting was started as soon as practicable and Crane No. 2, equipped with a ¾ cu. yd. bucket, followed and removed the balance of the cut to grade. The excavated material with the exception of the sand was dumped into a spoil bank along the opposite side of the trench from the track. The sand was dumped into a screen and used for concrete. Crane No. 3 brought up the rear and did all the back-filling and pulling of sheathing and timbering.

The following are the labor costs per working day of 10 hours.

Crane No. 1

1 engineer	$3.50	
1 fireman	2.00	
1 tagman	1.75	
1 signalman	1.75	
Total labor cost		$9.00
Average excavation		200 cu. yd.
Cost of excavation for labor		$0.045 per cu. yd.

Crane No. 2

1 engineer	$3.50	
1 fireman	2.00	
1 foreman	2.00	
8 laborers @ $1.75	14.00	
Total labor cost		$21.50
Average excavation		225 cu. yd.
Cost of excavation for labor		$0.095 per cu. yd.

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[1] Abstracted from *Engineering-Contracting*, June 29, 1910.

Crane No. 3

1 engineer	$3.50
1 fireman	2.00
1 signalman	1.75
Total labor cost	$7.25
Average excavation	500 cu. yd.
Cost of excavation for labor	$0.0145 per cu. yd.

The average amount of coal used per crane per day was 1200 lb. at a cost of $4 a ton. About 160 gal. of water were used per crane a day.

The cranes cost $5000 each and annual interest and depreciation was allowed for at the rate of 15 per cent.

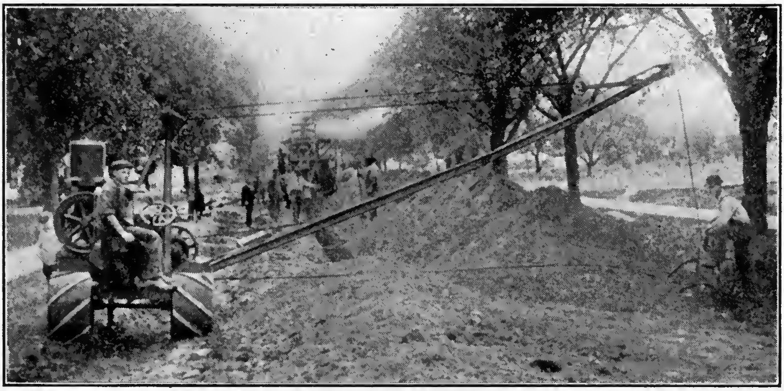

Fig. 181.—Backfilling machine operating on sewer trench. (*Courtesy of F. C. Austin Co.*)

327. Backfilling Machines.—During the last 5 years (1913–18), several backfilling machines have been put on the market and have proved to be efficient and economical. Backfilling is often an expensive part of sewer and water supply pipe trench work and the author knows of cases where this part of the work has cost more than the excavation. One machine should do the work of from 10 to 20 laborers and this is an economic necessity at the present time (1918), with the scarcity and high cost of common labor.

The backfilling machines of various makes are all of similar construction and method of operation. The following description is a detailed statement of a typical and well-known make.

The machine consists of a tractor and a scraper. See Fig. 181. The tractor comprises a frame 7 ft. × 10½ ft., mounted on four

30-in. wheels with 18-in. tires and having a wheel base of 5½ feet. At one side of the frame is an A-frame from the head of which is suspended a steel-framed boom having a reach of 22 feet. The operating equipment consists of a 10-h.p. gasoline engine which drives a double-drum hoisting engine, and the propelling gear. The clutches of the drums are operated by pedals, and the propelling-gear clutch by a lever. The machine is steered by a wheel. The excavating equipment consists of a steel-framed boom made in sections so that its length may be varied, and a steel scraper or scraper bucket. The scraper is operated by a drag-line and a hoisting line. When in position behind the spoil bank, the drag- or loading-line is hauled in, dragging the scraper to the edge of the trench. During this operation the hoisting line is paid out until the scraper is dumped, when this line is hauled in and the drag-line paid out. The scraper may be dropped into position or set into position by hand. One man is required to operate the tractor and one man to operate the scraper with some machines. Such a machine can operate at from 5 to 10 trips a minute depending on the soil and local conditions. This machine weighs about 6000 lb. and its traveling speed is about 2 miles per hour.

328. Continuous Bucket Excavators.—The continuous bucket excavator is especially adapted for the excavation of trenches, where the width does not exceed 6 ft. and the depth 20 ft., and the soil is not too hard or filled with obstructions. Such a machine is especially serviceable in the Middle West, where the surface is fairly level and the soil is a glacial clay, with few boulders or roots.

Recent makes of continuous bucket excavators are equipped with caterpillar tractors which allow the use of the heavy machines on soft, wet soils. Other important improvements are the reduction in the number and simplification of parts of the driving mechanism and the increased size and strength of the bucket chain. These recent developments have made it possible to use this type of excavator for the excavation of the harder soils such as indurated gravel, shale, etc. Figure 182 shows a trench excavator digging a trench 48 in. wide and 15 ft. 6 in. deep in Chicago.

A trench excavator is economical in the construction of trenches over 24 in. in width and 6 ft. in depth and one machine can perform the work of from 75 to 200 men. For an analytical comparison of trenching by machine and hand labor see Art. 86, page 124.

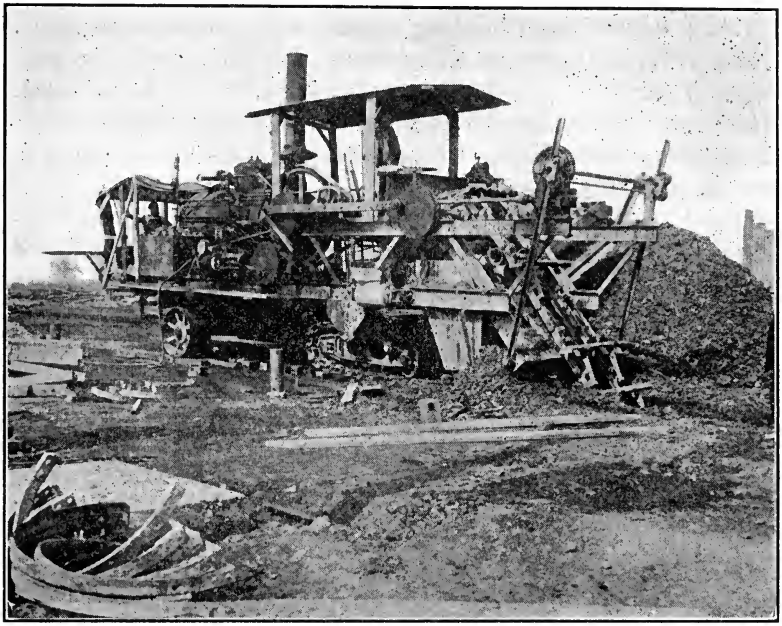

FIG. 182.—Continuous bucket excavator digging large trench. (*Courtesy of The Bucyrus Co.*)

329. Use of Trench Excavators in Illinois.[1]—Two Chicago Sewer Excavators were used in Glencoe, Illinois, for the excavation of trenches for a sewer system. The following gives a statement of the character of the work done.

15,500 lin. ft. of 8-in. pipe from 8-ft. to 12-ft. cut.
5,600 lin. ft. of 10-in. pipe from 7-ft. to 13-ft. cut.
250 lin. ft. of 12-in. pipe of about 13-ft. cut.
1,000 lin. ft. of 15-in. pipe of about 16-ft. cut.
4,700 lin. ft. of 18-in. pipe of shallow to 30-ft. cut.

The deepest cut of 30 ft. was made by grading down the street 3 ft. to 4 ft. and then using the excavator for the next 25 feet. The remaining foot or two was removed by hand in the bottom of the trench and the earth thrown into the boom or back upon the laid pipe. The width of trench cut was 33 in.,

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[1] Abstracted from *Engineering-Contracting*, April 5, 1911.

the sides were cut smooth and vertical and braced with vertical plank and jack screws placed about 3 ft. apart in the deep trenches.

The soil excavated was a hard clay. The upper 15 ft. was a brownish clay with slight traces of sand. During the fall and winter months, this material became hard, too hard to be dug by hand without the use of a pick. The excavator removed stones up to 1 ft. in size when wholly within the trench. When partly outside of the trench or when stones of larger size were encountered, they were removed by blasting. The ground was frozen at times up to a depth of from 14 in. to 16 in. but did not delay the work.

The work was carried on from August 1, 1910, to January 1, 1911. The following table gives the cost per day for the excavation of a trench 25 ft. deep, the laying of 18-in. pipe and backfilling.

1 foreman	$8.00
Excavating machine including operator	40.00
1 engineer	4.00
1 fireman	3.00
5 trenchmen @ $3.00	15.00
20 laborers, backfilling @ $2.50	50.00
2 teams @ $6.00	12.00
Coal	5.00
Repairs and sundry expenses	10.00
Total	$147.00
Length of trench excavated per day	80 ft.
Cost of work	$1.837 per lin. ft.

330. Use of Trench Excavator in Pennsylvania.[1]—A Pawling & Harnischfeger trenching machine, costing $5650.00, was used from May 1, 1917, to January 3, 1918, in the excavation of trenches for water mains in Erie, Pennsylvania.

During 1917, 10,000 ft. of trench for 6-in. water pipe was dug at a cost of $0.19 per lineal foot, with labor at $0.275 per hour. The material was clay with shale at the bottom of the trench.

The cost of excavation was based on the following unit prices: operator, $0.325 to $0.45 per hour; helper, $0.28 to $0.35 per hour; gasoline, $0.243 to $0.27 per gallon; oils, $0.095 to $0.115 per quart; and grease, $0.05 to $0.09 per pound. Eight jobs were

[1] Abstracted from *Engineering & Contracting*, May 8, 1918.

included in the work, the trench in all cases having a width of 2 ft. with depths varying from 5 ft. to 6 ft. and lengths of from 230 feet to 1000 feet. The cost per lineal foot of trench was about $0.009 for hard clay, $0.014 for sand, $0.12 for clay and gravel, $0.036 for hard shale and $0.065 for running sand and gravel.

A summary of the average cost of excavation for jobs Nos. 3 to 8 inclusive is given below.

	Cost per lineal foot of trench
Operator, 15 hr. @ $0.39	$0.0021
Helper, 15 hr. @ $0.315	0.0017
Gasoline, 61 gal. @ $0.251	0.0060
Oils, 13 qt. @ $0.11	0.0005
Grease, 5 lb. @ $0.065	0.0001
Total unit cost for 2727 lin. ft.	$0.0104

331. Use of Trench Excavator in Colorado.—A Buckeye ditcher, equipped with a 28-in. × 7½-ft. excavating-bucket chain, was used in the excavation of the earth section of a trench for a wooden water-pipe line in Greeley, Colorado.

The trench was 30 in. wide and 4 ft. deep and about 35½ miles long. The material for 8 miles was gravel, occasionally cemented together and containing many stones. For the remainder of the distance, the material was a tough clay.

The following data gives the amount of excavation, cost of operation of ditcher and of excavation.

Total length of ditch excavated	188,080 ft.
Total amount of excavation	69,659 cu. yd.
Total time employed	300 10-hr. days
Maximum excavation in gravel, per day	370 cu. yd.
Maximum excavation in clay, per day	925 cu. yd.
Average daily excavation	232 cu. yd.
Average daily progress	627 lin. ft.

Labor:		
1 engineer @ $5.00 per day	$1,500.00	
3 helpers @ $3.00 per day	2,700.00	
Total labor cost		$4,200.00
Fuel:		
300 tons of coal @ $5.00		1,500.00
Miscellaneous:		
Interest, depreciation and repairs @ $6.00		1,800.00
Total operating expense for 300 days		$7,500.00

The cost per lineal foot of trench was as follows:

Engineer	$0.008	
Helpers	0.014	
Coal	0.008	
Plant	0.010	
Total cost per lineal foot		$0.040

The cost per cubic yard of material excavated was as follows:

Engineer	$0.021	
Helpers	0.040	
Coal	0.021	
Plant	0.025	
Total cost per cubic yard		$0.107

The above cost data do not include general expenses, backfilling, moving the ditcher to and from the job, etc.

The original cost of the machine was $5200.00 and its working weight about 17 tons. The plant charges were estimated at about 30 per cent. per annum on the original cost and assuming the life of the machine as 5 years.

332. Trestle Cable Excavators.—The trestle cable excavator is especially adapted to the construction of large trenches where the working area is restricted as in city streets and alleys. This type of machine has the special advantage of operating systematically over the trench space and backfilling being carried on coördinately with the excavation. See Art. 89, page 130.

For ordinary trench construction, the simple, 6-bucket, single-track machine is efficient, but for very wide trenches and in hard material the double-track machine should be used.

333. Use of Trestle Cable Excavator in British Columbia, Canada.[1]—A Carson Trench Excavator was used in 1913, in the excavation of sewer trenches in Vancouver, British Columbia, Canada. The machine consisted of a 6-tub, single-track excavator occupying 340 ft. of street space and operating simultaneously in two 48-ft. lengths of trench.

The soft material required bracing which comprised sets of 1½-in. × 10-in. sheetings in 4-ft. lengths held in place by 3-in. × 12-in. stringers placed midway and braced by 4-in. × 4-in. transverse

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[1] Abstracted from *Engineering Record*, January 2, 1915.

struts on 8-ft. centers. This bracing was carried to a depth of 12 ft. 6 in. below which the trench width was decreased from 4 feet to 3 feet.

The operating crew consisted of 17 men as follows: 12 laborers to fill buckets, one lockman, one engineer, one timberman, one toolman and a straw boss. A gang of four men followed the excavation and laid the pipe. The following schedule of labor wage was used and gives the unit costs per hour based on an 8-hr. working day: Laborers, 40 cents; timberman, 42½ cents; lockman, 42½ cents; steam engineer, 53⅛ cents; toolman, 37½ cents; straw boss, 42½ cents; and one-half superintendent's time at 62½ cents.

The following statement is based on the excavation of 2700 ft. of trench for a 2-ft. trunk line sewer in a 20-ft. lane. The total output was 7700 cu. yd. and the average daily rate of excavation was 45 cu. yd. for 8 hours. The maximum depth of trench was 26 ft., the top width being 4 ft. and maintained to a depth of 12 ft. 6 in. and then carried on down with a width of 3 feet.

	Cost per cu. yd.
Labor (including superintendent and watchman)	$1.63
Hauling machine to job (total, $88.00)	0.0115
Erecting and dismantling machine (total, $96.00)	0.0125
Maintenance of plant	0.0428
Operating expenses	0.1126
Depreciation of plant[1]	0.0400
Interest @ 5 per cent	0.0200
Total	$1.8694

334. Trestle Track Excavators.—The trestle track excavator has about the same field of usefulness as the trestle cableway excavator. This type of machine is especially adapted to use on wide trench excavation particularly in congested city streets where part of the street must be kept open for traffic. See Art. 94, page 135.

On wide trenches, the use of a double-track machine equipped with two cars greatly increases the efficiency of the work.

335. Use of Trestle Track Excavator in Illinois.[1]—A Potter Trench Machine was used during the season of 1907 in the excavation of a large sewer trench in Chicago, Illinois.

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[1] Abstracted from *Engineering-Contracting,* October 9, 1907.

[1] Based on 10-year life and 5 per cent. rate.

The trench had a width of 21 ft. and an average depth of 30.5 feet. The materials excavated were, a top layer of black soil, then 15 ft. of soft blue clay, 6 ft. to 8 ft. of stiff blue clay, 1 ft. of sandy loam and finally about 2 ft. of hard blue clay.

The trench machine followed a derrick crane and excavated the last 12 ft. to 14 ft. in depth. Six buckets with a capacity of ½ cu. yd. each were used and so arranged that four were in the trench being filled while the remaining two were being carried away on the carriage and dumped.

The following table gives the cost of excavation on the basis of an 8-hr. working day.

Labor:		
1 engineer	$6.00	
1 fireman	2.50	
1 carriage operator	3.25	
1 carriage helper	2.50	
20 laborers in trench, @ $2.75	55.00	
1 laborer on dump	2.75	
1 foreman	3.50	
Total labor cost		$75.50
Fuel:		
½ ton coal @ $5.00		$2.50
Rent of machine @ $125.00 per month		$4.80
Total		$82.80
Average daily excavation		175 cu. yd.
Average cost of excavation, $82.80 ÷ 175 = $0.47 per cu. yd.		

336. Tower Cableway Excavators.—The tower cableway can be successfully utilized in trench excavation for work of large extent, where the width is over 6 ft. and depth greater than 15 feet. The machine is largely concentrated at the ends where the cableway is supported by light towers. The free space under the machine allows the placing of the excavated material and furnished protection from injury when blasting.

The cableway should be limited to a span of about 300 ft. in order to provide for the control of the buckets in hoisting and conveying. Even with short spans great care must be taken in operating the machine to prevent the displacement of the timbering and injury to the workmen.

337. Use of Cableway Excavator in Washington, D. C.—The following report is given to show the use of one of these cableways, for the excavation of a sewer trench in Washington, D. C., about 18 years ago (1895).

GENERAL DESCRIPTION OF THE WORK

The Easby's Point Sewer for about 1100 ft. from the outlet is D-shaped, 11 ft. 3 in. in width and 11 ft. 3 in. in height, and rests on a pile foundation. This is followed by a circular section 11 ft. 3 in. in diameter for a distance of about 2400 ft., then about 1000 ft. of 10 ft. 6 in., then about 1600 ft. of 9 feet 6 inches.

The first 1200 ft. of 11 ft. 3 in. circular is in a cut varying from 12 ft. to 40 ft. in depth, with about 10 ft. of clay and rotten rock on top of solid rock. This rock, while very hard, is badly broken up by seams running in every direction and at all angles with the horizon.

In spite of the most careful blasting and heavy bracing, the line of fracture would follow these seams to the surface, bringing in large masses outside the regular width of excavation. About 1000 lin. ft. of this work were done by steam derricks, and in places the slides were so extensive that the top width was more than 50 feet. The normal width of the trench was 18 feet.

As it was determined to increase the plant, a study of the different forms of trench machines was made, and the trench machines spanning the ditch were rejected for the following reasons:

1. Experience had shown that it would not be safe to do the heavy blasting required under them.

2. On account of the width of the trench, 18 ft., heavy timbering would be required to carry the machine, and in event of a slide the machine would be almost certain to go into the ditch.

3. As about 3000 ft. of the remaining distance would be made through ground where the banks could not be depended upon, it was not thought advisable to put any extra weight upon them or to subject them to the vibrations which would be occasioned by a machine spanning the trench.

As a cableway was not open to any of these objections, an order was given for one of the following:

General Dimensions

Length between end frames	300 ft.
Total length between anchorages	430 ft.
Height of frames	32 ft.
Diameter of main cable (steel)	1½ in.

Cylinder Dimensions

Engine, Lidgerwood	8¼ in. × 10 in.
Speed of hoisting	250 ft. per min.
Speed of conveying	400 ft. per min.
Lifting capacity	5000 lb.
Size of buckets	1 cu. yd.

CHARACTER AND AMOUNT OF WORK

Width of trench	18 ft.
Depth of lower shelf of trench on which cableway was started	15 ft.
Distance of carriage	150 ft.
Number of trips per hour	35
Number of hours per day	8
Number of cubic yards excavated per day	280

The material was cemented gravel and rotten rock which could have been removed cheaper by blasting than by picking.

OPERATING EXPENSES PER DAY

Engineer	$2.00	
Fireman	1.25	
Signal man	1.00	
Two dumpers @ $1.00	2.00	
Coal, oil and waste	1.50	
Interest and maintenance (estimated)	7.00	
Total		$14.75
Cost of picking and shoveling into tubs, 30 men at $1.00		30.00
Grand total		$44.75

Cost of picking, shoveling into tubs, hoisting from trench 15 ft. deep, conveying 150 ft. and dumping into wagons, 16 cents per cubic yard.

Cost for hoisting, conveying and dumping, 5³⁄₁₀ cents per cubic yard.

At the same time the excavating was going on, bracing and sheathing was being done, so that this represents what can be done in the regular order of working and was not a spurt to see what the machine could do when pressed. In fact, none of the men knew that the machine was being timed.

The conditions under which the machine was working were not favorable for making a record, as the bracing in the trench was too close together for the size of tub used. The engineer was a new man at the machine, although used to running a hoisting engine. Dumping into wagons consumed much more time than would have been required to dump on the work.

I think 300 cu. yd. can easily be handled in a day of 8 hr. in fairly good material in regular work, and no doubt under favorable circumstances the machine could be pushed much beyond this limit for a short time.

The machine has been at work about 3 weeks, but owing to the depth of the trench, 30 ft. to 40 ft., and the quantity of rock to be removed, it has not been moved. I am therefore unable to say how long this would take, but think the machine could be taken down, moved, and set up in a day or less.

Since the engine was fairly in working order the machine has not been stopped 10 min. for repairs or adjustment.

(Signed) FRANK P. DAVIS,
Civil Engineer.

B—TILE-TRENCH EXCAVATION

338. General.—Until about 20 years ago, trench excavation for drain tile was largely made by hand. However, in recent years with the rapid development of agricultural drainage, in the Middle West and South, has come the general use of machinery for tile-trench excavation and tile laying. In wet and soft soils machines equipped with caterpillar tractors must be used to distribute the weight of the machine over a large bearing area.

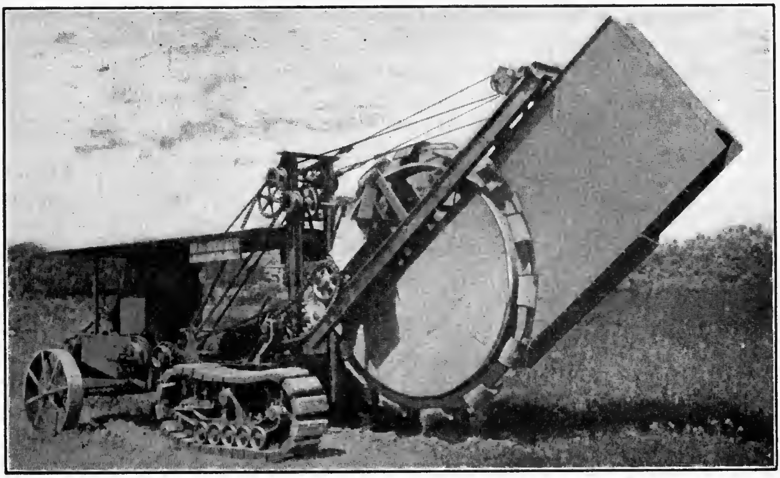

FIG. 183.—Tile-trench excavator with templet attachment.

One make of tile-trench machine uses a box or templet which follows the machine and automatically lays the tile. See Fig. 183. This is a useful device which requires careful machine operation and adjustment of the templet to secure satisfactory results. Hand laid tile is generally more accurate as to alinement and fitting of joints than that laid by machine.

Attempts have been made to use a longitudinal conveyor, which receives the excavated material from the transverse carrier and transports it to the rear of the work and dumps it over the newly laid tile. This device has not proved successful, as there is not sufficient time in which to lay the tile before the deposition of the excavated material.

The two general types of tile drain excavators are the continuous bucket or ladder machine and the wheel machine. The latter type has the more rigid excavating equipment and does away with the large number of parts and opportunities for breakage of the bucket chains. However, the wheel machine is generally more limited as to its field of work than the chain machine with adjustable frame and removable buckets.

339. Use of Tile-trench Excavator in Ohio.—During the year 1910, a Buckeye ditcher equipped with a gasoline engine and capable of digging a trench 14½ in. wide × 4½ ft. deep has been used near New London, Ohio. About 12 miles of trench were dug, with an average depth of 2½ feet. The soil excavated was loam and clay, which was rather hard during the dry season and sticky when wet. The excavator was equipped with apron or caterpillar tractions and passed through several swamps. The following table gives the average cost of excavation for the season:

	Cost per rod
Operator	$0.03
Gasoline @ 13¢ per gallon	0.018
Repairs	0.024
Oil and grease	0.001
Total cost per rod excavated	$0.073

One man was found sufficient to operate the machine satisfactorily. The average cost of excavation of tile trenches by hand in the same locality the previous season was 35 cents per rod.

Near Fremont, Ohio, the following record was kept of the use of a Buckeye ditcher during an 11-hr. working day in September, 1910. The excavator was a steam-power machine with a capacity of 11½ in. wide × 4½ ft. deep. The total excavation made was 270 rods of trench with an average depth of 2 ft. 4 inches.

The following table gives the cost of the work for the 11-hr. day:

Operator	$2.50
Fireman	1.50
Cylinder oil	0.23
Machine oil	0.10
Total cost of excavation	$4.33

Fuel and water were supplied by the land owner.

340. Use of Tile-trench Excavator in Indiana.—A Pawling & Harnischfeger Tile-trench excavator was used in 1915, for the construction of tile drain trenches in gumbo soil. The trenches were 11½ in. wide and from 36 in. to 44 in. in depth.

The following table gives a statement of the performance of the machine on several divisions of the job.

Table XXIX.—Cost of Tile-trench Excavation

Item	Division of work					
	A	B	C	D	E	F
Time operated, hours	10½	11	11	11	11	12
Time delayed, hours*	3	3	2	2	3	2
Net operating time, hours	7½	8	9	9	8	10
Gasoline, gal. @11½¢	12	13	15	15	13	20
Cost of fuel and lubricating oil	$1.68	$1.65	$2.17	$2.17	$1.85	$2.90
Number of laborers	3	3	3	3	3	4
Labor cost per day	$6.50	$6.50	$6.50	$6.50	$6.50	$8.00
Total cost per day	$8.18	$8.35	$8.67	$8.67	$8.35	$10.90
Trench, depth	42 in.	42 in.	42 in.	44 in.	42 in.	36 in.
Trench, length in ft	1650	1952	2887	2310	2838	5032
Cost per lin. ft	$0.0050	$0.0043	$0.0030	$0.0037	$0.0029	$0.0021
Cost per cu. yd	$0.0398	$0.0345	$0.0241	$0.0289	$0.0237	$0.0204

* Including noon period 1 hr. or 30 minutes.

341. Use of Tile-trench Excavator in Wisconsin.[1]—The following statement gives an analytical conception of the cost of operation of a drainage excavator with a four-cylinder motor of 20 h.p. and 700 r.p.m. The trenches were 15 in. wide and varied in depth from 30 in. to 36 inches. The material excavated was gumbo, which was in a wet, sticky condition during the work.

[1] From statement furnished by Pawling & Harnischfeger Company, Milwaukee, Wis.

TABLE XXX.—OPERATING COST OF TILE-TRENCH EXCAVATOR

Test No.	Time			Fuel				Labor[1]		Total cost	Output[2]		Unit cost	
	Operating time in hours	Delays in hours	Net operating time in hours	Gasoline in gallons	Gasoline cost per gallon	Lubricating oil cost	Total cost	No. of men	Cost		Depth of trench, in.	Length of trench, ft.	Cost per lin. ft.	Cost per cu. yd.
1	8.0	2.0	7.0	13	$0.095	$0.31	$1.55	3	$6.00	$7.55	36	2211	$0.0034	$0.0280
2	6.5	3.5	4.5	16	0.095	0.35	1.87	3	4.86	6.73	30	2640	0.0024	0.0235
3	10.0	1.5	9.0	15	0.095	0.35	1.78	3	7.50	9.28	30	2475	0.0037	0.0380
4	10.0	1.5	9.0	15	0.095	0.35	1.78	3	7.50	9.28	30	2475	0.0037	0.0380
5	10.0	1.0	0.0	20	0.095	0.45	2.35	3	7.50	9.85	30	3300	0.0029	0.0290
6	10.0	2.5	8.5	18	0.095	0.40	2.11	3	7.50	9.61	30	2970	0.0032	0.0360
7	10.0	0.5	10.0	21	0.095	0.60	2.60	3	7.50	10.10	30	3465	0.0029	0.0235
8	10.0	1.5	8.5	20	0.095	0.60	2.50	3	7.50	10.00	30	3300	0.0032	0.0293
9	10.0	0.5	10.0	21	0.095	0.60	2.60	3	7.50	10.10	30	3382	0.0029	0.0290
10	10.0	0.5	10.0	30	0.115	0.75	4.20	3	7.50	11.70	30	5115	0.0022	0.0150

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[1] The labor cost is based on wages of $3.00, $2.50 and $2.00 per day for the three men.

[2] The trenches were 15 in. in width.

II. FOUNDATION AND BASEMENT EXCAVATION

342. General.—Until recently, basement excavation of buildings and other foundation work was generally done by hand labor. With the development of building construction to high office buildings and large industrial plants, the great magnitude of excavation operations has occasioned the use of systematic methods and of machinery.

The type of excavator to use in any case depends largely upon the depth and area of excavation, the character and condition of the soil, the length of haul, the machinery available, the cost and availability of labor, fuel, etc., etc. When the magnitude of the job is 50,000 cu. yd. or over, some form of power excavator can generally be economically employed. For shallow excavation in light soft soils, the four-wheel scraper can be efficiently used, but for deeper cuts (usually over 3 ft.) the revolving shovel should be used. Cableways are especially useful in deep excavation for the raising and transporting of skips or buckets which are loaded by hand or by a power excavator. For shallow excavation of great extent and where the material is to be wasted along the side, a tower cableway may prove to be the most efficient machine. The author, in connection with a large industrial project recently, planned for the use of a loading platform with a tower cableway excavator. The scraper bucket would be drawn up over an inclined "run" and discharge through an open trap into dump wagons below. This method was not tried out, as four-wheel scrapers were available and used instead of the tower cableway, but the author believes that it could be economically used.

343. Scrapers.—The scraper is efficient in the removal of earth where the amount of material is small, the depth of cut light and the haul not too great. The slip or drag scraper can often be used satisfactorily for the stripping of the upper layers of soil and for hauls under 300 feet. The four-wheel scraper is the most efficient machine for hauls over 300 ft. and for all classes of earth. Where the material is dense and stiff, a traction engine shold be employed for loading the scrapers.

344. Use of Wheel Scrapers in Connecticut.—Wheel scrapers and hand excavation were used in a building being constructed for the Stanley works, of New Britain, Conn. The building is rectangular in form, 63 ft. wide and 203 ft. long. The general plan is shown in Fig. 184. The plans call for a seven-story building, of the mushroom system of reinforced-concrete construction, without a basement.

The building site is a plot of ground surrounded by one-story frame structures, and until recently used for the storage of great piles of thin sheet steel. This plot was formerly a peat bog, which was filled in with ashes, cinders and slag from the power plant. Six test pits were dug to a depth of about 6 ft. below the general ground level, which was nearly that of the finished basement subgrade. The ashes and cinders made a top fill of about 2½ ft. in depth. Underlying this fill was about 1 ft. of peat, then about 3 ft. of red clay and then the foundation material of a dense shaly gravel. In places a large number of glacial boulders ranging in size from 1 ft. to 4 ft. were found distributed through the gravel. At an average depth of about 7 ft. below the subgrade elevation, water was encountered, and in some pits an inflow in the form of a steady, continuous stream took place.

The problem was peculiar and difficult in this case, since there was not to be a basement and the net excavation was the removal of sufficient material for the building of 18 interior footings 15 ft. square and 6 ft. 9 in. below subgrade, 22 exterior footings 12 ft. square, and four corner footings 10 ft. square and 7 ft. 3 in. below subgrade. On account of elevator pits and a conduit tunnel terminal, two interior column footings were carried to a depth of 10 ft. 6 in. and one interior and two exterior footings to a depth of 8 ft. 6 in. below subgrade. Allowing for the side walls, column stubs, and tunnel, the total gross excavation required was about 2500 cu. yd., with a backfill to subgrade elevation of about 1500 cubic yards. It is, therefore, evident that 1000 cu. yd. of material was to be permanently removed and wasted. After a preliminary study of the conditions it was decided to scrape off from the surface with two-wheel scrapers the 1000 cu. yd. of superfluous material, and then excavate the footing pits to grade with pick and shovel.

The cinder fill was found to be very dense and compact, and a two-horse plow was necessary to loosen up this material for the scrapers. Four, five and six two-wheel scrapers were used on consecutive days to remove this surface material from the building site to the dump, which was located about 300 ft. from the south end of the site. Hence the average length of haul was about 400 feet. Each scraper was operated by two horses and a driver, and no snatch team was used for loading, as the plowing up of the material rendered it loose enough to be loaded easily into the scrapers by the regular team alone. The net capacity of each scraper was ½ cubic yard. The average time for the round trip for the average haul was 4½ minutes. Two men were used to load the scrapers and two to dump and spread the material. A foreman supervised the loading, and a clerk at the dump kept a time record and superintended the dumping. Following is a schedule of the labor cost of the wheel-scraper work per 9-hr. day:

1 foreman a $6.00 per day	$6.00
4 laborers at $0.25 per hour	9.00
1 clerk at $10.00 per week	1.67
6 teams at $0.60 per hour	32.40
Total	$49.07

Six scrapers gave the most efficient results and required the constant use of the plow for loosening. The average cost of excavation under these conditions was 25 cents per cubic yard. The local teamsters were inexperienced in wheel-scraper work, and strongly protested against the use of these machines. The writer believes that the use of the 1-yd. four-wheel scraper would have eliminated this discontent and inefficiency, and reduced the excavation cost to about 15 cents per cubic yard. This superficial excavation was made with an average cut of 1 ft. at the south and 3 ft. at the north end.

BULKHEADS BETWEEN FOOTINGS

If the hand-excavated material from the footing pits was shoveled into wagons, hauled away, dumped and then hauled again for the backfill, it was evident from the experience gained in digging the test pits that the cost would be excessive. Hence the author devised the scheme of building wooden bulkheads between the footings. These bulkheads were made about the length of the side of each footing and were placed only on the transverse spaces between footings. This arrangement left open two continuous aisles or runways longitudinally, between the exterior and the interior lines of footing pits. See Fig. 184.

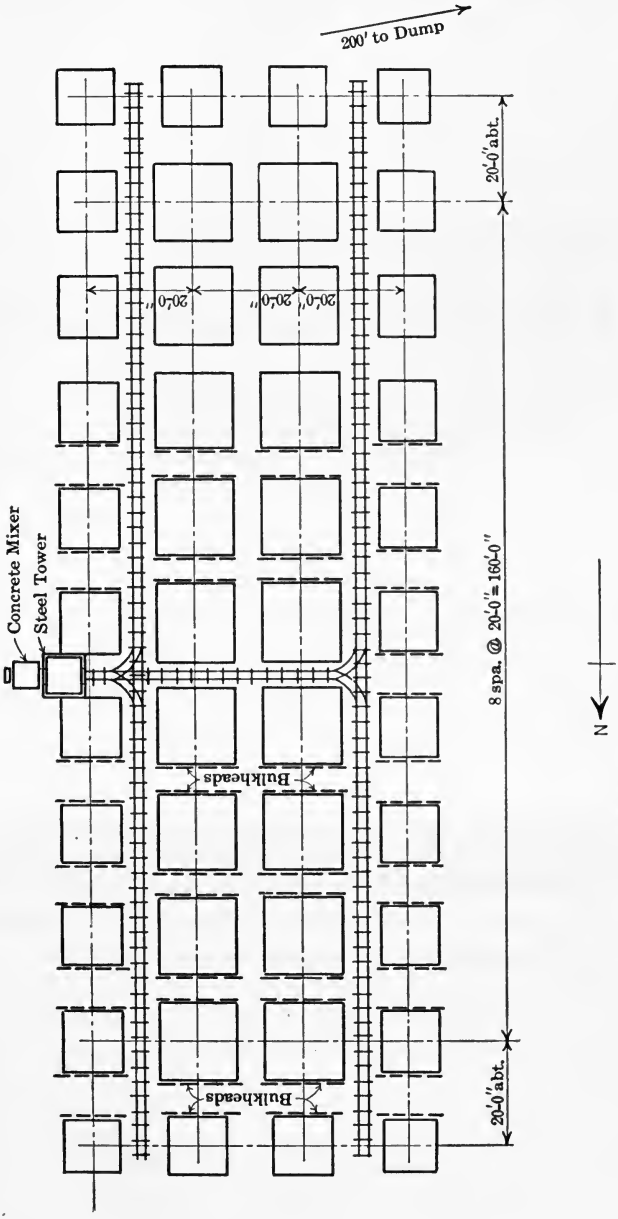

FIG. 184.—Excavation plan of reinforced concrete industrial building.

Each bulkhead was composed of two parallel walls of 2-in. × 12-in. planks, placed with the 12-in. face vertical, and held in position by three bents composed of two 4-in. × 4-in. posts and cross-bracing at top and bottom. These bents were erected first and the planks added as the excavated material from the pits was piled up. Figure 185 shows the bulkheads during the early part of the excavation of the pits for the footings. The excavated material was shoveled directly into the bulkheads until they reached a height of about 4 feet. Then it became necessary to shovel the material to the surface at the open sides and reshovel into the bulkheads. The latter were often carried to a height of 8 or 9 ft., and were cross-braced with 4-in. × 4-in. struts across the pits. After nearly a week of continued heavy rains it became necessary to sheath and brace the loaded sides of the pits, as the clay became saturated with water and began to slide and cave in. This rainy season necessitated a great deal of extra pumping, although the inflow of underground water ordinarily began about 6 ft. below the subgrade elevation. The excavation of the four deep pits at the north end of the site required the removal of a large number of big boulders and necessitated almost constant pumping to remove the inflow of subsurface water. One gasoline power diaphragm pump and four hand pumps were used.

Fig. 185.—View of bulkhead method of footing pit excavation. (*Photo by Author.*)

METHOD OF PROCEDURE

The excavation for the two end and the following eight interior footing pits was started first and carried down within about 1 ft. of grade during the erection of the pouring tower and mixer plant. As soon as the pouring of the concrete began, the pits were carried down to grade consecutively, so that the concreting closely followed the excavation and both operations became continuous.

The narrow-gage track for the side-dump cradle concrete cars was laid along the two aisles or lanes between the adjacent rows of interior and exterior footing pits. A cross track was also run directly from the tower, connecting the two longitudinal lines of track. The latter were laid on a grade of about 0.5 per cent. from the south to the north end of the excavation. As soon as the north footings were completed, the surplus material from the southerly pits was loaded into concrete cars, moved down to the completed work and dumped into the pits for backfill.

The excavation of the exterior footing pits, at the north end of the site, was begun as the pouring of the adjacent interior footings neared completion. The excavated material from the upper sections of these side pits was shoveled directly into the center pits of completed footings. All backfill was thoroughly tamped in layers with a heavy iron hand tamper.

LOOSENING THE MATERIAL

Before the excavation of the footing pits in the south half of the site was started, blasting was resorted to for the purpose of loosening the soil and thus reducing the amount of picking necessary. Each pit was blasted separately and the operation was as follows:

Two laborers, equipped with a conical-pointed iron bar 1½ in. in diameter and a sledge, drove two holes about 4 ft. deep and from 6 ft. to 8 ft. on centers on the axis of each pit. In each hole the blaster placed first a half-cartridge of 40 per cent. dynamite, which he had previously slitted with a knife, and then another half-cartridge containing the exploder. From the exploder lead wires extended up out of the hole to the two main wires of the firing machine. A small amount of earth was tamped upon the top of each charge with a 6-ft. wooden rod. Each blast was protected with a heavy tarpaulin and several heavy timbers. The surface of the ground was but slightly heaved by the blast, but had the appearance of having been thoroughly churned. A crowbar was easily thrust down to its full length into the loosened soil.

The following is an estimate of the cost of loosening up about 500 cu. yd. of soil in 20 pits during a working period of 5 hours:

Materials:		
20 lb. 40 per cent. dynamite @ 17¢	$3.40	
40 exploders @ $4.50 per 100	1.80	
Total		$5.20
Labor:		
1 blaster[1] @ $5.00 per day	$3.35	
2 laborers @ 20¢ per hour	2.40	
Total		$5.75
Grand total		$10.95
Cost of loosening 1 cu. yd., $10.95 ÷ 500 =		$0.0219

The bulkheads of the northerly footings were taken down and moved to the south end of the site and erected for the storing of the material being excavated from the pits at that point. The spoil banks left after the removal of the bulkheads were spread uniformly over the spaces between the column stubs, and the whole area was brought up to the subgrade or elevation of the concrete first floor.

COST

The average unit cost of excavation was $0.278 for the wheel scrapers, $0.407 for the drag scrapers, about $0.40 for hand excavation in dry soil and $0.78 for hand excavation in wet soil and rock.

345. Power Shovels.—The most universally used and efficient form of excavator for basement and foundation work of considerable magnitude is the power shovel. For jobs of 100,000 cu. yd. and over and where hard-pan and rock are to be handled, the large, fixed-platform type of shovel should be used. But for the lighter, softer materials, the revolving shovel is the most serviceable on account of its ease and rapidity of operation,

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[1] The blaster was an expert representative of a well-known power manufacturer and furnished the firing machine, wires, drill rod and tamp rod.

portableness and control. The efficiency of steam-shovel operation in this class of work depends to a great extent upon the handling of the shovel and the proper supply of wagons so as to keep the machine operating during at least 60 per cent. of the working time. The machine should be moved or routed over the area to be excavated so as to eliminate lost time and motion, and as far as possible, to work in one continuous path.

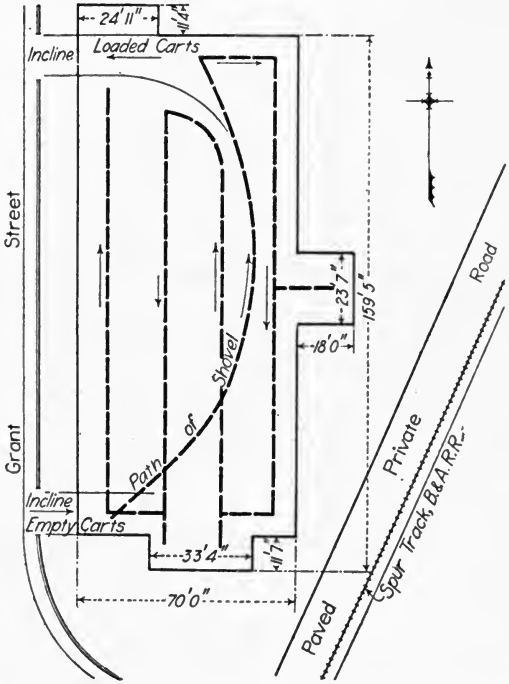

Fig. 186.—Path of steam shovel.

346. Use of Steam Shovel in Massachusetts.—A steam shovel was used in excavating for a modern building, which was constructed for the Dennison Manufacturing Company, of South Framingham, Mass. The building is rectangular in form, 70 ft. × 159 ft. 5 in., with two projecting stair towers and a toilet tower. The general plan of the building is shown in Fig. 186. There is a basement and four stories, and the girderless floor or mushroom system of reinforced-concrete construction was used throughout.

The west side of the building is nearly parallel to a public thoroughfare which winds around the south side, and this provides three points of access to the site. As the gate on the south side was used for the large traffic of the Dennison Manufacturing Company, however, it was not deemed advisable to use this gate in the excavation work for the passage of teams.

The soil excavated was a fine, clean, siliceous sand, in beds from 3 ft. to 7 ft. in depth, and separated by strata of yellow clay, of a depth of 1 ft. or 2 feet. The excavation was carried down to a gravel subsoil, upon which the footings were placed. The depth of excavation varied from 8.2 ft. to 10.5 feet.

The excavated material was used to fill up two low, swampy tracts of land which were located about 1/3 mile from the site of the building. This property belonged to the Dennison Manufacturing Company, and was being graded up for the building of houses for the company's employees.

METHOD OF EXCAVATION

A new Thew Automatic revolving steam shovel, type O, equipped with a 5/8-yd. dipper, was used for the bulk of the excavation. The manufacturers furnished an expert engineer who set up and operated the machine for several days, during which time he broke in a "green hand" as the runner. The latter operated the shovel without aid or supervision during the last 10 days of the work.

The shovel began operations near the southwest corner of the building plot, and excavated a cut about 15 ft. wide on a descending grade of about 10 per cent. As the shovel approached the northeast corner of the plot it reached the finished grade, which was about 10.5 ft. below the original ground surface at this point.

PATH OF SHOVEL

The path of the shovel is shown by the dash line in Fig. 193. The east side of the excavation was completed first, as it was desirable to construct the footings and erect the basement column forms along this side, adjacent to the mixer plant and pouring tower, as early as possible. While the shovel was excavating in a southerly direction along the east side, a slip scraper was used to cut an inclined road from the north gate on Grant Street, along the north side of the plot, and curving and descending on a grade of about 6 per cent. to the bottom of the excavation near the north end of the toilet tower. After the shovel had started on its second trip along the plot, the wagons came in at the south gate on Grant Street, passed down the incline along the south side of the plot, around the east side of the shovel, where they loaded and passed up the north incline and out the north gate on Grant Street, to the dump.

SUPPORT FOR SHOVEL

On account of the loose character of the soil and the inflow of water when the excavation reached grade, it was necessary to support the shovel on planking. A movable, sectional, platform was built of 4-in. × 8-in. timbers, bolted together to form sections 3 ft. wide and 12 ft. long. Four of these sections were used on straight stretches, and two triangular-shaped sections, half the size of the rectangular sections, were employed on the turns. Near the center of both ends of each section was placed a heavy iron eye by means of which the section could be shifted around with a chain attached to the dipper arm.

Neglecting time lost through breaks in machinery, inclement weather, etc., the shovel was excavating about 60 per cent. of the working time. Special effort was made to keep the shovel always supplied with wagons to load, and very little delay was occasioned from waiting for teams. From two to three shovelfuls were required to load each wagon to an average capacity of about 1⅓ cu. yd. (loose measurement). On account of the looseness of the material, the average shovelful was about ½ cubic yard. Based on a large number of observations, the average time to make a complete dipper swing was 26 sec. and the minimum time was 18 seconds. The average time to load a wagon, with three swings, was 1 min. 46 sec., and the minimum time was 1 min. 21 seconds.

LABOR AND FUEL COSTS

The labor crew consisted of one foreman, one engineer, one fireman and two pitmen, or laborers. Following is a schedule of labor expenses per day of 9 hours:

1 foreman @ $6.00 per day	$6.00
1 engineer @ $0.45 per hour	4.05
1 fireman @ $0.30 per hour	2.70
2 pitmen @ $2.03 per day	4.06
Total labor cost per 9-hr. day	$16.81

Water was supplied to the boilers through a rubber hose. Coal and coke were hauled thrice daily from a pile on the east side of the excavation and shoveled into a large wooden bunker built on the rear of the machine. The fuel cost for the operation of the shovel was as follows:

7 tons coal @ $6.25	$43.75
1 ton coke @ $6.75	6.75
Total cost of fuel	$50.50

The excavation was leveled up and made closely to grade by the use of a slip scraper, which was attached by a chain to the dipper handle. This work was done as far as practicable, during the short periods of waiting for wagons, at the beginning and end of each day's work. The method of operating the slip scraper is shown in Fig. 187.

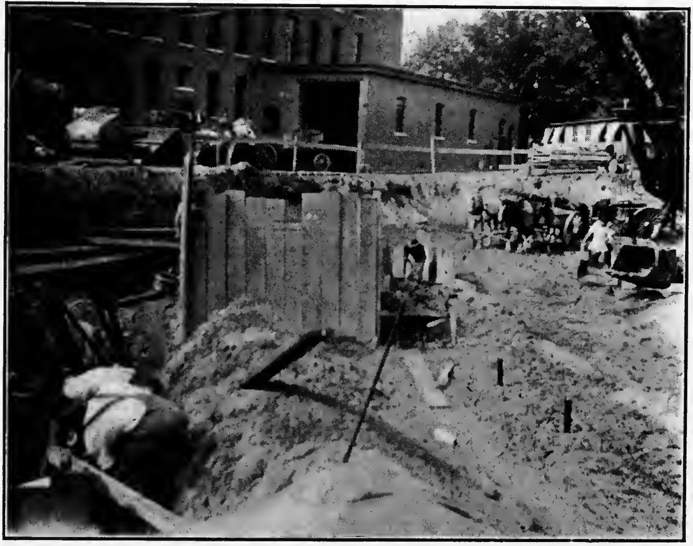

FIG. 187.—Levelling-up basement excavation with scraper. (*Photo by Author.*)

The hauling away of the excavated material was done by rear dump carts hauled by two horses. These carts had a rated capacity of 1 cu. yd., and were generally filled by three dipperfuls to a capacity of 1⅓ cubic yards. Care was taken to place the bulk of the load over the rear axle, so as to facilitate the dumping. From 8 to 14 teams were used and the latter number proved to give the most efficient operation of the shovel. The average haul was 1800 feet. The teams were run continuously in a circuit, and except for a short distance (about 200 ft.) the loaded teams were not allowed to pass the unloaded teams. Bunching of the teams was largely eliminated by careful supervision of the dumping and the movement of the carts along the road. A decided tendency to lag was noticed each day during the last hour of work. Some drivers would stop work during the last half hour if they thought that another load would take until after 5 o'clock to dump. In the morning several teams were usually late in arriving at the shovel for the first load. In order to eliminate these times losses, at the end of the first week's work, a bonus of 25 cents was offered to each driver who made 24 trips per day. During the first day's work under the bonus plan, one man made 25 trips, four men made 24 trips and seven others raised their previous day's record by one trip. After a study of this result, a bonus schedule was established as follows: 25 cents per day per man for 24 trips; 40 cents per day per man for 25 trips; 50 cents per day per man for 26 trips.

A study of the haulage record was made and shows that the average number of trips per day per team for the last full day's work (July 22) was nearly 25. Several teams made 26 trips per day.

TIME RECORDS

A timekeeper stationed near the building site kept a record of the time each team entered the south gate and left the north gate. This record served to show the character and length of delays in the yard, such as loss of time in pulling up to shovel, and delay at the shovel. The dump foreman kept a record of the time of arrival of each team at the dump, and also of any delay in dumping and leaving the dump. The watches of the yard timekeeper and the dump foreman were synchronized daily. At the end of each day's work, the two records were compared and a study was made to determine the number, character, length and cause of all delays, the inefficient teams, the proper size and distribution of the load in the carts for efficient hauling and dumping.

The average length of haul was 1800 feet. The average time to make a round trip was about 21.5 min., and the minimum time was 15 minutes. Each of the two dump sites was a low, swampy basin which it was desired to grade up to the level of the adjacent streets. The fill at each site was made at two points simultaneously and was built out from firm soil by rear dumping from platforms. These platforms were made of several sections of 2-in. × 12-in. planks 16 ft. long, cleated together on the under side. As the dump was carried out, the sections of platform were moved ahead. Railroad ties were used as dumping blocks. To facilitate the dumping, especially when the sand and clay was wet and sticky, the drivers greased the main axle trunnions and salted the inside surfaces of the carts each morning before starting work. The depth of fill varied from 0 ft. to 7 feet.

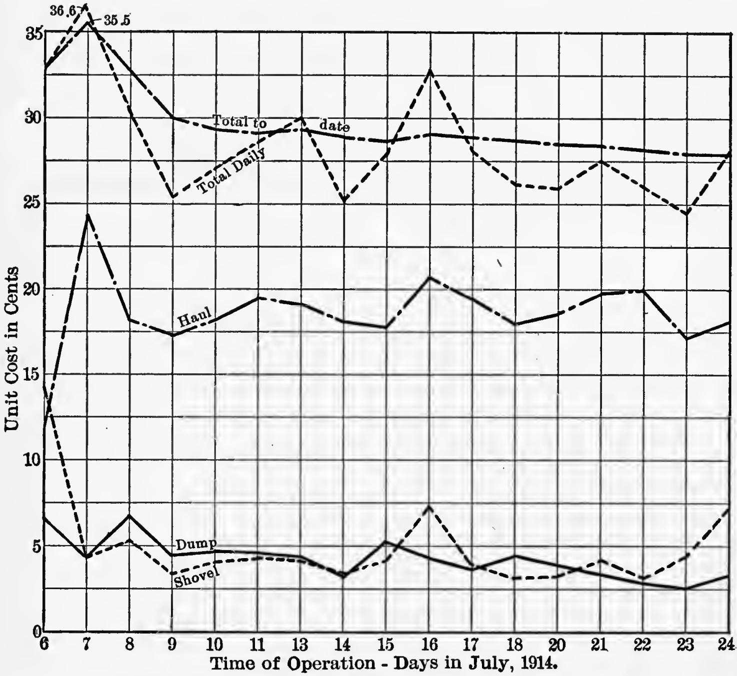

FIG. 188.—Cost of steam shovel excavation of basement of large industrial building.

The labor used in operating the dump during the first week consisted of a foreman, a subforeman and four laborers. This force was gradually reduced to a foreman and three laborers during the last four days of work. Thus an economy of 30 per cent. was effected during the time that an increased output of 16 per cent. occurred. Figure 188 and Table XXXI give a summary of the total daily and the unit costs for the various divisions of the work and the job as a whole.

Table XXXI.—Cost Summary—Steam-shovel Excavation of Basement for Building for Dennison Manufacturing Company, South Framingham, Mass.

Date, 1914	Daily cost of shovel excavation	Daily cost dump	Daily cost shovel repairs	Daily cost of hauling	Total cost to date	Daily yardage	Total yardage to date	Daily total unit cost	Average total unit cost to date
July 6.....	$11.89	$5.63	......	$9.76	$27.28	83	....	$0.329	$0.329
July 7.....	18.79	9.69	......	49.50	105.26	213	296	0.366	0.355
July 8.....	16.56	20.72	......	55.00	197.54	304	600	0.303	0.329
July 9.....	13.41	17.17	......	66.00	294.22	379	979	0.254	0.300
July 10.....	15.45	17.18	......	66.00	392.75	361	1340	0.273	0.294
July 11.....	15.41	15.71	......	66.00	489.87	336	1676	0.287	0.292
July 13.....	14.84	15.47	$10.24	66.00	596.42	343	2019	0.301	0.295
July 14.....	12.69	12.89	......	66.00	688.00	364	2383	0.251	0.289
July 15.....	15.96	19.31	2.35	65.38	791.00	369	2752	0.279	0.8275
July 16....	24.55	14.24	1.35	67.82	898.96	329	3081	0.328	0.292
July 17.....	15.50	14.24	2.49	74.54	1005.73	380	3461	0.280	0.290
July 18.....	13.23	18.51	1.57	73.49	1112.53	408	3869	0.261	0.2875
July 20.....	12.68	15.38	......	73.93	1214.52	395	4264	0.258	0.285
July 21.....	14.40	11.51	......	66.50	1306.93	335	4599	0.276	0.285
July 22.....	13.14	11.65	......	82.75	1414.47	412	5011	0.261	0.282
July 23.....	20.83	11.63	0.90	79.50	1527.33	461	5472	0.245	0.279
July 24.....	12.48	5.61	......	30.42	1575.84	167	5639	0.280	0.279

Item	Total cost	Unit cost per per cu. yd.[1]
Labor of shovel	$262.31	$0.0515
Labor at dump	236.53	0.0464
Labor on roads and inclines	18.90	0.0037
Teams and hauling	1058.59	0.2078
Superintendence, etc	150.00	0.0294
Lumber for inclines, platforms, etc	250.00	0.0491
Unloading, setting up, dismantling and loading shovel	179.05	0.0351
Rental of shovel	390.00	0.0765
Coal, oil, waste, repairs, etc	66.60	0.0131
Total	$2611.98	$0.5126

347. Résumé.—The trench excavator is an efficient and economical machine where the magnitude of the job warrants its installation and use. The depth of trench which governs the use of machinery is about 8 ft. for pipe-trench work and 3 ft.

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[1] Based on total computed excavation (place measurement) of 5095 cubic yards.

for tile-trench work. The type of excavator to use in any case depends upon the character and extent of the work, the dimensions of the trench, the kind and condition of the soil, the availability and cost of labor and fuel, etc.

The selection of a machine for pipe-trench work should be made with great care in order to secure the excavator best suited to local conditions. For ordinary trench excavation where the soil is firm and free from obstructions, and where the width and depth of trench do not exceed 72 in. and 20 ft., respectively, the continuous bucket excavator is the most efficient machine. Where the soil is very hard or where large boulders and other obstructions abound, the trestle cable or trestle track machine should be used. These latter types of machines are especially useful in the excavation of trenches over 6 ft. in width, and where the work is done in restricted areas. In rough country, such as valleys, the cableway excavator can be used to advantage to span the depressions and uneven surface conditions. The trestle cable, trestle track and cableway excavators have the special advantage of doing the work in sections and backfilling one part as the other part is being excavated.

For the construction of tile-drain trenches, the former may often use a form of ditching plow, where there is not more than about 3 miles of line. However, in hard or rocky soil and where a trench machine may be used, the latter is the more economical and efficient. Where any land owner has over 15 miles of tile trench to construct, the purchase of a trench excavator would be justified, assuming a sale value of about one-half the initial cost. Some forms of machine have a detachable excavating equipment, so that the operating section may be used as a tractor for general farm service. Such an arrangement would also be of use to the contractor for the purpose of haulage, etc.

Trench excavators are peculiarly susceptible to breakage and delays on account of faulty operation. The land owner or contractor in selecting a machine should have in mind the following requisites; simplicity of construction, small number of parts of operating and excavating equipments, high grade of material and excellence of the proportion of the various parts of the whole machine.

The excavation of basements and foundations for various kinds of structures is a problem which requires the careful study of the conditions of each case. There is probably no class of excavation work where there is greater opportunity for the use of judgment and the exercise of ingenuity in the selection and adaptation of machinery. The attention of the reader is called to Arts. 344 and 346, pages 458 and 465 for analytical discussions of two typical cases of basement excavation.

348. Bibliography.—The reader is referred to Art. 105, page 143, for further references.

CHAPTER XXII

QUARRIES, OPEN-CUT MINES, GRAVEL PITS AND BRICK YARDS

349. Preliminary.—Modern open-cut excavation of mines, gravel and sand pits, stone quarries, clay pits, etc., has undergone a great development during the last 18 years (1900–18). The former crude and uneconomical methods of hand, wheel-barrow and cart work have been largely superseded by the use of power equipment, consisting of excavating, conveying and transporting machinery.

The development of large open-cut mines, quarries and pits is most efficiently done with power excavators; the revolving shovel, the fixed-platform shovel, the drag-line excavator, etc. The type of excavator and transportation equipment to use, in any case, depends on the character of the material, the area of the excavation, the depth of cut, length of haul, etc. Special machinery has recently been devised for the excavation and operation of sand and gravel pits.

The method of excavation of quarries, open-cut mines and pits will be described in detail in the following series of articles, which are abstracted from data compiled in 1914 by the author for the "Concrete-Cement Age."

350. Use of Excavating Machinery in the Cement Quarry.—The development of the American Portland Cement industry and the universal use of concrete during the past decade, have necessitated the opening up and excavation of great quarries. Cement plants have been located near the natural deposits of clay, shale, marl and limestone, which are of sufficiently uniform character and in large enough quantity to warrant a permanent installation. In some cases, notably in the Middle West, the limestone is quarried from some great deposit of excellent character and shipped to the cement plants at a distance. Stone which is not suitable for the manufacture of cement or for building purposes is generally valuable for concrete aggregate, road metal and railroad ballast. Whatever the ultimate use of the stone, it must be removed from its native ledge, transported to the crusher, and broken into small fragments.

The purpose of this article is to discuss the methods of the excavation of the raw material used in the manufacture of cement and its transportation to the crushers or the material storage house. These are the first steps in the manufacture of cement and although of prime importance are rarely given proper consideration. Their performance is largely governed by local conditions of quality of material, geology and topography of quarry and plant sites. No general method or rule for the handling of the raw materials can be given and so the author will endeavor to describe some of the more common methods.

The method used in the excavation and transportation of the raw materials depend upon primarily the character, quantity, accessibility and relative location of the deposits. The following classification is suggested:

RAW MATERIALS

- Method of excavation:
  - Nature:
    - Limestone
    - Marl
    - Clay
    - Slate or shale
  - Quantity:
    - Small
    - Large
  - Quality:
    - Variable
    - Uniform
  - Accessibility:
    - In exposed deposits—quarrying
    - Extent and nature of overburden—stripping
    - In deep deposits—mining
  - Machinery:
    - Shovel
    - Scraper
    - Grader
    - Steam shovel
    - Scraper-bucket excavator
    - Locomotive crane
    - Floating-dipper dredge
- Method of transportation:
  - Relative location:
    - Proximity of deposits to mill
    - Proximity of deposits to each other
    - Elevation as to mill

Systems:
- Gravity
- Elevator
- Hauling
- Aerial conveying
- Pumping

Machinery:
- Wheelbarrows
- Wagons
- Dump cars in train
- Aerial tramway or cableway
- Marl pump

There are three general methods of excavating the raw materials:

A. Quarrying
B. Dredging
C. Mining

About 85 per cent. of all the raw material used in the manufacture of cement is quarried. Quarrying is the removal of materials from open excavations, such as pits, cuts, trenches, banks, etc., and comprises the methods used in the removal of clay, shale, slate and limestone.

Marl generally occurs in low, wet basins and must be removed by dredging. Occasionally the clay occurs with the marl.

When the shale or limestone occurs in strata which dip at a sharp angle below the surface, it becomes necessary to sink shafts or drive tunnels to remove the material. These underground methods are called mining.

QUARRYING

The necessary steps in quarrying may be enumerated as follows:

A. Stripping
B. Drilling and blasting
C. Excavating
D. Transporting

The rock is generally found in sub-soil deposits, which are overlaid with a surface soil of glacial clay or alluvium, called the overburden. The amount of the overburden depends upon the dip of the strata, the depth of surface soil and the method of opening up the excavation. The cost per ton of stripping should be kept as low as possible because this cost is indirect and a burden. The stripping should be thoroughly done so as to reduce to a minimum the cost of washing.

The excavating machinery, which can be efficiently used in stripping may be classed as follows:

(*a*) Scrapers
(*b*) Graders
(*c*) Shovels
(*d*) Scraper-bucket excavators
(*e*) Cableway excavators
(*f*) Power excavators
(*g*) Hydraulic

(*a*) and (*b*) Scrapers and graders are efficient and economical excavators for stripping where the amount of material to be moved is small and the haul not greater than 1000 feet. Hence these machines generally would not be economical to use in the cement quarry, as the quantity of material to be removed is usually very large and the haul excessive. Cases may occur where large size scrapers, such as the Maney four-wheel scraper or a large elevating grader may be used with traction engines to furnish the loading power, when the overburden is shallow and the haul short. Under favorable working conditions with an average haul of 600 ft., the stripping of loam and clay would cost from 10 to 15 cents per cubic yard moved.

(*c*) Shovels may be operated by steam or electric power and be fixed or revolving. The availability of local power will largely determine the most economical kind to use. Near a large city where electric power is cheap or along the lines of large power plants, electric power can be used advantageously. Generally steam must be used and the fuel and water problems become important. It is always economical to use a grade of bituminous coal high in heat value, say not less than 10,000 B.t.u. A small size lump, about No. 2 nut size is easy to handle and beds well upon the grate. The surface waters of the Middle West are generally heavy with sodium, lime and magnesium salts, iron and vegetable matter, which are scale-forming substances. It is highly desirable to purify and soften all water before it is fed to the boilers. This may be accomplished by treating the water with lime and alum and then passing it through a mechanical filter. The water softening plant and filter should be installed in the power house of the plant and all the water used for the operation of the machinery thus purified. The machinery in the quarry can be supplied by a pipe line through which the water is pumped from the power house. When the quarry is isolated and some distance from the plant, a feed water heater and purifier can be installed near the boiler on the floor of the steam shovel.

The depth and extent of the overburden will largely determine the most efficient type of shovel to use in any particular case. When the stripping is clay or loam and in shallow beds up to 10 ft. in depth, the small revolving shovel is the better type. It is light, quick in operation and easily moved along as the excavation progresses. When the overburden is sand or gravel and in layers up to 20 ft. the steam shovel with a fixed body is the best type.

The excavated material may be dumped into wagons hauled by teams or traction engines or into cars hauled by dinkey engines. For a permanent plant, and long hauls, the latter method is the most efficient.

The following statement is given as a typical example of stripping in an open cement quarry.

The overburden is a loam and sandy clay overlying the limestone in a depth varying from 3 to 8 feet. The soil is fairly uniform in character, and quite free from stone and stumps. A typical revolving shovel, equipped with a ⅞-yd. dipper, and a truck with four, wide-tired iron wheels, is used for the excavation. The shovel is operated by an engineer, fireman, and a general assistant and pitman. The fuel used is a good grade of Southern Illinois coal of No. 2 nut size, and is hauled to the shovel in the cars and shoveled directly into the bunkers of the shovel. Water is supplied by a hose attached to a 2-in. galvanized iron branch of the 4-in. C. I. main from the power plant. The water is purified in a Eureka water softener and filtered before it is pumped out to the quarry.

The excavated material is dumped into 6-yd. side dump cars which are hauled in trams of four cars each by a 35-ton dinky engine over a narrow-gage track. The haul is about 1000 feet. Under ordinary working conditions during a 10-hr. day, the average excavation is 200 cubic yards.

Following is an estimate of the cost of operation:

Labor:

1 engineer	$3.50	
1 fireman	2.00	
1 pitman	1.75	
Total labor cost		$7.25

Labor cost per cu. yd. excavated, $7.25 ÷ 200 = $0.03625

Fuel:		
1 ton No. 2 nut coal @ $2.75	$2.75	
Fuel cost per cu. yd		$0.01375
Oil:		
¼ gal. lubricating oil @ 45¢	$0.1125	
⅕ gal. engine oil @ 40¢	0.08	
½ gal. black oil @ 42¢	0.21	
Waste, packing, etc.	0.1975	
Total		$0.60
Cost of oil, waste, etc., per cu. yd. excavated, $0.60 ÷ 200 =		$0.0030
General Expenses:		
Depreciation (based on 5 per cent. and 20 year life)	$0.70	
Interest @ 6 per cent	0.84	
Repairs and incidentals	1.00	
Total cost of general expenses		$2.54
Cost of general expenses per cu. yd., $2.54 ÷ 200 =		$0.0127
Total cost of operation of 10-hr. day		$13.14
Cost of operation per cu. yd. of excavated material		$0.0557

FIG. 189.—Revolving shovel loading train with clay. *(Photo by Author.)*

A 24-ton shovel loading a train of side dump cars is shown in Fig. 189.

(*d*) The scraper-bucket or drag-line excavator is becoming a well-known type of dry-land machine for earth excavation. It can be operated by steam, gasoline or electric power, depending upon the relative availability and cost of the local supplies of power. The use of caterpillar tractors allows the machine to move over soft and marshy ground, and eliminates the track gang. The upper frame is generally mounted on a turntable, which allows the machine to operate in a complete circle, whose radius is governed by the length of the boom. The latter is usually made of trussed steel shapes, up to a length of 100 ft. and will permit of excavation to a depth of 30 ft. below the surface. There are several makes of scraper buckets on the market and most of them are of the two-line type. In selecting a bucket make sure that proper provision is made for quick action, positive control, and strength.

The excavated material may be dumped into wagons or cars which are hauled away in trains by traction or dinky engines. Figure 190 shows a scraper-bucket excavator stripping and dumping into a box car which will form part of a train, to remove the excavated material to a dump across the quarry.

Fig. 190.—Scraper-bucket excavator stripping quarry.

The author knows of one case where a drag-line excavator was used in conjunction with a cableway for the stripping of an open quarry. The overburden consisted of 5 to 20 ft. of loam, sand, and gravel. The cableway consisted of two sets of towers about 30 ft. apart, and each set supporting a 1000 ft. cable, over which moved a bucket containing 1 cubic yard. The head towers were located on the top of the quarry ledge and their tops were about 30 ft. above those of the tail towers located in the valley below. The bucket, when loaded directly by the bucket of the excavator, moved by gravity to the lower towers, where it was dumped. It was then hauled back by a 6-h.p. friction-drum engine. This equipment was operated for several years at an approximate cost of 8½ cents per cubic yard of excavated material. It was later replaced by a small steam shovel and narrow-gage dump car equipment with subsequent reduction of cost of excavation to 5 cents per cubic yard. However, it is probable that the cost of operation with the drag-line cableway equipment could have been somewhat reduced by the use of a large capacity, high-speed cableway.

(*e*) Cableway excavators have been little used in quarry stripping and generally as conveyors of the material which has been excavated by other machines. When the stripping can be done in long narrow areas and the dump is at a convenient distance from the excavation (not more than 1500 ft.) movable towers with a high speed power, hoisting and conveying equipment may be used to advantage. But it is doubtful that even under the most favorable circumstances of surface excavation that such a method would be economical and hence further discussion will be made in the article concerning quarrying.

(*f*) The tower excavator is a unique type of excavator which was developed and used with success several years ago on the Chicago Drainage Canal and recently on the construction of the New York State Barge Canal.

Although the author has not known of the use of a tower excavator for stripping in a quarry, he believes that it could be very efficiently used. An inclined loading platform and hopper could be framed out from the tower at a suitable height to provide for a train of standard dump cars to pass underneath. The filled bucket would be hoisted up the incline and dumped into the hopper. Two bucket loads would fill a 4-yd. car and three loads a 6-yd. car. The average loading time for a 6-yd. car would be about 3½ minutes.

(*g*) The hydraulic method of excavation has been used largely in the past in placer mining for gold. In recent years it has been utilized for the raising of large hills and the grading up of surfaces which are very uneven.

As a large number of cement quarries are in close proximity to rivers or lakes where water is plentiful in large quantities, hydraulicing or sluicing should be an economical and efficient method of removing the overburden.

A pumping plant of sufficient capacity to supply the desired number of monitors should be installed near the water supply at a low elevation. The equipment of such a plant would include large multiple stage centrifugal or turbine pumps, direct connected to electric generators or steam prime movers. The former is the more economical and satisfactory where electric power is available at a reasonable rate. The efficiency of such a plant under average working conditions should not be less than 50 per cent. See Fig. 191. The pumps should force water through pipes (preferably especially constructed wood-stave pipe) to the nozzle or monitors, which are mounted on the surface at suitable points. See Fig. 192. The water emerges from an orifice having a diameter of from 2½ to 6 in. and at a pressure of from 50 to 150 pounds. Ordinarily, a tip having a diameter of from 3 to 4½ in. giving a pressure of from 75 to 100 lb. is used.

The excavated material is highly diluted with water (generally about 4 to 20 per cent. of soil to water) and can be easily removed through pipes or flumes to the disposal point. In a cement quarry the monitors should be mounted on the higher land and operated so as to flush the soil toward the lower elevations along the river or lake. The fluid material could be directed and collected by constructing retaining walls to dam it up. A recent method is to use "sheer boards" to gradually build up an embankment. This method consists of a series of narrow boards laid parallel, with their lower edges a few inches above the ground surfaces and fastened to the inside of stakes. As the water deposits its suspended material, the embankment gradually rises. When it reaches the top of the first set of sheer boards, a second set is set on the top of the embankment and inside and parallel to the first set. Thus an embankment with any desirable side slopes can be easily and rapidly built up. The surplus water flows away to a low elevation where it can be drained off into the main supply or to a basin from which it is pumped into a reservoir or directly through the pipes.

The following brief statement of the hydraulic excavation of a large hilly district of Seattle, Wash., is given as suggestive. The soil excavated was a yellow clay 6 to 12 ft. in depth, underlaid with a hard blue glacial clay. The water supply was obtained from three sources. An old steam pumping plant furnished water to a reservoir having a capacity of 850,000 gal. and located about 1 mile from the works. The supply from

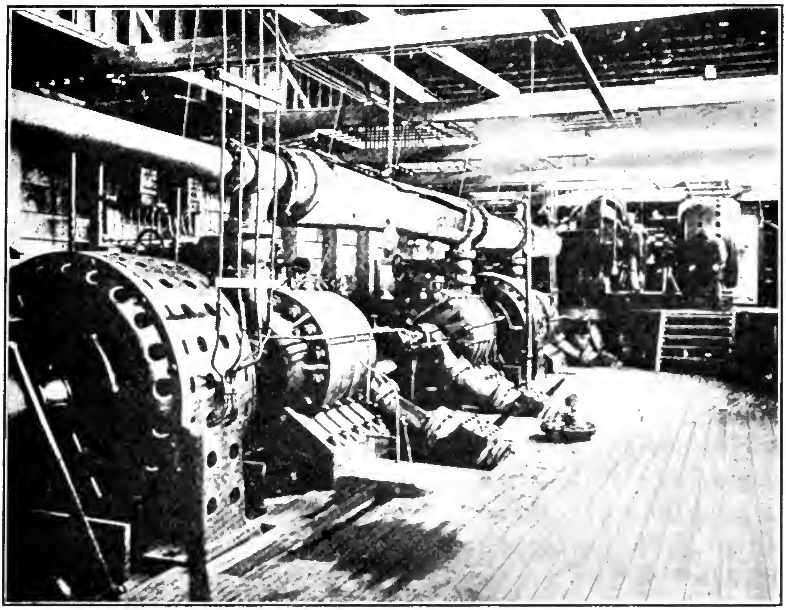

Fig. 191.—Pumping plant for sluicing equipment.

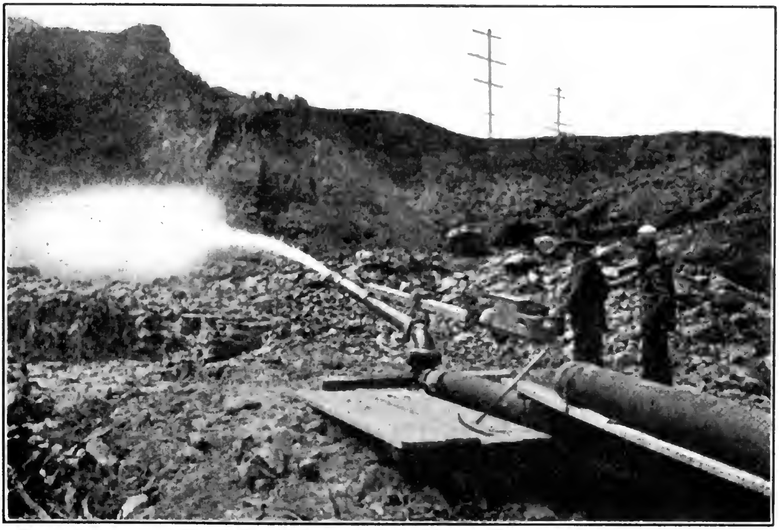

Fig. 192.—Excavation by hydraulicking.

this source was about 6,000,000 gal. per 24 hours. A portion of the city supply from another source was also diverted into this reservoir and augmented the first supply by about 8,000,000 gals. per 24 hours. The elevation of the overflow of the reservoir was such as to give a working gravity head of about 200 ft. at the monitors. The city water was paid for at the rate of $15.00 per million gallons. The third source of supply was an electrically operated pumping plant located on a small bay about 1¼ miles from the center of the job. The equipment of this plant consisted of four 1-in. five-stage Worthington turbine pumps direct connected in units of two each to two 650-h.p. two-phase 2000-volt alternating-current motors. The pumps were provided with a 12-in. suction and a 10-in. discharge. The combined efficiency of the plant was about 63 per cent. and the capacity when running at 690 h.p. under a 375-ft. head, was 8400 gal. per minute or 12,000,000 gal. per 24 hours. The maximum suction lift was 23.8 ft., minimum about 7 ft. and the average 15 feet. The discharge from the plant was through 6100 ft. of 24-in. machine-banded wood-stave pipe, having 1⅝-in. staves and No. 1 wire spaced 9⁄16 in., guaranteed to withstand 165 lb. pressure. Water was supplied to Risdon, and Hendy types of monitors of No. 2 and No. 3 sizes, supplied with 3- and 4¾-in. removable tips. The working pressure at the tip varied from 60 to 100 pounds.

The cost of operation of the pumping plant was $65,663.29 for a continuous period of from May 1, 1908 to December 3, 1909. 4,326,689,219 gal. of water were pumped at a cost of $15.18 a million gallons. The material excavated was highly diluted, the average percentage of spoil to volume of water being about 6.75. On the whole work, 10,095,179,594 gal. of water were used to remove 3,347,883 cu. yd. of clay and gravel during the period from May 1, 1907 to December 31, 1909. The water cost averaged $14.54 per million gallons. The amount of excavation varied from 19,320 cu. yd. to 235,952 cu. yd. per month. The contract price of excavation was 10 cents per cubic yard.

351. Handling of Excavated Material in the Cement Quarry.—The rock as it lies on the quarry floor after being blasted is in a mass of fragments, varying in size from a pea to those several feet in their least dimension. In order that the excavating machinery may handle these large pieces of rock, it becomes necessary to break them up into smaller pieces having a maximum size of 3 ft. in the greatest dimension. The following methods of breaking up large fragments of rock have been used:

(*a*) Dropping of heavy weights
(*b*) Use of sledge hammers
(*c*) Block holing
(*d*) Mud capping
(*e*) Undermining

(*a*) The method of dropping heavy weights from a considerable height is only practicable when a derrick, locomotive crane or cableway is available. The weight is generally a large block of cast iron weighing about 1 ton. The height of the drop should be from 15 ft. to 30 ft. and the weight released suddenly by a trip or friction-drum engine.

This method is advantageous in a small quarry where a derrick is used or in trench work, where the working space is limited and other methods are therefore impracticable. In a large open quarry of a cement plant however, this method is rarely used and is ordinarily not feasible with the equipment at hand.

(*b*) The sledge hammer has been used for the breaking up of stone fragments since time memorial. The sledge used should be of such proportions that a man of average strength can wield it efficiently. A lighter sledge of about 12 lb. weight used with rapid blows is much more effective than one weighing 16 lb. and used with slow strokes.

This method although crude, is efficient for the breaking up of fragments to about 1 cu. yd. in volume and for sedimentary or stratified stone such as shale. However, every pit gang in a quarry should be supplied with a sufficient number of sledges for the breaking up of those fragments of rock which are too small to be economically broken up by block holing or "mud capping" and yet too large and unwieldy to be handled by the shovel.

(*c*) "Block holing" is the simple application of the ordinary method of drilling and blasting to the breaking up of large rock fragments. The more efficient way is to drill a hole from a few inches to 2 ft. in depth and place the center charge of explosive in the hole. However, the more common and quicker way is to drill a shallow hole and place a lesser part of the explosive on the rock above the hole and cover up the entire charge with mud.

This method is the most effective one for the breaking up of rock larger than 1 cu. yd. in volume. It is universally used in open quarry excavation at the present time.

(*d*) "Mud capping" is probably the most popular method of breaking up rock, especially with pit-gang foremen. The placing of the explosive directly upon the surface of the rock and covering it with a mud blanket is a simple but an expensive and uneconomical process. The resulting efficiency of the explosive is very low.

This method should not be used except when it becomes necessary to break up a group of huge pieces of rock, which are delaying the operation of the excavating machinery.

(*e*) The method of "undermining" is little used and not generally known. It greatly resembles "mud capping" but differs essentially in that the explosive is placed under the rock rather than on top. Where large masses of rock are piled up together the charge of explosive can be placed on the upper surface of the lower fragments and thus have a suitable bed. The same results can be accomplished by this method as by "mud capping" with the use of about one-half the amount of the explosive.

The method of "block holing" is undoubtly the most direct, efficient and economical one to be used for the breaking up of rock on the quarry floor. "Mud capping" should only be resorted to where quick results are necessary. However, delays may often be prevented by moving large masses of rock to the rear of the excavator, where they may be broken up without interfering with the loading operations. Ordinarily, the time interval between the loading of the cars or skips, when the excavator is idle is sufficient in which to do the necessary breaking up of the rock.

The new materials with whose excavation we are concerned in the open cut quarry of a cement plant are (*a*) clay, (*b*) shale and (*c*) limestone.

These materials may be found in a nearly pure state in large deposits or in association to form a rock of mixed composition. Generally the clay or shale is excavated from surface deposits which are in close proximity to the limestone. In many cases the clay is part of the overburden which must be removed before the limestone can be quarried.

The following detailed descriptions are given in order to present to the reader a clear and comprehensive view of the methods in use at the present time, for the excavation of the raw materials in open cut quarries of cement plants. These descriptions will be limited to two examples which are composite views of several typical quarries in the eastern and western sections of this country.

EXCAVATING IN AN EASTERN CEMENT QUARRY

Description of Plant and Quarry.—The cement plant and quarry are located on the upper reaches of one of the many streams which course hurriedly down the eastern slope of the Allegheny Mts. The general layout of the plant and quarry is shown in Fig. 193. The plant is located on a bench above and on the west side of the river and on the main line of a large eastern and southern railroad.

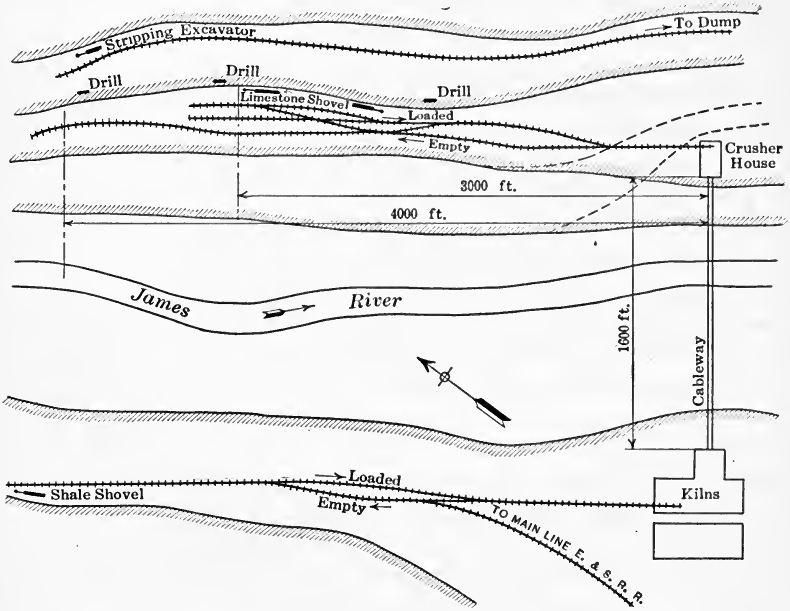

FIG. 193.—General plan of eastern cement plant.

The topography of the country is rugged and broken and the banks of the valley rise rather precipitiously from the river to a height of from one to two hundred feet. The sides of the valley are broken and irregular due to the outcropping at intervals of the ledges of rock. Natural benches have thus been formed and these contain enough alluvial soil to support a dense growth of vegetation. A loam and clay varying in depth from several inches to about 3 ft. covers the surface of the upper reaches of the banks. Underlying this is the native rock, of which the hills are largely formed and is an argellaceous limestone varying in quality. The quarry has been located at a point where the limestone outcrop is of an excellent quality and contains a small amount of shale. North of the plant along the west side of the valley is a large deposit of shale overlying the limestone. Thus the quarry is located north of the plant, on both sides of the valley as shown in Fig. 193.

The plant has a rated capacity of 5000 bbl. of standard portland cement per day. The dry process is used and the shale and limestone are mixed in the proportions of from 1 to 5 to 1 to 7, depending upon the composition of the limestone.

The general layout of the plant, the location of the excavating machinery and the system of transportation are clearly shown in Fig. 193. Note especially the method of excavation in benches and the cableway or aerial tramway from the crusher house to the storage bins in the kiln house of the plant across the river. On the west side of the river is located the shale shovel which removes the strata of shale down to the rock in a series of broad and shallow benches. The excavated material is loaded into 4-yd. side-dump cars which carry it directly to the crusher and kiln. On the upper part of the east bank of the river is located the stripping machine, which is a drag-line excavator mounted on caterpillar tractors. This machine removes the surface soil down to the rock surface and loads it into 6-yd. side-dump cars which carry it to the south end of the quarry where the material is dumped into the open cut. Below the stripping excavator on the lower part of the bench are three churn drills. Two drills are generally operating one in advance and the other in the rear of the shovel. Sufficient rock is broken down in periodic blasts to keep the shovel busy for at least 10 days. The rock shovels move along the face of the open cut and load the rock fragments on to steel skips which are carried on flat cars. A detailed description of the methods and costs of operation of the shale and rock shovels will be given below.

Shale Excavation.—The shale is of a loose friable character and is easily stripped with the 45-ton steam shovel. The latter is mounted on two standard-gage trucks which rest on short lengths of portable track. The dipper has a capacity of 2½ cu. yd. and the operating mechanism consists of the standard main swing and thrust engines which are operated by steam supplied by a locomotive type of boiler.

The crew consists of a craneman and a fireman, for the operation of the shovel and a pit gang of three men.

Pocahontas coal is used and is brought out to the shovel in the dump cars and shoveled directly into the bunkers of the shovel. Water is pumped directly from the river into a large storage tank above the quarry. From this reservoir the water flows through pipes to all parts of the quarry.

The shovel loads 4-yd. side-dump cars in trains of four cars each. Each train is hauled by a 35-ton dinkey.

Let us assume the following time analysis of the loading operations.

Average time for engine and four 4-yd. cars loaded to run from pit over about ⅘ mile of track to crusher house, dump the shale and return empty to pit is 38 minutes.

Average time to load a 4-yd. side-dump car is 2 min. 7 sec., the maximum time being 2 min. 54 sec., and the minimum time 1 min. 38 seconds. Number of dipper loads to fill one car varies from two to four depending upon quantity of shale in dipper. Average time for one swing is 37 seconds. Average loading time for trains of four 4-yd. cars is 15 min. 43 seconds. The cars are loaded to about 115 per cent. of their rated capacity.

The following is an estimate of the cost of operation for a 10-hr. day under average working conditions.

Labor:

1 engineer	$4.00	
1 craneman	3.00	
1 fireman	2.50	
3 pitmen @ $1.75	5.25	
Total labor cost		$14.75
Labor cost per cu. yd. excavated, $14.75 ÷ 300 =		$0.049

Fuel:

1½ tons coal @ $2.50	$3.75
Fuel cost per cu. yd. excavated, $3.75 ÷ 300 =	$0.0125

Oil and Supplies:

⅜ gal. cylinder oil @ 42¢	$0 167	
½ gal. engine oil @ 38¢	0.190	
Waste, packing, etc	0.273	
Total cost of oils, etc.		$0.630
Cost of oil, waste, etc., per cu. yd., $0.63 ÷ 300 =		$0.0021

Overhead Charges:

Depreciation (based on 20-year life)	$0.815
Interest @ 6 per cent	0.975
Repairs and incidentals	2.000

Total cost of burden $3.79

Cost of burden per cu. yd. excavated, $3.79 ÷ 300 = 0.0126

Total cost of operation per 10-hr. day $22.92

Cost of operation per cu. yd. excavated, $22.92 ÷ 300 = $0.0764.

Rock Excavation.—The drilling and blasting gangs work to the north and south along the face of the open cut and keep enough rock blasted down in front of each shovel to furnish about 6 days work at 1500 tons per day. The quarry face varies in height from 30 to 40 ft. and the rock is of quite uniform quality so that only a small amount of mud capping is necessary.

Fig. 194.—Loaded skips on way to crusher. (*Compliments of Edison Portland Cement Co.*)

Two steam shovels are used for loading the rock, the original machine of 70 tons and a recent acquisition of 95 tons. The shovels work away from each other and normally the 95-ton shovel handles the daily rock output while the 70-ton machine is held in reserve and used when the former is laid up for repairs or in case of emergency. The 70-ton shovel is equipped with a 2½-yd. dipper while the 95-ton shovel has a 3½-yd. dipper. Both machines are operated by the usual steam equipment of locomotive type boiler, and hoist, swing and thrust engines.

The rock is loaded into 4-yd. steel skips which are carried by four-wheel single-truck flat cars of standard make and gage. The cars are handled in trains of about 20 cars each by a 50-ton dinkey engine. Figure 194 shows a loaded train being hauled to the crusher house in the distance. The length of haul is about three-quarters of a mile.

The crew of each shovel comprises an engineer, a cranesman, a fireman, two jackmen, a driller and assistant and four pitmen. When either shovel is idle the pit gang assist with the loading of the other shovel, moving and laying track, charging of blast holes, etc.

Fuel and water are supplied to the shovel as has been previously described for the shale shovel.

Let us consider the operation of the 70-ton shovel and assume the following time analysis.

Average time for engine and twenty 4-yd. skip cars loaded to run from quarry over about ¾ mile of standard-gage track to crusher, dump the skips and return empty to pit is 32 minutes.

Minimum time to load one car is 53 sec., the maximum time is 1 min. 7 sec. and the average time is 59 seconds. The number of dipper loads required for each skip varies from two to four depending on amount of material in the dipper, varying from 40 to 110 per cent. capacity.

The average time for one complete swing of the dipper is 25 seconds. Average loading time for train of twenty 4-yd. skip cars is 27 min. 37 seconds. The skips are loaded to about their rated capacity.

An estimate of the cost of operation for an average 10-hr. day is given below:

Labor:

1 engineer	$5.00	
1 craneman	3.75	
1 fireman	2.50	
1 driller	2.50	
1 asst. driller	2.20	
4 pitmen @ $2.00	8.00	
Total labor cost		$23.95

Cost of labor per cu. yd. excavated, $23.95 ÷ 1000 = $0.0239

Fuel:

3¼ tons coal @ $2.50	$8.125

Cost of fuel per cu. yd. excavated, $8.125 ÷ 1000 = $0.0081

Oil and Supplies:

½ gal. lub. oil @ 42¢	$0.210	
¾ gal. engine oil @ 38¢	0.285	
1 gal. black oil @ 35¢	0.350	
Waste, packing, etc.,	0.875	
Total		$1.720

Cost of oil, waste, etc., per cu. yd., $1.72 ÷ 1000 = $0.00172

Overhead Charges:

Depreciation (based on 20-year life)	$1.32	
Interest @ 6 per cent	1.575	
Repairs, incidentals, etc	3.000	
Total burden cost		5.895

Cost of burden per cu. yd. excavated, $5.895 ÷ 1000 = $0.0058

Total cost of operation for 10-hr. day equals .$39.69

Cost of operation per cu. yd., $39.69 ÷ 1000 = $0.0397

EXCAVATING IN A WESTERN CEMENT QUARRY

Description of Plant and Quarry.—The cement plant is located near a small city in a prosperous agricultural state of the Middle West. The topography of this section of the country is flat with an occasional river whose waters flow in a general southwesterly direction toward that great drainage channel, the Mississippi River. A reference to Fig. 195 will show that the plant is on the east side of Rapid River. The banks at this point rise upward from the river with a gentle slope for a distance of several hundred feet and then there is an abrupt rise of from 50 to 80 ft. to a slightly undulating area which stretches back from the river for several miles.

The surface soil is a rich black loam, which is underlaid with a clay of excellent quality. The clay and loam have an average depth of about 4 ft. and overlie a deposit of gravel which has a thickness of from 7 to 12 feet. Under the gravel is a ledge of limestone which is highly impregnated with clay. Such is the geological conditions existent over a great area near the plant. At present the quarry consists of an area of about 1500 ft. long- and 500 ft. wide, which has been opened up at a distance of ½ mile from the plant.

The plant has a rated capacity of 3000 bbl. of standard portland cement per day. The dry mix method is used and the clay and limestone are mixed in the proportions of one part clay to seven parts limestone. These proportions are varied with the composition of the limestone.

Figure 195 shows the general layout of the quarry, the location of the excavators, the transportation facilities, etc. At the north end of the quarry upon the highest level is located the clay shovel which removes the clay and loam down to the gravel. To the south, upon a lower bench is the stripping shovel, which removes the gravel deposit down to the surface of the rock. Two churn drills operate along the face of the quarry and drill series of large holes about 10 ft. centers and 8 ft. back from the face for the blasts. Sufficient rock is blasted out to keep the rock shovel busy for about a week. The latter operates on the floor of the quarry along the face which has a height of from 30 to 50 feet. Following are given detailed descriptions of the excavation of the clay and rock. The stripping has been described in the first part of this article on page 478.

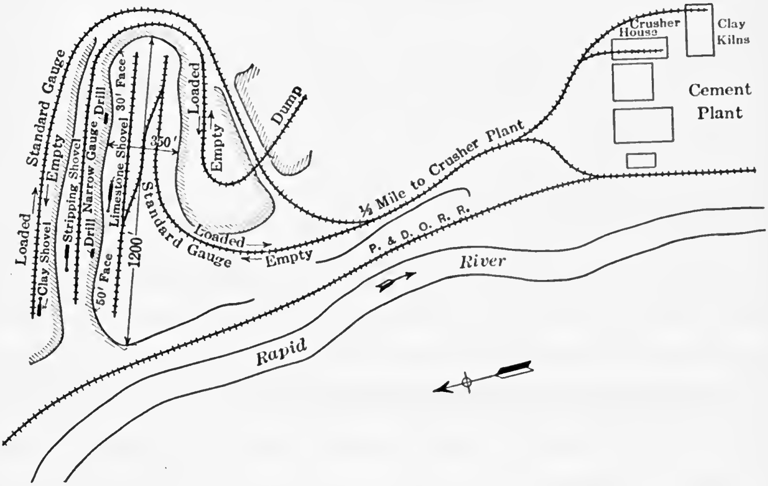

Fig. 195.—General plan of western cement plant.

Clay Excavation.—The clay is excavated with a small revolving shovel which is mounted on a truck with four broad-tired iron wheels. The latter rest upon heavy planks over which the shovel may move under its own power. The machine is equipped with a ¾ yd. dipper, which can be thrust into the bank by a special crowding device. The operating mechanism consists of a hoisting engine, a swinging engine and a small engine for operating the crowding device. A vertical boiler supplies steam at 125 lb. pressure for all the power equipment.

The crew consists of an engineer, who has general charge of the work and personally operates the shovel, a fireman, and a laborer for general service in the pit, loading coal and making repairs.

Southern Illinois soft coal of nut size is used for fuel. The coal is shipped into the plant in gondola cars of 50 tons capacity. A locomotive crane, equipped with a clam-shell bucket, transfers the coal to the 5-yd. side-dump clay cars which carry it out to the shovel as it is used.

Water is supplied through a 2-in. cast-iron pipe, which is a branch of a 6-in. cast-iron supply main from the power plant. All the water used to supply the steam shovels and drills is pumped from the river into a large patent water softener. Here the water is treated with lime and aluminum sulphate and filtered. From the filter the water passes into a sump or pit, from which it is pumped through the 6-in. main to the quarry. Water thus purified is used in the entire plant and no record is kept of the amount treated and used.

The shovel loads 6-yd. side-dump cars in trains of four cars each. Each train is hauled by a dinkey locomotive of standard make.

Let us assume the following time analysis of the loading operations.

Average time for engine and four 6-yd. cars loaded to run from clay pit over about ¾ mile of standard-gage track to dry house, dump the clay and return empty to pit is 40 minutes.

Average time to load a 6-yd. side-dump car is 8 min. 20 seconds. Number of dipper loads to fill one car is 10. The average time for shovel to commence excavation in pit, fill dipper, swing over to car, dump, swing back and drop dipper into pit is 42 seconds. Average loading time for train of four 6-yd. cars is 3 minutes. The cars are loaded to about 120 per cent. of rated capacity.

The following is an estimate of the cost of operation for a 10-hr. day under average working conditions:

Labor:

1 engineer	$3.50	
1 fireman	2.00	
1 pitman	2.00	
Total labor cost		$7.50

Labor cost per cu. yd. excavated, $7.50 ÷ 120 = $0.0625

Fuel:

½ ton nut coal		$1.50
Fuel cost per cu. yd. excavated, $1.50 ÷ 120 =		$0.0125

Oil and Supplies:

⅙ gal. cylinder oil @ 40¢	$0.067	
1/10 gal. engine oil @ 30¢	0.030	
Waste, packing, etc	0.120	
Total cost oil, waste		$0.217
Cost of oil, waste, per cu. yd. excavated, $0.217 ÷ 120 =		$0.0018

Overhead Charges:

Depreciation (based on 20-year life)	$0.70	
Interest @ 6 per cent	0.84	
Repairs and incidentals	1.00	
Total burden		$2.54
Cost of burden per cu. yd. excavated, $2.54 ÷ 120 =		$0.0212
Total cost of operation per 10-hr. day		$11.757
Cost of operation per cu. yd. excavated, $11.757 ÷ 120 =		$0.098

Rock Excavation.—The rock is blasted down in masses of about 3000 cu. yd. which extend for a distance of from 30 to 50 ft. along the quarry face. This rock is largely of a size which can be handled by the shovel, but large masses of rock are prevalent and are broken up by "block holing" using Jap hand drills and 40 per cent. forcite.

The steam shovel used for loading the rock is of a well-known make, 95-ton size and equipped with a 3-yd. dipper. A locomotive type of boiler furnishes steam at 125 lb. pressure to the power equipment. The swinging and hoisting motions are controlled by chains and the dipper is provided with heavy manganese steel teeth.

The rock is loaded into wooden box cars of 6 yd. capacity and mounted on four-wheel, single-truck standard-gage frames. The cars are hauled in trains of from 5 to 10 cars each, by a dinkey engine. The distance from the shovel to the crusher house is about ½ mile. The cars when loaded with rock, average 9 tons in net weight.

The crew of the shovel comprises an engineer, a craneman, a fireman, two jackmen, a driller and assistant and four pitmen. The size of the crew depends largely upon the condition of the labor market and will vary from 7 to 10 men with a general average of 9 men.

Fuel and water are supplied to the shovel as has been described above in the case of the clay shovel.

Let us assume a time analysis of the loading operations as follows.

Average time for engine and ten 6-yd. cars loaded to run from quarry over about ½ mile of standard-gage track to crusher, dump the rock and return empty to pit is 24 minutes.

Fig. 196.—Steam shovel loading train of box cars.

Minimum time required to load a 6-yd. car is 1 min. 20 sec. and the maximum time is 2 min. 5 seconds. Three or four dipperfulls are required to load each car, depending on quantity in dipper, varying from 50 to 110 per cent. capacity.

The average time for shovel to commence excavation in pit, fill dipper, swing over to car, dump, swing back, and drop dipper into pit is 30 seconds. The minimum time is 22 sec. and the maximum time 45 seconds. Average loading time for train of ten 6-yd. cars is 18 min. 40 seconds. The cars are loaded to about their rated capacity.

Figure 196 shows the shovel loading a train of cars.

The following is an estimate of the cost of operation for an average 10-hr. working day:

Labor:		
1 engineer	$5.00	
1 fireman	3.60	
1 craneman	2.20	
1 driller	2.50	
1 asst. driller	2.25	
4 pitmen @ $1.75	7.00	
Total labor cost		$22.55
Cost of labor per cu. yd. excavated, $22.55 ÷ 600 =		$0.0376
Fuel:		
4 tons nut coal @ $3.00		$12.00
Cost of fuel per cu. yd. excavated, $12.00 ÷ 600 =		$0.020
Oil and Supplies:		
$\frac{2}{3}$ gal. lub. oil @ 40¢	$0.267	
1 gal. engine oil @ 36¢	0.360	
1 gal. black oil @ 35¢	0.350	
Waste, packing, etc.,	1.000	
		$1.977
Cost of oil, waste, etc., per cu. yd., $1.977 ÷ 600 =		$0.0033
Overhead Charges:		
Depreciation (based on 20-year life)	$2.85	
Interest @ 6 per cent	3.42	
Repairs, incidentals, etc.	3.50	
Total cost of burden		$9.77
Total cost of operation per 10-hr. day		$46.297
Cost of operation per cu. yd. excavated, $46.297 ÷ 600 =		$0.077

The data of steam-shovel operation shows a wide variation as to operating efficiency and results. It is clearly impossible to lay down any fixed rule which may be used to determine the output of a shovel. In a cement quarry the shovel rarely works to full capacity, as the output required is generally much less than the shovel can handle. Ordinarily a shovel will be in actual operation about 40 per cent. of the time. Some of the conditions affecting steam-shovel performance are: hardness of the rock; amount and nature of stripping; amount, area and depth of seams in rock; height of face; method of drilling and blasting; size, make and capacity of shovel; style, weight, capacity, height and length of cars; number of cars in train; length of haul, style, size and power of locomotives; weight of rail; and condition and gage of track; labor equipment to operate machinery; character of water and fuel; hours worked per day; wage system employed; amount of rock breaking necessary; management of quarry and plant; etc. Several cases of shovel operation give 10 to 78 per cent. actual loading time, 10 to 72 per cent. waiting for cars, 5 to 60 per cent. delays due to mud capping, repairs, etc. An efficient shovel operation should result in the following log:

	Per cent.
Moving shovel	10
Waiting for cars	15
Breaking up rock	10
Repairs	5
Actual loading cars	60
Total	100

352. Open-cut Mining.—A class of excavation which has been greatly developed in recent years, and which has made possible the opening of great ore and coal deposits on an economic scale, is the stripping of the overlying material from seams of ore and coal. The enlargement and improvement of the steam shovel and drag-line excavator have been important factors in this new development work.

The method of stripping and mining a typical open-cut mine is simple and economical. The stripping shovel, which is generally of the revolving type and of large capacity makes a series of parallel cuts. The material from the first cut is piled on the surface along the edge of the cut. The ore or coal shovel, generally of smaller capacity, follows along behind the stripping machine. On the next cut the big shovel deposits its spoil in the pit made by the first cut, and that from the third cut into the pit made by the second cut and so on. Thus the transportation cost of the removal of the overburden is eliminated.

In many mines, the dip of the ore seams, the depth of cut, the presence of "horsebacks" and other local conditions, necessitate the removal of the overburden to a distant dump. For this purpose trains of dump cars and dinkey locomotives are used; the size of car and length of train depending on the size of excavator, depth of cut, length of haul, etc.

In coal mining, where the depth of cut is over 30 ft., and in cases where "horsebacks" frequently occur, a new method of handling the dump cars has been successfully developed. A stiff leg derrick or a drag-line excavator is mounted on rails at the head of the cut on the coal and transfers the cars from the loading track along the side of the cut to the floor of the pit where they are loaded by hand, and then are lifted back to the track. This method provides for the taking out of deep cuts in several "lifts" and also for the digging around of "horsebacks." Figure 197 gives a diagrammatic view of a drag-line excavator operating in a coal pit with a 50-ft. cut. This same method could be more economically utilized in deep cuts with a small power shovel for the excavation of the coal, in place of hand labor.

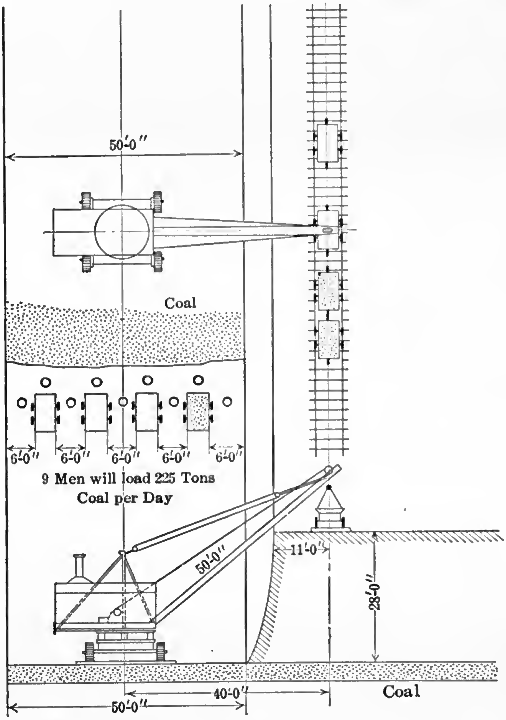

Fig. 197.—Loading coal with locomotive crane. (*Courtesy of The Excavating Engineer.*)

353. Use of Power Shovels in Kansas.—In 1911, in southwestern Kansas, near Pittsburg, began the development of the large fields of a good quality of bituminous coal. This section has not been previously developed on account of the inaccessibility of the coal which lay in nearly horizontal veins of from 18 in. to 48 in. in thickness and at depths of from 8 ft. to 200 ft. below the surface. The deep coal, lying from 40 ft. to 200 ft. below the surface has been mined for many years by the underground method of sinking shafts and drifting into the coal. The attempts to strip the overburden by hand, teams and scrapers, during the last 20 odd years (1895–1918), have not been very successful on account of the excessive costs; varying from 13 cents to 18 cents per cubic yard. At depths greater than 15 ft., the cost per ton of coal uncovered became prohibitory.

The development of this field was made possible by the introduction of revolving steam shovels of large capacity. The first three machines were built by the Vulcan Steam Shovel Company of Toledo, Ohio and installed in the Spring of 1911. Since that time about 20 additional steam shovels have been introduced and used in these fields. These shovels are all of the revolving type and vary in size from 150 tons to 270 tons. The 150-ton machine is equipped with a 60-ft. boom and a 2½-yd. dipper and has a capacity of 1800 cu. yd. per day of 9 hours. The 185-ton shovel has a 75-ft. boom, a 3½-yd. dipper and a capacity of 2300 cu. yd. per working day of 9 hours. The 270-ton machine has an 80-ft. boom, an 8-yd. dipper and an average output of 3500 cu. yd. per day. The average cost of excavation in typical overburden of loam, clay, shale or soapstone and at a depth of from 10 ft. to 30 ft. varies from 2.3 cents to 3.6 cents per cubic yard.

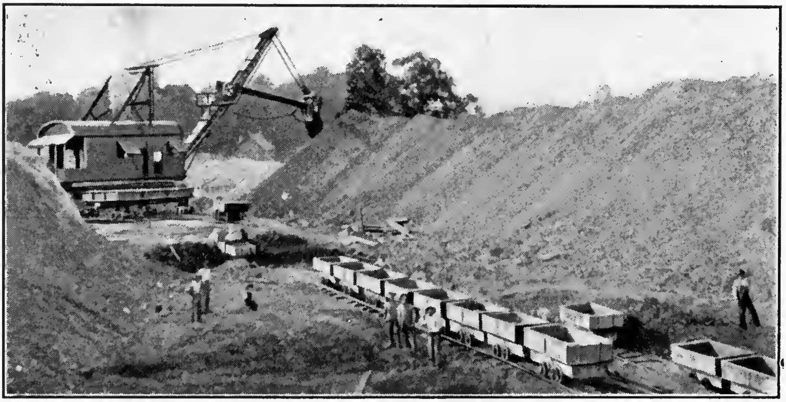

Fig. 198.—Large revolving shovel stripping coal field. (*Courtesy of The Excavating Engineer.*)

The coal in 3 ft. strata will average 4000 tons to the acre, allowing 10 per cent. for "horsebacks." The coal will average about a ton for every square yard of surface uncovered. The hand loading of coal into the tram cars has been to some extent superseded by the use of revolving steam shovels of small size. A ¾-yd. revolving shovel of 18 tons weight, operated by four men, two on the machine and two in the pit, averaged 160 tons of coal per day. A shovel of 30 tons weight and equipped with a 1½-yd. dipper makes a cut of 40 ft. in width, and has an average output of about 400 cu. yd. per 9-hr. working day.

Figure 198 shows a 175-ton shovel stripping a field near Pittsburg, Kansas.

Fig. 199.—Steam shovel excavating iron ore in Minnesota. (*Courtesy of The Bucyrus Co.*)

354. Use of Steam Shovel in Iron Mines in Minnesota.[1]—A study of the operation of a 90-ton Bucyrus steam shovel was made on September 5, 1910 at the Oliver Iron Mining Company's mine near Chisholm, Minn. The work consisted of the removal of a stock pile of ore, 35 ft. high.

The equipment consisted of the 90-ton steam shovel, equipped with a 3½-yd. dipper and material trains of 50-yd. steel and 35-yd. wooden cars. The labor crew operating the shovel consisted of a runner, a craneman, a fireman, 6 pitmen and a trim-

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[1] Abstracted from Handbook of Steam Shovel Work, Construction Service Commpany, New York.

mer. The cars were loaded by the shovel, the dipper being loaded by hand with such pieces as do not readily pick up. The pitmen also watch the loading to remove rock which may get into the cars during the loading. The shovel is kept busy by spotting a train of empties at the pit when the loaded train pulls out.

The shovel loaded sixty-four 50-ton and thirteen 35-ton cars with 3655 tons or 1828 cu. yd. of ore in an actual working time of 6 hr. 42 min. and 5 seconds. Of this time, 69.3 per cent. was spent in actual operation of the shovel, 19.3 per cent. in waiting for cars, 6.7 per cent. in moving shovel and 4.7 per cent. in miscellaneous delays. The following is the cost of operation for labor, based on the assumed standard basis of the Construction Service Company.

Fig. 200.—Atlantic type steam shovel excavating iron ore. (*Courtesy of The Bucyrus Co.*)

	Per 10-hr.day
1 runner	$5.00
1 craneman	3.60
1 fireman	2.40
6 pitmen @ $1.50	9.00
1 trimmer	1.50

Total	$21.50
Total output in 6 hr., 42 min., 5 sec.	1828 cu. yd.
Total output in 10 hr.	2728 cu. yd.

Labor cost, $21.50 ÷ 2728 = $0.79 per cu. yd.

Figure 199 shows a 90-ton shovel and Fig. 200 an Atlantic type shovel excavating iron ore in Minnesota.

355. Use of Drag-line Excavators in Michigan.[1]—Since 1913, open-cut methods have been successfully used in the development of the Balkan iron mine on the Menominee Range near Alpha, Michigan.

The overburden varies in depth from 60 ft. to 100 ft., 15 ft. on the north end and 80 ft. on the south end being of a treacherous quicksand formation. The conditions rendered the use of steam shovels impracticable and led to the employment of two drag-line excavators; one a Bucyrus Class 24 machine equipped with an 85-ft. boom and a 4½-yd. bucket and the other a Marion Model 261 of the same size. These machines moved over runways composed of 4 in. × 12 in. planks 12 ft. long laid four wide on each side of the machine.

The stripping was done in the form of a pit oval in shape about 1200 ft. long, 700 ft. wide and a depth of from 87 ft. to 107 feet. The work was done by the machines working downward on spiral benches on opposite sides of the pit, and generally on different levels. The quicksand was drained by sinking a sump at each lift and pumping out the water. By thus draining out the quicksand to a depth of from 3 ft. to 4 ft., a suitable and stable foundation was furnished for the drag-line excavators.

The material was removed by trains of 4-yd. dump cars on an inclined grade of about 2.6 per cent. The equipment was narrow gage and the cars were loaded through hoppers. The total haul from bottom of pit to dump was 5650 feet.

The output of the two drag-lines for the season of 1914 was 896,421 cubic yards. The best monthly record was 207,184 cu. yd. and the best daily record was 2670 4-yd. cars for two 10-hr. shifts for two machines and 800 4-yd. cars for one 10-hr. shift for one machine.

356. Excavation of Sand and Gravel Pits.—The recent development of large sand and gravel deposits has led to the use of power machinery in place of the hand and scraper methods of former times. The smaller pits do not justify the large initial expense of a power equipment and should be operated by simple, inexpensive methods.

Probably the most common method of excavating sand and gravel pits is by the use of one or more power shovels, either

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[1] Abstracted from *The Excavating Engineer*, August, 1915.

of the revolving type filling dump wagons or cars for the smaller pits or of the fixed-platform type operating on tracks and loading trains of dump or hopper cars. The use of specially designed hopper cars is often desirable. See Art. 358. Two shovels are sometimes used coördinately to facilitate the opening up of deep cuts.

Recently, the great demand for sand and gravel for road building and concrete has led to the development of a large number of pits of moderate size. The most efficient plant for such a deposit is a combination excavation, washing and screening equipment which uses the drag-line cableway for the excavation, conveyance and elevation of the material. The adaptability, wide range of operation, simplicity of construction and operation and low cost of operation make this type of excavator a very economical one for this class of work. A plant of 400 cu. yd. capacity requires a force of four or five men, one engineer, a fireman and the rest laborers. The method of operation of a typical cableway equipment for a gravel plant is shown in Fig. 201. The capacity of such an excavator depends on the working span and depth, the size and character of bucket, the efficiency of the operator, the nature and condition of the material, etc., etc. The machine is more efficient in handling wet material than dry. Under ordinary working conditions, a 1-yd. machine should excavate from 200 cu. yd. to 250 cu. yd. and a 1½-yd. machine from 350 cu. yd. to 400 cu. yd. per 10-hr. day.

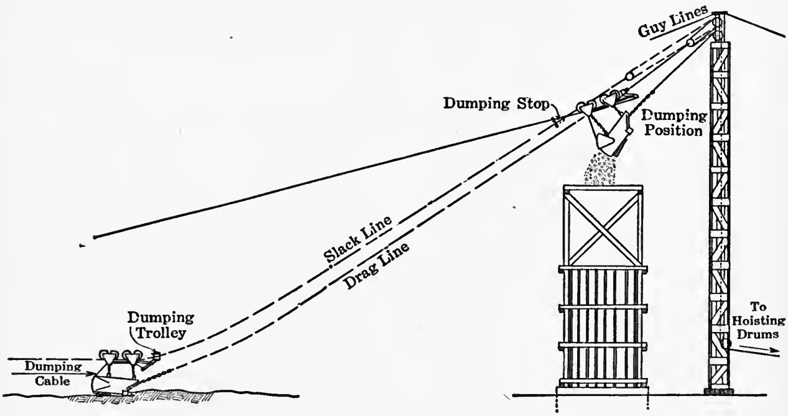

FIG. 201.—Diagrammatic view of cableway operating gravel plant. (*Courtesy of Raymond W. Dull Co.*)

Figure 202 shows a typical plant in operation.

The following are recommended sizes of operating equipment for drag-line cableway excavators.[1]

Capacity of bucket, cu. yd.	Double-drum skeleton hoisting engine	Diameter of front drum, in.	Boiler capacity, 100 lb. pressure
¾	8¼ × 10 or equivalent	20	30
1	9 × 10 or equivalent	24	40
1½	10 × 12 or equivalenr	26	60

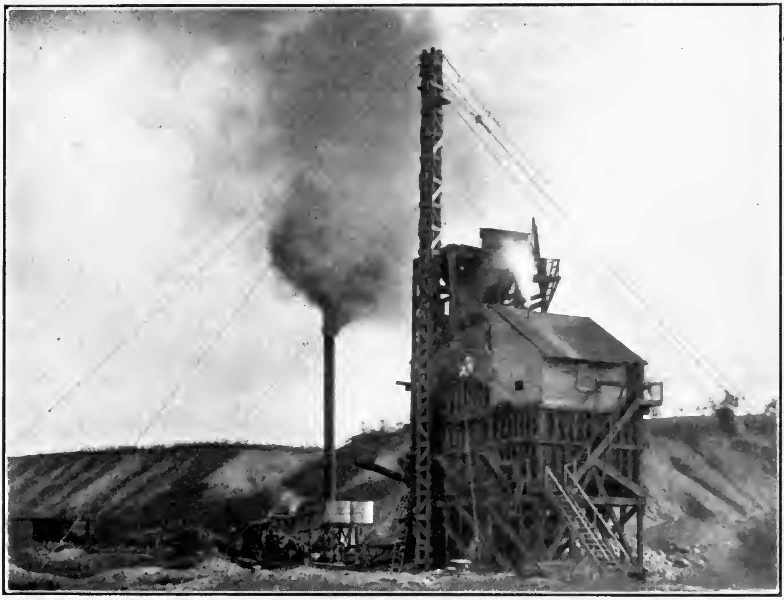

Fig. 202.—Cableway excavator operating a gravel pit. *(Courtesy of Raymond W. Dull Co.)*

357. Use of Steam Shovel in Gravel Pit in Illinois.[2]—The plant of the Chicago Gravel Company at Rockdale, Illinois uses a large revolving shovel for the excavation of the gravel. This plant is one of the largest of its kind in the world and has an equipment of crushing, conveying, screening and washing machinery of unusual design.

[1] From *Engineering Record,* June 5, 1915.

[2] Abstracted from *The Excavating Engineer,* September, 1914.

The earlier equipment of the plant comprised a Bucyrus 65-ton shovel, an Atlantic type Class 45 shovel, and two 70-ton Victor shovels equipped with 2⅝-yd. dippers. The two former machines were used for loading gravel but have been recently superseded by a large revolving shovel. The regular fixed-platform shovels did not prove to be satisfactory on account of the difficulty of handling the maximum face of banks occasionally encountered, and of maintaining a suitable loading track. Hence in order to eliminate these troubles and to reduce the labor expense for pitmen, a large revolving type of shovel, a Bucyrus 175-ton type B, machine was introduced in 1914. This shovel is equipped with a 75-ft. boom, a 48-ft. dipper handle and a 3½-yd. dipper. The machine can excavate directly a cut having a face height of 61 ft. and can remove a 100-ft. face by under-cutting and allowing the upper section to fall into the dipper. The machine has a dump height of 52 ft., and can cut a level floor to a maximum width of 112 feet. The average output of the shovel is 2000 cu. yd. per 10-hr. working day. Figure 203 shows the shovel loading Rogers ballast cars of 40 cu. yd. capacity.

Fig. 203.—Large revolving shovel operating gravel pit. (*Courtesy of The Excavating Engineer.*)

358. Use of Steam Shovels in Sand Pit in Wisconsin.[1]—An efficiently operated sand plant is that of the Atwood Davis Sand Company near Beloit, Wisconsin. Two special schemes are used in this plant to meet the peculiar requirements of local

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[1] Abstracted from *The Excavating Engineer*, August, 1915.

conditions. First, the construction of a through-cut, 38 ft. deep, 140 ft. wide on top and 55 ft. wide on bottom, was affected by using two shovels operating coördinately. An 18B Bucyrus revolving shovel with a ⅞-yd. dipper commences the cut, excavating to a depth of about 25 feet. This machine moves over three timber floats 5½ ft. wide and 14 ft. 6 in. long. The revolving shovel is followed by a 70-ton Vulcan shovel of the fixed-platform type equipped with a 3-yd. dipper. The shovels are so arranged as to load a hopper car simultaneously. The loading time averages about 2½ min. per car, and two cars are hauled by one 55-ton locomotive. Each car has a capacity of about 22 cu. yd. and the round trip is made in about 8 minutes.

Fig. 204.—Hopper car discharging on to belt conveyor at a sand plant. (*Courtesy of The Excavating Engineer.*)

The hopper cars were especially designed for this plant to provide for the direct delivery of the material to a belt conveyor, which directly supplies the preliminary crushers. Figure 204 shows a hopper car discharging on the outer end of the conveyor.

The average daily output is about 45 cars or 1350 cu. yd. per 10-hr. day. This has been increased to 55 cars or 1600 cu. yd. on occasions. The revolving shovel overcasts in front of the larger machine during delays caused by waiting for cars, etc.

359. Excavation of Clay and Shale Pits.—The operation of clay products plants has undergone marked changes in recent years due to the rapid development of the ceramic industry.

The great demand for brick and tile for building, road building and agricultural purposes has led to the increase in size and efficiency of operation of the older plants and the opening up of many new plants. The original, crude, hand methods of excavating and handling the clay have been largely replaced, especially in the larger plants, by the use of power excavators operated in a systematic manner.

The power shovel and the drag-line excavator are the two types of machinery which have been generally used and are especially adapted to this class of work. The location of the pit, the condition of the material, method of transportation of the material, the mixing of the clay, etc., are all important factors in the determination of the proper type of machine to be used. If the pit is located on low land and subject to periodic flooding, a drag-line excavator which can operate from higher ground is the most practical machine to use.

When there is considerable variation in the clay or shale and mixing is necessary, the use of a broad, open dipper on a shovel may effectively serve the purpose. The dipper is run through the bank with the door open, thus slicing up the clay and allowing it to collect in a loose pile at the bottom of the bank. When the entire face has been cut over once, the loose material is picked up and allowed to pass through the dipper. This process is done once or twice, as may be necessary to secure a uniform mixture.

The use of a long-handled dipper with a crowding device is desirable for the excavation of the bank when frozen near the top. Usually a bank frozen to a depth of not more than 2 ft. can be excavated directly by the shovel, but for greater depths of frost, blasting must be resorted to.

360. Use of a Drag-line Excavator in Georgia.[1]—The Cherokee Brick Company of Macon, Georgia, uses an electrically operated drag-line excavator for the removal of the clay. The excavator is equipped with a 45-ft. boom and a 1¼-yd. bucket. It is operated by an electrical equipment consisting of a 50-h.p. hoist motor and a 20-h.p. swing motor. The former is controlled by a hand-operated controller of the drum type. The latter is provided with a multiple solenoid control designed for automatic acceleration of the motor as well as plugging resistance circuit breaker and a drum type master controller. The main motor

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[1] Abstracted from *The Excavating Engineer*, August, 1913.

also drives a compressor, which furnishes air for the operation of the cylinders for the main hoisting gear and the brake cylinder for the bucket tipping drum on the boom. Current is furnished at 550 volts, three phase, and 60 cycle.

The clay pit consists of about 400 acres located about 1½ miles from the plant. The drag-line machine operates from the top of the bank and cuts a face of from 12 ft. to 16 ft. in height. The material is selected from different strata for the various qualities of brick. The material is loaded on trains of 6-yd. side-dump cars. See Fig. 205.

Fig. 205.—Drag-line excavator operating clay pit. (*Courtesy of The Excavating Engineer.*)

The labor crew consists of an operator and a laborer for the excavator and three men for the track. The operating expense in 1913 was $3.00 per day for the operator and $1.25 per day for each laborer. The cost of electrical current ran about $80.00 per month. The output in 1913 was sufficient to supply the capacity of the plant for 125,000 brick per day.

361. Use of Revolving Steam Shovel in North Dakota.[1]—A 15-ton revolving shovel has been used in the excavation of clay at the plant of the Red River Valley Brick Company of Grand Forks, N. D.

The shovel cut a bank 4 to 5 ft. in height and required the service of three men for operation.

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[1] Compiled from data furnished by the Thew Automatic Shovel Company.

The following statement[1] gives the cost of operation for 1909, 1910, and 1911 and the average cost for the three years.

COST PER WORKING DAY FOR SEASON

	1909	1910	1911	Average
Wages of engineer	$ 2.69	$3.45	$3.66	$3.29
Wages of fireman	2.11	2.00	2.16	2.09
Wages of one laborer	1.68	2.00	2.18	1.96
Oil and waste	0.12	0.08	0.08	0.09
Coal @ $5.65 per ton	1.53	1.81	1.65	1.67
Water	0.08	0.10	0.08	0.09
Repairs	....	0.33	0.54	0.29
Total cost	$8.21	$9.77	$10.35	$9.48
Pounds coal consumed daily	565	643	597	602
Gallons water consumed daily	486	639	489	538
Cubic yards clay used daily	197	320	273	264
Number bricks made daily	90,000	144,000	124,000	120,000
Cost loading clay per M	0.09	0.07	0.084	0.082
Cost loading clay per yard	0.04	0.03	0.038	0.036
Cost shovel repairs per yard	None	0.0009	0.0019	0.0009

362. Résumé.—The development of a quarry, open-cut mine, gravel, sand or clay pit of large size involves the efficient and economic use of excavating machinery. The selection of the proper type of excavator and its method of operation and coördination with the other processes of a plant depend on the size and output of plant, the character, location and condition of the material to be excavated, the length and manner of haul, the availability and cost of labor and fuel, etc. On general principles, the machinery should be of such a character as to require a minimum labor force and to utilize the cheapest source and kind of power locally available.

The opening-up of a quarry, open-cut mine or pit should be so planned as to allow for the future development of the plant, to utilize the output to the best advantage, to maintain a minimum length of haul, and to secure a minimum expense of excavation, transportation and operation of plant.

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[1] Furnished by the Thew Automatic Shovel Company, Lorain, Ohio.

The hard materials of quarries and open-cut mines must ordinarily be blasted down before it can be handled, and this should so be done as to minimize the cost of removal and loading. A large amount of breaking up of the material at the foot of the slope or face necessitates expensive delays in excavator operation. The routing and operation of the transportation equipment is another matter of great importance so as to cut down the delays due to waiting for cars, etc. Empty cars should be available on the main track or a siding and "spotted" under the shovel dipper so as to provide for continuous operation. Some types of machinery such as the drag-line excavator can "spot" its own cars by the use of the bucket. The type of car to be used depends on the nature of the material and the method of dumping. A large number of quarries and mines use a revolving cradle dump above the crusher and this requires the use of a small box car. Ordinarily a side dump car is used, and the use of compressed air for dumping has made practicable the utilization of large capacity cars.

The moderate-sized sand and gravel pit should be operated by a power-operated excavating, screening, and washing plant. The drag-line cableway excavator is the most economical form of machinery to use in this class of work. For large size plants, it may be found desirable to use a steam shovel or drag-line machine of large capacity, either in coördination with a cableway or independently. In the former case, the cableway would probably be used solely for handling the excavated material.

The excavation of clay and shale pits requires a power excavator of wide latitude, flexibility and range of operation. The revolving shovel or drag-line machine are best adapted for this line of work. The large capacity "stripping" shovel of the revolving type is a very efficient and economical machine for the removal of clay, shale and other material that can be handled directly. The drag-line excavator is especially adapted to locations where the low wet soil conditions necessitate the machine operating from higher and more stable ground.

The author would urge all plant managers and operators to study carefully the excavation of their raw material not only to secure the most efficient and economical methods but to ensure the proper coördination of this initial operation with the other operations of the plant.

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CHAPTER XXIII

TUNNELS AND UNDERGROUND MINES

364. General.—The use of machinery for tunneling and underground mining is a recent practice which is still largely in the experimental and development stage. The time-honored and customary hand methods are still in general use both for the excavation of earth and rock. The latter material must generally be broken up by drilling and blasting before it can be handled, although shale, coal and other of the loose rocks can often be directly excavated by a power machine.

The restricted space of a tunnel or underground chamber renders the use of a power machine difficult and relatively inefficient. However, in recent years several types of excavators for use in tunnel headings and mine drifts have been devised and used with considerable success. This chapter will be devoted to a discussion of several of these machines, but a lack of space precludes any attention being given to tunnel shields, channeling machines, coal cutters and other special types of machinery, descriptions of which are given in books on mining and tunneling.

365. Clay Excavator.—A machine for the excavation of clay, stiff sand and similar soils has been successfully used during the past 5 years (1914–1918), in the construction of a sewer in Detroit, Michigan, and of the new water tunnel under Lake Erie at Cleveland, Ohio.

The machine was devised by Charles Bonnet of Port Huron, Michigan and is illustrated in Fig. 206. As will be seen from an inspection of the cut, the essential feature of the machine is a horizontal axis which is directly operated by an electric motor and carries at its outer end the excavating equipment, consisting of a boring knife and an arm with a cutting tool. The latter is mounted on an arm parallel to the main arm and so geared thereto that the tool moves out along the transverse main arm as the shaft revolves.

The excavator is mounted on a track of rails or plank and set with the shaft on the tunnel axis. The plowshare-shaped knife makes the initial cut of 15 in. into the center of the heading. The boring knife is then thrown out of gear and the crossarm thrown into gear and the cutting tool starts at the edge of the cut made by the knife. As the arm revolves, the tool removes a slice of material 6 in. wide and 6 in. deep, progressing spirally from the center hole to the periphery of the tunnel section. The material falls upon a belt conveyor below the shaft, and is carried back to a second conveyor which deposits it into dump cars. When the 6-in. cut has been completed the shaft is thrown out of gear, the car moved ahead, and the process continued.

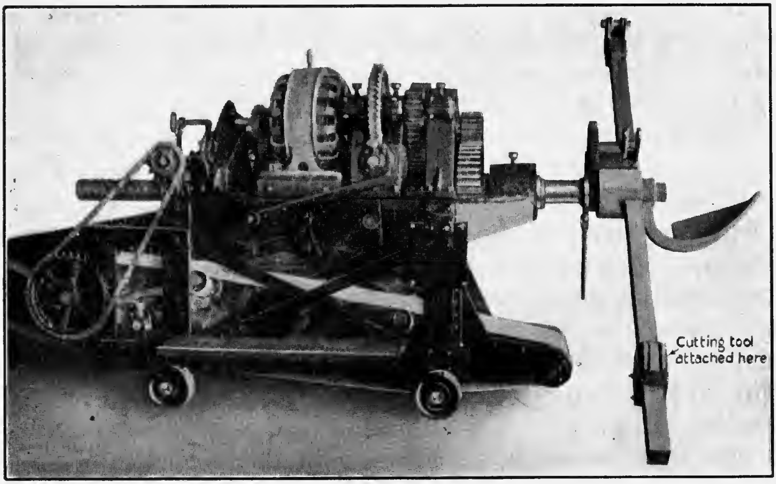

Fig. 206.—Bonnet tunneling machine. (*Courtesy of Engineering News-record.*)

The weight of the machine with a number of jacks from the tunnel periphery to the machine are generally sufficient to take up the reaction of the cut.

366. Use of Bonnet Excavator in Michigan.—The Bonnet clay excavator was used in the construction of the Mount Elliott Avenue sewer in Detroit, Michigan in 1914.

The excavation comprised a cut 11 ft. 2 in. in diameter and 5-000 ft. long. The material was a stiff blue clay with occasional sand pockets and large boulders. The tunnel was dug from three shafts and sections were dug by machine and the ordinary hand labor method. The following is a comparative statement of these two methods:

	Cost per 8-hr. day	
Hand Labor:		
6 miners @ $5.50	$33.00	
3 muckers @ $2.75	8.25	
3 laborers @ $2.75	8.25	
Total		$49.50
Excavation		8 ft. per day

Cost of excavation, $49.50 ÷ 8 = $6.1875 per lin. ft.

Machine:		
1 machine operator	$4.00	
1 knife operator	3.00	
2 muckers @ $2.75	5.50	
2 laborers @ $2.75	5.50	
Total		$18.00
Excavation		12 ft. per day

Cost of excavation, $18.00 ÷ 12 = $1.50 per lin. ft.

367. Rock Excavators.—Rock excavators in tunneling and mining may be considered in two general classes: (1), the well-known and universally used machines adapted to this class of work and (2), new types of machines especially devised for underground operations.

The best known type of power excavator adapted to underground excavation is the power shovel, operated by compressed air or by electricity. In tunneling, small shovels have been used since 1900 on various large projects and in mining operations special types are used in the zinc mines at Joplin, Missouri, in the Lake Superior region and elsewhere. Such shovels are specially adapted for low head room, limited swing, etc., by the use of low A-frames, short booms and dipper handles and narrow car bodies. Figure 207 gives a diagrammatic view of a power shovel on tunnel excavation.

The restricted area of operation in tunneling and mining offers special problems in trackage, grades, handling the material, etc., which must be considered for each case to best satisfy local conditions. The most economical type of power to use depends on the power available at the site or in the mine. Electric power is generally the cheaper where both are available, but compressed air has been generally used in the past on account of its reliability and adaptability. In recent years only, has electric power been successfully applied to the operation of shovels.

368. Use of Air-operated Shovels in Pennsylvania.—Four air-operated shovels were used during the summer of 1915 in the construction of the Woodhill and East Brady Tunnels on the Allegheny Division of the Pennsylvania Railroad in northern Pennsylvania.

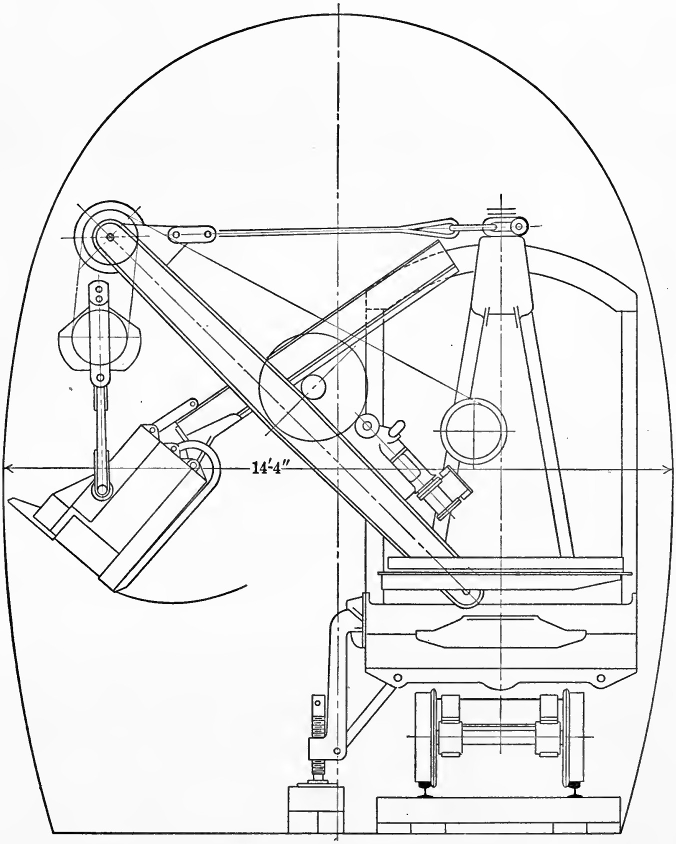

FIG. 207.—Diagrammatic view of power shovel in tunnel. (*Courtesy of The Bucyrus Co.*)

One machine was used at each end of two tunnel sections; the Marion Model 40 being equipped with a 1½-yd. dipper, and the Bucyrus 40R having a 21-ft. height of boom and a 1½-yd. dipper. The material was soapstone and sandstone which crumbled rapidly when exposed to the air. The top headings were cut by hand, the benches were blasted down and the material was loaded by the shovels into 4-yd. Western dump cars. The latter were hauled by Vulcan 18-ton locomotives in 6 car trains. The material was hauled outside the tunnel and dumped along the river bank.

The average output was about 200 cu. yd. per 6-hr. working day per shovel. The shovels could operate on an air pressure of 40 lb. but were most efficient when a 100-lb. pressure was used.

369. Use of Air-operated Shovels on the Pennsylvania Tunnels, New York.[1]—The construction of the Bergen Hill Tunnels of the North River Division of the Pennsylvania Tunnels of New York from 1905 to 1908, involved the use of four air-operated power shovels. Except for 1000 ft. in each tunnel at the Weehawken end where the muck was loaded by hand, one shovel was used at each working face.

One shovel was a Marion Model 20, weighing 38 tons and equipped with a 1¼-yd. dipper, and the other three were Vulcan Little Giants of about 30 tons weight. All shovels were operated on standard-gage track and moved back from the face of heading 300 ft. to 500 ft. during the blasting.

The material was largely a trap rock varying in texture from a very hard, fine-grained rock at the eastern end to a very coarse-grained, granite-like material at the Hackensack portal.

The shovels were operated by three crews, two day crews and one night crew; the day crews generally averaged from 45 to 60 hr. over time during the month. The shovels loaded wooden box cars of 60 cu. ft. capacity, and the average load was about 1 cu. yd. (place measurement). The cars were used generally in trains of four, hauled by 12-ton Vulcan locomotives.

The best method of operation was found to be the making of a complete blast every 36 hr., securing an advance of 9 ft. of full section. During the first shift, the shovel moved forward and cleaned up the floor of the tunnel to the main muck pile, which was generally distributed for a distance of from 150 ft. to 300 ft. from the working face along the floor. During the second shift, the shovel removed a large part of the main muck pile. During the third shift, the shovel completed the removal of the muck. During the second shift, the drillers mucked the heading and set up the drills, which were used for drilling the lift holes during the third shift.

The best average output for any one shovel was 60 cu. yd. per shift. The maximum output was 159 cu. yd. per shift of

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[1] Abstracted from *Transactions of A. S. C. E.*, September, 1910.

8 hours. As the shovels were generally idle for one shift out of three, the quantity actually handled averaged 90 cu. yd. per shift during the working time. Figure 208 shows one of the shovels in operation.

During 1906, 1907 and 1908,[1] four Marion Model 20 air-operated shovels and two Browning, 15-ton locomotive cranes were used in the construction of the Cross-Town Tunnels, East River Division of the Pennsylvania Tunnels of New York.

Fig. 208.—Power shovel operating in Bergen Hills tunnels. (*Courtesy of Marion Steam Shovel Co.*)

The shovels were operated on standard-gage track of 40-lb. rails, and loaded trains of 3-yd. steel buckets carried on flat cars. The trains were hauled by General Electric, standard, 10-ton mine locomotives operated by 220-volt current.

The material excavated was Hudson schist with occasional pockets of sand and sections of disintegrated rock. The presence of large quantities of water delayed the work at times and required heavy timbering.

The progress made in full-sized twin tunnel was an average of 5.5 ft. per day during a period of 56 working days on one section of 311 ft. length and of 4.7 ft. per day during a period of 173 days on a section of full-sized twin tunnel, 810 ft. long.

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[1] Abstracted from *Transactions of A. S. C. E.*, September, 1910.

370. Special Rock Excavators.—Special types of rock excavators may be classified as to the method of cutting: (1), the rectilinear groove cutter and (2), the circular groove cutter.

The first type has several forms as follows:

1. Mechanical chisels or drills.
    - (*a*) Hand machines.
    - (*b*) Mounted on columns or bars.
    - (*c*) Mounted on carriages on rails.
2. Circular saws and disc machines.
3. Endless cutter chains.
4. Wire saws.
5. Revolving toothed bars.

1. (*a*) A drill or chisel is operated by steam or compressed air and chips out a groove by the impact of a large number of blows. The machine is generally mounted on a small truck and is guided by hand.

(*b*) The groove is made by boring a succession of holes near together and later chiseling out the small partitions. The machine consists of a power drill mounted on a frame or bar, along which the machine moves.

(*c*) The third form is the well-known channeling machine or channeller, which consists of a self-contained motor-operated carriage. The latter moves along a track and carries one or two series of drills or chisels which cut one or two vertical grooves in the floor.

2. Circular saws or disc machines are used to make horizontal grooves for the undercutting of coal or salt in mines. The usual form of machine consists of a circular steel plate with removable teeth on its periphery and made to revolve by a power-operated pinion. The machine moves ahead as the groove is cut by pull of a wire cable wound up on a revolving drum.

3. A typical form of cutter is that equipped with an endless chain armed with teeth. The chain travels over a frame which is generally triangular in shape. The machine is automatically fed ahead as the groove is cut. With such a machine cuts 44 in. wide and 5 ft. deep may be made at one set up of the machine.

4. In the marble quarries of Carrara, Italy and elsewhere, endless cords of twisted wires or cables have been used to saw out stone. These cords move over guides or pulleys and are provided with sand and water as the groove is cut into the material.

5. The latest form of cutter is the revolving bar machine.

This consists of a cutter bar upon which are arranged bits or teeth; the bar being revolved and moved sidewise and vertically by power. One form of machine is designed so that the cutter bar may be used in any position from the floor to a height above it of about 7 feet. The speed of the bar is about 450 r.p.m. and the machine may be fed into coal at the rate of from 3 ft. to 4 ft. per minute. The machine is electrically operated and moves along a track under its own power.

The second type of machine consists of a cross-bar or disc provided with bits or teeth and made to revolve in a vertical plane. One machine of this type has a 5-ft. diameter disc and actually drove a heading of 39 in. in 46 minutes. Another machine of similar type made an average weekly record of 51 ft. through sandstone and with a diameter of 7 ft. 4 inches.

The use of the disc machine requires a suitable method of "mucking" or the removal of the excavated material. In most cases, this has been provided for by the use of a stream of water playing upon the heading at a pressure of from 30 lb. to 50 pounds. The water washes the material away from the face of the heading and carries it back toward the portal or to a convenient place where it may be loaded in dump cars for final removal.

371. Shoveling Machines.—Several types of shoveling machines have been devised for the elevation of material and its disposal in cars, wagons or on to a spoil bank. These are largely mechanical loaders and the reader is referred to Chapter XVI for a more complete description of various types. The following is a brief description of a low-clearance machine which has recently been put upon the market by the Myers-Whaley Company of Knoxville, Tennessee.

An inspection of Fig. 209 will give a general idea of the construction and method of operation of this machine. The essential features are a shovel with tipping gear dumping the spoil on to a conveyor which passes it on to a second conveyor and thence into cars or wagons. The machine is made in several sizes and capacities.

The machine is mounted on a steel-framed truck which is built to run on a narrow-gage track. The operating equipment generally consists of an electric motor which is mounted on the truck and propels the machine by gears and operates the shovel and conveyors by chain drive.

A No. 4 machine has an overall width of 5 ft. 4¼ in. and a minimum height of 4 ft. 6 inches. It is operated by a 20-h.p. electric motor, and has a working speed of 12 shovel moves per minute and an average output of 40 cu. ft. per minute in loose material.

The output of a No. 4 machine in a lead ore mine at Flat River, Missouri, has averaged about 7000 tons per month. In a salt mine at Retsof, New York, a similar machine has handled from 250 tons to 300 tons in a 9-hr. working day. The power consumption averages about 0.22 k.w.-hour per ton of material handled.

Fig. 209.—Shoveling machine operating in a coal mine. (*Courtesy of Myers-Whaley Co.*)

372. Use of Low-clearance Shoveling Machine in Africa.—Two Myers-Whaley machines were used in 1914 in the Crown Mines on the Witwatersrand in Africa. The machines were operated on 500-volt direct current and each had an operating weight of about 17,000 pounds.

The material loaded was hard in the first level and the drilling was slow, requiring about 24 hours. Hand mucking required from 5 hr. to 7 hr. to clean up the face while the machine accomplished the same task in about 3 hours. The increased progress due to the machine was about 10 per cent.

In the second heading, also 10 ft. × 14 ft. in cross-section, the rock was much softer and the breaking down of the face required only 9 hours. The saving of time in mucking due to the use of the machine was from 3 hr. to 4 hr. or a net gain in progress of about 25 per cent.

The number of Kafirs required to operate a machine averaged about 10 for a working period of 10 hours. The labor wage rate was $0.775 per boy for 10 hr., and the muck boss received $4.85. The labor cost for 3 hr. was $1.44 for muck boss and $1.78 for boys; total $3.22.

373. Résumé.—Since 1900, the great development in the construction of railroad tunnels and underground mines has led to the use of power excavators for both earth and rock excavation. The earliest and simplest form of excavator is a special, low-clearance type of power shovel operated by compressed air or electricity. Recent experience has brought about the use of specially devised cutters and loaders which are very efficient for certain classes of work.

Where the material is a clay or similar material of a uniform consistency or character, an excavator of the Bonnet clay excavator type is very efficient and economical. However, such a machine is used with difficulty in material of a varying nature, and especially where rock occurs in the bottom of the section or quicksand pockets abound.

Few special rock excavators have proved to be as successful for general use as the use of a low-clearance power shovel for the loading of rock, previously broken up by drilling and blasting. The best form of power to use depends on local conditions of availability and relative cost of power. Electric power is generally available in tunneling and mining operations and can be easily adapted to the operation of shoveling machines and special forms of excavators. However, in the operation of many mines and tunnel plants, compressed air is preferred to electricity for the operation of machinery on account of its safety, simplicity and convenience. Ordinarily, where both forms of power are available, electricity is more economical, especially when secured from water-power developments.

The loading or belt conveyor type of shoveling machine is a very efficient form of loading device and can be used to advantage in the headings of rock tunnels and mines. The author has been surprised that this form of excavator has not been more widely utilized in the field of excavation.

Tunneling and underground mining offers a new and attractive field for the development of excavating machinery, and the next decade will doubtless witness the more general adoption of the present forms and the introduction of several new types.

374. Bibliography.—For further information, consult the following:

Books

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2. "Elements of Mining," by G. J. Young, published by McGraw-Hill Book Company, New York. 6 in. × 9 in., 628 pages, 271 figures. Cost, $5.00.

3. A Manual of Mining," by Ihlseng and Wilson, published by John Wiley & Sons, New York. 6 in. × 9 in., 337 figures, 723 pages. Cloth, $4.50.

4. "Mining without Timber," by R. B. Brinsmade, published by John Wiley & Sons, New York. 6 in. × 9 in., 309 pages, figures. Cost, $3.00.

5. "Modern Tunneling," by Brunton and Davis, published in 1914 by John Wiley & Sons, New York. 6 in. × 9 in., 450 pages, 80 figures. Cost, $3.50.

6. "Modern Tunnel Practice," by D. Mc N. Stauffer, published by McGraw-Hill Book Company, New York. 6½ in. × 9¾ in., 314 pages, 138 figures. Cost, $3.50.

7. "The Subways and Tunnels of New York," by Gilbert, Wightman and Saunders, published by John Wiley & Sons, New York. 6 in. × 9 in., 372 pages, figures. Cost, $4.00.

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13. Self-Propelled Low-Clearance Shoveling Machine. *Engineering*, London, July 9, 1915. Illustrated, 1500 words.

14. A Square Working Face with an Overcutting Machine, E. C. De Wolfe. *Coal Age*, April 24, 1915. Illustrated, 2000 words.

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16. Successful Shoveling Machine, E. H. Coxe. *Coal Age*, July 17, 1915. Illustrated, 1500 words.

17. Working with a New Type of Coal Cutter, J. G. Bart. *Coal Age*, February 27, 1915. Illustrated, 1500 words.

18. Work on the Sand Patch Tunnel, B. & O. *Excavating Engineer*, July, 1913. Illustrated, 2500 words.

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