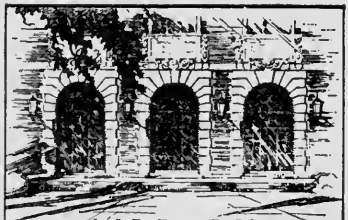

A Cost Analysis of FERTILIZER BULK-BLENDING PLANTS In Illinois

By B. J. Bond
Earl R. Swanson

BULLETIN 632

UNIVERSITY OF ILLINOIS
AGRICULTURAL EXPERIMENT STATION in cooperation with
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CONTENTS

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Acknowledgment is also due the personnel of Illinois Farm Supply Company for the valuable insights they provided, based on their considerable experience in bulk blending. Appreciation is expressed, too, to the bulk-blending plant operators whose plants are described in this report. The cooperation of these operators was excellent.

Urbana, Illinois June, 1958

Publications in the Bulletin series report the results of investigations made or sponsored by the Experiment Station

A Cost Analysis of Fertilizer Bulk-Blending Plants in Illinois

By B. J. Bond and Earl R. Swanson[1]

Bulk blending of fertilizers is the physical mixing of straight fertilizer materials. The blended product is usually not bagged and stored; rather it is spread on fields immediately after mixing. Hence, bulk-blending plants serve a relatively small market area.

DEVELOPMENT AND IMPORTANCE OF BULK BLENDING IN ILLINOIS

Development. The practice of bulk blending has become rather common in Illinois. Early attempts at bulk blending originated from the practice of fall plowdown of rock phosphate. Since most of the rock phosphate was spread by trucks with limestone-spreader attachments, it was a simple process to dump a few hundred pounds of potash on top of the rock phosphate and thereby spread a rock phosphate-potash "mixture" on the soil. Furthermore, it was found that ammonium sulfate could be blended with potash and rock phosphate without causing an immediate chemical reaction. Later refinements, such as granulation of the materials, increased the quality of the blends.

The first bulk-blending plants in Illinois were in operation in 1947 in Woodford county. The growth in the number of plants from 1947 to 1957 was as follows:

Year	*Cooperatives*	*Private firms*	*Total*
1947	..	4	4
1948	..	4	4
1949	1	4	5
1950	1	5	6
1951	1	5	6
1952	3	7	10
1953	5	9	14
1954	10	23	33
1955	31	28	59
1956	42	36	78
1957	48	44	92

[1] B. J. Bond, Assistant in Farm Management; and Earl R. Swanson, Professor of Agricultural Economics.

During the early period of development, plants were established primarily in the northern counties of the state. The large expansion from 1954 to 1957 occurred in the cash-grain area of central Illinois.

Sales. Operators of bulk-blending plants sell both blended and unblended materials. In 1956, 75 of the 78 bulk-blending plants sold 91,740 tons of fertilizer materials (excluding rock phosphate). This accounted for 27 percent of the total fertilizer materials (excluding rock phosphate) sold in Illinois that year. Of the 91,740 tons sold by the bulk-blenders, approximately 62,760 tons, or 68 percent, were blended. Thus about 18 percent of all fertilizer materials (excluding rock phosphate) sold in 1956 was blended.

Rock phosphate sales by bulk blenders totaled 125,785 tons in 1956. Most of this material was distributed by cooperative plants. Some plants use rock phosphate in their blends, but most of the rock phosphate is spread as unblended fertilizer.

Table 1. — A Comparison of Costs to Farmers of Blended and Cured Fertilizer Containing Equivalent Plant Food, September 15, 1957[a]

Analysis	Bulk-cured fertilizer		Bulk-blended fertilizer		Differential in price
	Price[b]	Pounds	Price	Pounds	
3–12–12	$50.00	2,000	$41.80	1,219	$ 8.20
4–16–16	65.00	2,000	54.80	1,625	10.20
5–20–20	78.00	2,000	67.80	2,032	10.20
10–10–10	66.00	2,000	53.95	1,722	12.05

[a] Based on average prices paid by Illinois farmers for fertilizer materials. *Agricultural Prices*, September 15, 1957, USDA.
[b] For bag price add $5.00 per ton to cover the cost of bagging. If the fertilizer is hauled and spread, the hauling and spreading charges are about the same for cured and blended fertilizers.

Retail price. Bulk-blended fertilizers generally cost less at the retail level than cured[1] fertilizers, containing equivalent plant food, produced by conventional fertilizer manufacturers (Table 1). The difference in cost between blended and cured fertilizer depends on the analysis, but in general a farmer can save $8 to $12 an equivalent ton[2] by buying a blend.

[1] The term *cured* describes fertilizer in which a chemical reaction occurs during the manufacturing process.
[2] The term *equivalent ton* describes a mixture which contains fertilizer materials equal to that found in 2000 pounds (a short ton) of cured fertilizer. The weights vary because of the addition to the fertilizer of non-nutritive ingredients. In this bulletin, the term *ton* is used in the sense of *equivalent ton.*

PURPOSE OF BULLETIN

The purpose of this bulletin is to show how costs and revenues of bulk-blending plants are affected by the methods of operation and the equipment used. The bulletin has two main parts. The first part describes the three types of bulk-blending plants and the facilities used by each. The second describes the operations of eight Illinois bulk-blending plants, including an estimate of the costs and revenues of each plant.

Prospective plant operators should find the analysis of aid in selecting their facilities and equipment. Managers of plants already in operation may find the information of value in suggesting improvements in their present operations.

METHOD OF ANALYSIS

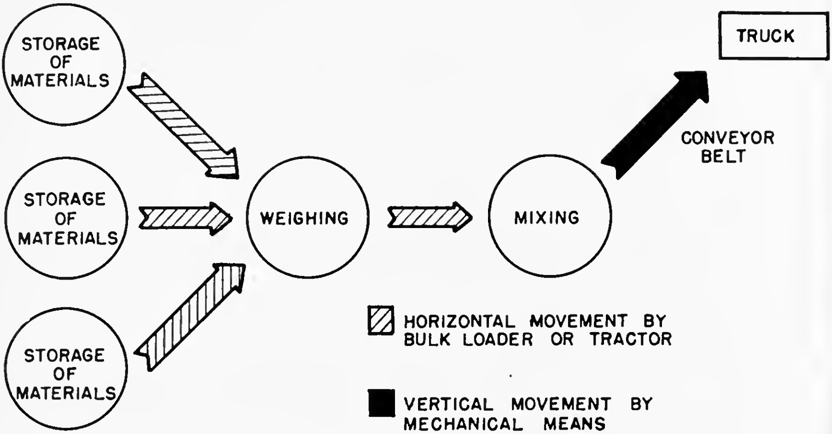
During the spring of 1957, visits were made to all of the private firms that were registered as fertilizer bulk blenders with the Division of Foods, Dairies and Standards of the Illinois Department of Agriculture. Visits were also made to several of the cooperative plants. On the basis of these initial visits, eight plants were selected for more intensive study. An attempt was made to select plants with wide differences in plant layout, equipment, and capacity.

The eight selected plants were revisited several times, and a complete description of their equipment and plant layout was obtained. Time studies were also made of their operations. Based on these descriptions and on current cost information, investments necessary to establish various types of plants were estimated. Outputs necessary to break even, based on current market prices for raw materials and blended products, were also estimated for each plant in the study. These projections should be useful in selecting a plant to fit a given expected market demand.

TYPES OF PLANTS

In general, bulk-blending plants can be divided into three categories according to the primary direction in which materials flow during the blending cycle: horizontal flow, vertical flow, and combination horizontal-vertical flow.

Horizontal-flow plants. In the horizontal-flow type of plant, the blending equipment is fixed to the plant floor, and materials flow from one process to another by horizontal movements (Fig. 1). A minimum



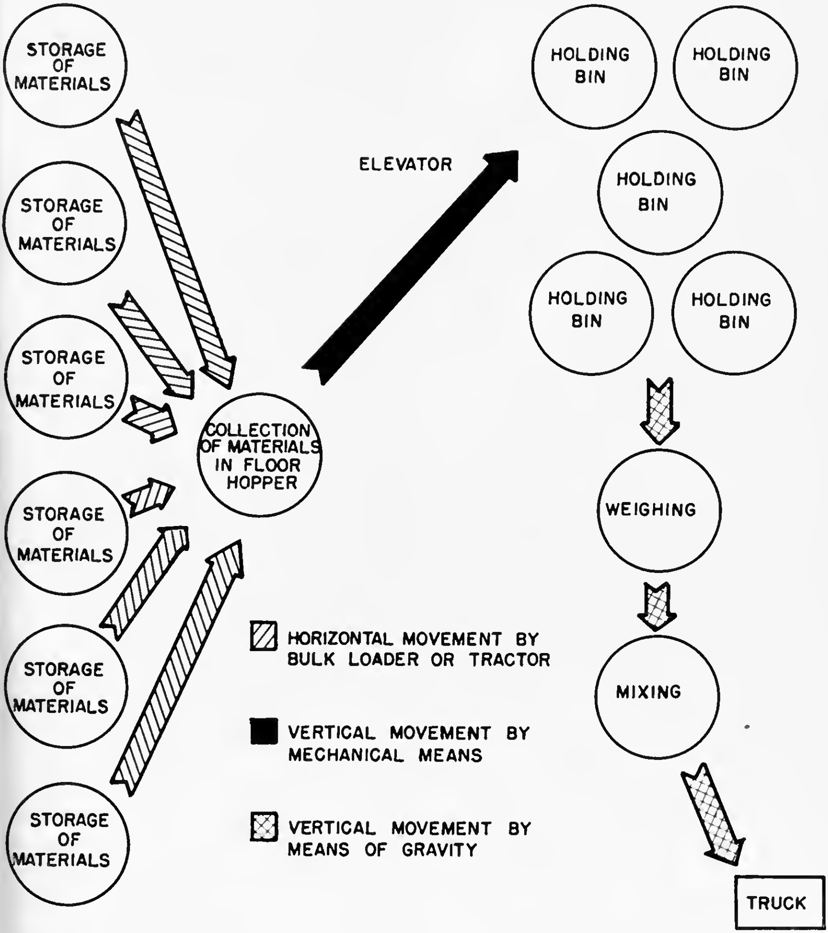
Horizontal flow of materials. (Fig. 1)

of equipment and storage capacity characterizes this type of plant; consequently the shelter requirement is low. A rectangular-type structure is used, with space divided between equipment and raw material storage (Figs. 4 and 7). The various operations cannot be performed simultaneously. Hence, adding labor to that of the plant operator will not result in a significant increase in daily output.

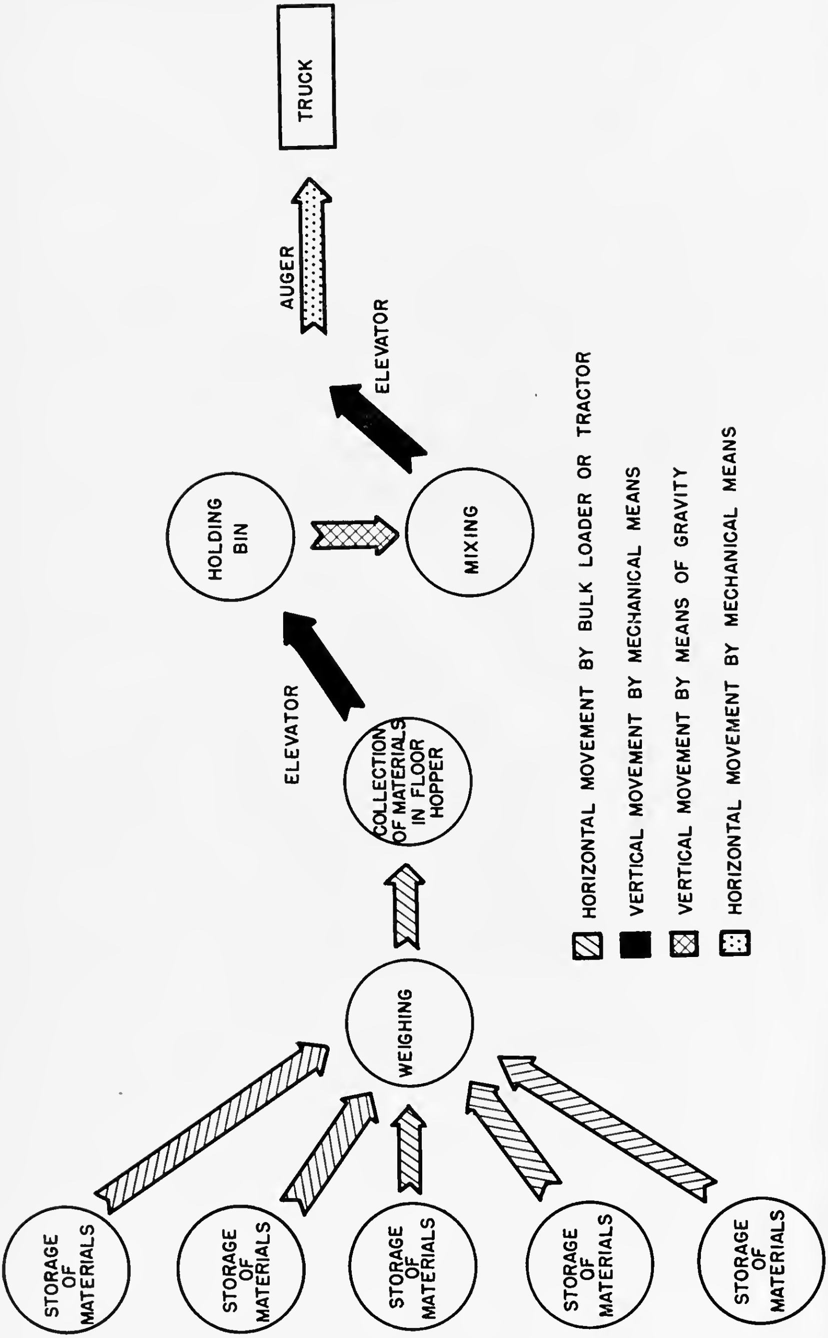
The equipment ordinarily consists of a bulk loader, platform scales, batch mixer, and inclined conveyor. The bulk loader is used to move raw materials from the storage bins to the mixer. Between the storage bins and mixer the bulk loader stops on the scales, and the operator records the weight of the materials. After the required materials are dumped into the mixer and mixed, the blended product is carried to the truck by an inclined conveyor belt.

Vertical-flow plants. In the vertical-flow type of plant, the blending equipment is in a tower arrangement in order that materials may utilize gravity in flowing from one process to another (Fig. 2). Equipment and storage capacities are large in this type of plant, necessitating a large shelter. The floor space allocated to blending equipment is reduced. To shelter the blending equipment a structural steel tower covered with either wood or metal siding is built above the roof of the main part of the building (Figs. 6 and 7). Processes may be performed simultaneously; thus labor in addition to that of the plant operator will increase daily output.

The equipment usually consists of a bulk loader, floor hopper, elevator, hammer mill, holding bins, vibrating screen, batcher, and mixer. The bulk loader is used to move materials from storage to the floor hopper. The materials are lifted from the floor hopper by an elevator and dumped into overhead holding bins. A vibrating screen is situated over the holding bins, so that materials not passing through the screen can be circulated through a hammer mill which removes lumps. The operator stands in the tower below the holding bins and controls the weighing of materials as they fall from the holding bins into the batcher. From the batcher, materials fall into the mixer, are blended, and are then forced by action of the mixer to pass into the truck.

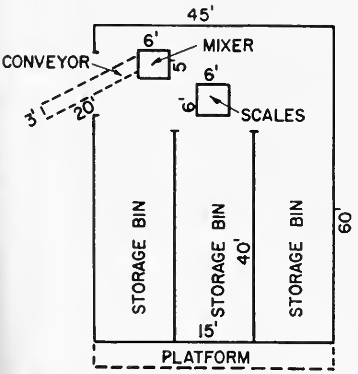


Vertical flow of materials. (Fig. 2)

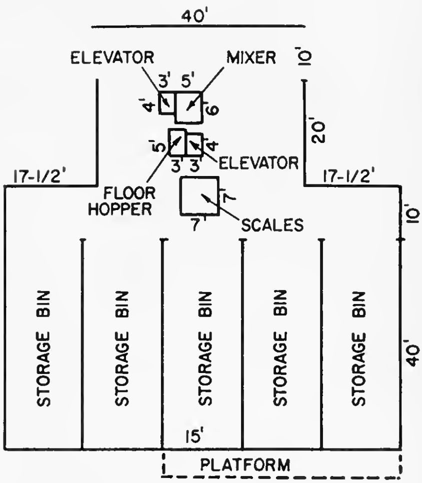


Combination horizontal-vertical flow of materials. (Fig. 3)

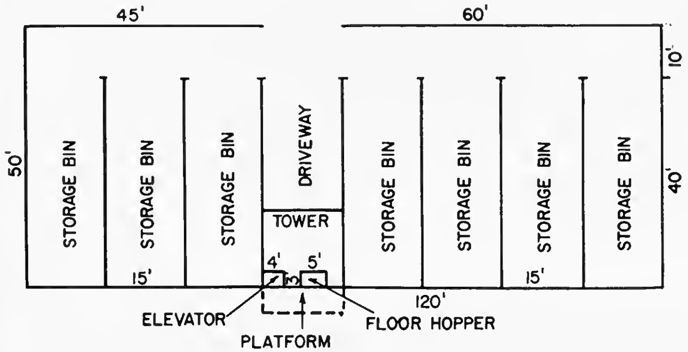
Combination horizontal-vertical-flow plants. The combination horizontal-vertical-flow type of plant incorporates some of the features of both the horizontal and vertical types (Fig. 3). To perform some operations simultaneously additional equipment is added to that usually found in horizontal-flow plants. Storage capacity and shelter requirements are higher than for the horizontal type but lower than for the vertical type (Figs. 5 and 7). Generally a separate room adjacent to the storage bins is constructed for the blending equipment. The size and shape of this room vary with the equipment arrangement.



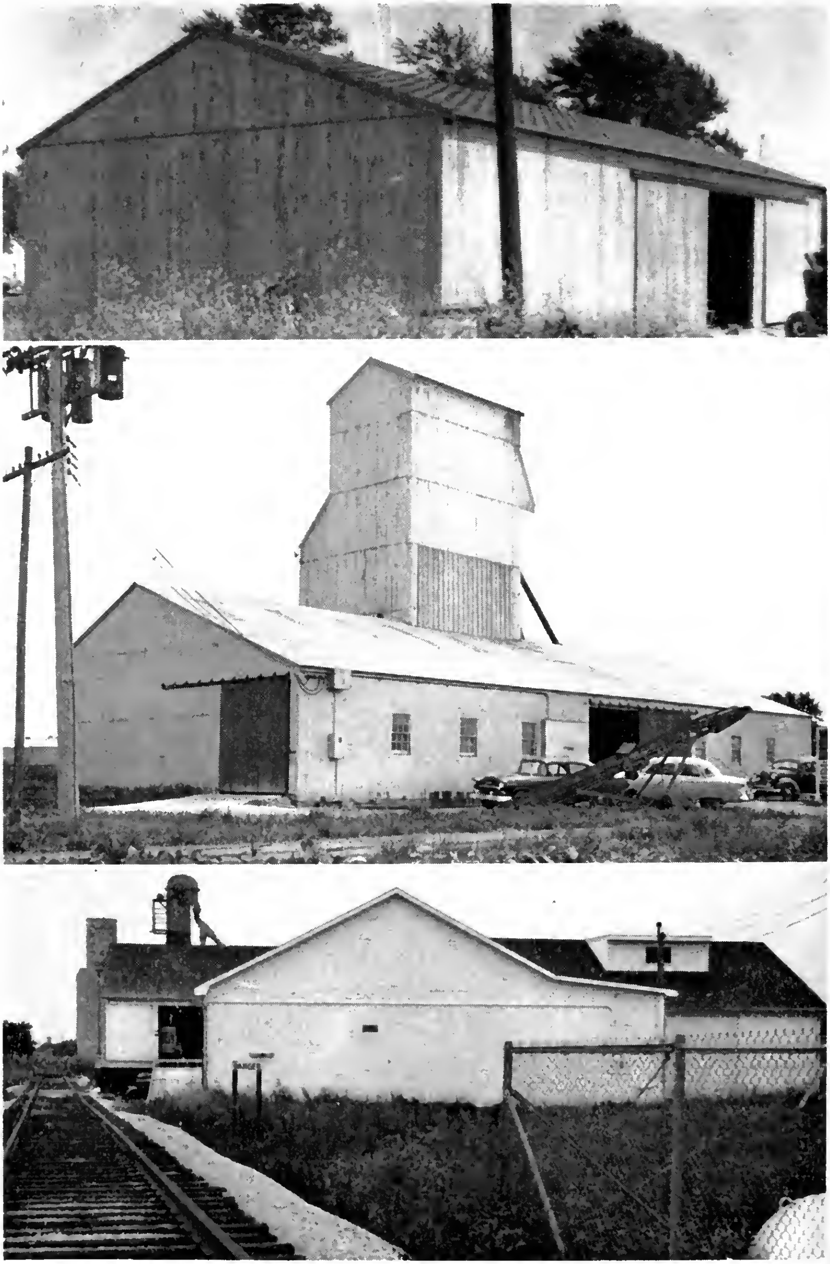
Typical layout of horizontal-flow plants. (Fig. 4)



Typical layout of combination horizontal-vertical-flow plants. (Fig. 5)



Typical layout of vertical-flow plants. (Fig. 6)



Types of structures commonly used in horizontal (top), vertical (middle), and combination horizontal-vertical (bottom) plants. (Fig. 7)

The equipment usually consists of a bulk loader, platform scales, hammer mill, floor hopper, two elevators, holding bin, mixer, and enclosed auger. In some plants an inclined conveyor belt is substituted for one elevator and the enclosed auger. The bulk loader moves the materials from storage to the floor hopper. Between the storage bins and floor hopper the bulk loader stops on the platform scales, where the operator records the weight of the materials. The materials pass from the floor hopper through a hammer mill, and are then lifted by the elevator and dumped into the overhead holding bin. The materials either flow directly into the mixer or are held in the holding bin while another batch is mixing. After mixing, the blended product is forced by action of the mixer into another elevator, lifted to the overhead auger, and dumped into the truck.

BULK-BLENDING FACILITIES[1]

All bulk-blending plants require the same basic facilities — land, shelter for materials and equipment, and equipment for storing, moving, weighing, and blending materials. The kinds of facilities used depend on the type of plant.

Land

Bulk-blending plants usually can be built on about 1 acre of land. Desirable site features are accessibility to a railway siding, to roads, to fire protection, and to high-voltage power lines. Often the land and siding are already available because the total operation includes other enterprises, such as a grain elevator, bagged fertilizer sales, or feed sales, which do not completely utilize all the space. The cost of the land depends on its location and size. An average of several land purchases by bulk blenders indicates that an adequate plant site can usually be obtained for $1,500.

Shelter

Housing is necessary to protect equipment and raw materials from moisture. Fertilizer materials even under ideal conditions have a very corrosive action on equipment, and exposure to weather merely increases the rate of deterioration.

Many of the present bulk-blending structures were not originally constructed as such. Warehouses, barns, and other buildings have been

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[1] The investment estimates for buildings and equipment presented in this section resulted from consultations with engineering personnel of Illinois Farm Supply Company, Chicago, Illinois; Gates Manufacturing Company, Morris, Illinois; and the Department of Agricultural Engineering, University of Illinois.

remodeled for use in bulk-blending plants. This remodeling has usually taken the form of either partitioning the structure into storage bins and mixing room or partitioning the structure into storage bins and adding a new room to shelter the blending equipment. The use of existing buildings has frequently meant an incomplete utilization of space.

In recent years a few structures have been built with the primary purpose of sheltering bulk-blending equipment and raw materials. Three basic types of construction are generally used: pole-supported with metal siding, frame, and concrete block. Investment costs for the different types of construction, based on 1957 building materials and construction costs, appear in Table 2. Storage bins are fairly uniform in shape and do not differ in appearance, although they frequently differ among plants in quality and quantity. The buildings usually differ in appearance, depending on the space allocated for the mixing equipment and on the arrangements for unloading materials from freight cars.

Storage-bin walls are usually lined to a height of 10 feet. Material may be piled higher than the wall height. (Fig. 8)

Table 2. — Estimated Construction Costs, Central Illinois, 1957

Type of construction	Mixing room	Storage bins	Wiring
	(per square foot)		
Pole-supported, metal siding (low quality)....	$1.75	$2.75	$200 for entrance $5-10 per light outlet $50-300 per motor outlet
Pole-supported, metal siding (high quality)...	$2.75	$3.75	Same as above
Frame (low quality).....	$2.00	$2.00, plus 65 cents per sq. ft. for non-partitioned bin walls	Same as above
Frame (high quality)....	$2.50	$4.50	Same as above
Concrete block..........	$2.50	$4.50	Same as above

The space allocated for mixing equipment is determined by the type of plant (Figs. 4, 5, and 6).

Arrangements for unloading freight cars differ from plant to plant and bear no necessary relation to the equipment layout within the plant. In general, there are five types of unloading arrangements.

Platform with access to back of bins. This arrangement consists of a platform at the back of the bins, equal in height to the floor of a freight car. Doors in the back walls of the bins permit access to the platform. Unloading is accomplished by a bulk loader moving back and forth across the platform between the freight car and bin. As the back of the bin is filled, boards are laid on the material to support the weight of the bulk loader.

Platform with access to front of bins. This consists of a platform constructed at the back of the bins, but with a ramp leading into the plant. The platform need not extend the width of the storage bins. The bulk loader moves down the ramp from the freight car and dumps the material into the bin from the front.

Floor hopper and elevator on platform. This arrangement has a platform at the back of the bins with a floor hopper resting on it. A bulk loader moves the materials from the freight car to the floor hopper. The floor hopper feeds into an elevator, and a distributor at the elevator head dumps the materials into any of the storage bins. Where the angle between the top of the elevator and the bins is too steep for gravity feed, a cross-conveyor belt over the bins is used.

Platform with access to blending elevator and floor hopper. This consists of a platform constructed at the back of the bins with a ramp leading down into the plant. Materials are moved from the freight car into the plant by a bulk loader and dumped into the floor hopper. The elevator lifts the materials and dumps them into the storage bins. This arrangement can be used only in vertical-flow plants with high elevators.

Under-the-track conveyor. This is used as a supplement to the platform-hopper-elevator arrangement. It consists of a screw conveyor laid under the railway siding track. The conveyor feeds into the same elevator as the floor hopper. For the screw conveyor to be useful, hopper cars — freight cars which are separated into three hoppers — must be provided by the railroads. Materials flow from the bottom of the car into the open conveyor, are carried by the conveyor to the elevator, and are dumped into the storage bins. The operations of the bulk loader are thus eliminated. At the present time only a few hopper cars are available to bulk-blending plants for raw material shipments.

Equipment

Costs of equipment vary depending on the location of the individual plant. In order to provide a fair comparison of the equipment costs of various plants, the costs in this report refer to f.o.b. factory prices. Frequently the installation costs on various pieces of equipment amount to 10 to 25 percent of the purchase price. These must be included in the investment cost.

The equipment used in bulk-blending plants can be separated into four general categories according to its use in the blending cycle. These categories are: moving equipment, holding bins and hoppers, weighing equipment, and mixing equipment.

Moving equipment. Bulk loaders are the primary means of transporting fertilizer materials in bulk plants. These vehicles are fast, easily maneuvered, and especially efficient in handling loose materials in close quarters. The bulk loader commonly used in bulk plants has a carrying capacity of 1,000 pounds of granular material when traveling at speeds of less than four miles an hour. Bulk loaders range in price from $4,000 to $5,000.

Tractors with loaders are used in place of bulk loaders in some plants. Tractors have the same carrying capacity as bulk loaders but are less efficient because they have less mobility. Tractors with loaders range in price from $2,700 to $3,200.

Enclosed and open augers are used for short, horizontal movements of materials in a few plants. An 8-inch auger can move approximately

30 tons of fertilizer material an hour. The open floor auger costs about \$2.50 a foot plus the cost of a power unit. Augers tend to overload easily when used to transport fertilizer materials.

Elevators used in bulk plants are usually of the bucket type. Chain and sprockets have been replaced by belts because of the high corrosive effect of fertilizer materials. Elevators range in height from 20 to 60 feet and in carrying capacity from 30 to 100 tons of material an hour. The price ranges from \$1,200 for a 20-foot elevator to \$4,000 for a 60-foot elevator. When the elevator is used to fill permanent storage bins, a distributor and spouting is necessary, adding \$1,800 to \$2,000 to the cost of the elevator.

Belt conveyors have replaced other methods of moving materials in many plants. Two types are used — horizontal and inclined.

In larger plants reversible horizontal conveyors are permanently installed to fill storage bins. Fastened on tracks, they can be moved to discharge into any one or several bins. This type of belt conveyor can handle about 100 tons of material an hour and costs \$1,600 to \$2,000 per 30-foot section of 18-inch belt.

Bulk loaders are used in many plants to carry material from the storage bins to the floor hopper. (Fig. 9)

Horizontal conveyor belts, situated above the storage bins, are used in large plants to fill the bins with materials. (Fig. 10)

Inclined belt conveyors are used for unloading boxcars and for unloading mixers. The capacity of these conveyors is below that of horizontal sectional conveyors. Inclined belt conveyors cost $600 to $800. Electric motors necessary to power conveyor belts cost $100 to $200 each.

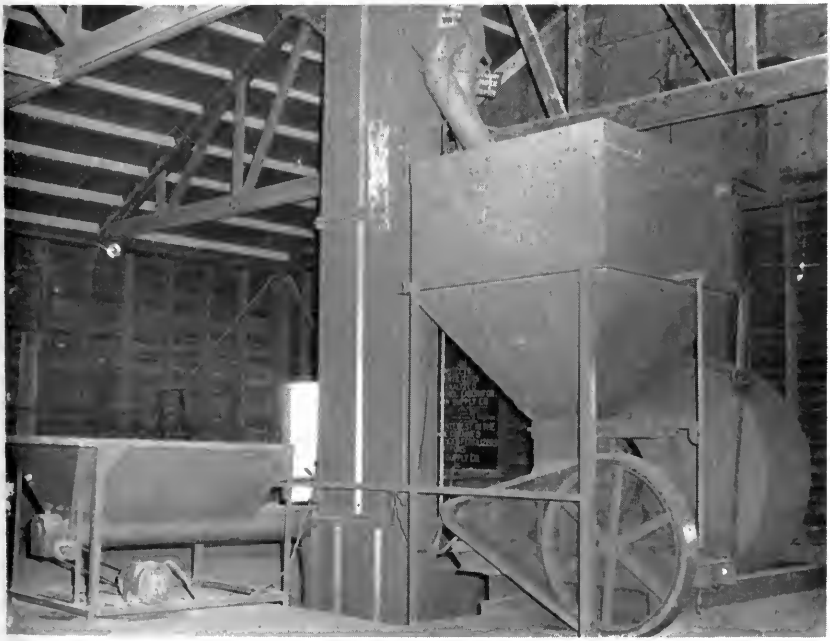
Holding bins and hoppers. Preblending holding bins are an integral part of vertical-flow plants, which ordinarily have four or five bins clustered at the top of the weighing and blending equipment. Preblending bins in vertical-flow plants have capacities of 5 to 25 tons. The bins are constructed with steep sides for easy materials flow. The valves to discharge the individual bins may be hand operated or controlled by air pressure. These bins cost $500 to $700. Vibrating screens are frequently located above the holding bins to separate out large granules which would impede the flow of materials. These cost $1,700 to $2,000. The air compressor system necessary for air pressure-controlled valves costs $600 to $800.

Preblending holding bins in combination vertical-horizontal plants have a 1- to 5-ton capacity, and cost less than $500.

Postblending holding bins are used in only a few plants. The bin is situated at the end of the blending cycle, and located overhead for dumping directly into a truck. A postblending bin has a 5- to 25-ton capacity and costs from $500 to $800.

Floor intake hoppers are used as dumps in bulk plants to feed materials into elevators. In the bottom of the hopper is a screw which forces the material into the elevator. Floor hoppers cost from $300 to $600.

Weighing equipment. Platform scales are used mainly in horizontal and combination horizontal-vertical plants. There are two basic types. One type consists of a platform at floor level, with a scales dial located at the side of the platform. The bulk loader is moved onto the platform and the weight of the material is registered on the dial. The load capacity of the platform scales must be enough to compensate for the weight of the bulk loader. Scales of this type cost from $900 to $1,200.

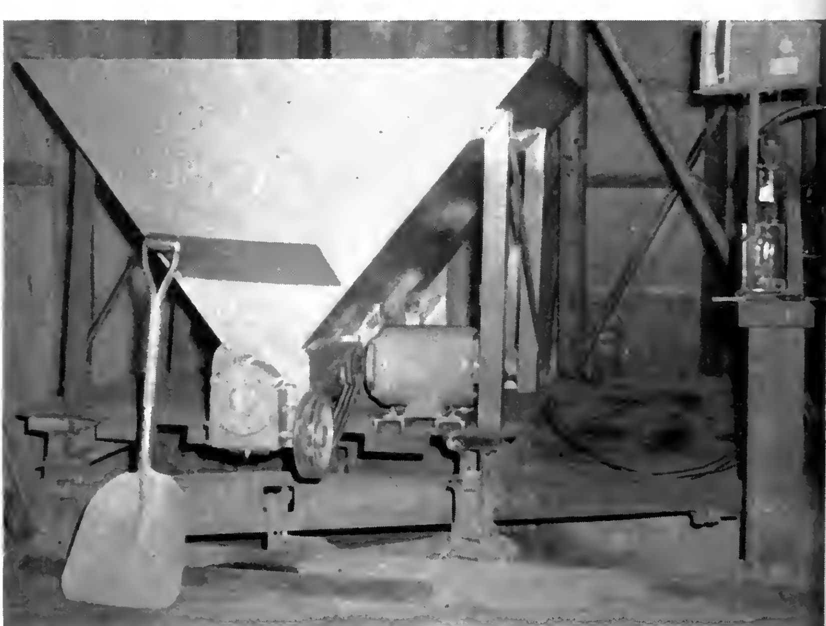


Materials are collected in the floor hopper (left) and are lifted by the elevator to the holding bin (right) above the mixer (rear). (Fig. 11)

The other type of platform scale has a hopper secured to the platform, with a scales dial or balance at the side. The bulk loader dumps the material into the hopper until the correct weight is registered. The load capacity of this type of scale can be lower than the "drive-on" type, since the bulk loader does not have to be weighed. The hopper has an auger in the bottom which forces the material out. The price of this unit is $700 to $900, excluding the cost of the hopper.

Suspended hopper scales, or batchers, are used in vertical-flow plants. The batcher is suspended below the holding bins so as to be free of vibration. Materials are discharged from the holding bins into the batcher for weighing. The scales dial or balance is located at the holding bin valve controls, where it is easily visible to the operator. These batchers are available in 1- or 2-ton capacities. The sides are steep for easy materials flow and the discharge is air controlled for fast and easy operation. Batchers cost from $3,500 to $4,500.

Mixing equipment. Drum-type mixers are used in most blending operations. The mixing principle of drum mixers is based on a tum-



In platform scales of this type, materials are dumped into the hopper, weighed, and forced out by an auger in the bottom of the hopper. (Fig. 12)

In most combination horizontal-vertical plants, materials flow from the holding bin into the mixer. After mixing, the materials are discharged into an elevator. (Fig. 13)

bling action. Ingredients are tumbled, turned, and folded by the slowly rotating drum. Closely spaced around the inside of the drum are oddly shaped blades which continuously cut out and lift up portions of the ingredients. Drum mixers can be equipped with either a force or gravity feed intake, but ordinarily have a gravity feed discharge. Rated capacities of these mixers range from ½ to 2½ tons of fertilizer materials. Recommended mixing time varies from 1 to 5 minutes. Drum mixers cost from $3,000 to $4,000.

Converted feed mixers are used in some plants. These mixers have higher speeds than drum-type mixers and have been reinforced to handle fertilizer materials. The mixing principle of the converted feed mixers is opposite to that of the drum-type mixer — the drum remains stationary while blades inside the drum rotate. Rated capacities of these mixers usually do not exceed 1 ton, and costs range from $500 to $3,000, depending on the conversions made.

Auger-type mixers are comprised of a series of hopper units, usually three or four in a series, and a collecting auger. Each hopper unit is on a scale so that each ingredient can be weighed separately. The hopper units each have a variable-speed drive which is adjusted in proportion to the amount of material in the unit. The hopper units generally are placed under individual overhead holding bins for easy filling and, in turn, discharge into the collecting auger. In the collecting auger the materials are blended and conveyed to the truck. Each unit costs from $700 to $800.

Hammer mills are located in the blending cycle either before or after the mixing process. As the materials pass through the hammer mill, lumps are pulverized. Hammer mills cost between $300 and $500.

A STUDY OF EIGHT SELECTED BULK-BLENDING PLANTS

Facilities

Two horizontal-flow plants were included in the study.

Plant A had an extremely low investment in facilities. The equipment consisted essentially of that used in mixing concrete. A tractor with scoop was used to carry materials from the storage bins to three holding bins situated over the batching unit. A scales hopper that could be moved below the holding bins weighed the materials. This method of weighing materials deviates from the normal horizontal-flow plant operation. The scales hopper dumped the materials into the mixer scoop, which elevated the materials into the mixer. After mixing, the blended product was moved from the mixer to the truck by an inclined conveyor belt. The batch capacity of this plant was ½ ton.

In Plant B a bulk loader moved materials from the storage bins to the mixer, stopping along the way on a floor-level scales platform, where the materials were weighed. If the weight was not exactly correct for the prescribed blend, material was either added to or removed from the bulk-loader scoop. Supplementary fertilizer was stored for this eventuality in small bins near the scales. The bulk loader dumped the materials into the mixer, and the blended product was moved from the mixer to the truck by an inclined conveyor belt.

Two vertical-flow plants were included in the study.

In Plant C the materials were pulled from the permanent storage bins by a portable auger and were carried by a floor screw auger to the elevator, which lifted the materials to the overhead holding bins. Before the materials entered the holding bins, they had to pass through a vibrating screen; lumps not passing through the screen were circulated through a hammer mill. The operator stood in the tower and controlled the discharge of the materials into the suspended scales hopper, where they were weighed. The materials then fell directly into the mixer. From the mixer the blended product fell into the truck stationed below the mixer.

In Plant D a bulk loader was used to move materials from storage to a floor hopper. The materials were lifted from the floor hopper into overhead holding bins by an elevator. Before the materials could pass into the holding bins they had to flow through a vibrating screen. The operator, working at a control center on the plant floor, controlled the discharge of materials by air-operated valves from the holding bin into the scales bin. The materials were weighed and then fell from the scales bin into the floor hopper. From there they were elevated to a holding bin over the mixer. The materials flowed from the holding bin into the mixer and, after mixing, the blended product was discharged into a truck located below the mixer. Since the same elevator was used to move materials to the holding bins above the scales and to move materials to the bin above the mixer, these two operations could not take place simultaneously. An additional elevator will eventually be installed to alleviate the demands on the present one.

Four combination horizontal-vertical-flow plants were included in the study.

In Plants E and F equipment arrangements were identical. A bulk loader moved the materials from the storage bins to the floor hopper. Between the bins and the hopper the bulk loader stopped on platform scales, where the operator recorded the weight of the materials. From the floor hopper an elevator lifted the materials to a holding bin over the mixer. A hammer mill was located between the floor hopper and elevator and the materials passed through it. The materials stayed in the holding bin until the mixer was empty. After mixing, the blended product was discharged from the mixer into another elevator. The material was then lifted to an overhead horizontal auger, which dumped the blended product into a truck.

In Plant G a bulk loader moved materials from the storage bins to a floor-level scales hopper. After the correct amount of each material was dumped into the scales hopper and weighed, an auger in the bottom of the hopper moved the materials to an elevator, where they were elevated to an overhead mixer. After mixing, the blended product fell from the mixer into the truck.

In Plant H the elevators were higher than those usually found in combination horizontal-vertical plants, and the mixer was located above floor level. A bulk loader moved the materials from the storage bins to a floor hopper, stopping along the way on platform scales where the weights of the materials were recorded. From the floor hopper the materials were elevated to a holding bin above the mixer. The materials flowed into the mixer from the holding bin and, after mixing, fell from the mixer into a bagging machine hopper. Here it was either bagged or allowed to pass through into another elevator. After being elevated, the blended product was moved by an overhead conveyor belt to a postblending holding bin. This bin dumped directly into the truck located below it.

Estimates of costs

Investments. Using the equipment and building costs previously described, the investments of the eight selected bulk-blending plants were computed and compared (Table 3). The horizontal-flow plants averaged the lowest total investment, and the vertical-flow plants the highest, while the combination horizontal-vertical-flow plants had investment totals averaging between the two. Of the average total investment, equipment cost accounted for 48 percent, building cost for 49 percent, and land cost for 3 percent.

Table 3. — Investments of Eight Selected Illinois Bulk-Blending Plants, 1957

Plant	Equipment cost	Building cost	Land cost	Total investment
Horizontal-flow plants				
Plant A	$11,100	$ 3,936	$1,500	$16,536
Plant B	10,574	15,347	1,500	27,421
Vertical-flow plants				
Plant C	39,832	61,196	1,500	102,528
Plant D	34,561	20,219	1,500	56,280
Combination horizontal-vertical-flow plants				
Plant E	22,207	28,120	1,500	51,827
Plant F	22,207	25,465	1,500	49,172
Plant G	12,667	7,667	1,500	21,834
Plant H	49,500	45,108	1,500	96,108
Average	25,331	25,882	1,500	52,713

Fixed costs are those costs which remain constant regardless of the total output or the use of equipment. In bulk-blending plants fixed costs include depreciation, interest on the investment, property taxes, insurance, administrative and maintenance labor, and rent.

Depreciation. Because of the corrosive action of fertilizer materials on metals, equipment in the fertilizer industry depreciates rapidly. Although it is not known exactly how long the equipment will last with proper care and repair, plant operators in general use a ten-year depreciation rate.

The length of life of plant structures varies according to the type of construction. Pole-supported metal-siding structures have the same corrosion problem as equipment; on many buildings low-quality metal siding has rusted in less than five years. For this reason, depreciation rates vary according to the type of structures housing the bulk-blending operation. Probable rates of depreciation are: pole-supported metal siding (low quality), 8 years; pole-supported metal siding (high quality), 12 years; frame (low quality), 12 years; frame (high quality), 16 years; and concrete block, 20 years. The straight-line depreciation rate was used in computing depreciation charges.

Interest on the investment was computed at the annual rate of 5 percent of the total original cost.

Property taxes are based on the assessed valuation of the total operation. The average tax rate in Illinois is 3 mills on each assessed dollar of valuation. The assessed valuation is approximately 50 percent of the current market value.

Insurance. Liability insurance was charged at $120 a year for each man working in the plant. Fire insurance rates in Illinois depend on the location of the plant. Within city limits, rates are much lower than in rural areas. An average rate of 80 cents per $100 current market value was assumed for plant facilities and equipment.

Administrative and maintenance labor. The plant manager's labor was charged at $300 a month. Secretarial workers and full-time laborers were paid $240 a month.

Rent. In some plants rent is paid to railroads for the use of land along the track siding. This charge is usually minor, approximately $50 a year.

The total annual fixed costs for the eight selected plants ranged from a low of $6,423 in Plant A to a high of $20,106 in Plant H when the operator and supplemental labor were used (Table 4).

Table 4. — Annual Fixed Costs for Eight Selected Illinois Bulk-Blending Plants, 1957

Fixed cost	Horizontal-flow plants		Vertical-flow plants		Combination horizontal-vertical-flow plants			
	A	B	C	D	E	F	G	H
Depreciation	$1,448	$2,335	$7,043	$5,140	$3,978	$3,812	$2,225	$7,882
Interest on investment	827	1,371	5,126	2,814	2,591	2,458	1,091	4,805
Property taxes	248	411	1,538	844	777	738	328	1,442
Insurance								
Operator only	240	327	120	570	523	501	283	877
Operator and supplemental labor[a]	300	387	180	630	583	561	343	933
Administrative and maintenance labor	3,600	3,600	5,040	7,080	3,600	3,600	3,600	5,040
Rent	0	0	0	50	0	0	0	0
Total								
Operator only	6,363	8,044	18,867	16,498	11,469	11,109	7,527	20,046
Operator and supplemental labor	6,423	8,104	18,927	16,558	11,529	11,169	7,587	20,106

[a] When labor is hired to supplement the plant operator, an additional liability insurance cost of $60 is added to total fixed costs.

Variable costs are those costs directly related to output and the use of equipment. They are also called operating costs. Variable costs in bulk-blending plants have been divided into six categories: materials, operating labor, power, inventory losses, repair and maintenance, and unloading materials from freight cars to storage bins.

Materials. Costs of fertilizer materials differ somewhat among plants, depending on freight charges, but the f.o.b. price is assumed to be constant. For comparative purposes, the costs of shipping materials to Decatur, Illinois, were used. Illinois law requires a tonnage tax of 10 cents a ton to be paid on all fertilizer sold in Illinois. Costs per ton (including tonnage tax) of the three primary raw materials were:[1]

Material	*F.o.b. shipping point*	*F.o.b. price*	*Freight*	*Total cost (including tonnage tax)*
Ammonium sulfate (21% N)	Chicago, Illinois	$32.00	$ 4.30	$36.40
Triple superphosphate (46% P_2O_5)	Tampa, Florida	47.08	15.74	62.92
Muriate of potash (60% K_2O)	Bonneville, Utah	21.60	15.12	36.82

[1] The f.o.b. price and freight costs are those which were effective in September, 1957, for bulk plants in the Decatur, Illinois, area. Costs do not include brokerage fees.

In 1 ton of a 10-10-10 blend[1] the amounts of each of the three raw materials used, and the costs of each were:

Material	*Pounds*	*Cost*
Ammonium sulfate	953	$17.34
Triple superphosphate	435	13.69
Muriate of potash	334	6.15
Total	1,722	$37.18

Operating labor. Although most labor costs in bulk blending do not vary directly with volume, supplemental labor can be considered a variable cost. Supplemental labor is needed when it is desired to increase output beyond the point where the plant operator alone can handle the work. Variable labor costs were charged on the basis of $1.25 an hour. The hourly labor costs were then converted to labor costs per ton.

Power. Power and fuel costs were estimated from engineering studies and from various machine requirements.[2] Utilities were supplied from outside sources, and charged on an hourly basis. Bulk-blending plants were assumed to pay an average of 2.4 cents a kilowatt hour for electricity. A gasoline expense of 25 cents a gallon and an oil expense of 30 cents a quart were assumed to be incurred. Power costs per hour of blending time were converted to power costs per ton of blended material.

Inventory losses. Losses of material in transit and during plant operations annually cost 1¾ percent of the total materials handled.

Repair and maintenance. Lubrication, replacements due to wear, and painting or cleaning are considered a function of use. Allowances for repair and maintenance varied from plant to plant, depending on the amount and quality of equipment. The allowance was ordinarily lower in plants with high equipment investments. These plants usually blended larger tonnages of materials than low-investment plants, and, since the more the equipment is used the less susceptible it is to corrosive deterioration, their maintenance costs per ton were thereby reduced.

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[1] For comparison purposes, plant outputs are presented in this bulletin in terms of equivalent tons of a 10-10-10 mixture. This analysis is representative of blends used throughout the state.

[2] Henderson, S. M., and Perry, R. L., *Agricultural Process Engineering* (New York, 1955), chapter 14.

Table 5. — Variable Costs per Ton of 10-10-10 Equivalent for Eight Selected Illinois Bulk-Blending Plants, 1957

Variable cost	Horizontal-flow plants		Vertical-flow plants		Combination horizontal-vertical-flow plants			
	A	B	C	D	E	F	G	H
Materials and tonnage tax	$37.180	$37.180	$37.180	$37.180	$37.180	$37.180	$37.180	$37.180
Operating labor[a]	.112	.090	.051	.082	.095	.091	.105	.063
Power[b]								
Operator only	.200	.062	.014	.022	.053	.059	.035	.049
Operator and supplemental labor	.135	.054	.014	.021	.052	.058	.034	.038
Inventory losses	.740	.740	.740	.740	.740	.740	.740	.740
Repairs and maintenance	.420	.430	.250	.270	.340	.340	.400	.250
Unloading material from freight cars to storage bins	.111	.029	.012	.027	.022	.022	.029	.031
Total								
Operator only	38.651	38.441	38.196	38.239	38.335	38.341	38.384	38.250
Operator and supplemental labor	38.698	38.523	38.247	38.320	38.429	38.431	38.488	38.302

[a] There is no operating labor cost when only plant operator is working.
[b] Electric motors were assumed to operate at 70 percent of load capacity, gasoline engines at a varying load rate.

Investment in equipment	*Annual repairs and maintenance cost per ton* (cents)
$ 8,000–12,000	45–40
12,000–20,000	40–35
20,000–30,000	35–30
30,000–40,000	30–25

Unloading materials from freight cars to storage bins. This operation is not part of the blending cycle. It is performed during slack periods or at night. The cost of unloading materials includes power and labor costs, both of which were computed at the rates previously mentioned.

Table 5 shows a comparison of operating costs for the eight selected bulk-blending plants. Normal operating conditions assume a 5-minute delay between each 7-ton load of materials blended. This delay allows for the positioning of a different truck and for checking equipment. An 8-hour working day is also assumed, with enough orders to keep the plant in continuous operation.

The operating cost of blending depends on the blend used; different blends require different materials in varying quantities. Using a 10-10-10 blend, total operating costs of the selected plants varied from $38.25 to $38.70 an equivalent ton, including the cost of supplemental labor. The costs were approximately the same for all plants because the inventory losses and costs of materials ($37.92) remained constant. Vertical-flow plants had the lowest variable costs per ton, while horizontal-flow plants had the highest.

Estimates of output capacities

In estimating output capacities for bulk-blending plants, considerations must be given to both the equipment and the storage capacities. Both depend on the supply of raw materials and on the demand for blends.

Supply of raw materials. Raw materials are not always in plentiful supply; at certain times it is difficult to have an order filled quickly. In addition, the in-transit times of raw materials vary. Ammonium sulfate, shipped from Chicago, Illinois, to Decatur, takes at least 5 days in transit. If shipped to Decatur from Youngstown, Ohio, another primary supply location, it takes 10 days. The in-transit time for triple superphosphate, usually shipped from Tampa, Florida, is about 8 to 10 days. Decatur plants obtain their muriate of potash from Carlsbad, New Mexico, or Blair, Utah, and the in-transit time is from 8 to 9 days. These figures represent actual in-transit times experienced by bulk-blending plants in the Decatur area. The uncertain supply of raw materials and the differences in in-transit time sometimes complicate the scheduling of orders.

Demand for blends. Equipment and storage capacities must be large enough to provide for the busiest bulk-blending periods. The busiest periods for bulk blenders occur in the spring and fall. In the first three years of operation, from 1954 to 1957, one blending plant had the following average sales distribution:

Month	*Volume of material* (tons)	*Percent of total*
January	5	.1
February	28	.5
March	1,003	20.9
April	545	11.4
May	1,491	31.1
June	10	.2
July	0	0
August	36	.8
September	675	14.1
October	804	16.7
November	164	3.4
December	39	.8
Total	4,800	100

Nearly 95 percent of the three-year sales volume took place within five months: 63.4 percent in March, April, and May, and 30.8 percent in September and October.[1] Sales were low in November, December, January, and February because during those months the ground was usually too wet to support the weight of the spreader trucks. The materials that were distributed in the winter were spread when the ground was frozen.

Equipment capacities. The speed and ease with which materials move through the plant depend on the equipment arrangement within the plant. The eight selected plants, each with different equipment arrangements (except Plants E and F), required different operating times.

[1] Because the volume during these five months is essentially the same as for the whole year, estimates of volume capacities are presented in this bulletin on a five-month basis instead of a yearly one.

Consecutive operations. The plant operations were divided into six categories. If each operation were to be performed consecutively, it would take from 4 to 12 minutes in the selected plants to blend 1 ton of 10-10-10 (Table 6).

Operation 1 is the combination of starting, adjusting, and stopping equipment. Under continuous operation the blending equipment runs constantly; under discontinuous output Operation 1 is repeated several times. Ordinarily this operation takes very little time — less than half a minute — as most plants use electric motors for power. Plant A had a high operating time because of occasional difficulty in starting a gasoline engine on the mixer.

Operation 2 consists of filling temporary storage bins (holding bins) with material from the permanent storage bins. This operation is normally performed only in vertical-flow plants. However, Plant A had a concrete blending unit which used temporary storage. The operating time of filling holding bins varied from 1 to 3 minutes a ton, depending on the method of moving materials.

Operation 3 consists of moving materials from permanent storage bins or holding bins to the scales and weighing the materials. In the vertical-flow plants this consisted of gravity flow of materials from the holding bins into the batcher, and took approximately 0.8 to 1.4 minutes a ton. In all plants other than vertical-flow this operation consisted of moving materials by bulk loader from the storage bins to the scales, and took from 1.5 to 2.3 minutes, depending on the distance between the storage bins and scales and on the efficiency of the bulk loader operator.

Operation 4 is the moving of materials from the scales to the mixer. In horizontal-flow plants, such as Plant B, this operation takes about half a minute. Plant A, because of its equipment limitations, took longer than is usual for horizontal-flow plants. In the combination horizontal-vertical-flow plants, materials could move directly from the scales through the holding bins above the mixer into the mixer. This took from 0.8 to 1.9 minutes, depending on the size and speed of the elevator. Or Operation 4 could have two parts: (1) moving materials to the holding bin, and (2) moving them from the holding bin to the mixer. The first step took 0.8 to 1.9 minutes, and the second 0.4 to 0.5 minute. In Plant C, where materials moved by gravity from the batcher into the mixer, Operation 4 took less than half a minute. Plant D, although a vertical-flow plant, had a holding bin incorporated into the blending cycle, and materials could not pass directly from the scales to the mixer. As a result, its operating time was longer than is usual for vertical-flow plants.

Table 6. — Times Required for Operations in Eight Selected Illinois Bulk-Blending Plants, 1957
(Blending a 10-10-10 equivalent)

Operation	Horizontal-flow plants		Vertical-flow plants		Combination horizontal-vertical-flow plants			
	A	B	C	D	E	F	G	H
				(minutes per ton)				
1. Starting, adjusting, and stopping equipment........	1.460	.167	.166	.166	.333	.277	.481	.167
2. Filling holding bins with raw materials from storage bins..........	3.060	....	2.370	1.180	....	....	....	....
3. Moving materials from storage bins or holding bins to scales and weighing..........	2.090	1.475	.756	1.358	1.835	2.256	1.902	1.503
4. (a) Moving materials directly from scales to mixer..	2.240	.402	.288	....	1.941	1.743	2.205	.826
(b) Moving materials from scales to holding bins....	....	....	....	.633	1.941	1.743	....	.826
(c) Moving materials from holding bins to mixer....	....	....	....	.363	.463	.510	....	.348
5. Mixing materials..........	.953	.794	.346	.491	2.183	2.275	.943	.885
6. Unloading mixer and conveying materials to truck..	2.020	1.610	.346	1.233	2.950	2.457	.393	1.288
Total..........	11.823	4.448	4.272	5.424	9.242[a]	9.008[a]	5.924	4.669[a]

[a] Includes Operation 4a, omitting Operations 4b and 4c.

Operation 5 consists of the mixing. Since no standards are set as to how long the materials should remain in the mixer, the time varied greatly among plants. The mixing time does not depend on the type of plant, although it was noticed that those plants (primarily horizontal-flow plants) not having the ability to perform operations simultaneously tended to reduce the mixing time to increase the hourly output. Because of their extremely high speeds, converted feed mixers need only about 0.5 to 1.0 minute to do an adequate blending job. Drum-type mixers need a longer mixing period — about 1.5 to 2.0 minutes.

Operation 6 consists of unloading materials from the mixer and moving them to the truck. When the mixer is located above ground level, the operation consists merely of gravity flow directly from the mixer into the truck. This was the case in Plants C, D, and G, where 0.4 to 1.2 minutes a ton were needed to complete the process. Operation 6 was performed by an inclined conveyor belt in Plants A and B (1.6 to 2.0 minutes), by an elevator and auger in Plants E and F (2.5 to 3.0 minutes) and by an elevator and conveyor belt in Plant H (1.3 minutes).

Continuous operation. Since some operations can be performed simultaneously, the summation of all operating times given in Table 6 does not indicate the capabilities of various plants under continuous operation. Further, a delay between truck loads is not included. The total potential output of bulk-blending plants under continuous operation depends on how much equipment and labor flexibility they have.

Under continuous operation, all the plants had some equipment flexibility, that is, more than one operation could be performed at the same time. The degree of equipment flexibility depended on the amount and arrangement of the equipment.

In the horizontal-flow plants one trip was made with the bulk loader between the storage bins and mixer for each material included in the batch. While the materials were mixed and unloaded into the truck, the bulk loader could make a trip to the storage bins and be prepared to dump one of the materials into the mixer as soon as it was emptied. This was the extent of the equipment flexibility in the horizontal-flow plants.

The vertical-flow plants, with gravity flow of materials to the mixer, had additional equipment flexibility. While one batch was mixed and unloaded into the truck, another batch could be moved from storage to the holding bins or from the holding bins to the scales bin. For instance, in Plant C the total blending time was reduced because Opera-

Table 7. — Potential Outputs of Eight Selected Illinois Bulk-Blending Plants Under Continuous Operation, 1957[a]

(Blending a 10-10-10 equivalent)

Rate of output	Horizontal-flow plants		Vertical-flow plants		Combination horizontal-vertical-flow plants			
	A	B	C	D	E	F	G	H
				(tons)				
Hourly								
One man	6.74	12.02	15.17	13.95	12.34	12.43	11.34	14.53
Two men	11.13	13.68	24.43	15.23	13.04	13.69	11.87	19.85
Daily[b]								
One man	54	96	121	112	99	99	91	116
Two men	89	109	195	122	104	109	95	159
Monthly[c]								
One man	1,404	2,500	3,146	2,912	2,574	2,574	2,366	3,016
Two men	2,314	2,834	5,070	3,172	2,704	2,834	2,470	4,134
5-month								
One man	7,020	12,500	15,730	14,560	12,870	12,870	11,830	15,080
Two men	11,570	14,170	25,350	15,860	13,520	14,170	12,350	20,670

[a] Includes a 5-minute delay between each 7 tons of blended product to permit the next truck to move into position.
[b] Daily output is based on an 8-hour working day.
[c] Monthly output is based on 26 work days per month.

tions 5 and 6 could occur simultaneously with either Operation 2 or Operation 3.

In the combination horizontal-vertical-flow plants, the holding bin over the mixer was added to increase equipment flexibility. For example, if there were no holding bin in Plants E and F, the total time to complete Operations 3, 4a, 5, and 6 would be about 9 minutes. The addition of the holding bin permitted Operations 3 and 4b to be performed simultaneously with Operations 5 and 6, requiring that only the time to complete Operation 4c — about half a minute — be added to the total time of processes 5 and 6. Thus the total time of Operations 3 through 6 was reduced from about 9 minutes a ton to about 5.5 minutes.

Besides equipment flexibility, under continuous operation all the plants had some labor flexibility, that is, ability to divide operations between two men. For instance, Operation 2 could be performed independently of the other processes in Plants A and C, and the addition of supplemental labor would increase the potential output of Plant A by 65 percent and of Plant C by 61 percent (Table 7). In Plant D, potential output could not be increased greatly with additional labor. This is because the elevator used to fill the holding bins above the scales was also used to fill the bins above the mixer. Supplemental labor in the other plants slightly increased potential output. The usual procedure in most plants with two men was to have one operate the bulk loader, and the other the blending equipment controls.

With two men working, the total potential outputs of the selected blending plants ranged between 11.1 and 24.4 tons an hour (Table 7). If mixing times were standardized among the plants, the horizontal-flow plants would have had the lowest hourly outputs, the vertical-flow plants the highest, and the combination horizontal-vertical-flow plants between the two.

Storage capacities. The maximum storage required by a blending plant is that which is adequate to maintain continuous operation for the period of time necessary to obtain materials to refill the storage bins, plus a safety factor. For example, if materials normally require six days transit time after ordering, then a blending plant with an equipment capacity of 100 tons a day would need at least 600 tons of storage capacity. If the operator desired never to be without materials, then storage capacity in excess of 600 tons would be needed. This extra space would also protect him against the possibility of bad weather during peak periods preventing the spreading of fertilizer on farms, thus causing a backlog of materials at the plant.

The storage capacities in the selected plants varied considerably (Table 8), although in general the vertical and combination horizontal-vertical plants had higher storage capacities than the horizontal plants. The ratio between daily potential output (two men) and storage capacity ranged from 1:2.7 in Plant A to 1:14.9 in Plants E and H.

Prior to the spring and fall fertilizer seasons, all the plants sent a tentative schedule of orders to the suppliers of raw materials. This tentative schedule stayed in effect throughout the season, but could be changed at any time up to the actual shipment date. During busy blending periods Plants A, C, D, and G had to check their tentative schedules very closely, for these plants, because of their low storage-output ratios, required more materials en route to them than their storage bins could hold at one time.

Some plant managers used a scheduling method which kept their bins full at all times. They operated on the principle of always having materials available for blending, risking adverse price changes of materials in order to reduce the risk of losing revenue because of empty storage bins.

Table 8. — Raw Materials Storage Capacity of Eight Selected Illinois Bulk-Blending Plants, 1957

Plant	Number of bins	Storage capacity		Total storage capacity of plant in terms of ammonium sulfate	Ratio between daily potential output (2 men) and storage capacity[a]
		Ammonium sulfate	Triple superphosphate and potash		
		(tons)[b]	(tons)[b]	(tons)[b]	
A	3	70	80	210	1 to 2.7
B	4	200	230	800	1 to 8.5
C	5	144	165	720	1 to 4.3
	1[c]	274	315	...	....
	1[c]	248	284	...	....
D	4	174	200	696	1 to 6.6
E	8	167	190	1,336	1 to 14.9
F	6	195	224	1,170	1 to 12.5
G	5	78	90	390	1 to 4.8
	1[c]	63	72	...	....
H	6	340	390	2,040	1 to 14.9

[a] The ratio between daily potential output (two men) and storage capacity is computed by multiplying 1.161 by the total storage capacity and dividing the product by the daily potential output.

[b] *Ton* here refers to a short ton (2,000 pounds). Since an equivalent ton of 10-10-10 weighs 1,722 pounds, 1 short ton = 1.161 equivalent tons of 10-10-10.

[c] These bins were used primarily for rock phosphate storage.

Other plant managers used a different method of scheduling. They ordinarily began the season with full bins but tried to maintain a level of 50 to 60 percent of capacity in the bins for the remainder of the season, thereby reducing losses from price changes but increasing the possibility of losing revenues because of inadequate supplies. This type of inventory control requires much more accurate scheduling. Some managers kept records of the daily volume of materials blended in past seasons, and based the future seasons' scheduling on the past distribution of sales.

Cost-output relationships

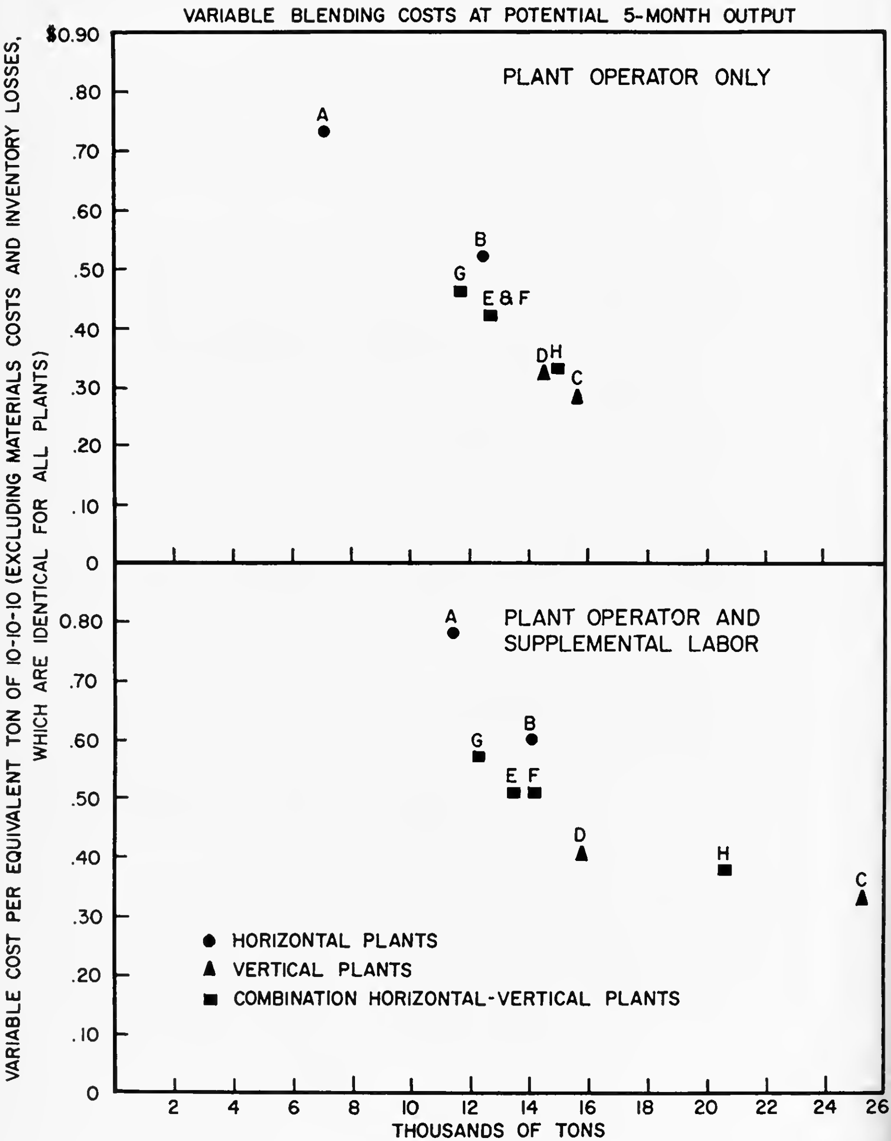
In deciding on the size of plant and method of operation to be used, it is important to consider the expected level of demand and the costs involved in meeting that demand. This cost-output relationship is greatly affected by the facilities and equipment used in the plant. The objective, therefore, is to choose facilities and equipment that will enable the expected output to be produced at the lowest possible cost per unit.

Investment-output relationship. Facing a continuously low demand, the plant manager would need to construct a plant with minimum output capabilities, requiring a low investment. Facing a high continuous demand, the plant manager would require a plant with high output capabilities, necessitating a high investment. With an anticipated variable demand, additional investment in equipment would be necessary to allow for flexibility of output.

Variable costs-output relationship. As has been indicated previously, variable blending costs per ton and potential output both depend on the materials-flow system used. The relationship of variable costs to potential output in the three types of plants was as follows:

Under operating conditions using only the plant operator, horizontal-flow plants had the highest variable cost per ton and the lowest potential output, while vertical-flow plants had the lowest variable cost per ton and the highest potential output. The variable costs and potential output of combination horizontal-vertical-flow plants fell between those of horizontal and vertical plants. When supplemental labor was added, the above relationships also held true (Fig. 14).

Supplemental labor helps increase output but it also increases variable costs, with the ratio of the increased output to the increased variable costs depending on the degree of labor flexibility in the plant. For instance, if Plant C, where labor flexibility was high, were to add



At maximum output with either one man or two men, vertical-flow plants averaged the highest potential output and lowest variable costs; horizontal-flow plants had the lowest potential output and highest variable costs; and combination horizontal-vertical-flow plants had averages between the other two types of plants. (Fig. 14) an extra man, its variable costs would increase by 5 cents a ton and its output for five months would increase by 9,620 tons. On the other hand, in Plant E, where labor flexibility was low, an additional man would increase variable costs by 9 cents a ton and output by 650 tons. However, even in this case the increased variable costs would be more than offset by the additional revenues (at September, 1957, fertilizer prices) gained from the increased output.

Fixed costs-output relationship. The relationship of fixed costs per unit to annual output is:

$$\text{Fixed costs per unit output} = \frac{\text{Total annual fixed costs}}{\text{Units produced per year}}$$

Since the total fixed costs remain constant regardless of output, it is evident from this equation that as the output increases the fixed cost per unit of output decreases.

Total cost-output relationship. At maximum output with one operator, the average total cost per ton was lowest in combination horizontal-vertical-flow plants (Table 9). In these plants, average fixed costs were relatively low, and a high degree of equipment flexibility with one man resulted in low variable costs per ton. The average total cost was higher in vertical plants because the high fixed costs per ton offset low variable costs. Horizontal plants had the highest total costs, mainly because of their high variable costs. Because of its speeded-up mixing process, Plant B had lower variable costs and a higher potential output than it would have had if mixing times were standardized among the plants.

With the addition of supplemental labor, the vertical-flow plants had the lowest total cost per ton (Table 10). This is because the high labor flexibility in vertical-flow plants increases the potential output relatively more than it increases variable costs, and the resulting increased output reduces the fixed costs per unit. Plant D was an exception only because of the lack of labor flexibility; when an additional elevator is installed in the plant, the total costs of blending will decrease and potential output will increase.

Under operating conditions using two men, it can be assumed that, if mixing times were standardized for all the plants, the horizontal plants would have the highest total costs per unit of output, the vertical plants the lowest, and combination horizontal-vertical plants between the two.

Table 9. — Cost-Output Relationships for Eight Selected Illinois Bulk-Blending Plants, 1957
(Blending a 10-10-10 equivalent with plant operator only)

Output	Costs per ton for horizontal-flow plants				Costs per ton for vertical-flow plants			
	Plant A (VC[a] = $38.65)		Plant B (VC[a] = $38.44)		Plant C (VC[a] = $38.20)		Plant D (VC[a] = $38.24)	
	Fixed cost	Total (incl. VC)	Fixed cost	Total (incl. VC)	Fixed cost	Total (incl. VC)	Fixed cost	Total (incl. VC)
(tons)								
100	$ 63.63	$102.28	$ 80.44	$118.88	$188.67	$226.87	$164.98	$203.22
500	12.72	51.37	16.08	54.52	37.37	75.57	32.99	71.23
1,000	6.36	45.01	8.04	46.48	18.87	57.07	16.49	54.73
5,000	1.27	39.92	1.61	40.05	3.77	41.97	3.30	41.54
10,000	.90[b]	39.55	.80	39.24	1.89	40.09	1.65	39.89
15,000	...	...	.64[b]	39.08	1.25	39.45	1.13[b]	39.37
20,000	...	...	...	...	1.19[b]	39.39	...	...

Output	Costs per ton for combination horizontal-vertical-flow plants							
	Plant E (VC[a] = $38.34)		Plant F (VC[a] = $38.34)		Plant G (VC[a] = $38.38)		Plant H (VC[a] = $38.25)	
	Fixed cost	Total (incl. VC)	Fixed cost	Total (incl. VC)	Fixed cost	Total (incl. VC)	Fixed cost	Total (incl. VC)
(tons)								
100	$114.69	$153.03	$111.09	$149.43	$ 75.27	$113.65	$200.46	$238.71
500	22.94	61.28	22.22	60.56	15.06	53.44	40.09	78.34
1,000	11.47	49.81	11.11	49.45	7.53	45.91	20.05	58.30
5,000	2.29	40.63	2.22	40.56	1.51	39.89	4.01	42.26
10,000	1.15	39.49	1.11	39.45	.75	39.13	2.00	40.25
15,000	.88[b]	39.22	.87[b]	39.21	.64[b]	39.02	1.34	39.59
20,000	...	...	...	...	...	...	1.33[b]	39.58

[a] Variable cost.
[b] This figure is based on maximum output capacity for five months as shown in Table 7.

Table 10. — Cost-Output Relationships for Eight Selected Illinois Bulk-Blending Plants, 1957
(Blending a 10-10-10 equivalent with plant operator and supplemental labor)

Output	Costs per ton for horizontal-flow plants				Costs per ton for vertical-flow plants			
	Plant A (VC[a] = $38.70)		Plant B (VC[a] = $38.52)		Plant C (VC[a] = $38.25)		Plant D (VC[a] = $38.32)	
	Fixed cost	Total (incl. VC)	Fixed cost	Total (incl. VC)	Fixed cost	Total (incl. VC)	Fixed cost	Total (incl. VC)
(tons)								
100	$ 64.23	$102.93	$ 81.04	$119.56	$189.27	$227.52	$165.58	$203.90
500	12.84	51.54	16.20	54.72	37.86	76.11	33.11	71.43
1,000	6.42	45.12	8.10	46.62	18.93	57.18	16.55	54.87
5,000	1.28	39.98	1.62	40.14	3.79	42.04	3.33	41.65
10,000	.64	39.34	.81	39.33	1.89	40.14	1.67	39.99
15,000	.57[b]	39.27	.57[b]	39.09	1.26	39.51	1.10	39.42
20,000	...	...	...	...	.94	39.19	1.04[b]	39.36
25,000	...	...	...	...	.75	39.00	...	...
30,000	...	...	...	...	.74[b]	38.99	...	...

Output	Costs per ton for combination horizontal-vertical-flow plants							
	Plant E (VC[a] = $38.43)		Plant F (VC[a] = $38.43)		Plant G (VC[a] = $38.49)		Plant H (VC[a] = $38.30)	
	Fixed cost	Total (incl. VC)	Fixed cost	Total (incl. VC)	Fixed cost	Total (incl. VC)	Fixed cost	Total (incl. VC)
(tons)								
100	$115.29	$153.72	$111.69	$150.12	$ 75.87	$114.36	$201.06	$239.36
500	23.06	61.49	22.34	60.77	15.17	53.66	40.21	78.51
1,000	11.53	49.96	11.17	49.60	7.59	46.06	20.11	58.41
5,000	2.31	40.74	2.23	40.66	1.52	40.01	4.02	42.32
10,000	1.15	39.58	1.12	39.55	.76	39.25	2.01	40.31
15,000	.85[b]	39.28	.78[b]	39.21	.62[b]	39.11	1.34	39.64
20,000	...	...	...	...	...	...	1.01	39.31
25,000	...	...	...	...	...	...	.97[b]	39.27
30,000	...	...	...	...	...	...	...	...

[a] Variable cost.
[b] This figure is based on maximum output capacity for five months as shown in Table 7.

Revenue

The main source of revenue to bulk blenders is the retail price of the blended product. Spreading operations offer another source of revenue, but, since costs and income of spreading are independent of those of blending, they are discussed in a separate section (page 43).

The September, 1957, retail price of 1 ton of bulk-blended fertilizer was calculated to be $48.12.[1] It includes the following charges:

Cost of raw materials	$37.18
Margin between cost and retail price of raw materials	8.09
Blending charge	2.85
Total	$48.12

The sum of the raw materials margin and the blending charge is $10.94. This amount must cover all fixed and variable costs other than raw materials. The remainder after these costs are paid is profit.

Cost of raw materials. The costs per ton of the three primary raw materials used in a 10-10-10 blend were estimated on page 22.

Margins between the cost and retail price of materials differ slightly among blending plants because of different competitive conditions and different freight rates. For Decatur plants, the costs and retail prices per ton, and the margins between them, of the three primary raw materials in 1957 were:

Material	*Cost*	*Retail price*	*Margin*
Ammonium sulfate (21% N)	$36.40	$48.00	$11.60
Triple superphosphate (46% P_2O_5)	62.92	70.00	7.08
Muriate of potash (60% K_2O)	36.82	43.00	6.18

In 1 ton of 10-10-10 the costs, retail prices, and margins were:

Material	*Cost*	*Retail price*	*Margin*
Ammonium sulfate	$17.34	$22.87	$ 5.53
Triple superphosphate	13.69	15.22	1.53
Muriate of potash	6.15	7.18	1.03
Total	$37.18	$45.27	$ 8.09

[1] This figure is based on costs of materials to bulk-blending plants in the Decatur, Illinois, area. Because materials costs change according to locality, the average retail cost of bulk-blended fertilizer for the whole state of Illinois (Table 1) is different from that used in the calculations in this bulletin.

Blending charges depend on local competitive conditions. In areas where blending plants compete only with bagged-fertilizer plants, blending charges are normally higher than in areas where blending plants compete with each other.

The method of charging for blending varies. Some plants make allowances for the number of materials included in the blend, the charge being higher for three materials than for two. Other plants have a flat charge per ton blended, regardless of the number of materials included in the blend.

In a sample of fifteen plants, the charge for blending 1 ton of 10-10-10 ranged from $2 to $5, with the average charge being $2.85 (Table 11). This average is the charge used in revenue computations in this bulletin.

Table 11. — Blending Charges of Fifteen Selected Illinois Bulk-Blending Plants, 1957

Number of plants	Method of charging for blending	Charge for blending one equivalent ton of 10-10-10
5	$2.00 per equivalent ton	$2.00
1	1.50 for blend containing 2 materials	....
	2.00 for blend containing 3 materials	2.00
1	2.50 per equivalent ton	2.50
3	1.00 per material included in the blend	3.00
2	3.00 per equivalent ton	3.00
1	4.00 per equivalent ton	4.00
1	.25 per 100 pounds of materials	4.31
1	5.00 per equivalent ton	5.00
15	Average	$2.85

Farmers tend to object to the blending charge, and many plant managers have yielded to this protest by eliminating the blending charge. However, the total price per ton of blended product is usually not lowered; to compensate for the eliminated blending charge, the margin between the cost and the retail price of raw materials is increased.

Break-even outputs

A knowledge of cost-output relationships and of sources of revenue is useful in determining at what point a plant will produce enough to furnish income adequate to cover all costs. Outputs above this break-even point would indicate a profit, and outputs below it a loss.

The break-even outputs for the eight selected plants were determined by setting the per-ton cost of blending a 10-10-10 mixture equal to the retail price per ton. The blending cost includes the price of materials. The retail price ($48.12) was based on the wholesale and retail prices of materials in effect in September, 1957.

With only the plant operator working in the plant, the break-even outputs for the eight plants were between 672 and 2,031 equivalent tons of 10-10-10 (Table 12). The lowest break-even outputs were required in the horizontal-flow plants while the highest were required in the vertical-flow plants. The days of operation necessary to produce the break-even outputs ranged from 8.49 to 17.51 days, with the horizontal-flow plants averaging the smallest number of necessary operating days and the vertical-flow plants the largest.

When supplemental labor was used in the blending plants, variable costs per unit increased only slightly, because the increase due to additional labor costs was partially compensated for by the decrease in power costs per unit. Fixed costs also increased somewhat with additional labor because of increased insurance expenses. These increases

Table 12. — Break-Even Ouputs for Eight Selected Illinois Bulk-Blending Plants, 1957

(Blending a 10-10-10 equivalent)

Plant	Plant operator		Plant operator and supplemental labor	
	Break-even output	Days of blending to reach break-even output	Break-even output	Days of blending to reach break-even output
Horizontal-flow plants	(tons)		(tons)	
Plant A	672	12.44	682	7.66
Plant B	841	8.76	844	7.74
Vertical-flow plants				
Plant C	1,902	15.72	1,918	9.84
Plant D	1,670	14.91	1,690	13.85
Combination horizontal-vertical-flow plants				
Plant E	1,173	11.85	1,189	11.43
Plant F	1,136	11.48	1,153	10.58
Plant G	773	8.49	783	8.24
Plant H	2,031	17.51	2,047	12.87

in costs were so slight that the break-even outputs were approximately the same whether or not an additional man was used (Table 12). However, the number of days of operation necessary to break even was reduced in all the plants by the addition of supplemental labor. The largest reduction in days of operation occurred in Plants A, C, and H because of the large increase in output resulting from the additional labor. Horizontal-flow plants in general still had the smallest number of necessary operating days and vertical-flow plants the largest.

Table 13. — Break-Even Outputs for Eight Selected Illinois Bulk-Blending Plants, if 1957 Retail Prices of Materials Increase or Decrease

(Plant operator and supplemental labor)

Plant	Break-even output, 10 percent increase in retail price of materials	Break-even output, 10 percent decrease in retail price of materials
Horizontal-flow plants	(tons)	(tons)
Plant A	461	1,313
Plant B	574	1,598
Vertical-flow plants		
Plant C	1,314	3,544
Plant D	1,155	3,142
Combination horizontal-vertical-flow plants		
Plant E	811	2,234
Plant F	785	2,164
Plant G	535	1,486
Plant H	1,401	3,801

A change in the retail price of materials, because of local competitive conditions, can alter considerably the cost-output-revenue relationship which determines the break-even point. To illustrate the effect of a price change on the break-even point, outputs necessary to break even were estimated for conditions under which a 10-percent decrease and a 10-percent increase in the September, 1957, prices would be in effect (Table 13). An increase in the retail price of materials would result in a decrease in the output necessary to break even. The reverse would be true with a decrease in the retail price.

In all eight plants the outputs necessary to break even were considerably below the potential outputs of the plants.

COSTS AND OUTPUTS OF THE THREE TYPES OF BULK-BLENDING PLANTS

On pages 3 through 9 of this bulletin, a description is given of three hypothetical bulk-blending plants, each representing one of the three general types of plants. Using the cost analysis in this bulletin of eight actual bulk-blending plants as a basis, it is possible to analyze the costs and outputs of each of the three typical plants (Table 14). The differences in costs and outputs among these three types can be attributed solely to the fact that they have different amounts and arrangements of equipment.

To indicate only the effect of plant type on output and costs, it was necessary to standardize operating times. For example, it was assumed that the same type of mixer would require the same mixing time in all three types of plants. Actually, in the eight plants studied, plants with identical equipment frequently had widely different operating times.

Table 14. — Comparison of Different Types of Bulk-Blending Plants[a]

	Type of plant		
	Horizontal	Combination horizontal-vertical	Vertical
Investment			
Equipment	$10,500	$22,200	$42,205
Building[b]	12,900	21,575	28,150
Land	1,500	1,500	1,500
Total	24,900	45,290	71,855
Potential daily output, tons			
One man	80	105	128
Two men	88	110	168
Potential five-month output, tons			
One man	10,400	13,650	16,640
Two men	11,440	14,300	21,840
Annual fixed costs			
One man	$ 7,381	$10,504	$14,930
Two men	7,441	10,564	14,990
Variable costs per ton			
One man	$ 38.492	$ 38.342	$ 38.220
Two men	38.593	38.435	38.280
Break-even output, tons			
One man	767	1,074	1,508
Two men	781	1,091	1,523

[a] Costs and revenues are computed on the same basis as in previous tables.
[b] Plant structures are assumed to be of frame construction (high quality) and to conform to the plant layouts shown in Figs. 4, 5, and 6.

The basic differences in costs and outputs among the three types of plants are as follows:

Vertical-flow plants have the highest building and equipment investments and the highest potential output of the three types of plants. Further, the relative increase in potential output from adding labor is greatest in this type of plant because the greater investment permits more flexibility in using labor. The break-even outputs — those necessary to cover all costs — are highest for the vertical type of plant, mainly because of the higher initial investment cost.

Costs and outputs of the horizontal-flow plants follow a pattern which is the reverse of that of vertical-flow plants. Horizontal-flow plants have the lowest investments, lowest potential output, and lowest break-even outputs of the three types of plants.

Costs and outputs of the combination horizontal-vertical-flow plants fall between those of the horizontal and vertical types.

DELIVERY AND SPREADING OF FERTILIZER

Many bulk-blending firms own and operate spreader trucks in conjunction with their blending operations. The spreading operation offers two possible kinds of revenue: (1) revenue from the spreading charge and (2) increased revenue from the blending operation due to expansion of the market area.

Equipment. The delivery and spreading equipment consists of a truck with a spreader bed. A continuous conveyor belt in the truck moves fertilizer to the rear of the spreader bed, where it is dropped on either one or two rapidly rotating spreader disks or fans. Both the speed of the conveyor belt and a sliding gate in the rear of the spreading bed control the flow of materials to the spreader fans. The sliding gate can be adjusted for a minimum of 100 pounds an acre.

A hood attached to the rear of the truck covers the spreading disks. It is built of metal and has a canvas drop which reaches to the ground. The width of the spread is controlled by the width of the hood, with most spreader trucks using a hood width equivalent to the turning radius of the truck. The width of the hood may vary from 20 to 25 feet, but a width of 24 feet seems to be preferred by many truck operators.

The spreading pattern (the distribution along the width of the hood) of the blended fertilizer varies, depending on the moisture content, condition, and texture of materials used in the blend. The spreading pattern can be regulated by changing the point at which materials

Table 15. — Variable Cost per Ton to Operate Spreader Trucks[a]
(Spreading rate = 300 pounds an acre)[b]

Size of load (tons)	Distance to point of delivery (miles)						
	3	5	10	15	20	25	30
2	2.09	2.29	2.78	3.28	3.77	4.27	4.75
3	1.99	2.13	2.47	2.82	3.16	3.51	3.85
4	1.94	2.05	2.31	2.58	2.85	3.12	3.38
5	1.91	2.00	2.23	2.45	2.67	2.90	3.13
6	1.89	1.97	2.16	2.35	2.54	2.74	2.93
7	1.88	1.85	2.12	2.29	2.47	2.64	2.81

[a] In computing variable costs in this table, labor costs were charged at $1.35 an hour, and gasoline at 30 cents a gallon.
[b] Source: Agricultural Experiment Station Special Bulletin 408, Michigan State University, June, 1956.

fall onto the spreader fans. The most uniform spreading pattern is obtained when the raw materials in the blend are all of the same particle size and density; granulated materials perform best in blends.

Fixed costs. Trucks used in spreading fertilizer range in cost from $3,000 to $3,500. A 12-foot 3-inch spreader bed with a belt feed and two spreader fans costs from $2,800 to $3,000. The common depreciation rate for both truck and spreader bed is five years, making the maximum annual depreciation cost $1,300 for each complete spreading unit. Other fixed costs are estimated at $140 a year for insurance, and $200 a year for licenses and other fees. Total annual fixed costs are $1,640, excluding storage costs. Many bulk-blending plants do not have truck storage facilities.

Variable costs include gas and oil, repairs and maintenance, tires, and labor.

Variable truck costs incurred in spreading and delivering fertilizer are related to (1) distance to point of delivery, (2) size of load, and (3) spreading rate.[1] The variable truck cost per ton decreases both as the load size increases and as the spreading rate increases; the variable truck cost per ton increases as the delivery distance increases. The combination of these relationships determines the variable cost per ton of fertilizer delivered and spread (Table 15).

Labor costs for the truck driver assume that the driver is paid only for the time actually engaged in hauling and spreading. If labor is hired by the month there must be other uses for the driver when the

[1] Sorenson, Vernon, and Hall, Carl, *Handling Fertilizer in Bulk*, Agricultural Experiment Station Special Bulletin 408, Michigan State University, June, 1956.

truck is not operating, or an extra allocation must be made for the additional labor expense incurred.

Spreading charges. Both the method of charging and the spreading charge itself vary greatly among those plants owning and operating spreader trucks. In a sample of thirteen plants, seven different methods of charging for spreading bulk-blended fertilizer were noted (Table 16).

The charge for spreading 300 pounds of 10-10-10 an acre ranged from $1.00 to $1.50, with the average charge being $1.16. A majority of the plants reported no increase in the spreading charge for increased applications an acre. These plants were willing to accept less return from the spreading operation in order to increase the sales volume of blended materials.

Expanding the market area. The main determinant in deciding whether to increase the market area is the net effect this expansion will have on spreading and blending operations. An expansion of the

Table 16. — Spreading Charges of Thirteen Selected Illinois Bulk-Blending Plants, 1957

Number of plants	Method of charging for spreading	Charge for spreading 300 pounds of 10-10-10
4	$1.00 per acre with no limitation on quantity applied	$1.00
2	1.25 per acre with no limitation on quantity applied	1.25
3	1.25 per acre for less than 700 pounds applied	1.25
	3.35 per ton for over 700 pounds applied	....
1	1.50 per acre with no limitation on quantity applied	1.50
1	1.00 per acre on unplowed ground with no limitation on quantity applied	1.00
	1.25 per acre on plowed ground with no limitation on quantity applied	1.25
1	1.25 per acre for less than 300 pounds applied	1.25
	1.50 per acre for more than 300 pounds applied	....
1	1.00 per acre for less than 400 pounds applied	1.00
	1.25 per acre for 400 to 600 pounds applied	....
	3.60 per ton for more than 600 pounds applied	....
13	Average	$1.16

market area may result in a reduction in the profit from spreading operations because of the relatively large increase in truck costs. However, expanding the market area may also result in increased revenue from blending operations. Neither the reduced spreading profit nor the increased blending revenue is of value in itself in determining whether it is worthwhile to expand the market area; rather the two must be considered jointly.

For example, Plant E might be assumed to be serving a market area with an annual demand of 1,400 tons, of which 700 are spread by the firm's spreading truck and 700 are spread by the farmers. Assuming that Plant E's truck spreads at a rate of 300 pounds an acre, at an average trip distance of 10 miles, and with an average load of 10,000 pounds (approximately 6 equivalent tons of 10-10-10), it would take between 30 and 35 full days of continuous spreading to spread 700 tons in a year. If the spreading charge were $1.00 an acre, the net income from the spreading enterprise would be $793. Based on the costs and revenues computed in the preceding analysis, the net income to Plant E from the blending operation would be $2,030. The net income from both the spreading and blending operations would be $2,823.

To increase the market area, an additional truck might be purchased. In order to obtain an additional demand of 500 tons the average trip distance is assumed to be increased to 20 miles. One result of this is that, because of the increased time each trip takes, during a 30- to 35-day period of continuous spreading, 600 instead of 700 tons a truck could be spread. The effect of the market expansion on the spreading operation would be that the profit from the spreading enterprise would be reduced from $793 to $364. However, at the same time, the income from the blending plant would increase from $2,030 to $6,878. The total net income would be $7,242, as compared with a net income of $2,823 before the market area was increased. It is evident that the reduction in blending costs per ton would be more than enough to offset the increased hauling and spreading costs per ton.

SUMMARY

The practice of local mixing of straight fertilizer materials (bulk blending) has expanded greatly in Illinois. Since the first plant was established in 1947, the number of bulk-blending plants has increased to 92. In 1956 bulk blenders distributed 27 percent and blended 18 percent of the total fertilizer materials (excluding rock phosphate) sold

in Illinois. The retail price of bulk-blended fertilizer is generally less than that of cured fertilizer containing equivalent plant food.

Based on the primary direction in which materials flow in the blending cycle, bulk-blending plants may be divided into three general types: (1) horizontal flow, (2) vertical flow, and (3) combination horizontal-vertical flow. In the horizontal-flow plant the equipment is fixed to the plant floor, while in the vertical-flow plant the equipment is placed in a tower arrangement. The combination horizontal-vertical-flow plant contains certain features of each of the other two plant types.

All bulk-blending plants require the same basic facilities: (1) land, (2) shelter for materials and equipment, and (3) equipment for storing, moving, weighing, and blending materials. In general three types of construction are used: (1) pole-supported metal siding, (2) frame, and (3) concrete block.

This bulletin reports the results of a study of eight bulk-blending plants. Buildings ranged in cost from $3,936 to $61,196, with an average cost of $25,882. Equipment costs ranged from $10,574 to $49,500, with an average cost of $25,331. The total investment (including site) for the eight plants varied from $16,536 to $102,528, with an average of $52,713.

For a comparison of costs and revenues, plant outputs were assumed to be in terms of equivalent tons of a 10-10-10 mixture.

Annual fixed costs in the plants were directly related to total investment, and ranged from $6,363 to $20,046. Variable costs per ton were related to plant type, and varied from a high of $38.65 in the horizontal-flow plants to a low of $38.20 in the vertical-flow plants, when only the plant operator was working. The variable cost per ton increased by 5 to 10 cents when additional labor was included in the plant operation.

If each operation in the blending cycle were performed successively, the blending time per ton would range from 4.3 to 11.8 minutes. By performing some of the operations simultaneously, it is possible to reduce blending time per ton, thus increasing daily output per plant. Under continuous operation the daily output varied among the plants from 89 to 195 tons when labor in addition to the operator was utilized.

Storage requirements are dependent on the daily output and in-transit delivery times for raw materials. The ratio between daily potential output and storage capacity ranged from 1:2.7 to 1:14.9. The minimum in-transit delivery time for any material was five days, creating scheduling problems in many plants.

In Illinois more than 90 percent of all blended fertilizer materials is sold during a five-month period. Assuming that the plants studied operated continuously for a five-month period, the total cost of blending (including variable and fixed costs) with two men working in the plant ranged from a high of $39.39 a ton to a low of $38.99 a ton.

The main source of revenue to bulk-blending plants is the retail price of the bulk-blended fertilizer. This price includes: (1) costs of materials, (2) margins between costs and retail prices of materials, and (3) blending charges. The September, 1957, retail price in the Decatur area was $48.12 a ton. Of this, $37.18 was the cost of materials, $8.09 was the raw materials margin, and $2.85 was the blending charge. Some plants also deliver and spread the fertilizer. This additional operation offers two kinds of revenue to the bulk-blending enterprise: (1) revenue from the spreading charge and (2) revenue due to an expanded market area. In 1957, on the basis of a 300-pound-an-acre application, spreading charges averaged $1.16 an acre spread. Profitable expansion of the market area depends on the net effect of increased delivery costs per ton and decreased fixed blending costs per ton.

Break-even outputs for the various plants were considerably lower than potential outputs. At a blend selling price of $48.12, with only the plant operator, break-even outputs ranged from 672 tons to 2,031 tons; the days of blending required to produce the break-even outputs ranged from 8.5 to 17.5. Small increases in the retail price of materials decreased break-even outputs extensively in all plants.

Standardization of process times among the three plant types permits comparisons to be made based solely on the differences in amount and arrangement of equipment within the three types of plants. These comparisons show that vertical-flow plants have the highest potential outputs as well as the highest outputs necessary to break even. Horizontal-flow plants have the lowest potential and break-even outputs, while in the combination horizontal-vertical-flow plants, the potential and break-even outputs are between those of the vertical-flow and horizontal-flow plants.

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