MANUAL OF HYDRAULIC MINING

for the use of

THE PRACTICAL MINER

VAN WAGENEN

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OF

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THE PRACTICAL MINER.

BY

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PREFACE.

The following pages are written solely for the use of the practical and working miner, who, while rarely deficient in common sense, is generally unacquainted with the principles of physics and more or less rusty in arithmetical methods. In the daily discharge of his business he is continually confronted with engineering problems of more or less complexity, and compelled to depend for their solution—trained engineering advice being unobtainable or too expensive—upon his own limited experience or upon that of his co-laborers.

Under these circumstances, errors in construction and operation are frequently repeated. The author ventures the hope that the study and use of the following pages will, to some extent at least, obviate the necessity for costly experimenting, now so common.

The Manual does not claim to cover the whole subject, nor to answer all questions in hydraulic engineering. Nor will it take the place of an experienced and competent engineer in important enterprises. On the contrary, no miner who is not himself an expert, and who can afford it, should be without such advice and assistance as can be afforded by a well-educated and practised hydraulic engineer.

THEO. F. VAN WAGENEN.

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INTRODUCTORY REMARKS.

Hydraulic mining is the art of separating gold from gravel, sand, and clay cement, through the medium of moving water and the force of gravity.

The process is one lying wholly within the domain of the science of mechanics—a branch of human knowledge now so well understood that results may be predicated with extreme accuracy, if correct premises are obtained.

Hence, hydraulic mining presents fewer risks and more certainties than any other department of mining, other things being equal. It is simply a question of moving gravel or soil from one place to another. Given, therefore, in addition to an abundance of water to move and wash the gravel, ample space to deposit it again after it has been washed, and the problem of obtaining a profit is reduced to a minimum.

Gold occurs in gravel deposits in a metallic condition. The chemical and mechanical operations required to separate it from the vein substances with which it was originally associated have all been performed by nature. That wonderful agency has also supplemented her work by again collecting the particles of metal within certain limits. In other words, degradation and erosion of quartz-veins has been followed by the partial concentration of the material so broken up; and while this operation has not resulted in an enrichment of the gold-bearing material (on the contrary, it is much poorer, bulk for bulk), the metal is placed in association with substances from which it may be separated with extreme ease and very small cost.

As an example, the gold-bearing veins of the western United States have an average value of about ten dollars per ton of quartz extracted, which ten dollars can be mined, transported to mill, crushed, amalgamated, refined, and sold at a gross cost of about eight dollars per ton, or eighty per cent. The same gold vein, after passing through the laboratory of nature, will consist of a gravel-bed or deposit worth about twenty cents per ton, which twenty cents may be secured and marketed at a cost not over five cents, or twenty-five per cent. Other things being equal, therefore, hydraulic mining presents three times the chance for profit that is found in gold quartz-mining, and one-third the risk, with the additional advantage that the extent and richness of the gravel-bed may be completely studied and ascertained before working it, and at a slight cost; while vein-mining is from first to last more or less of an experiment and a chance.

The records of mining show that over seventy-five per cent. of all the gold mined within historic times has been derived from the working of gravel-beds. It is also a matter of fact that the area of auriferous gravel deposits is vastly greater than that of quartz-veins. This is especially the case on the Pacific coast of both North and South America. The immense chain of mountains extending from Alaska to Patagonia bears evidence of having been at once one of the loftiest and oldest of the great upheavals of geological time. From one extremity to the other it is ribbed with metallic veins, which through the ages have been worn down and away, and their débris deposited by rivers and lakes and glaciers in all the various ways in which nature works. And these great deposits, consisting of old channel-beds, forsaken bars, grass and forest covered moraines, and sterile terraces, contain, beyond a doubt, more millions than have yet been mined. The great Blue Lead of California, which has been traced for seven hundred miles along the western flank of the Sierras ; the channels and bars of Montana, which represent the pathway of the Missouri of old ; the great morainal deposits of Western Colorado; and the arid and dry terraces and ravines of Arizona—all these are nature's gold-filled vaults, inviting the enterprise, the energy, and the ingenuity of the white man, and promising, not the irregular and doubtful returns which characterize precious-metal mining of the present day, but steady and continuous results, based on an industry as legitimate and safe as agriculture or general trade.

CHAPTER I.

GENERAL PHYSICAL CONDITIONS.

GRAVEL.

GRAVEL deposits containing gold are generally considered to be the disintegrated remains of mountains which were originally seamed with auriferous quartz-veins, or of strata of rock in which the metal was disseminated, or both. The material forming these deposits consists of gravel, rounded boulders, sand, and clay, generally being in conformable layers or strata, but at times disposed without regularity. These deposits are beyond doubt the result of mechanical precipitation. The occurrence of gold disseminated through the gravel is generally ascribed to the same cause, though some are inclined to believe that chemical action has supervened in the case of the metal. The point is one of more scientific than practical interest, though the latter theory will perhaps explain why placer gold is purer than vein gold.

Gravel deposits may be subdivided as follows:

(*a*) Ancient river-channels.

(*b*) Recent " "

(*c*) Bars.

(*d*) Moraines.

(*e*) Terraces.

(*f*) Lake-bottoms (ancient and recent).

In general it may be stated that gold will be found in greater quantities and in coarser fragments in deposits which are—

1. Nearest to the original deposits.
2. Have been deposited on the steepest grades.
3. Contain the most gravel and boulders.
4. Contain the most iron.

There are many cases in America, however, where the gold is found almost exclusively in the clay or cement layers, but this does not appear to be the rule.

Where gravel deposits are made up of several layers of differently-sized material, often some of these layers are wholly barren, or at least unprofitable. In general the metal is found in greater quantities in the lower layers of the gravel, near and on the bed-rock.

Frequently in exploring and testing gravel deposits it is necessary or convenient to find the weight of the mass ; this operation will be facilitated by the following table :

One cubic ft.	of	dry, loose loam	weighs	.... 72 to 80	lbs.
"	"	" packed "	"	.... 90 to 100	"
"	"	wet, loose "	"	.... 66 to 68	"
"	"	" packed "	"	.... 85 to 95	"
"	"	solid quartz	"	165	"
"	"	broken "	"	 94	"
"	"	solid limestone	"	170	"
"	"	broken "	"	 96	"
"	"	fine sand, dry,	"	....100 to 117	"
"	"	ordinary gravel, free from cement, and containing no heavy boulders (dry), weighs	....	90 to 100	"
One cubic ft. filled with boulders not over six inches in diameter (dry) weighs			.....	95 to 105	"

Auriferous gravel deposits are formed on all kinds of bed-rock, such as granites, limestones, slates, and quartzites, and even sandstones. The nature of the bed-rock rarely, if ever, affects the quality of the deposit, though, as will be seen hereafter, it may affect its economic value.

GOLD.

The precious metal is of a fine yellow color when chemically pure, and weighs about nineteen times as much as an equal bulk or volume of water. Hence

One cubic inch of gold weighs.......	.696 lbs.
One cubic foot " "	1204 "

Its value per standard Troy ounce is $20 67, and per pound (Troy) $248 04

In nature gold never occurs pure, but is invariably accompanied with some silver, and often with other metals. In this condition it presents a whitish or reddish yellow color, according as the bulk of the accompanying metal is silver or copper.

The metal is exceedingly tenacious, malleable, and melts at a temperature of 2,016 deg. Fah.

In practice its comparative purity is expressed by the term "fineness," and this is estimated on the basis of 1,000 as a unit of measurement.

Thus, a mass or nugget of gold containing 78 per cent. of gold, 18 per cent. of silver, and 4 per cent. of other substances will be said to be .780 (seven hundred and eighty thousandths) fine.

In the gravel deposits gold occurs as *nuggets* (masses of irregular shape and size); *shot-gold* (rounded pellets like very small bird-shot); *leaf-gold* (thin sheets sometimes one-tenth of an inch square); *coarse flat gold* (same size as the latter, but thicker); and *dust*, which is often so fine as to be inappreciable to the naked eye. Occasionally wire-gold is found, but that is rare. The physical qualities of this metal are such that, while it will remain almost wholly intact under the action of chemical reagents, it is easily affected by abrasion, and, if carried for considerable distances together with gravel and ice, is ground rapidly to the finest powder.

It does not always follow that a gravel deposit containing even a goodly quantity of gold per yard can be worked with profit. The particles of metal, to be capable of being saved by cheap mechanical means, must possess a combination of weight and shape which will permit the action of gravity to a maximum degree. In other words, if the bulk of the gold in a deposit is either in the condition of a very fine dust or very flat, thin scales, it will float away and resist the most careful endeavors to precipitate it.

WATER.

At ordinary temperatures water is a clear, colorless liquid, weighing about 62½ lbs. per cubic foot. At 32 deg. Fah. it becomes a solid, and in the act of solidification expands one-twelfth of its volume. At 212 deg. (sea-level) it boils, and passes off as vapor. Water is slightly compressible at a pressure of 4,500 lbs. per square inch, but on removal of the force returns instantly and completely to its former volume. When expanding under the influence of heat or cold it is capable, as is well known, of exerting enormous force.

The following table of equalities will be found at times useful:

1 cubic inch of water weighs		....	.036 lbs.
1 " foot "	"	....	62.5 "
1 " yard "	"	....	1680.75 "
1 " foot of ice	"	....	57.3 "
1 U. S. gallon	"	....	8.34 "

The standard measure for water in hydraulic mining is the miner's inch.

The quantity of water which will escape from a reservoir through an aperture in its side 1 inch square, whose centre is 6 inches below the constant level of the water, is termed a miner's inch. This measure is necessarily a rough one, and has doubtless been often erroneously applied. The aperture should have no tube or conduit leading from it, and its section throughout should be uniform and possess practically no length. These conditions are not, however, attained in common practice. The most common illustration of the miner's inch is a hole 1 inch square through an inch board. In this case the length of the aperture is clearly equal to its diameter. Where the aperture discharges a large number of inches at once its diameter is of course much larger, and the proportion of its length to its diameter is much less.

In round numbers the miner's inch has the following values:

	Cubic feet.		*Pounds.*		*U. S. gal.*
Discharge per second.	.0271	=	1.69	=	0.2026
" min...	1.626	=	100.	=	11.99
" hour..	97.56	=	5937.	=	711.96
" day (12h.)	1170.7	=	71250.	=	8543.29
" day (24h.)	2341.4	=	142560.	=	17095.78

The miner's inch as a standard of water measurement is very defective. In the early days of placer-mining, when the water was owned by one set of people, who sold it in small quantities to another set (the miners), this standard was a necessity. At present it would be better if the cubic foot could be used as a measure, but the change is one impossible to be made.

= 1.5 cu. ft. per min.

CHAPTER II.

GENERAL METHODS OF PLACER-MINING.

THE general theory of hydraulic mining comprehends—first, breaking down the gravel; second, passing it through sluice-boxes while held in suspension by water; and, third, cleaning up the gold caught in the boxes.

The pan, rocker, long tom, sluice, boom, and hydraulic have been successively adopted in almost every gravel-mining district in America. Unfortunately, exact records of the possible work with each are almost unattainable, and, even if they were, variations in the character of the gravel would to a large extent nullify their value. The following comparative table, giving figures of work performed, first, on ordinary gravel, which is quite tractable, and, second, on cemented gravel, which is perhaps the most refractory known, will perhaps be of value to the miner. The two may be regarded as extremes. The table shows the number of cubic yards of dirt which may be washed per day of 10 hours per man—in the first two cases each man working alone, and in the last four in pairs, or economically-arranged gangs:

	Ordinary.		*Cemented.*	
By the pan.......	1	cu. yd.	¾	cu. yd.
" rocker.....	2	"	2	"
" long tom...	5 to 6	"	3 to 5	"
" sluice......	10 to 20	"	6 to 12	"
" hydraulic..	100 to 1000	"	100 to 1000	"
" boom......	unlimited.		unlimited.	

It will be understood by every miner that no exact figures can be given in a comparison of this nature, and that the character of the ground will very largely affect the amount of work done. With the pan, which will hold from fifteen to thirty pounds of gravel, only a very little ground can be washed under any circumstances. If the ground abounds in large boulders which can be removed by the hand with ease, a miner will wash twice as much as otherwise. One hundred pans are considered as a good day's work for a careful operator. The same consideration—that of boulders—applies to the work in a rocker and long tom. The latter permits a more easy and thorough breaking up of cement, and the water generally being supplied automatically, it is operated at a smaller cost. But neither are adapted for operations on a large scale, nor in any ground carrying less than three to five dollars per yard.

The ground-sluice is a device which commends itself for banks not too high to cause danger from caving, and when a good grade in the pit can be obtained. The unfavorable point in this system lies in the fact that all boulders must be moved twice, and that no clean-up can be made till the end of the season. In consequence, either the work is prolonged, with great discomfort to the men, into the period of cold weather, or much water is allowed perforce to run to waste.

Where extensive operations are contemplated the miner has to decide between the boom and hydraulic, or a favorable combination of the two. In California the boom is wholly abandoned in favor of the hydraulic, and in Colorado it is rapidly being superseded. Yet, as a system of placer-mining, it has many strong recommendations, and, according to some of the best Colorado authorities, is often the superior method. It seems to possess most merits when either the water is very abundant or very scarce.

The boom will undoubtedly cave more ground per day and at a less cost than the hydraulic, unless it is a very hard cement. In its operation it is the counterpart of the work of nature in natural ravines. For the purpose of cleaning off top dirt of poor quality it has no superior, and for ground carrying no leaf-gold it is claimed by some to be greatly preferable. Much depends upon the sluice and the manner of operating it.

But where the ground is hard and force is necessary to tear it to pieces, where the banks are low and the gravel tenacious, the hydraulic is, by the testimony of most practical miners, the most advantageous. In many cases the two can be combined with most beneficial results.

In deciding which plan to adopt the miner will do well to bear in mind the principle that he is working, as a first consideration, to make money—not only to tear away the largest possible amount of gravel. Consequently, that method or combination of methods is the correct one which will deliver the largest quantity of gravel (*with its gold*) at his head box in the shortest time—provided always that he has sluice capacity and water sufficient to wash it thoroughly.

In nine cases out of ten the method to be adopted is decided by the amount of water available; and if the supply is unlimited (which is very rarely the case) the hydraulic is always better than the boom, if the two cannot be used. The quantity of work possible to be done with the hydraulic varies, of course, with the nature of the gravel, the size of the stream, and the head. A very sound practical authority gives the following rough estimates:

No. 1 nozzle, supplied with 100 miners' inches of water, under a head of 100 feet, assisted by a ground-sluice of 100 inches, will wash 600 cubic yards per day ; 3 men.

No. 4 nozzle, supplied with 700 inches, under a head of 150 feet, will wash 3,000 cubic yards per day ; 4 men.

CHAPTER III.

DIRECTIONS FOR THE MINER.

I ATTEMPT in this work to give rules and directions for solving all the simpler engineering problems which the practical hydraulic miner (who in most cases is unacquainted with higher mathematics) will have presented to him. To be successful the miner must make himself thoroughly acquainted with the contents of this chapter, which is intended to be explanatory of such mathematical operations as will be noted. He who is able to add, subtract, multiply, and divide will find nothing in this book beyond his ability, if this chapter is carefully studied, and if the same hard common sense and intelligence which in all other matters distinguishes the American miner from other classes of workingmen is brought to bear on the subject. Hydraulic mining is a branch of engineering, and *because* its operations can be guided wholly by mathematical rules it presents so much of certainty and so little of risk. Consequently, the miner who desires to improve his property and increase his profits, but is unable from various causes to obtain the assistance of an experienced engineer, will certainly find it to be worth his while to gain the power of solving, alone and unaided, a majority of the problems which will be presented for consideration in the ordinary course of his business.

I will call the reader's attention, therefore, to the following subjects:

1. The use of decimals;

2. The method of transforming fractions into decimals; and,

3. The principle of expressing the terms of a problem in a uniform and correct manner.

DECIMALS.

The decimal system is a method of numerical expression based upon a division of the unit one (1) by ten (10) or multiples of ten (as, 100, 1,000, 10,000). For example, instead of saying one-half ($\frac{1}{2}$) say five-tenths ($\frac{5}{10}$), and instead of saying one-quarter ($\frac{1}{4}$) say twenty-five one-hundredths ($\frac{25}{100}$). The system, however, does not stop here, but includes a system of notation which does away completely with the form of the fraction—thus :

$\frac{5}{10}$	is written	.5
$\frac{25}{100}$	"	.25
$\frac{84}{100}$	"	.84
$\frac{12}{1000}$	"	.012
$\frac{611}{1000}$	"	.611
$\frac{9262}{10000}$	"	.9262
$\frac{14}{100000}$	"	.00014

Hence, to write down a decimal fraction decimally, follow this rule :

1. Replace the figure 1, which is always the first figure of the lower part of the fraction, by a dot (.).

2. Rub out as many of the last figures of the lower part of the fraction as there are

figures in the upper part, and place these figures in the room of the figures rubbed out.

For instance, to express decimally the fraction four hundred and eleven ten-millionths ($\frac{411}{10000000}$).

Replacing the 1 by a dot, we have .0000000.

Second, as there are three figures in the upper part of the fraction, we rub out the last three ciphers of the above, and replace them with 411, making .0000411

Again, express decimally three hundred and one thousandths ($\frac{301}{1000}$).

Replacing the 1 by a dot gives .000
and placing in the 301 gives .301

Again, express thirty-two tenths ($\frac{32}{10}$). This fraction is evidently the same as three and two-tenths ($3\frac{2}{10}$), which, treated by the rule, gives 3.2.

The addition of decimals is performed exactly as any other addition. Place the two or more quantities under each other, taking care that the decimal-points, the dots (.), are in a line, and place the decimal-point in the answer or result in the same position, thus:

```
   .0104
  3.26
   .192
114.
--------
117.4624
```

In subtracting adopt precisely the same course, thus:

```
1.242
 .012
-----
1.230

.61306
.4
------
.21306
```

In multiplying place the quantities in the ordinary way, multiply as usual, and point off as many figures in the result as there are decimals in the two quantities multiplied, thus:

```
 1.264
   .06
------
.07584
```

Again:

```
      .1103
     .17014
     ------
       4412
      1103
    7721
   1103
 ----------
 .018766442
```

The division of decimals is performed as follows:

Set down the figures as in the ordinary style of long division. Annex to the dividend (the quantity to be divided) first as many ciphers as may be necessary to make the number of decimal figures in the dividend equal in number to those in the divisor, and, second, as many more as may be necessary to obtain a figure large enough to divide.

Divide as in the ordinary method.

Point off in the result as many places for decimals as the number of decimals in the dividend exceeds those in the divisor.

NOTE.—If the divisor or dividend consists of decimals commencing with a cipher or several ciphers (as, .0218 or .00014), these ciphers may be wholly disregarded in the *operation of division.*

The following examples cover all cases :

(*a*) When the divisor is larger than the dividend—as, to divide 1.265 into .04:

```
1.265).04000000(3162
        3795
        ----
         2050
         1265
         ----
          7850
          7590
          ----
           2600
           2530
           ----
```

In this case, there being 8 decimals in the dividend and 3 in the divisor, the difference 5 will be the correct number for the quotient or answer, which, instead of being 3162, will be .03162.

(*b*) When the divisor is less than the dividend—as, to divide .142 into 4.6:

```
.142)4.600(32
     426
     ---
      340
      284
      ---
```

There being an equal number of decimals in both divisor and dividend in this case, the quotient remains unaltered as 32. But if, instead of annexing two ciphers, we had annexed, say, six, the quotient would have been 323943, we would have had four more decimals in the dividend than in the divisor, hence the result would have been 32.3943.

In the division of decimals, ciphers may be annexed to any extent desirable until no remainder occurs; this makes the division perfect. Otherwise it is an approximation. But in all calculations except those of a most delicate nature it is sufficiently accurate to annex only enough ciphers to produce three decimal figures in the result.

(*c*) Where ciphers are prefixed to dividend or divisor, or both, a study of the following operation will explain the method. Thus, to divide .0014 into .0000403 :

```
.0014).0000403(28
            28
            —
            123
            112
            ——
```

There being 7 decimals in the dividend and 4 in the divisor, the answer should contain the difference, or 3 figures, giving, in place of 28, the quantity .028.

TRANSFORMATION OF FRACTIONS INTO DECIMALS.

When a problem under consideration contains fractions it is always necessary to reduce these to decimals. This is done by simply dividing the numerator of the fraction (the top figure) by the denominator (the bottom figure). Thus, to reduce $\frac{1}{2}$ to decimals divide 1 by 2=.5 ; or to reduce $\frac{3}{8}$, divide 3 by 8=.375 ; or to reduce $\frac{3}{4}$, divide 3 by 4=.75. The division need not be carried to more than three figures.

This must be done in all cases. As an example, if the grade of a flume is found by experiment to be $3\frac{5}{12}$ inches per box, the fraction is to be reduced to decimals by dividing 5 by 12, thus:

```
12)5.000(416
   48
   —
    20
    12
    —
     80
     72
     —
```

Pointing off the result (416) according to the rule of division of decimals, the grade is found to be 3.416 inches per box.

THE PRINCIPLE OF EXPRESSING THE TERMS OF A PROBLEM UNIFORMLY.

At the beginning of a problem it is necessary to reduce all the elements to the right shape and form. If this is done confusion will be avoided.

If it is not done the results will be false almost invariably. Hence,

Express perimeter, lengths of flumes, ditches, piping, head, diameters, etc., in linear feet and decimals of a foot.

Express areas (such as sections of flumes and piping, and mouths of nozzles) in square feet and decimals of a foot.

Express discharge in cubic feet per second.

Express velocity in linear feet per second.

Express grade in decimals of a foot per linear foot.

Thus, discharge from a flume or pipe, which is frequently given in miners' inches, should be reduced to cubic feet (see Miner's Inch); grade, which is generally expressed in inches per box (12 feet) or inches per rod (16 feet), must invariably be altered to feet per foot; as, for instance, a grade of 1 inch per box equals 1 inch per 12 feet, or $\frac{1}{12}$ of an inch per 1 foot. But $\frac{1}{12}$ of an inch equals $\frac{1}{144}$ of a foot, which, reduced to decimals, equals .007 of a foot nearly. The correct mode of expression, therefore, will be .007 feet per foot.

Velocity must be expressed in feet per second, and perimeters in decimals of a foot. A flume having a perimeter of 20 inches measures $1\frac{2}{3}$ of a foot. Reducing this to decimals, we have, in place of 20 inches, 1.666 feet.

DEFINITIONS.

The subjoined definitions and explanations will be found necessary to a perfect understanding of the technical phrases used in succeeding pages. The reader is therefore invited to impress on his mind the exact meaning and value of each term defined:

Mass.—The *quantity of matter* which a body contains—irrespective of whether that quantity be diffused through a large space, through the influence, for example, of heat (as in the case of steam); or compressed into a small space, through the influence, for example, of cold (as in the case of ice)—is called its mass.

Volume.—The amount of *space occupied* by a body is denominated its volume.

Weight.—When a body is freely acted upon by gravity, but is prevented from moving by some supporting obstacle, the *pressure* on the point of support is termed its weight.

Jet.—A jet is the *mass* of water escaping from a vessel through an orifice in its side or bottom, which orifice, of course, must be below the level of the water.

Flow.—The *volume* of water which escapes from a vessel through an orifice (which may be wholly or partly under the water) in any given time is its flow for that time.

Velocity.—The *distance passed over* by any given mass of water in any given time is called its velocity. The direction of the motion is immaterial.

Head.—The *vertical distance* between the level of standing water in a reservoir, and the centre of the orifice from which it flows into the air, is called its head.

Wet Perimeter.—If a flume or ditch is 20 inches wide, 6 inches deep, and full of water, its wet perimeter is $20+6+6=32$ inches. If of the same dimensions, but only containing 3 inches of water, the wet perimeter is $20+3+3=26$ inches. The same flume again, if empty, has no wet perimeter at all. In other words, the wet perimeter of a water-channel is the *length of so much of its base and sides as is wetted by* the water. This measurement determines friction.

Friction.—When one body slides upon another, the inequalities and roughnesses of the two surfaces interlock and cause a resistance, which is termed friction. If, now, the sliding body has not sufficient weight and cohesion to create abrasion or wear among these irregularities and roughnesses, the degree of friction which arises bears a well-known proportion to the weight of the sliding body. This is the case when water slides along the floor of a flume or ditch, and the proportion of friction developed to the weight of the water is called

THE CO-EFFICIENT OF FRICTION.

This co-efficient, of course, varies as the water is muddy or clear, or as the flume floor is rough or smooth. It is however, wholly independent of the *areas* of the surfaces in contact. In other words, two flumes of different size, if made of the same quality of lumber and carrying similar water, will develop identical co-efficients of friction—the *proportion* of friction to the moving weights will be the same. But the weights of water in each being different, the *amount* of friction developed in the larger flume will be greater than in the smaller.

Momentum.—The quantity of force which a body in motion is capable of exerting when stopped suddenly is called its momentum. Probably the best illustration of this is the power exhibited by a jet of water when it strikes a bank of gravel. It may be measured by multiplying the weight of the striking body by the velocity at which it moves. For example: A nozzle delivering a stream of water 3 inches in diameter, with a velocity of 150 feet per second, will hurl against a bank every second a force equal to the weight of a column of water 3 inches in diameter and 150 feet high, multiplied by 150, or 34½ tons nearly. But it is to be remembered that this is the amount of force developed at the mouth of the nozzle only. Immediately on passing into the air the stream of water, acted upon by the force of gravity and the resistance of the air, and further weakened through its own disintegration, becomes less powerful. At a sufficiently great distance from the mouth of the nozzle the velocity will be wholly lost, and no force or power remains except that due to the weight of each particle of water under the influence of gravity. Again, it is not to be thought that if a gravel-bank is struck with the force above mentioned 34½ tons of earth must be moved per second. This statement appears to be unnecessary, though it may be logically deduced from the first, unless it be remembered that vast quantities of force must be expended in destroying the cohesion of the gravel and overcoming its inertia. Once in a state of motion, the force transmitted from the nozzle to the gravel would, if the force could be applied at a point which would equally affect the whole, give it as rapid motion as the water, less friction. But this can never be accomplished in practice.

MENSURATION.

A few questions in mensuration will arise in working the problems presented in the following pages. These are as follows:

1. *To find the Area of a Circle.*—Multiply the diameter (in inches) by the decimal 3.14 and the product by one-quarter of the diameter. The result will be the area in square inches. Divide this by 144, and the result will be the area in square feet.

EXAMPLE.—What is the area of a circle 16 inches in diameter?

16 multiplied by 3.14=50.24 multiplied by 4 (which is one-quarter of the diameter)=201.06 square inches, which divided by 144=1.32 square feet.

2. *To find the Area of a Section of a Flume with Straight Sides.*—Multiply the width of bottom (in inches) by the height of sides (in inches); the product will be the area in square inches, which, divided by 144, gives the area in square feet.

EXAMPLE.—What is the area of a section of a flume 20 inches wide and 15 inches high?

20 multiplied by 15=300, which divided by 144=2.08 square feet.

3. *To find the Area of the Section of a Ditch with Sloping Sides.*—Add together the width at top and bottom (in inches), multiply this sum by the depth (in inches), and divide the result by 2. The quotient, divided by 144, will be the area in square feet.

EXAMPLE.—What is the area of the cross-section of a ditch 60 inches wide at the top, 36 inches at the bottom, and 12 inches deep ?

60 plus 36=96, which multiplied by 12=1152, and this divided by 2=576 square inches, which divided by 144=4 square feet.

4. *To find the Area of the Cross-Section of a Ditch whose Sides slope to a Point at the Bottom.*—Multiply the width (in inches) by half the depth (in inches), and divide the product by 144. The result is the area in square feet.

EXAMPLE.—What is the area of a pointed ditch 60 inches wide and 18 inches deep in the centre ?

60 multiplied by 9 (half the depth)=540 square inches, which divided by 144=3.75 square feet.

CHAPTER IV.

THE PROPERTIES OF WATER.

In hydraulic mining the properties of water are to be considered in but two conditions:

(*a*) When at rest—as in the case of dams, retaining walls, and pressure-boxes; and

(*b*) When in motion—as in ditches and flumes.

WATER AT REST.

The three principles here laid down will be worth consideration by the miner who desires to work understandingly.

1. *Water at Rest transmits Pressure equally in all Directions.*—If a pressure of 100 lbs. is exerted on the entire surface of the water in a reservoir whose section is 10 square feet, this pressure is transmitted in its entirety not only to the base, but to every 10 square feet of its sides. Thus, if the interior surface of the reser-

voir (base and sides) measures 250 square feet, and a pressure of 100 lbs. is placed on the water-surface (of 10 square feet), the base and walls will receive a total pressure of 2,500 lbs. Or if the box be so closed at the top as to leave but one square foot of water exposed, and if a pressure of 100 lbs. be applied on this one square foot, an equal pressure will be transmitted to every square foot of interior surface, and the total will consequently be 25,000 lbs. Or, to illustrate this remarkable property still more thoroughly, suppose the top of the vessel to be covered with the exception of one square inch. If on this a pressure of 100 lbs. is placed, every square inch of interior surface will be pressed outward with this weight, which, for the size box under consideration, would amount altogether to 1,800 tons.

This is the principle utilized in the hydraulic press.

2. *The Pressure exerted by Water on the Horizontal Bottom of a Vessel* is wholly independent of the shape of the vessel, and is equal to the weight of a column of water whose base is

the area of the horizontal bottom, and whose height is equal to the depth of the liquid.

3. *The Pressure of Water on the sides of a Vessel* is equal to the weight of a column of water whose base is equal to the area of the side, and whose height is equal to one-half the depth of the liquid.

Owing to this law the pressure on the walls and base of a cubical vessel is equal to three times the weight of the water contained.

The two principal problems in hydraulic mining arising under the head of water at rest are those connected with the construction of dams and reservoirs and water-boxes.

Referring to the third principle just enunciated, it will be seen that the pressure on any surface under water depends upon two things—the depth of water and the area of the surface pressed. For example, what will be the pressure against the inner slope of a dam 50 feet long, 12 feet wide, and 12 feet deep at the *bottom?* Multiply the area of the slope ($50 \times 12 = 600$) by the average vertical depth in feet of the centre of gravity of the slope $(6) = 3,600$, and multiply this by 62.5 (the weight of a cubic foot of water) =225,000 lbs.

It will be noted that the pressure is not a pound greater if the water reaches back from the face of the dam for miles, than if it were a reservoir only a few feet broad. Hence, if a reservoir is built simply for storage, make it large and shallow rather than small of area and deep. The loss by solar evaporation will, it is true, be much greater, but this disadvantage will be counterbalanced, first, by the small leakage; second, by the cheapness of the dam; and, third, by the great safety of the construction. A miner cannot go to his work under more depressing circumstances than with the thought that at the head of the gulch in which he is imprisoned is a dam whose embankment of 15 or 20 feet in height may at any time give way and destroy not only himself and comrades, but every trace of improvements that have been the labor of years.

Probably the best and safest embankment, where there is no carpentry or masonry, is that one which is modelled on the plan of the beaver-dam. This is a familiar sight in the West, and its details can be easily studied. The beaver-dam is seldom if ever known to give way, and this quality of stability is what is of all things most desirable.

The water or pressure box has three uses. It determines permanent and steady head ; it offers an opportunity to clear the water from gravel and other débris before passing it into the pipe, and it should be the means of freeing it from a large portion of the air which it absorbs while travelling at a high velocity.

Construction.—The pressure-box should be a deep vessel, with a pyramidal bottom pointing downward and provided with a trap. This, on being opened from time to time, will clear out gravel and sand which has collected in the bottom, and which, if allowed to accumulate, would in time rise to the level of the outflow. The pressure-box is best built when its height, exclusive of pyramidal bottom, is three times its greatest width. The section should be longer one way than another. It should have a lip overflow on one of the short sides, and the water should enter the box at the centre of its top, and from the same side as the discharging-lip. All screening should be done in the flume. A partition reaching down below the outflow, and parallel with the longest sides, is highly recommended by good authorities. The discharge-hole should be two-thirds of the distance from top to bottom (no increase of power is gained by placing it at the bottom), and should be in one of the long sides. If these directions are observed a large quantity of the gravel unavoidably carried into the box will be prevented from passing into the pipe, much of the air will also be kept out, and a steady and even head will be secured.

We have now to consider only the strength of the box. That this is an important point may be judged by the fact that if its height is 12 feet, and its section 3 by 4 feet, it will have to sustain a pressure of not less than 35 tons.

MEASURING THE WATER OF STREAMS.

If the channel of the stream has a moderately even outline, measure its depth at regular intervals from shore to shore. Add all these depths together, and divide the sum by the number of soundings. An average depth is thus gained. Calculate then the area of the section according to Rule 2, page 41. Measure the velocity by means of a float, and make the test about half-way between the bank and the centre. Multiply the area by the velocity, and the product will be the flow. Of course the test for velocity should be made at the same point where the measurements for depth are made, and a place on the stream should be selected for both where the banks are as nearly parallel as may be, and where the current and flow is the most tranquil.

EXAMPLE.—A stream is 24 feet broad, and ten soundings at every two feet on a line from bank to bank give 2, 6, 8, 9, 7, 11, 11, 10, 9, and 2 inches as the depths. The average velocity as determined by float is 4 feet per second. What is the flow?

The sum of the 10 soundings is 75 inches, which gives an average depth of 7.5 inches, equal to .625 of a foot. The area of the section then is 24 multiplied by $.625 = 15$ square feet.

The velocity being 4 feet per second, the flow is equal to 15 multiplied by 4=60 cubic feet per second.

If the stream runs over a bottom so irregular that an average depth cannot be gained or an average velocity measured, there is no recourse but to construct an artificial channel having no grade, into which it may be turned while measures are made. The same rule applies in this case as before, and it should be understood that in both the results are very rough approximations. To reduce the result to miners' incnes refer to the table of equalities, page 18.

CHAPTER V.

CONSTRUCTION OF WATER-WAYS.

WHEN the miner has measured the stream from which he is to draw his water-supply, and has determined that point where he will tap it, he is prepared to consider the question of water-channels. These may be of three kinds—the ditch, the wooden flume, and the iron pipe. The ditch is the most indestructible, the cheapest, and the easiest to repair. Instead of deteriorating, it improves in condition year by year if carefully built. On the other hand, more water is lost by evaporation, and in stormy seasons it is subject to injury by overflows, land-slides, caves, etc., etc. The wooden flume eliminates the element of loss by leakage, but not by evaporation. It occupies the middle ground in point of cost, but requires much watching. It is, moreover, the most easily destroyed by fire and flood. The iron pipe prevents all loss on the way, is most easily cared for, and costs the most. It is seldom considered to be the best method of water transportation, except when a necessity, as in the case of siphon-bends or very steep grades, or on the rocky side of mountains where ditching would be costly.

It is generally desirable to have the least possible fall in a water channel, or, in other words, to bring the water to as high a point of the ground to be worked as circumstances will allow. As the friction of the sides and bottom of a channel retards the flow, and necessitates a higher grade than would be necessary if there were none, it becomes of importance to decrease this element as much as possible. On this score wood and iron water-ways present decided advantages, owing to their comparative smoothness. In any case, however, the quantity of friction developed depends upon the wet perimeter of the channel used. The following law will therefore be found of service:

The least wet perimeter that will hold or carry a given volume is attained when the width of bottom is from $1\frac{3}{4}$ *to* $2\frac{1}{4}$ *times the depth of the sides.*

For example, a channel having a cross-section of 510 square inches will develop the least amount of friction when its dimensions are 15 by 34, or 17 by 30, or somewhere between these measurements.

A knowledge of this fact will be found serviceable in constructing flumes. The least perimeter, of course, requires the least lumber, and many thousand or million feet may be saved in a long flume by building in the correct proportion.

When the head of the flume is above timber-line, or in high altitudes where ice forms early in the fall, it is an advantage in many respects to have it so narrow in width that an ice-crust can easily form itself from bank to bank. If this is secured water will often flow a month or six weeks longer than otherwise. The reasons are obvious.

In making the preliminary survey of a placer-claim a sound authority advises as follows: First, lay off the dump; second, decide how much grade and fall to give the sluices; and, third, find the least fall necessary between source of water and water-box. The remaining distance will then be the greatest head attainable. The suggestion is pertinent, because it brings to mind the fact that a good dump and an abundant grade for sluices are fully as necessary for economical gravel-washing as a heavy head of water.

When the linear distance between the sources of supply and the water-box is determined, and the least fall that will carry the water ascertained (after considering the questions of friction, evaporation, and leakage), the grade per foot is found by dividing the total fall in feet by the total length in feet. Multiplying the result (which will generally be a decimal) by 100 or 1,000 will give the grade per 100 or 1,000 feet. Having now the grade per foot and the quantity of water to be carried (as determined by gauging the stream or streams tapped by the ditch or flume—the proper deductions having been made for leakage and evaporation), the area of cross-section of the water-way may be determined by the rule for the determination of the least wet perimeter, which has just been given.

Solar evaporation is very active at high altitudes. The ordinary figures representing loss through evaporation ($\frac{1}{10}$ to $\frac{3}{10}$ of an inch of surface per day) are much too small for ditches above an altitude of 6,000 feet. Evaporation also proceeds much more rapidly in shallow water than in deep, and when the velocity is high. Experiments made during 1877 on the 12-mile wooden flume of the Fuller Company, on the Swan River, Colorado, indicated a loss of from 10 to 18 per cent. daily. This flume is, however, an extreme case, being about 10,000 feet above sea-level. Probably an inch of surface would be an average loss.

Leakage occurs most extensively in gravelly soils. From 1 to 5 inches of surface per day are extreme losses, with an average, perhaps, of about 2 inches, which it will be always safe to count on, except in old ditches. A high velocity decreases loss through the soil.

Water-channels of uniform section should always have a uniform grade. Otherwise there will be an accumulation in some points and a thinning-out in others, with deposits of sand and silt in the latter case, and in each case with increased danger of breakage. It will also be found highly advantageous in earth ditches to have a complete system of waste-weirs to carry off surplus waters occasioned by floods and to lessen the damage of breaks. These should be put in just below wherever a new stream falls into the ditch, and just above those places where, by reason of a shelly or crumbly soil, the ditch is weak. A break is bad, not only because it must be repaired, but because while being mended all mining operations must cease.

In the spring, difficulty is often encountered in starting the water through the heavy accumulation of snow in the ditch, which, if it be long, can be flushed out only with great trouble. This operation will be materially hastened if the ditch is cleaned out in short sections of a mile or two each. Cut a hole in the bank a mile from the head, and when the water has soaked that far it will carry off the unmelted snow through this break with great rapidity. As soon as clear the hole is mended and another made a mile further on. Time will be saved by thus taking the ditch in sections.

Cost.—When the plough and scraper can be used ditching can be done at 20 cents per cubic yard. If the soil is so rocky as to call for the pick and shovel, it will cost from 30 to 40 cents. A safe figure to be taken for the construction of a ditch 3 feet wide at bottom, 4½ feet wide at top, and 18 inches deep is $1.25 per rod. It can be done for less. The larger the ditch the less costly it will be in proportion.

CHAPTER VI.

FLOW OF WATER IN FLUMES AND DITCHES.

THE following rules for the solution of problems concerning the flow of water in ditches and flumes are commended to the miner, only with the proviso that the directions laid down in Chapter V be strictly complied with. Before doing any figuring let every element of the problem, as grade, area of section, velocity, wet perimeter, discharge, and length, be reduced from the ordinary measurements usually given to those laid down in the "Directions." If this is done the results may be depended upon; otherwise they will be of no value.

It is to be remembered, however, that these rules do not take into account leakage and evaporation—two elements of loss which have been spoken of already. It will be impracticable in this manual to enter into the details of these elements of loss, as the subjects are too intricate; and, in addition, it would be unnecessary, inasmuch as the records of experience are more satisfactory and nearer the truth.

1. *What grade per foot* must be given to a flume or ditch of uniform section to enable it to discharge a given quantity of water in a given time?

RULE 1. Divide the number of cubic feet of discharge required by the area in square feet of the section of the flume. This result is the velocity necessary, expressed in feet per second.

Multiply this result by itself.

Multiply this product by the wet perimeter, expressed in feet, and multiply this product by the decimal .0001114.

Divide this product by the area of the section of flume, expressed in square feet. Call the result A.

Multiply the velocity in feet per second by the wet perimeter, expressed in feet, and multiply this product by the decimal .00002426.

Divide this product by the area of the section of the flume, expressed in square feet. Call the quotient B.

Add together A and B.

The result is the grade per foot (expressed in decimals of a foot) which must be given to the flume to make it carry the required water.

EXAMPLE.—What grade per foot of length must be given to a 20-inch flume whose sides are 12 inches high, in order that it may deliver 28 cubic feet of water per second steadily?

Wet perimeter, say 42 inches	= 3.5	feet.
Area of section, 240 sq. inches	= 1.66 sq.	"
Discharge,	=28.00 cubic	"

Then, dividing the discharge (28) by the area of section (1.66), we have 16.86 as the velocity in feet per second.

Following the rule, the velocity (16.86) multiplied by itself equals 284.25; multiplying this by wet perimeter (3.5) produces 994.87; multiplying again by the decimal .0001114 produces .1108; dividing this by area of section (1.66) gives .0667. Call this A. Multiplying the velocity (16.86) by wet perimeter (3.5), and the product by .00002426, produces .0014315, which divided by the area of the section of the flume (1.66) =.00086. Call this B. Adding A (.0667) to B (.00086), we have as a final result .06756, which is the grade per foot (expressed in decimals of a foot). If we multiply this result (.06756) by 1,000, we have the grade per thousand feet, which will be 67.5 feet (near enough).

To reduce this result to the ordinary terms—viz., inches per box of 12 feet—divide first 1,000 by 12, which produces 83.33 (which of course represents the number of 12-foot boxes in a 1,000-foot flume). Then, the grade being 67.5 feet in 83.33 boxes, for each box it would be the result of dividing 67.5 by 83.33, which is .79, or the grade would be .79 of a foot per box of 12 feet. Finally, there being 12 inches in a foot, we multiply .79 by 12 and obtain 9.48 inches per box, or nearly 9½ inches.

2. *What is the average velocity and discharge* secured in a flume or ditch of uniform cross-section and grade?

Rule 2.—Multiply area of cross-section in square feet by the grade in feet per foot, and the product by 9,000.

Divide this result by the wet perimeter in feet.

Extract the square root of the quotient. (See table at end of book.)

From the result subtract .1089.

The result equals the mean velocity of the water (expressed in feet per second).

Multiply the area of cross-section by the mean velocity.

The result equals the discharge (expressed in cubic feet per second).

EXAMPLE.—What is the discharge attained in a 30-inch flume with 12-inch sides, having a uniform grade of $\frac{1}{100}$ (.01) of a foot for every foot of length ?

Multiplying the area of cross-section (2.5 square feet) by the grade (.01) produces .025 ; multiplying this by 9,000 yields 225 ; dividing this by the wet perimeter (4.5) gives 50, whose square root is 7.0711; subtracting from this the decimal .1089, we have 6.9622, which is the mean velocity (expressed in feet per second).

This calculation is in reality accurate only for a flume. In a ditch, where friction is greater, it will be necessary to subtract about 10 per cent. (or .6962) from the result found, leaving 6.266

as the correct figure. Then continuing, multiply the mean velocity (6.9622) by the area of cross-section (2.5); we have 17.40, which is the discharge (expressed in cubic feet per second).

3. *What must be the section* of a ditch or flume of uniform grade which will discharge a given quantity of water in a given time?

There is no simple rule that will solve this problem, and an answer must be sought experimentally upon the following plan:

RULE 3. Assume a convenient section, and, the grade being known, calculate its discharge according to Rule 2, page 61. If this discharge is greater or less than the required one try again with a smaller or larger section until the correct one is found.

Cost.—With lumber at $12 to $15 per thousand, delivered at the head of the flume, so that it can be floated down, a flume 2½ feet wide and 2½ feet high can be finished at a cost of $3.85 per box (of 12 feet in length); and one 6 feet wide and 3½ feet high at $8.50 per box.

CHAPTER VII.

IRON PIPING.

The problems which arise in operating iron pipes are the following:

1. *What is the velocity attained* in a cylindrical iron pipe, laid straight or with easy curves, its head, length, and diameter being known?

RULE 1. Multiply the diameter in feet by the head in feet. Call this product A.

Add together the total length of pipe in feet, and 54 times its diameter in feet. Call this sum B.

Divide A by B.

Extract the square root of the quotient (see table at end of book); multiply this root by 48. The product will be the velocity in feet per second.

EXAMPLE.—What velocity will be attained in a pipe 12,600 feet long, 6 inches (.5 of a foot) in diameter, and having a head of 200 feet?

Multiply diameter (.5) by head (200) =100; call this product A. Add to the total length (12,600 ft.) 54 times its diameter: .5 multiplied by 54 equals 27=12,627. Call this sum B. Divide A (100) by B (12,627) =.0079. Extract the square root of this result, which=.0889. Multiply this root by 48=4.26, which is the velocity per second, in feet.

2. *How many cubic feet of water* per second will be discharged from a cylindrical iron pipe, straight or with easy curves, its head, length, and diameter being known ?

Rule 2. Ascertain the velocity by preceding rule. Then multiply the velocity thus attained by the area in square feet of a section of the pipe. The result will be the discharge per second, in cubic feet.

3. *What head of water is necessary* for a cylindrical iron pipe, straight or with easy curves, its diameter and length being known, to produce a given discharge per second ?

Rule 3. Multiply the required discharge (expressed in cubic feet) by itself. Call this A.

To the total length of pipe add 54 times its diameter. Call this B.

Multiply A by B. Call the product C.

Divide the diameter (expressed in feet) by .235.

Multiply this product by itself continuously four times.

Divide C by this product.

The quotient will be the head in feet.

EXAMPLE.—What head is necessary to produce a discharge of 12 cubic feet per second at the end of a pipe 8 inches (.666 feet) in diameter and 350 feet long, the pipe being straight or with easy curves ?

Multiply the discharge (12) by itself = 144; call this A. To the total length (350) add 54 times its diameter (36) = 386; call this B. Multiply A (144) by B (386) = 55,584 (C). Divide the diameter (.666) by .235 = 2.834. Multiply this product (2.834) by itself continuously four times = 182.801. Divide C (55,584) by this product (182.801) = 3.04 feet nearly, which is the required head.

4. *What diameter of pipe is necessary* to carry

a given quantity of water per second, its length and total head being known ?

RULE 4. Multiply the head in feet by 5,280, and divide the product by the length in feet. Call this A.

Multiply the discharge in cubic feet per second by itself, and multiply this product by 5,280. Call this B.

Divide B by A.

Extract the fifth root of the result (see tables at close of book).

Multiply this by the decimal .235.

The product is the diameter (in feet).

EXAMPLE.—What must be the diameter of a pipe 6,000 ft. long, with a head of 400 feet, which will discharge 6 cubic feet of water per second ?

Multiply the head (400) by 5,280=2,112,000, and divide this product by the length (6,000) = 352 (A).

Multiply the discharge (6) by itself =36, and multiply this product by 5,280=190,080 (B).

Divide B (190,080) by A (352) =540.

Extract fifth root of this quotient (540) =3.52.

Multiply this root (3.52) by .235=.8272, which is the required diameter (expressed in decimals of a foot).

Curves.—Curves and bends in pipes always cause some loss of power. They also furnish a place for the accumulation of air and sediment, as well as weaken the tube. They are, however, unavoidable in practice, and the rules by which to calculate the additional amount of head necessary to counteract their influence, or the amount of power lost, are perhaps too complex for the aim of this work. An angular bend in a pipe should be avoided, if at all possible. In most placer districts there are workers of sheet-metal of sufficient ability to produce circular elbows. The latter should be made with a radius *never less than five times the length of their diameter.* To ascertain this curve measure the diameter of the pipe, and cut a string that will be just five times this length. Then if one end of the string be held fast the other will describe the correct curve. A still larger radius is better when possible. In fact, the gentler the curve the better.

Care should be taken to back up piping very solidly at each change of direction. The necessity of this precaution will be self-evident. Cases have occurred where whole sections of piping poorly backed have been torn to pieces as soon as the head was put on.

The cost of piping, finished and set up, may be approximated as follows :

Cost at manufactory..............	4½c.	per lb.
Freight, 1,500 miles	3½c.	"
Making into pipe..................	3½c.	"
Grading, laying, ballasting, and fastening.........................	½c.	"
	12c.	per lb.

The hydraulic grade-line is an imaginary straight line, extending from a point on the side of the water-box or reservoir, denominated the velocity-head, to the mouth of the nozzle. If the pipe be constructed exactly on this line, the water flowing through it, no matter what its velocity or volume, will exert no bursting pressure. In other words, the grade of the hydraulic grade-line is such that the velocity caused by the grade is exactly sufficient to carry down all that the pipe will hold, and there is no outward pressure exerted except that on the bottom of the pipe due to the water's weight. If, however, there be a change in the diameter of the pipe at any point this equilibrium ceases to exist. It is never possible in practice to adopt this line as a course, but generally close approximations can be made to it. As will be shown further on, it is highly advantageous to do this wherever possible.

To find the Hydraulic Grade-Line.—RULE 1. Calculate the velocity in pipe due to the total head. (See Rule 1, page 64.)

Look in Table 3, and find the head corresponding to this velocity.

Lay off this head on the side of the reservoir from the surface of the water. Its termination will mark the line of the velocity-head. From this point sight to the nozzle of the pipe; the line of sight is the hydraulic grade-line.

In constructing a line of piping three cases may arise by reason of the inequalities of the ground to be passed over:

1. The pipe may lie below the hydraulic grade-line.

2. The pipe may lie above the hydraulic grade-line.

3. The pipe may lie both above and below.

Case 1. *Pipe below Hydraulic Grade-Line.*—There is here a bursting pressure, varying in amount according to its distance below the line. To find this pressure at any point, ascertain the distance of that point vertically below the hydraulic grade-line. Call this measurement the bursting-head—as, for example, A, E, Fig. 1, which assume to be 6 feet. The pressure, then, on each square inch of pipe at that point is equal to the weight of a column of water whose base measures 1 square inch and whose height is 6 feet. Thus, 1 square inch multiplied by 6 feet (72 inches) = 72 cubic inches = .04166 cubic feet multiplied by 62.5 (wt. of cubic foot of water) = 2.6 lbs., which is the pressure per square inch. Consequently, if the pipe lies considerably below the hydraulic grade-line, it will need to be of thicker iron than the rest. This law applies in crossing deep hollows.

Case 2. *Pipe above the Hydraulic Line.*—There is now a decided loss of head, and consequently of power, in portions of the pipe, if it be of the same diameter throughout. Find now that point in the pipe which is highest above the hydraulic grade-line (H), and from that point draw two new grade-lines, one to the pressure-box (H V) and one to the nozzle (H N). Along the former calculate the bursting pressure as above, measuring the different heads from the new line (as F E). Along the latter there will be no bursting pressure, for the grade of the nozzle end of the pipe will be so much greater than that of the reservoir end that it will carry off the water very much faster, and will, in fact, act like a gutter, and be partially empty. The remedy for this is to put in pipes having a decreased diameter. To calculate the requisite diameter, assume that the pipe ended at that point where it is highest above the hydraulic grade-line (H). Calculate the discharge in cubic feet at that point according to Rule 2, page 65. This will give the amount of water in cubic feet per second which the nozzle section (H N) must carry. The head will be the vertical distance from H to N. Then, by Rule 4, under the head of Iron Piping, the requisite diameter may be calculated.

CASE 3. *Pipe both above and below the Hydraulic Grade-Line.*—The problem now becomes more complicated.

Divide the pipe into sections for every passage it makes above the hydraulic grade-line, and make the divisions at the several points (A, H, and I) where the pipe attains its highest position. Calculate (Rule 2, page 61) the discharge at the end of each section. The first section will have a head equal to the vertical distance between its discharge and the velocity-head in the pressure-box. All succeeding heads will be measured from the level of the discharge just below them to their own discharge. For example, the head at A is the vertical distance between A and the water-level in the reservoir, less the velocity-head. At H the head is the vertical distance between H and A. At I it is the distance between I and H, etc. These measurements will furnish a series of heads and grades from which the diameters of pipe necessary may be calculated according to Rule 4, p. 66.

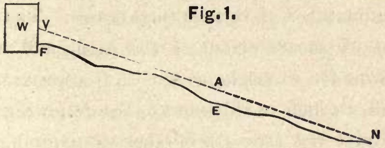
If it be desired to calculate bursting pressure in Case 3, measure the heads of different points from the new hydraulic grade-lines, and proceed as directed in Case 1.

In building and laying lines of iron piping, whether to conduct water from one reservoir to another or from the water-box to the pit, money will be saved by paying close attention to this subject. It will easily be seen that if the pipes are larger than is necessary, iron, which is generally costly in mining communities, will be unnecessarily used, while at the same time the pipes will become filled with air, and much of the force thereby lost. Again, if the pipes are too small, the danger from bursting is greatly augmented.

The pipe, after being laid, should be carefully anchored at many points, and, when possible, protected from the weather.

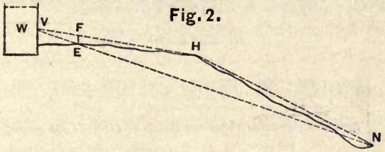
The three conditions arising under unequal and varying grades are shown by the following figures:

Fig. 1.—Pipe below Hydraulic Grade-Line.



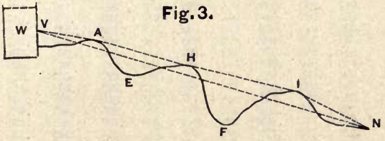
W.—Water-box. F. E. N.—Line of Pipe. V. A. N.—Hydraulic Grade-Line. A. E.—Bursting-head.

Fig. 2.—Pipe above Hydraulic Grade-Line.



W.—Water-box. E. H. N.—Piping. V. N.—Hydraulic Grade-Line. F. E.—Bursting-head. V. H. and H. N.—Supplementary Hydraulic Grade-Lines.

Fig. 3.—Pipe above and below Hydraulic Grade-Line.



W.—Water-box. A. E H. F. I. N.—Piping. V. N.—Hydraulic Grade-Line. V A, A H, H I, I N—Supplementary Hydraulic Grade-Lines.

Sheet iron, from which the piping is made, is manufactured of various thicknesses. The standard of measurement is the inch, and a size known, for example, as No. 16 is approximately $\frac{1}{16}$ of an inch in thickness. The following table will give the strength of sheet-iron piping, and will be found of service.

STRENGTH OF IRON PIPING.

This table gives the thickness in inches and decimals of an inch which iron piping must have to stand a given pressure.

Diameter of Pipe, in inches.	*Head of Water, in feet.*									
	100	150	200	250	300	400	500	600	800	1,000
	Resulting Pressure against Sides of Pipe, in lbs. per sq inch.									
	43.4	65.1	87	109	130	174	217	260	347	434
	Required Thickness of Pipe, in inches or decimals of an inch.									
2	.009	.013	.018	.022	.027	.036	.045	.055	.075	.095
3	.013	.020	026	.033	.040	.054	.068	.082	.112	.143
4	.017	.026	.035	.045	.053	.072	.090	.110	.149	.191
5	.022	.033	.044	.056	.067	.090	.113	.137	.186	.237
6	.026	.040	.053	.067	.080	.108	.136	.165	.224	.287
7	.030	.046	.062	.078	.093	.126	.159	.193	.261	.333
8	.034	.053	.071	.089	.107	.144	.181	.220	.298	.382
9	.039	.059	.079	.101	.120	.163	.205	.247	.335	.427
10	.044	.066	.089	.112	.134	.181	.227	.275	.373	.475
12	.053	.080	.106	.134	.161	.217	.273	.330	.448	.575
14	.061	.093	.124	.156	.187	.253	.318	.387	.523	.666
16	.069	.106	.142	.178	.214	.288	.363	.440	.596	.763
18	.078	.120	.159	.201	.242	.326	.409	.495	.670	.850
20	.088	.132	.177	.223	.267	.361	.454	.549	.746	.950
24	.105	.159	.213	.268	.321	.433	.545	.660	.895	1.150
30	.132	.198	.267	.336	.402	.543	.681	.825	1.120	1.420
36	.156	.238	.318	.402	.483	.651	.8 9	.990	1.340	1 710
42	.184	.279	.372	.469	.562	.759	.955	1.160	1.570	2.000
48	.210	.317	.425	.535	.641	.866	1.090	1.320	1.790	2.290

For example: What thickness of iron should be used to make a 20-inch pipe which must bear 200 feet head of water? The figure given in the table is .177 inch, which, by the following table, corresponds to between No. 5 and No. 6 iron. Or, the head being 100 feet and the pipe 10 inches in diameter, the thickness will be .044 inches, which corresponds nearly to No. 17. In selecting the iron it will always be safer to take the size one larger than that called for by the figures.

Table showing the thickness, in decimals of an inch, of the different sizes of sheet-iron from No. 4 up to No. 30:

No.	4	has a	thickness	of	.204	of	an inch.
"	5	"	"	"	.181	"	"
"	6	"	"	"	.162	"	"
"	7	"	"	"	.144	"	"
"	8	"	"	"	.128	"	"
"	9	"	"	"	.114	"	"
"	10	"	"	"	.101	"	"
"	11	"	"	"	.090	"	"
"	12	"	"	"	.080	"	"
"	13	"	"	"	.071	"	"
"	14	"	"	"	.064	"	"
"	15	"	"	"	.057	"	"
"	16	"	"	"	.050	"	"

No.	17	has a	thickness	of	.045	of an inch.
"	18	"	"	"	.040	" "
"	19	"	"	"	.035	" "
"	20	"	"	"	.031	" "
"	21	"	"	"	.028	" "
"	22	"	"	"	.025	" "
"	23	"	"	"	.022	" "
"	24	"	"	"	.020	" "
"	25	"	"	"	.017	" "
"	26	"	"	"	.015	" "
"	27	"	"	"	.014	" "
"	28	"	"	"	.012	" "
"	29	"	"	"	.011	" "
"	30	"	"	"	.010	" "

It must be remembered that these figures apply only in cases where the end of the pipe is closed and no discharge occurs, or where the discharge is on the same level as the inflow. Of course if the pipe is discharging at one end the pressure is relieved, and the pipe is called upon to sustain only that bursting pressure due to its depression below the hydraulic grade-line. As in practice the depression of the pipe leading from the water-box to the pit is rarely more than 5 to 20 feet below the hydraulic grade-line, the iron will be compelled to resist a pressure never over 10 lbs. to the square inch. This, ordinary stove-pipe iron would generally do.

CHAPTER VIII.

NOZZLES AND DISCHARGE.

THEORETICALLY, the quantity of water discharged from the nozzle of a pipe may be determined by the following rule:

RULE 1. Extract the square root of the head, and multiply this root by 8.03. The product will be the velocity in feet per second with which the water escapes from the mouth-piece.

Multiply the area of the mouth-piece (see page 41) by this velocity, and the result will be the discharge in cubic feet per second.

EXAMPLE.—What quantity of water will be discharged from a pipe, under a head of 100 feet, through a 3-inch nozzle?

The square-root of the head (100) is 10, which, multiplied by 8.03, gives 80.3 feet as the velocity per second. The diameter of nozzle being 3 inches (.25 of a foot), its area would be .25 multiplied by 3.14 multiplied by .0625= .04906 square feet, which, multiplied by the velocity 80.3, equals 3.93 cubic feet, which is the discharge per second.

The actual discharge is probably about 80 per cent. of the theoretical one in well-made nozzles, provided with inside flanges to prevent revolution of the stream, and in this case would be 3.14 cubic feet per second.

This, reduced to miners' measure (see page 18), would represent about 115 inches. The power of the stream thrown by a nozzle has been discussed under the head of Momentum (page 39), and nothing remains to be said on the subject, except that every precaution should be taken to prevent the stream from issuing in a ragged condition. Its effectiveness depends very largely upon its smooth and cylindrical form. If this is secured it will travel through the air for a much longer distance without disintegration than otherwise. The mouth-piece, therefore, should be very smooth, and the arrangements of the pressure or water box so perfect as to exclude *all* sand and gravel, and, if possible, all air. Fine specks of quartz passing through the mouth-piece will not only cut the metal, but will spoil the shape of the jet.

CHAPTER IX.

THE SLUICE.

UPON the construction and operation of these channels almost everything in placer-mining depends. It is a comparatively simple matter to disintegrate the most cohesive gravel-bank and deliver it at the head-box, but by no means so easy to so conduct the washing as to save even a respectable amount of gold. In former days miners were content with saving from 30 to 50 per cent., for the ground worked at those times was rich enough to pay handsomely even then. The miner of to-day, however, has to deal with a lower grade of material worth from 15 to 25 cents to the cubic yard, and must work closer to produce a profit. In California ground worth only 4 cents to the cubic yard is worked successfully. In Colorado and Montana there is no need as yet (and in fact there is none in California) to touch such poor gravel, for there are millions of acres still unopened which will produce 20 to 30 cents. This circumstance, however, affords no legitimate excuse for careless working. It will be found at the present day to be just as expensive to save 50 as 90 per cent. in mines where there is any pretence to careful work. And the sooner the business of gravel-washing is reduced to a science, the sooner it will attract the attention of investors and receive the benefit of their assistance.

Steadiness of flow in a sluice is of great importance. The quantity of water passing, and its velocity, must be uniform to secure the deposition of a maximum of gold. Again, it is no economy to crowd a flume with dirt beyond certain limits, which will be noted further on. If the gravel is caved in too large quantities it will be found economical to erect other sluices. It is to be remembered, also, that water always travels faster in the centre of the channel, and is also higher in level. Consequently the bulk of the gravel and boulders will travel down the middle of the flume.

Dimensions.—The maximum quantity of water which may be advantageously used in a single sluice of correct dimensions when the ground is ordinarily full of boulders, is set down by good practical authorities at 1,000 miners' inches. This corresponds to a discharge of 95,000 cubic feet per hour, which, with gravel and boulders, would represent about double that amount of moving substance in the sluice. When more than this is used the current will be so strong that men cannot work to any advantage in the head-box. Sluices intended to clear off top dirt must be short and large. In this case the top dirt is presumed to be nearly free of gold and of boulders.

The test of friction is perhaps the correct one on which to base calculations for the correct dimensions. The general behavior of this force is referred to on page 38, and on page 52 will be found the law of the least wet perimeter. In a sluice, the object being to move all the gravel from the head-box to the dump by means of the forces of water and gravity, it is important that the least amount of the former should be lost in overcoming extraneous resistance. We may increase the work of the water by giving it velocity through the instrumentality of heavy grade, but if the flume is of incorrect dimensions there is always a loss for which the miner receives no compensation, and which may be avoided.

To secure this point let the miner first decide upon the largest sized boulder which he will allow to go through his flume. If it be 2 feet in diameter, then it is clear that his flume must carry at least 2 feet in depth of water. We have then a figure for a side measurement. According to the law on page 52 the bottom should be from $1\frac{3}{4}$ to $2\frac{1}{4}$ times the height of the side, or, taking the side at 30 inches, the bottom should be $52\frac{1}{2}$ to $67\frac{1}{2}$ inches wide. If, however, the ground is free from large boulders, and it be merely necessary to ascertain the dimensions best adapted to carry the greatest economical quantity of water (1,000 inches), Rules 2 and 3, on pages 41 and 42, will furnish the correct area of section. 1,000 inches is equal to 27.1 cubic feet per second. Double this discharge to make room for the gravel. The flume must then discharge 54.2 cubic feet of material per second.

Having ascertained the area of section in square feet, we may resolve it into correct dimensions by the following rules:

RULE 1. *The width to be* $2\frac{1}{4}$ *times the sides.*

Multiply the area in square inches by 4, and divide the product by 9. Extract the square root of the quotient. The result will be the height of side in inches.

RULE 2. *The width to be* $1\frac{3}{4}$ *times the sides.*

Multiply the area in square inches by 4, and divide the product by 7. Extract the square root of the quotient. The result will be the height of side in inches.

Those who have a preference for shallow boxes will adopt Rule 1, and those who incline towards deep ones will take Rule 2.

Grade.—Grade creates velocity. Velocity increases the work of water, and consequently where the quantity of water is small it must be assisted by giving it a greater velocity. As practically the whole question of power with water in sluices depends upon the velocity with which it moves, the question of grade is of great importance. The miner, however, does not merely seek for power in his sluice. While there are boulders and gravel to wash away there is gold to be saved. Consequently, that velocity is the best which will wash away a maximum quantity of gravel and rock and a minimum of gold. Let the miner, therefore, study for a while the composition of his banks.

If the boulders are rounded and well worn they will roll down the sluice with ease under a small head, but if flat they will need more power. And the same is true if they be angular, though not to so great an extent.

Scale and leaf gold will float a long distance in a turbid and rapid stream.

Generally the physical quality of gold may be determined by an examination of the gravel. The miner should not trust to that caught in his riffles, for much may be washed away which he can never examine. If the gravel and boulders are angular and large the gold will have the same characteristics; but if the former are polished the gold is round or leafy, and much will be a fine dust.

The moving power of water in sluiceways may be approximately judged by the following table:

16	feet	per minute	begins to wear away fine clay.			
30	"	"	just lifts fine sand.			
39	"	"	lifts sand as coarse as linseed.			
45	"	"	moves find gravel.			
120	"	"	"	inch pebbles.		
200	"	"	"	pebbles as large as eggs.		
320	"	"	"	boulders	3 to 4	inches thick.
400	"	"	"	"	6 to 8	"
600	"	"	"	"	12 to 18	"

We have, then, the following rule for the establishment of grades in sluices when the velocity needed is decided upon:

RULE 3.—Multiply the velocity expressed in feet per second by itself, and the product by the wet perimeter in feet.

Divide this result by twice the area in square feet. The result is the total fall in feet per mile.

EXAMPLE.—What grade must be given to a sluice 12 inches broad and 6 inches deep, that it may carry a velocity of 320 feet per minute, or 5.3 feet per second?

Multiplying the velocity (5.3) by itself, and the product by the wet perimeter (24 inches =2 feet), we have 56.18. This, divided by the area (72 square inches =.5 of a foot), and doubled =56.18, which is the fall in feet per mile.

To reduce grades expressed in feet per mile to inches per box of 12 feet, multiply by the decimal .027. Thus, a grade of 56.18 feet per mile equals a grade of 1.5, or 1½, inches per box. To reduce to inches per rod (16 feet), multiply by the decimal .036.

Prof. Silliman's calculations on California cement gravel, after being disintegrated by blasting, indicate that 17½ cubic yards of water, equal to nearly 15 tons, are necessary to wash 1 cubic yard of gravel. For ordinary gravel, after being caved, probably 8 to 12 tons would suffice.

When the course of the sluice is curved the outer edge must be raised, to prevent unequal wear and an accumulation of material. This is much more imperative in the sluice than in the flume.

Riffles.—It is not possible within the limits of this work to discuss the subject of riffles thoroughly. Nor is it yet decided which of the systems (wood, boulder, or railroad iron) presents the most advantages in the majority of cases. The first is the most extensively used, and will probably always hold its place. Some experiments made in California with railroad iron demonstrate that that style of riffle was strongly to be recommended for very rocky ground at least. The great efficacy of boulder riffles is well known, and is thoroughly illustrated in the ground-sluice.

As already stated, the bulk of gravel and boulders travels down the centre of a sluice, where there is at once the most water and the greatest velocity. Consequently, it will be found advantageous to have the riffles higher in the centre than in the sides. This will cause a distribution of deposit over the entire width of box, and will also prevent the formation of a channel of depression in the bottom of the sluice.

The cost of wooden block-riffles, cut from peeled round lumber and squared, will average about $50 per 1,000. A thousand of these blocks averaging about 8 inches diameter will cover 80 square yards of bottom. Laying and fastening, and all other expenses concurrent with arranging the bottom of the sluice for work, will bring the total cost to 75 cents per square yard. It will be impossible to quote the expense of railroad-iron riffles. Old irons are, of course, just as good as new. The cost will be mainly that of transportation.

TABLE I.

TABLE OF SQUARE ROOTS.

The following table of the square roots of numbers from 1 to 200, inclusive, will probably answer all requirements of problems proposed in the preceding examples. If the figure whose root is to be extracted is not found in the table, take the root of the figure nearest to it. For example, if it is necessary to extract the root of 132.6, take the root of 133.

No.	Root.	No.	Root.	No.	Root.	No.	Root.	No.	Root.
1	1.	41	6.4031	81	9.	121	11.	161	12.6886
2	1.4142	42	6.4807	82	9.0554	122	11.0454	162	12.7279
3	1.7321	43	6.5574	83	9.1104	123	11.0905	163	12.7671
4	2.	44	6.6332	84	9.1652	124	11.1355	164	12.8062
5	2.2361	45	6.7082	85	9.2195	125	11.1803	165	12.8452
6	2.4495	46	6.7823	86	9.2736	126	11.2250	166	12.8841
7	2.6458	47	6.8557	87	9.3274	127	11.2694	167	12.9228
8	2.8284	48	6.9282	88	9.3808	128	11.3137	168	12.9615
9	3.	49	7.	89	9.4340	129	11.3578	169	13.
10	3.1623	50	7 0711	90	9.4868	130	11.4018	170	13.0384
11	3.3166	51	7.1414	91	9.5394	131	11 4455	171	13.0767
12	3 4641	52	7.2111	92	9.5917	132	11.4891	172	13.1149
13	3.6056	53	7.2801	93	9.6437	133	11.5326	173	13.1529
14	3.7417	54	7.3485	94	9.6954	134	11.5758	174	13.1909
15	3.8730	55	7.4162	95	9.7468	135	11.6190	175	13.2288
16	4.	56	7.4833	96	9.7980	136	11.6619	176	13.2665
17	4.1231	57	7.5498	97	9.8489	137	11.7047	177	13.3041
18	4.2426	58	7.6158	98	9.8995	138	11.7473	178	13.3417
19	4.3589	59	7.6811	99	9 9499	139	11.7898	179	13 3791
20	4.4721	60	7.7460	100	10.	140	11.8322	180	13.4164
21	4.5826	61	7.8102	101	10.0499	141	11.8743	181	13.4536
22	4 6904	62	7.8740	102	10.0995	142	11.9164	182	13.4907
23	4.7958	63	7.9373	103	10.1489	143	11.9583	183	13.5277
24	4.8990	64	8.	104	10.1980	144	12.	184	13.5647
25	5.	65	8.0623	105	10.2470	145	12.0416	185	13.6015
26	5 0990	66	8.1240	106	10.2956	146	12.0830	186	13.6382
27	5.1862	67	8.1854	107	10.3441	147	12.1244	187	13.6748
28	5.2915	68	8.2462	108	10.3923	148	12.1655	188	13.7113
29	5.3852	69	8.3066	109	10 4403	149	12.2066	189	13.7477
30	5.4772	70	8.3666	110	10.4881	150	12.2474	190	13.7840
31	5.5678	71	8.4261	111	10.5357	151	12.2882	191	13.8203
32	5.6569	72	8.4853	112	10.5830	152	12.3288	192	13.8564
33	5.7446	73	8.5440	113	10.6301	153	12.3693	193	13.8924
34	5.8310	74	8.6023	114	10.6771	154	12 4097	194	13.9284
35	5.9161	75	8.6603	115	10.7238	155	12.4499	195	13.9642
36	6.	76	8.7178	116	10.7703	156	12.4900	196	14.
37	6.0828	77	8.7750	117	10.8167	157	12.5300	197	14.0357
38	6.1644	78	8.8318	118	10.8628	158	12.5698	198	14.0712
39	6.2450	79	8 8882	119	10.9087	159	12.6095	199	14.1067
40	6 3246	80	8.9443	120	10.9545	160	12.6491	200	14.1421

TABLE II.

FIFTH ROOTS.

The following table of numbers and roots will cover all problems that come to the miner. The numbers are printed in heavy type and the roots in light. If the exact number is not found, take the roots of the number nearest to it :

No.	*Root.*	*No.*	*Root.*	*No.*	*Root.*
7.59	1.5	**5032.84**	5.5	**59049.**	9.
32.	2.	**7776.**	6.	**77378.**	9.5
97.65	2.5	**11603.**	6.5	**100000.**	10.
243.	3.	**16807.**	7.	**136638.**	10.5
525.21	3.5	**23730.**	7.5	**161051.**	11.
1024.	4.	**32768.**	8.	**201035.**	11.5
1845.28	4.5	**44370.**	8.5	**248832.**	12.
3125.	5.				

TABLE III.

VELOCITIES AND DISCHARGES.

Head in feet per 100 feet.	*Head in ft. per mile.*	*Velocity in feet per second.*	*Discharge in cu. ft. per second.*	*Discharge in cu. ft. per 24 hours.*
.0019	.1	.208	.1633	14,114
.0038	.2	.293	.2301	19,880
.0057	.3	.359	.2819	24,360
.0076	.4	.415	.3267	28,229
.0 95	.5	.464	.3638	31,435
.0114	.6	.508	.3989	34,464
.0132	.7	.549	.4311	37,427
.0151	.8	.585	.4602	39,760
.0170	.9	.623	.4901	42,343
.0189	1.1	.656	.5144	44,431
.0237	1.25	.735	.5753	49,701
.0284	1.50	.805	.6322	54,604
.0331	1.75	.871	.6832	59,011
.0379	2.	.928	.7276	62,870
.0426	2.25	984	.7696	66,484
.0473	2.50	1.040	.8168	70,572
.0521	2.75	1.080	.8482	73,284
.0568	3.00	1.130	.8914	76,982
:0758	4.	1.310	1.028	88,862
.0947	5.	1.47	1.150	99,403
.1136	6.	1.61	1.264	109,209
.1325	7.	1.74	1.366	118,022
.1514	8.	1.86	1.455	125,740
.1703	9.	1.96	1.539	132,969
.1894	10.	2.08	1.633	141,145
.2273	12.	2.27	1.782	153,964
.2552	14.	2.45	1.924	166,233
.3030	16.	2.62	2.057	177,724
.3409	18.	2.78	2.183	188,611
.3788	20.	2.93	2.301	198,806
.4735	25.	3.28	2.572	222,156
.5682	30.	3.59	2.819	243,604
.6629	35.	3.88	3.047	263,260
.7576	40.	4.15	3.267	282,288
.8523	45.	4 40	3.451	298,209
.9470	50.	4.64	3.638	314,352

TABLE III.—*Continued.*

VELOCITIES AND DISCHARGES.

Head in feet per 100 feet.	*Head in ft. per mile.*	*Velocity in feet per second.*	*Discharge in cu. ft. per second.*	*Discharge in cu. ft. per 24 hours.*
1.1360	60.	5.08	3.989	344,649
1.3260	70.	5.49	4.311	372,470
1.5150	80.	5.85	4.602	397,613
1.7040	90.	6.23	4.900	423,435
1.8940	100.	6.56	5.144	444,312
2.0830	110.	6.87	5.395	466,128
2.2720	120.	7.18	5.639	487,209
2.4620	130.	7.47	5.866	506,822
2.8410	150.	8.05	6.322	546,048
3.0300	160.	8.30	6.534	564,576
3.2190	170.	8.55	6.715	580,176
3.4080	180.	8.80	6.903	596,418
3.5960	190.	9.04	7.100	613,440
3.7880	200.	9.28	7.276	628,704
4.2610	225.	9.84	7.696	664,848
4.7350	250.	10.40	8 168	705,728
5.2080	275.	10.8	8.482	732,844
5.6820	300.	11.3	8.914	769,824
6.6290	350.	12.3	9.621	831,168
7.5760	400.	13.1	10.280	888,624
8.5320	450.	13.9	10.910	943,056
9.4700	500.	14.7	11.50	994,032
10.4100	550.	15.4	12.09	1,044,576
11.3600	600.	16.1	12.64	1,092,096
12.3000	650.	16.7	13.11	1,132,704
13.2500	700.	17.4	13.66	1,180,224
14.2000	750.	18.	14.13	1,220,832
15.1500	800.	18.6	14.55	1,257,408
16.0900	850.	19.1	15.00	1,296,000
17.0400	900.	19.6	15.39	1,329,696
17.9900	950.	20.3	15.94	1,377,216
18.9400	1000.	20.8	16.33	1,411,456
22.7300	1200.	22.7	17.82	1,539,648
26.5200	1400.	24.5	19.24	1,662,336
30.3000	1600.	26.2	20.57	1,777,248
37.8700	2000.	29.3	23.01	1,988,064

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	Yield per cu. yd.	Cu. yds. moved per inch water.	Cost of water.	Cost of material.
Light Claim	$0.066	1.82	$0.1062	$0.0318
Chesman	.16	1.37	.0082	.0497
Sicard	.13	2.89	0039	036
Johnson	.04	1.76	.0063	.0286
La Grange		1.5	0.06	
French Hill.	.133	1.08	.0104	.0526
Bloomfield	.0399	4.8	.0286	
"	.066	4.17	.0325	
"	.1268	3.86	.0619	