Supplemental Irrigation in Michigan
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Supplemental Irrigation in MICHIGAN

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TABLE OF CONTENTS

	Page
Rainfall Distribution	3
Benefits	4
Water Supply	5
Soils and Crops	6
Efficient Use	8
Frost Control	10
Small Acreages and Home Gardens	12
System Capacity	13
Pressure	14
Field Systems	14
Field Application Equipment	16
Pipe and Couplers	22
Fittings and Special Equipment	24
Pumps	28
Power Units	30
Equipment Maintenance	33
Selecting an Equipment Dealer	38
Annual Cost	38

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Supplemental Irrigation in Michigan

By E. H. Kidder *and* R. Z. Wheaton[1]

Since the term "irrigation" is often thought of only in connection with areas of extremely low rainfall, "supplemental irrigation" may need an explanation.

Supplemental irrigation is the use of irrigating systems in areas where the average monthly rainfall is usually enough for profitable farming. It is the artificial watering of fields, to furnish the moisture needed for good crop production.

It helps carry crops over the dry periods which can occur even in a normal growing season, by preventing any serious lagging of growth or early ripening. In years when the rainfall is less than normal, or comes at the wrong times, irrigation is especially helpful for the high-return, shallow-rooted crops grown on light soils.

Most likely it will not be needed every year. There will be years of higher-than-normal rainfall when little or no gain can be expected from supplemental irrigation. It is also possible to put too much water on some crops and soils, causing lower yields.

RAINFALL DISTRIBUTION

To appreciate the value of supplemental irrigation to Michigan agriculture, it is important to know certain facts concerning the distribution of rainfall throughout the state.

The average annual precipitation for Michigan varies between 25 and 36 inches; 25 inches at Lake City, in Missaukee county, and 36 inches in Branch and St. Joseph counties. The April-through-September rainfall, so important to growing crops, varies between 16 and 22 inches. Roughly, the eastern one-third of the Upper Peninsula and the northern half of the Lower Peninsula, can expect an average of 16 inches of rainfall during those "growing season" months.

An annual precipitation of 20 inches is probably enough to produce good yields of most Michigan crops — IF the precipitation occurs when it is actually needed, and IF it falls slowly enough so that none

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of it runs off. Actually, that seldom happens. In some cases, almost the entire rainfall for the month may occur in a single storm.

Rainfall records for East Lansing, Bloomingdale, Lake City, and Saginaw over 20 years, show periods of drought varying from 2 to 15 weeks. (A drought is considered to be a period of at least 2 weeks, during which less than 0.25 inches of rain falls in 24 hours.) The same records show that we can expect a dry period 4 weeks long every 2 years. During that time most of the truck crops will have used all of the water available to their roots. A dry period occurring at the time a plant has its greatest need for water usually results in a serious decrease in both quantity and quality of the harvest.

Under such conditions, many Michigan farmers are finding the investment in a supplemental irrigation system well worthwhile.

BENEFITS

There are several benefits besides better quality and more quantity which you can expect from the use of supplemental irrigation.

For example, supplemental irrigation lets a grower capitalize on higher prices during years of not enough rainfall. With irrigation, you don't need to wait for rainfall when all other conditions are at their best for planting. And with crops such as beans and sugar beets, a light irrigation a few days after a beating rain can soften the soil crust so the plants can emerge. You can always apply water during transplanting, to reduce the loss of plants.

In dry years, side-dressed fertilizer may not reach the roots without irrigation. You can also apply soluble nitrogen and potash to a crop during the growing season, through the irrigation water (Fig. 1). (See Extension Bulletin E324, "Fertilizing through Irrigation Water".) And wetting by irrigation can reduce the loss from blowing of dry muck soils and sandy soils subject to wind erosion.

Growers who have irrigation mainly for truck crops, have found another good use for their equipment — irrigating legume pastures. Research studies in Michigan, and in Illinois, indicate a higher plant population of desirable legumes in those second-year stands where irrigation has been used.

In 1957, about 5,000 acres of strawberries were protected from frost damage by the continuous application of water during frost periods in the early growing season. Other crops, such as lima beans, peppers, tomatoes, and some flowers, have been protected.

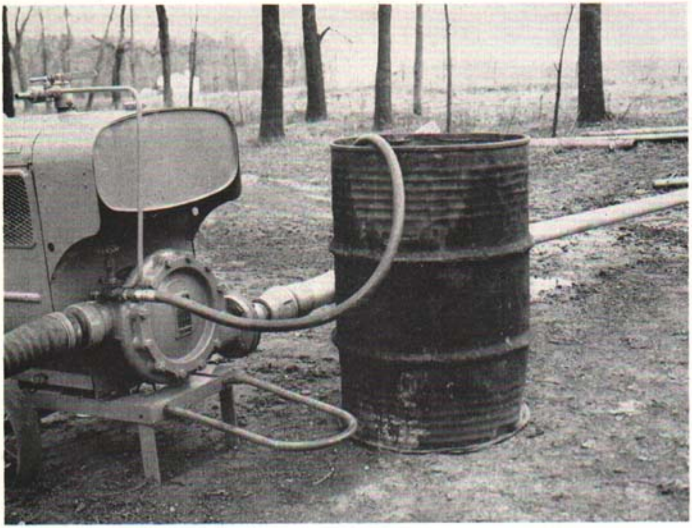

Fig. 1. Centrifugal pump drawing fertilizer solution from a drum, for application to a field through the irrigation water.

A few irrigators have paid off their systems after just 1 or 2 dry years. On the average, however, it takes several years for benefits from supplemental irrigation to pay the entire cost of the system. In the years having enough rainfall at the right times, you may not need irrigation. It is seldom possible to buy and set up irrigation equipment in time to prevent serious drouth injury to a crop which already lacks moisture.

WATER SUPPLY

Source

Rivers, streams, drainage ditches, dug out reservoirs, lakes, and wells are the most common sources of water. If several sources are available, it is best to choose the most dependable. When more than one equally good source of water is available, choose the more convenient source.

Since the Michigan laws on surface water rights are not well defined, irrigators drawing from lakes, streams, and drainage ditches face possible injunctions limiting or forbidding use of such water. Where stream flow is used, a new irrigator upstream may seriously reduce the water supply available to a downstream irrigator.

The cost of pumping is usually lower where the water is obtained from a surface supply, rather than from a deep well. When only low capacity wells are available, it may be a good idea to pump 24 hours a day into a storage reservoir for use later through a larger capacity irrigation pump and system.

You can get information on underground water supplies from the Water Section, Geological Survey Division, Michigan Department of Conservation.

Quality

Many factors can affect the quality of irrigation water. The amount of salt in it is very important, because many plants cannot tolerate salt. Brine wells are a questionable source of water for irrigation. Generally speaking, however, any drinkable water is suitable.

Some waters containing sediment and organic matter, which may not be considered drinkable, are also used. You must screen out vegetable matter which would clog applicator nozzles. Also, industrial wastes in the surface water supply may be harmful to plants.

Quantity

The amount of water available limits the area which can be satisfactorily irrigated. It takes 27,154 gallons of water to apply just 1 inch of water to 1 acre of land. To illustrate, a well or stream from which 453 gallons per minute can be pumped would supply enough water for 1 inch on 1 acre in 1 hour.

The amount of water flowing in a stream or ditch *at the driest time of the year* will determine how many acres you can irrigate directly from it. When you need more water than this amount, it is a good idea to dig a reservoir to collect water. Reservoirs are usually excavated near the stream and connected to it by an inlet channel or a pipe.

SOILS AND CROPS

Soils

You can expect a sandy soil to absorb water faster than a silt or clay soil. A soil covered with a good growth of grass or legume will absorb water faster than a bare soil because the impact of falling drops tends to seal the soil surface. Applying water faster than the soil will absorb it, can produce puddling, run-off, and soil erosion — as well as raising pumping costs.

Most soils will absorb water rapidly for several minutes, but as time goes on, they absorb water more slowly until a nearly uniform rate is reached. Experiments by the Michigan Agricultural Experiment Station have shown that on a Hillsdale sandy loam, ½ inch of water per hour caused a small amount of run-off near the end of the second hour of application. Remember that too much water (large amounts of rain following irrigation) does more damage on fine textured soils than on coarse textured, well drained soils. Water filling the soil pores for several days causes the plant to suffer from lack of air.

Crops

In general, the irrigation of high-value, shallow-rooted crops, grown on coarse-textured soils has been profitable. Field crops that are grown on light soils are being irrigated, and, in dry years, substantial increases in production have been obtained. There has generally been less increased profit on field and forage crops than on vegetables and small fruits. There is some doubt about profits from irrigating pastures.

Crops which have been irrigated in Michigan are listed in Table 1.

Irrigation will not give you sustained high yields unless you follow

TABLE 1—Irrigated crops in Michigan

Truck Crops	Small Fruits	Tree Fruits	Flowers	Field Crops	Pasture
Cabbage Carrots Cauliflower Celery Cucumbers Egg Plant Melons Onions Peas Peppers Snap Beans Spinach Squash Sweet Corn Tomatoes	Blue Berries Raspberries Strawberries	Apples Cherries Peaches Pears	All, especially bulbs	Beans Corn Mint Potatoes Sugar Beets	Alfalfa Brome Grass Ladino Clover

a good soil and water management program that furnishes enough organic matter, maintains good soil structure, and controls erosion.

Plant enough good quality seed to grow a plant population that will make the best use of water and plant food under the existing climatic conditions.

Larger plant populations with plenty of soil moisture will need more fertilizer to get high yields.

EFFICIENT USE

Effect on Farm Operations

In using supplemental irrigation you will need to revise your usual schedule of farm operations and labor distribution. Vegetative cover, soil texture, and structural conditions will determine the highest possible rate of applying water. However, the labor available and farm operation schedules may allow only a lower rate.

For example, a very porous soil may permit water to be applied at the rate of ¾ inch an hour. In this case, you could apply 1½ inches in 2 hours. However, if you must move the lateral lines as often as that, it will be difficult to do other field work.

A more convenient set up is a "chore-time" schedule of pipe moves. If the ¾ inch an hour rate were reduced to 3/10 inch an hour, it would take 5 hours to apply the 1½ inches desired.

In this way, the pumping could begin in the morning, leaving the equipment on while you do other work. At noon it would be time to move the lateral lines. Irrigation would continue in the second position for another 5 hours, until late afternoon. With another move of the lateral lines, irrigation could continue into the evening.

You could use a time switch to turn off the system automatically so no one would have to visit the motor late in the evening. Or, you can place just enough fuel in the tank to run the engine about 5 hours. When this method is used on an engine with battery ignition, you will need a switch such as an oil pressure failure safety switch to turn off the ignition after the engine has stopped.

How much water each time?

Base the amount of water to be applied at each irrigation upon the crop and the moisture-holding ability of the soil. Apply enough water to go to the depth of a majority of the roots, and no more.

For example, the bulk of strawberry roots are found within 6 to 8 inches of the soil surface. Nothing is gained by applying more water than is needed to soak down to that depth. Too much water will result in leaching of the plant food below the plant roots.

It is a good idea to set a few straight-sided, open-topped cans along the lateral lines between sprinklers, and between the lateral lines themselves, to check on just how much water is being applied. Then, by digging down in the soil after a day or 2, you can tell how far down the moisture has actually gone. Soil-moisture block readings will also help tell how deep the moisture has gone.

How often?

Crops on sandy soils will need water more often, in smaller amounts, than crops on heavier soils. Shallow-rooted plants (such as strawberries, and truck crops) will need less water each time, but will need it more often than corn and other deep-rooted crops.

Normally, you can expect that most crops need no more than about 1 to 1½ inches of water a week, *including rainfall.* Stage of growth and temperature greatly affect the plants' daily water needs. Water is needed more often when the temperature is high and winds are moderate to strong, than when the air is cool and the sky is cloudy. Under extreme conditions, some crops, such as tree fruits, field corn, and potatoes, may need as much as 2 inches of water per week.

When to Irrigate?

The moisture content of the soil in the crop-root zone should determine when to irrigate. This calls for the development of a special sense of judgment—based on experience; a knowledge of the water requirements of the crop; and the capacity of the irrigation system, in terms of how long it will take to cover all of the area to be irrigated. A general rule is to start irrigation when there is still about 50 to 60 percent of the available moisture in the upper 2/3 of the root zone. Irrigate the whole field before the available moisture supply drops to 20 percent. If the moisture supply in a soil is too low the plants, will wilt and sustain serious injury, or die—depending on how quickly water is supplied.

Portable "meters" are used with plaster-of-paris blocks buried in the soil to show the percentage of water available at the location of the block (Fig. 2). This method may not work well on sands.

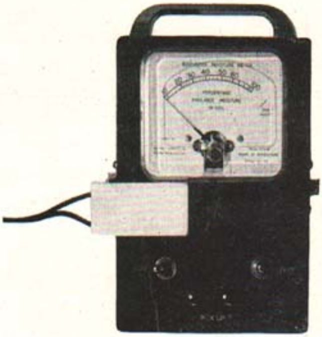

Fig. 2. Bouyoucos soil-moisture meter with plaster-of-paris block.

In the western states, the "tensiometer" has been developed to show the moisture-content of the soil. This instrument may work better in sands.

A third method often used is the "soil feel." To do this well you need to develop a sense of "feel" of the soil in relation to its water content available to the plant. An experienced irrigator takes a soil auger or spade, and digs down in the root zone. Then, by the feel of the soil at different depths, he can estimate the percentage of moisture available to the crop. A "feel chart" is illustrated by the following table (Table 2).

Topography

Sprinkler irrigation systems can be used on rolling land, and hence are well adapted to most Michigan fields. The main lines are usually run up and down the slope. It is best to keep the lateral lines level or on a slight down grade from the main. Michigan has also some large flat areas. There, a small amount of leveling may make it right for surface irrigation methods, such as "gated" pipe systems, which discharge water through gated openings into the furrows between crop rows. Some use is made of sub-irrigation in blueberry production. Water is pumped into ditches and allowed to seep into the soil to keep up a high water table.

FROST CONTROL

Growers have used overhead irrigation to prevent frost damage from temperatures as low as 20°F. Continue to apply water until all of the ice that formed during the night has melted.

The smallest rate needed to prevent damage has not yet been determined. However, tests made during a 24° frost in October 1950 showed that 0.07 inches per hour was not enough to prevent frost

TABLE 2—How to estimate moisture content by the feel of the soil

Percentage of available remaining moisture	Feel and Appearance of the Soil			
	COARSE	LIGHT	MEDIUM	HEAVY
0% (Dry)	Dry, loose, single-grained, flows through fingers	Dry, loose, flows through fingers	Powder-dry; sometimes slightly crusted but easily breaks down into powdery condition	Hard, baked, cracked; sometimes has loose crumbs on surface
50% or less (low)	Still appears to be dry; will not form a ball with pressure*	Still appears to be dry; will not form a ball*	Somewhat crumbly, but will hold together from pressure	Somewhat pliable, will ball under pressure*
50% to 100% (Good to Excellent)	Tends to stick together slightly, sometimes forms a very weak ball under pressure	Forms weak ball, breaks easily, will not slick	Forms a ball and is very pliable; slicks readily if relatively high in clay	Easily ribbons out between fingers; has a slick feeling
Above-field-capacity (Over-irrigated)	Free water appears when soil is bounced in hand	Free water will be released with kneading	Can squeeze out free water	Puddles and free water forms on surface

*Ball is formed by squeezing a handful of soil very firmly in the palm of the hand.

damage to tender young bean plants. Under most conditions, 0.10 inch per hour has been enough.

You can expect considerable waterlogging on some soils, if you must apply water for frost control several nights in a row. It might be helpful to apply more fertilizer after a frost-control period, to replace the plant food which has been leached deeper into the soil.

Some growers have made up an alarm bell system set off by a temperature switch, which is set to operate at 34° F. This switch is placed a few inches above the ground (at plant level) in the field to be protected. An electric circuit connects it to a bell in the house. Be sure there is a second switch in the house to shut off the bell, once it has awakened you.

If you do not have enough equipment to provide frost protection for all of the area normally irrigated, use what equipment you do have to the best advantage, on your most valuable crop. Irrigation equipment, as set up for normal summer operation, usually provides considerable overlap of the wetted areas of each sprinkler. You can have frost protection for a larger area when you space the sprinklers and laterals to provide a very small amount of overlap. With this arrangement, there may be a little frost damage to the plants in the center area, between the sprinkled circles. You may need more lateral lines and sprinklers to "blanket" an entire field. The water supply will also limit the area that can be covered.

For more information see Extension Bulletin E327, "Frost Protection With Sprinkler Irrigation."

SMALL ACREAGES AND HOME GARDENS

With a pressure tank and pump, you can often use the farmstead or home well for irrigating small areas. If the well is within a few feet of the area, you may be able to use a ¾-inch garden hose to carry the water to the sprinkler. When the well is located some distance away, you can avoid high pressure-loss by using 1- or 1¼-inch water pipe. Where the field is long, it is often better to run the pipe into the field, spacing outlet tees along it for connecting the garden hose and sprinkler.

Fig. 3. Garden sprinkler mounted on a sled-type base.

You can move sprinklers mounted on either sled-type (Fig. 3) or roller-type bases to new locations by pulling on the hose. Revolving low-pressure sprinklers are made for operating pressures as low as 3 pounds. You can get commercial sprinklers to operate on the pressure and amount of water actually available at the field. Conventional moderate- to high-pressure sprinklers usually do not work unless the pump can produce a higher water pressure than the 20-30 psi normally produced by most household water systems, when a moderate amount of water is being drawn off.

A pump delivering 600 gallons per hour can place 1 inch of water on 1 acre in 46 hours. That is the same as more than 9 hours of operation each day for 5 days.

If the pump will be driven by an electric motor, it is best to contact the manufacturer of the pump, or the dealer. The electric motor may not be large enough to stand continuous operation of the pump without over-heating and perhaps burning out, unless it has a temperature cutout switch. For more detailed information on pipe sizes and designs for small areas, see Extension Bulletin E320, "Irrigating Small Acreages."

SYSTEM CAPACITY

When you make plans to irrigate a field of a certain size, you need to figure how many gallons of water must be pumped each minute.

For example, a 1-inch depth of water will be applied to a 20-acre field, in 5 days of 10 pumping hours each day. Use this formula:

$$Q = \frac{453\ Ad}{FH}$$

"Q" is pump discharge in gallons per minute.
"A" is the area to be irrigated in acres.
"d" is depth of water to be applied in inches.
"F" is the number of days to irrigate the area.
"H" is the number of hours of pumping per day.

You would then find that *at least* 182 gallons of water must be pumped each minute.

$$Q = \frac{453 \times 20 \times 1}{5 \times 10} = 182 \text{ gallons per minute.}$$

Even in well-designed systems there will be some variation in the distribution of water on the field and there is a loss of water by evaporation. An allowance for efficiency should be added to the required pump discharge. Using the suggested efficiency of 75 percent, the required capacity needed is $\frac{182}{0.75}$, so the pumping rate would then be 243 gallons per minute.

PRESSURE

"Pressure" is the force needed to move the water through the pipe, and make the applicator distribute it properly. Pressure is often called pounds-per-square-inch, or "feet of head." (One pound per square inch of pressure is equal to the pressure on 1 square inch of the base of a pipe filled with 2.31 feet of water.)

A pump used for irrigation purposes must be able to deliver the needed amount of water in gallons-per-minute at the right pressure.

To find how much pressure will be needed, total the pressure requirements of the entire system in terms of "feet of head." Those requirements will be:

1. Friction loss to be overcome in the supply line and main pipe line.
2. Friction loss to be overcome in the lateral pipe line.
3. Vertical distance from the source of water to the pump, when the pump is operating.
4. Vertical distance from the level of the pump to the level of highest part of field.
5. Operating pressure of the sprinkler.

The sum of those items equals the total "pumping head." For example, in the 20-acre field cited above, your requirements might be (1) a loss of 20 feet; (2) a loss of 12 feet; (3) 10 feet; (4) 27 feet; and (5) 50 psi or 116 feet. The pumping head would then be 185 feet (80 psi). To irrigate this one field properly, you would have to have a pump that could deliver 243 gallons per minute at a pressure of 80 pounds per square inch.

FIELD SYSTEMS

Permanent

A permanent irrigation system can be installed first as a complete system, or it can be the result of step-by-step additions through a number of years. The pump, power unit, main lines, laterals—and at times the applicators—are in fixed positions. The main lines and laterals are placed underground to keep them out of the way of normal farming operations. Risers are installed at the points-of-outlet on the laterals. Application equipment, such as nozzle lines or rotary field-sprinklers, is attached to the risers.

Such a field system takes the least labor to operate. You do not need to move pipe (unless you move nozzle lines from one set of standards to another), so that the only labor needed is to move the applicators from one riser-outlet to another, and to start and stop the motor.

To have enough lateral lines to cover the entire irrigated area means buying much more equipment for a permanent system than you need for the portable type. This means that the early cost of a permanent system is relatively high. Also, the riser-outlets on the permanent lateral lines get in the way of normal farming operations.

Semi-portable or Portable

To overcome the high cost of installing a permanent system, you can install a partially or completely portable system. You can install the main distribution lines permanently with portable lateral lines. Or, the pump can be the only fixed part of the system, with all lines—main and lateral—portable.

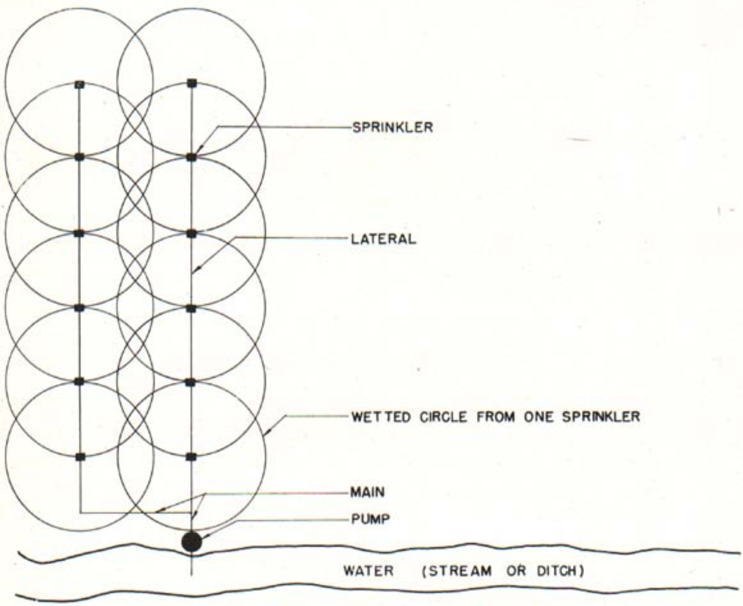

Fig. 4. Field layout for a portable system.

The simplest system, using the least equipment, consists of a portable pump and power unit—with one or two lateral lines and a short length of main. This is especially good where a water supply in a ditch or stream forms one of the boundaries of the field. (Fig. 4.).

A portable system usually costs least to buy. However, it takes more labor to operate than a more permanent system would. Many irrigators start with a minimum amount of equipment. As their operations grow, the system takes more and more labor unless they invest in more equipment to reduce labor needs.

FIELD APPLICATION EQUIPMENT

Oscillating Pipe

Nozzle lines consist of ¾-inch to 1½-inch pipe, with small brass nozzles spaced from 2 to 4 feet apart along the pipe. A water-operated motor swings the pipe back and forth, so the water falls on both sides. It operates at pressures ranging from 25 to 40 pounds per square inch, with the lines being spaced about 50 feet apart. The application rate is about 1 inch in 8 hours.

The oscillating-pipe applicator operates the same from one irrigation to the next, and takes less labor than most other systems. However, it has the same disadvantages as other permanent installations.

Perforated Pipe

Lightweight portable pipe, with small holes evenly spaced in a pattern along the pipe, gives a low-pressure method of applying water (Fig. 5.). Lines can be from 2 to 6 inches in diameter. Water under pressure of 4 to 20 pounds forces the streams upward and outward, for a distance along the ground of from 10 to 25 feet on each side of the pipe.

Place this type of equipment, operating under low pressure, along the contour of the field for most efficient distribution. The water pattern is likely to be interfered with by close-growing crops. Wind can seriously affect the water pattern. Many Michigan soils cannot take the water at the high rates of application offered by the perforated pipe, although different sizes and spacings of the holes in the pipe can provide rates of 2 inches, 1½ inches, 1 inch, and ½ inch per hour. Take care in selecting equipment; be sure the application rate will not produce a run-off on your land.

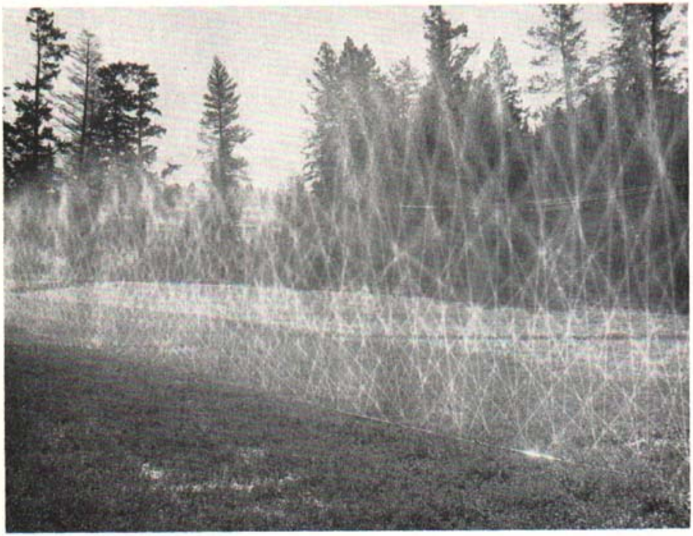

Fig. 5. Perforated pipe lateral in operation.

On the credit side, the perforated-pipe system, operating at a low pressure, needs less horsepower to run it than systems using higher pressures. A perforated-pipe system also has the advantage of being able to irrigate rectangular areas.

Rotary Sprinklers

Rotary sprinklers are most commonly used in Michigan (Fig. 6). Their rate of discharge varies from less than 2 gallons per minute for the low-pressure, single nozzle type to more than 600 gallons per minute for the high-pressure, multi-nozzle "big gun" type. In general, larger sprinklers need more pressure and have high application rates. Equipment dealers have the manufacturers' figures to help you choose the sprinkler with the right nozzle size and operating pressure for your crop and soil.

Each sprinkler applies more water close by than it applies at the outer edge of the spray pattern. To apply the water as evenly as you can, overlap the spray as shown in Fig. 7. Rectangular or square spacing of sprinkler is usually most convenient. One of the major

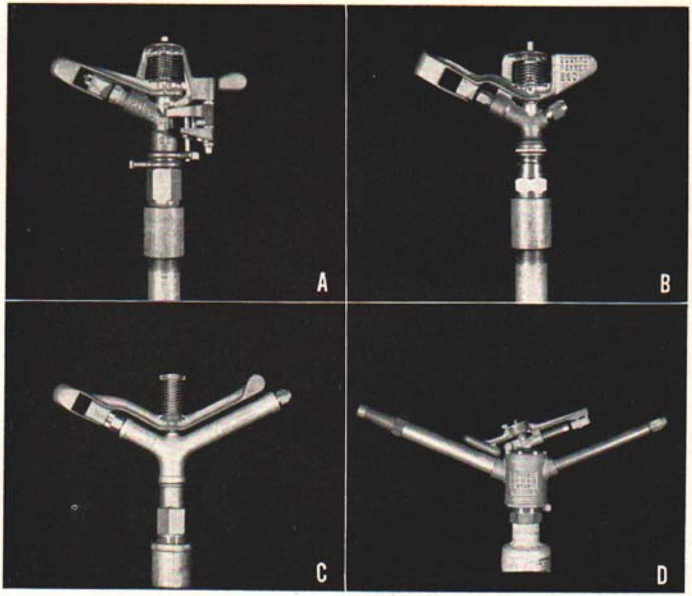

Fig. 6. Rotary irrigation sprinklers: A. Part Circle; B. Buchner sprinkler; C. Rainbird sprinkler; D. Skinner sprinkler.

sprinkler manufacturers suggests the following rule to decide on spacing intervals, under the conditions shown.

Wind Conditions	*Sprinkler Spacing on Lateral*
No wind	65% of the diameter of the circle covered by the sprinkler
Up to 6 mph	60% 〃 〃
Up to 8 mph	50% 〃 〃
Over 8 mph	22% to 30% 〃 〃

This rule applies to lateral lines at right angles to the direction of the wind. The distances you figure are the spaces between the sprinklers, along the laterals. If the wind *velocity* changes, the distance a lateral is to be moved can stay the same—but you should change the sprinkler-spacing along the laterals accordingly.

To illustrate, the layout in Fig. 7 would be correct in an 8-mile-an-hour wind. Each sprinkler throws a 60-foot circle of water, but the sprinklers are spaced along the lateral line at only 30 feet, which is 50 percent of the diameter of each circle.

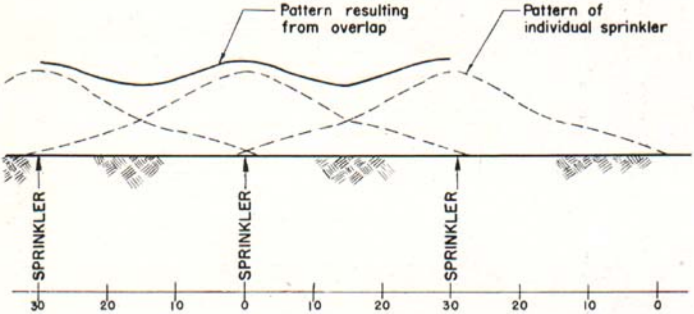

Fig. 7. Distribution of water from overlapping sprinklers.

"Big gun" sprinklers permit wider spacing of sprinklers and laterals than is suggested for smaller sprinklers. With "big gun" sprinklers, you can rapidly cover large fields and with less labor for moving pipe than you can with the smaller sprinklers. The cost of running the pumping unit will usually be higher because they need higher pressures than small sprinklers. Use them only when soil and cover condition permit rapid absorption of water.

If you apply water at a faster rate than the soil can absorb it, there can be run-off and erosion. Choose a sprinkler with a rate of water application low enough so that no water is standing on or running off the area. With heavy soils, and/or clean tilled crops, this rate of application must be quite low. Consider all possible cover and soil conditions when choosing sprinklers.

The spacing of the sprinklers along the lateral pipe, and the distance between the laterals will affect the rate of application. The table on page 20 shows the relationship between the spacing, distance of each move, the rate-of-discharge of each sprinkler, and the rate at which the water is applied to the soil (Table 3).

TABLE 3—Rates of application for irrigation sprinklers in inches of water per hour.
(Directions for use on page 21.)

SPRINKLER SPACING* (in feet)	RATE OF DISCHARGE FOR EACH SPRINKLER (in gallons per minute)																	
	1	2	3	4	5	6	8	10	12	15	18	20	25	30	35	40	45	50
20 x 20	.24	.48	.72	.96	1.20													
20 x 30	.16	.32	.48	.64	.80	.96	1.28											
20 x 40	.12	.24	.36	.48	.60	.72	.96	1.20										
30 x 30	.11	.21	.32	.43	.54	.64	.86	1.07	1.28									
30 x 40		.16	.24	.32	.40	.48	.64	.80	.96	1.20								
30 x 60		.11	.16	.21	.27	.32	.43	.53	.64	.80	.97	1.07						
40 x 40		.12	.18	.24	.30	.36	.48	.60	.72	.90	1.08	1.20						
40 x 60			.12	.16	.20	.24	.32	.40	.48	.60	.72	.80	1.00	1.20				
40 x 80				.12	.15	.18	.24	.30	.36	.45	.54	.60	.75	.90	1.05	1.20		
60 x 60				.11	.13	.16	.21	.27	.32	.40	.48	.53	.67	.80	.93	1.07	1.20	
60 x 80					.10	.12	.16	.20	.24	.30	.36	.40	.50	.60	.70	.80	.90	1.00
60 x 90						.11	.14	.18	.21	.27	.32	.36	.45	.54	.62	.71	.80	.89
80 x 80							.12	.15	.18	.23	.27	.30	.38	.45	.53	.60	.68	.75
80 x 90							.11	.13	.16	.20	.24	.27	.33	.40	.47	.53	.60	.67
80 x 100							.10	.12	.14	.18	.22	.24	.30	.36	.42	.48	.54	.60
80 x 120								.10	.12	.15	.18	.20	.25	.30	.35	.40	.45	.50
90 x 90						.07	.10	.12	.14	.18	.21	.24	.30	.36	.42	.48	.54	.60

*The first dimension stands for the distance between sprinklers along a lateral; the second, either the distance a lateral will be moved from position to position, or the distance between lateral lines.

(HOW TO USE THE CHART: Locate your sprinkler spacing dimensions in the far left column of Table 3, and the rate of discharge indicated by the gallons-per-minute headings across the top. Follow a straight line to the right from the sprinkler spacing until it crosses your correct vertical column. The figure given there is the rate of application, in inches of water an hour. Or, match any two of the three necessary factors—Sprinkler Spacing, Rate of Discharge, and Rate of Application—and read off the third.)

Examples:

(1) The sprinkler you choose discharges 12 gallons per minute, and the sprinklers will be 40 feet apart along the lateral—which will be moved 60 feet down the field with each change of position. Table 3 shows you that the rate-of-application will be 0.48 inches of water each hour.

(2) The soil will absorb water at rates up to 1 inch per hour. The sprinklers to be used are rated at 8 gallons per minute. The chart shows that when sprinklers are spaced along the lateral at 20-foot intervals, with moves of only 40 feet, the application rate is 0.96 inches per hour. A careful study of Table 3 will show how nearly you can meet any field condition by varying the sprinkler sizes and spacings.

When the spacings to be used are not shown in Table 3, you can figure the application rate with the following formula:

$$R = \frac{96.3 \times GPM}{S \times M}$$

"R" is application rate in inches per hour.

"GPM" is gallons per minute rating of the sprinkler.

"S" is distance between sprinklers on the lateral line.

"M" is the distance the lateral lines are moved (spacing between lateral settings).

For example:

A sprinkler is rated at 250 gallons per minute. The spacing of sprinklers on the lateral line will be 180 feet. The lateral lines will be moved 210 feet.

$$R = \frac{96.3 \times 250}{180 \times 210} = 0.64 \text{ inches per hour}$$

Fixed Heads

Fixed sprinkler heads that have no moving parts are available; they can apply water over a circle 15 to 25 feet in diameter. Some types are also made to cover square areas. You can use either head on lawns, or for under-tree orchard watering. The initial cost is high because they must be spaced closely. Such a system interferes with field cultivation, and should be used only on quite porous soils. The rate of application ranges from 0.7 to 3 inches of water per hour.

PIPE AND COUPLERS

Pipe

The water conveyance system consists of:

(1) A supply line from pump to the field.
(2) A main line from the supply line to the laterals.
(3) Lateral lines to carry water from the main to the applicators.
(4) A suction line to connect the water source to the pump (where needed).

The pressure loss due to friction varies with diameter and length of pipe, the quantity of water carried, and the material of which the pipe is made. Couplers, elbows, reducers, enlargements, valves, etc., all add to the overall friction loss in a pipe system.

In the supply line and the main line, the size of pipe used will be determined by comparing costs. The greater initial cost of a large size of pipe is compared to the higher operating cost with a smaller size. There must be a high discharge pressure at the pump to overcome the greater friction loss as a result of using a smaller pipe. This takes more fuel for the power unit and more maintenance.

There must be limited pressure differences along a lateral line for the applicators to apply water evenly. The American Society of Agricultural Engineers recommend that you limit pressure differences along a lateral to 20 percent of the highest pressure; even this loss may be too great in some low-pressure systems. Where several laterals are operating from the same main line, you may need to regulate the pressure at the entry end of each lateral with a control valve. This would give the correct pressure for proper operation of the applicators.

As a general rule the diameter of the suction line should be greater than or equal to the diameter of the supply line.

Aluminum

Most of the portable pipe lines used for carrying water to applicators are made of an aluminum alloy. This material is strong enough for normal operating pressure and is light enough for hand moving of portable lines. Aluminum tubing is available in standard and lightweight classes for the hand-move systems.

Aluminum pipe manufacturers, generally, do not recommend these weights of pipe for underground systems. Special coatings and thicker pipe walls are used for underground lines. Corrosion usually does not take place in Michigan when the pipe is used above ground. You may need heavier weights of pipe in the side roll, tow type, and mechanized laterals.

Steel

Steel pipe has been largely displaced by aluminum for hand-move mains and laterals because of aluminum's lighter weight. However, steel can fit any condition of pressure and quantity of flow in irrigation design. It is often used for permanent lines, and when well coated, it is good for underground use. It can also be used in side roll and mechanized laterals.

Concrete

You can use well-made concrete pipe, built to satisfy the American Society of Agricultural Engineers' recommendations, for underground, low-pressure systems. The total pressure requirements for such a system must be 10 pounds per square inch or less, thereby making it more practical for a surface irrigation system. A sprinkler system will normally require higher pressures.

Asbestos-Cement

Asbestos-cement pipe is made of a mixture of Portland cement and asbestos fibre. This pipe is used for underground main lines. Sections come 10 and 13 feet long; they are joined in the field with sleeves made of the same material and rubber ring gaskets. There are four ranges of working pressures—50, 100, 150, and 200 pounds per square inch. You can buy it in sizes ranging up to 24 inches in diameter.

Plastic

Small diameter plastic pipe is being used for sublateral and lateral lines in sprinkler irrigation. Large diameter gated pipe lines are used to carry water for surface irrigation.

Pipe Couplings

Different types of quick-coupling devices let you put together and take apart the lines quickly. They are available from equipment distributors and most often made of pressed steel or cast aluminum. Many are so much alike that you can choose yours simply by which you like best (Fig. 8).

They make use of some or all of the following good features: (1) You can couple or uncouple them when you are anywhere along the pipe; (2) There is some flexibility in the coupler to let you lay the pipe on uneven ground; (3) You can fasten a footing to the under side of the pipe coupling to prevent rolling when a riser and sprinkler are attached; (4) There is a gasket or pressure-holding device that prevents leakage at operating pressures. You can buy coupling devices of a more permanent type for main lines, which are not moved often during the irrigation season. Special couplers for tow type, side roll, and other mechanized laterals that are moved as a unit are usually more rigid.

FITTINGS AND SPECIAL EQUIPMENT

Fittings

Besides the pump and equipment mentioned, you need other fittings to complete the irrigation system. You may need some of these: (1) a debris screen around the intake; (2) a foot valve on the end of the suction line; (3) an adapter to connect the suction line to the pump; (4) a pressure gage at the pump; (5) a gate valve at the pump; (6) an adapter to connect the pump to the supply lines; (7) elbows; (8) reducers; (9) tees and crosses to connect the lateral or laterals to the main; (10) risers to connect the rotary sprinkler to the lateral. (The length of the riser depends on the height of the crop and the capacity of the sprinkler); and (11) end plugs or caps to close the ends of the main and laterals.

It is possible to shut off and move a lateral of a multi-lateral system while the rest of the system continues to operate. To do this, use valve tees instead of couplers, at points on the main line where laterals are to be attached with valve opening elbow (Fig. 9). You can dissolve soluble fertilizers in water and put them into the irrigation system with tanks, valves, pipe, and other necessary equipment.

Use reducers where it is desirable to change from a larger to a smaller size line, such as from a main to a lateral.

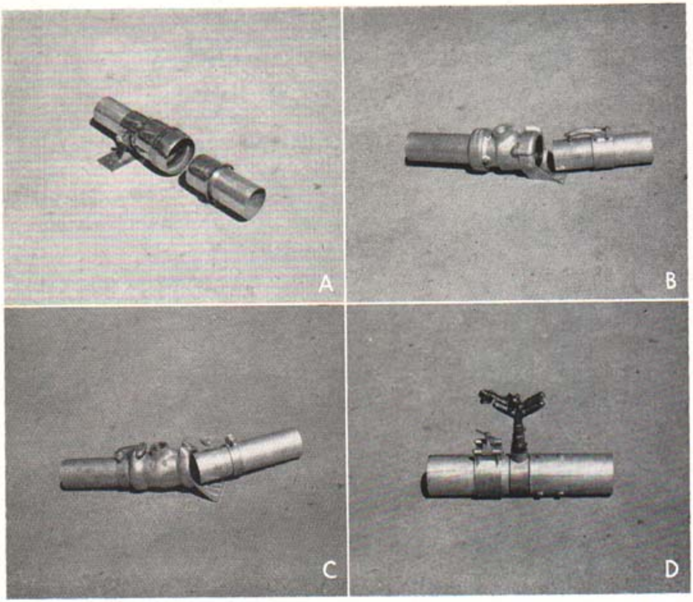

Fig. 8. Pipe couplings used in supplemental irrigation. (A) No latch lock. (B) Single latch lock. (C) Double latch lock. (D) Tractor-tow latch lock.

A Pitot tube gage can help you check the operating pressure of each sprinkler. Just insert it into the discharging stream from nozzles of each sprinkler along the lateral.

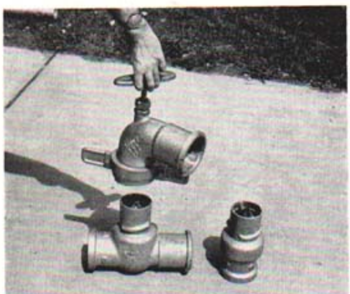

Fig. 9. (Upper left) Valve-opening elbow used for operating laterals from the main line. (Lower left) Outlet-valve tee for the main line. (Right) Outlet-valve on a riser from underground main.

Side Roll and Tow Systems

To reduce the labor needed to move lateral lines, several companies have made "tractor tow" and "side roll" laterals (Fig. 10). With a "tractor tow", one whole length of lateral line is coupled behind the tractor (Fig. 10), is "snaked" across the field and re-attached to the main line with flexible hose, and irrigation is continued.

In a "wheel move" system, wheels spaced 20 to 40 feet apart support the pipe line. The pipe serves as an axle when the system is rolled from one setting to another. A ratchet drive, with an adjustable lever, lets one man move a full 40-rod length of pipe to a new position, in normal field operation (Fig. 10). Small air cooled engines are also used, through a reduction gear and chain or belt system, to roll the lateral to its new position (Fig. 11.). The side roll and tractor tow

Fig. 10. Two types of labor-saving irrigation equipment, which simplify the moving of lateral lines. Both use flexible hose couplings for quick re-attaching to main line valves. A ratchet drive allows one man to roll a 40-rod lateral into position in the "wheel move" system. In a "tractor tow" system (inset), the entire length of the lateral is simply snaked across the field.

Fig. 11. A side roll irrigation lateral power moved by a small engine.

have another feature in that they are self-draining when pressure is released. The side roll system is limited to low-growing crops and generally uniform terrain with very few major obstructions.

Tractor tow systems of the skid type are best suited to well-sodded areas and non-abrasive soils. The tractor tow wheel-supported systems are best suited to forage crops or sodded strips between row crops.

Self-Propelled Systems

A single lateral mounted 6 to 7 feet above the ground on wheel-supported A frames rotates about a central pivot. Water is pumped into the lateral at the pivot. The supporting wheels are driven by pistons using water supplied under pressure from the lateral. The system is generally adapted to fairly level fields ranging in size from 20 to 160 acres.

Boom Type Sprinkler

A trailor-mounted, boom-type sprinkler ranging from 140 to 260 feet in diameter has been introduced and is being used in the western part of the corn belt. It is being developed further and offers promise of reducing the labor cost of irrigating.

PUMPS

After the total head for an irrigation system has been figured (See Pressure, page 14) and the total quantity of water needed has been decided upon, you must choose a pump. You can choose from several possible types, each having its own characteristics and limitations.

Centrifugal Pumps

The horizontal centrifugal pump is usually placed a short distance above the water source. Centrifugal pumps are simple in construction, occupy little space, come in a wide range of sizes, and are easy to operate and maintain. Usually some type of primer, such as the diaphragm pump or exhaust primer is needed to fill the suction line and pump housing. The "suction lift" generally should not exceed 15 feet. The pump can operate at greater lifts, but the general performance may be quite poor and it may damage the impeller of the pump.

Because of these factors, the centrifugal pump is normally used with surface supplies of water, such as lakes, ponds, streams and shallow

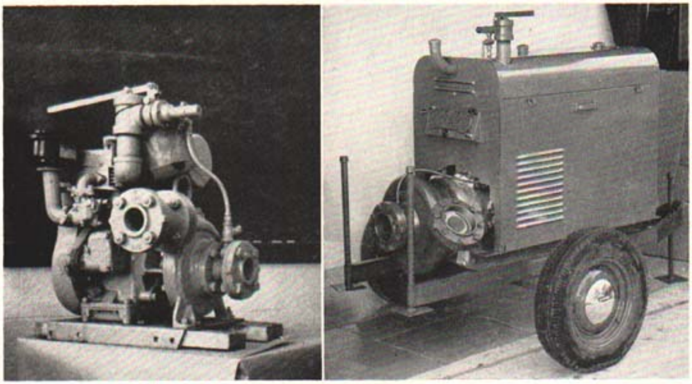

Fig. 12. Centrifugal pumps equipped with exhaust primers. Moderate capacity pump (left); high capacity (right).

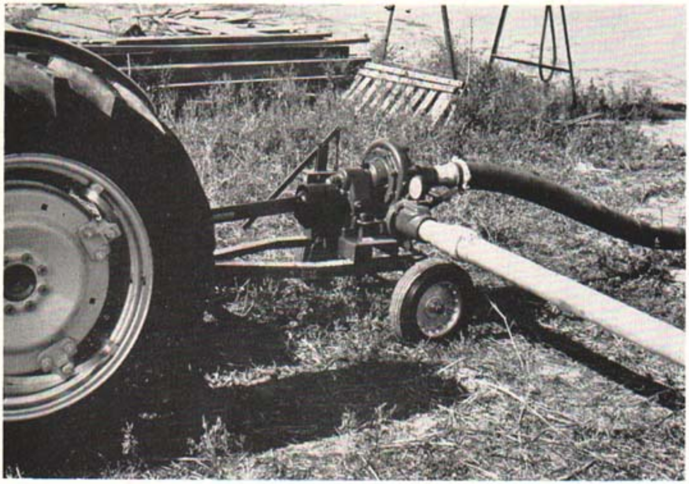

Fig. 13. A PTO pump driven by the farm tractor.

wells. If the level of water supply changes widely, you must provide some way to keep the power unit dry. Most manufacturers of pumps market close-coupled units, made up of the pump and power unit; or, the pump unit, itself with a pulley or power take-off arrangement to let some separate power unit drive the pump (Figs. 12 and 13).

Special conditions of "high-discharge head" may face the irrigator who must pump water from a supply several hundred feet below the level of his field. There are pumps available designed to meet those conditions.

Deep Well Turbine Pumps

Deep well turbine pumps are placed so that the lowest impeller stage is always in the water. The power unit, when placed above ground, is connected to the impellers by a drive shaft in the discharge column of the pump. A submersible electric motor power unit placed below and close coupled to the pump is available and is adaptable to locations where flooding occurs or where the well bore may be crooked—so that the drive shaft of a conventional turbine would not operate.

In Michigan, deep well turbine pumps for irrigation are generally found in 8- to 12-inch diameter wells. Turbine pumps are available for wells as small as 4 inches in diameter.

Other Pumps

The gear-type of pump, commonly called a "rotary pump" is generally unsatisfactory for use with water. There is too much wear in the gears, and they must be replaced often.

A piston or "reciprocating pump" will handle quite small amounts of water against rather high heads. It must have, however, some sort of pressure or surge-tank to keep flow rates constant. A "multiple-piston pump" will aid in keeping the flow uniform.

A "jet pump" is often used in farm water-supply systems. When the lift in the well exceeds 100 feet, the capacity of the jet pump drops off very rapidly. Many present installations use a ½-horsepower electric motor, with a pump capacity of about 400 to 500 gallons per hour.

POWER UNITS

Horsepower Requirements

The theoretical horsepower requirement of an irrigation system can be computed from the following formula:

$$\textit{theoretical h-p.} = \frac{\textit{gallons-per-minute} \times \textit{total head (in feet)}}{3960}$$

The power required to operate the pump, usually called brake horse power (BHP) is figured by the following formula:

$$BHP = \frac{\textit{gallons per minute} \times \textit{total head (in feet)}}{3960 \text{ x } \textit{pump efficiency (expressed as a decimal)}}$$

For example: Calculate the brake horse power for an irrigation pump to deliver 500 gallons per minute against a total head of 200 feet. The performance curve of the selected pump indicates an efficiency of 70 percent (0.70).

$$BHP = \frac{500 \text{ x } 200}{3960 \text{ x } 0.70} = 36.1$$

The power unit used must be able to produce this brake horse power continuously. For approximate design purposes with internal combustion engines, the horse power rating of the engine should be 2 to 2.5 times the theoretical horsepower. For final design, get the horsepower requirement from the characteristic performance curves provided by pump and motor manufacturers.

Gasoline Engines

The most commonly used power unit for supplemental irrigation in Michigan is the gasoline engine. It is the one which the farmer knows best how to operate and maintain. However, do not use engine maximum horsepower rating curves for field application. Such ratings are obtained under ideal conditions, with the engine operating for only a few minutes. Use ratings for continuous duty, or 75 percent of the maximum rating. In the above example where 36.1 brake horse power was needed for the pump, the engine horsepower rating at designated pump speed should be

$$\frac{36.1}{0.75} = 48.1$$

There should always be enough horsepower available to handle the load and still have a reserve at hand for extreme pumping conditions that might occur.

The method of cooling any internal-combustion engine should be carefully considered. A lower cost engine may have an air-cooled system. Such engines are generally less efficient and need repair more often than water-cooled engines.

In the water-cooled system, water in the engine cooling system normally passes through a radiator to be cooled by forced air circulation past the radiator core. Another method of cooling uses the cool discharge water of the pump to carry away heat from coils through which the engine water is circulated. This device is usually called a heat exchanger.

Gasoline engine carburetor settings and compression ratios can usually be changed to comply with the requirements of different fuels —such as natural gas or LP-gas. Be sure there is an economical supply of natural gas or LP-gas available, if you plan to use either of these fuels for the irrigation power unit.

Diesel Engines

Diesel engines have a higher initial cost than gasoline engines. Also, it will be harder to find a qualified repair or service man than for the gasoline engine. Most of the irrigation installations in Michigan are not used enough hours each year to make up for the extra cost of a Diesel engine.

Electric Motors

Reliability, compactness, high efficiency and low cost of upkeep make an electric motor very desirable for irrigation installations. Nearly all rural electrical lines in Michigan are single phase. This limits the size of motor that can be used. If you need more than 5 horse power, you may have to use a three-phase motor. Since three-phase power lines are generally not available at the farm, a line may have to be constructed—sometimes at considerable expense to the farmer.

Unlike the internal combustion engines, the electric motor can perform continuously at 100 percent of its rated horsepower. In the earlier example in which 36.1 brake horsepower was required, you could use a 36 hp motor; but, since it is not available, you would use the next larger size.

Farm Tractor

The farm tractor can be used to power the irrigation pump either by belt or through a power-take-off shaft. Using the tractor for this purpose may seriously interfere with other farm needs. Irrigation pumping means continuous, heavy-duty power output from the tractor for periods of from several hours to many days. With this constant power demand, the design power requirement of the pump for any irrigation system should not exceed 75 per cent of the available maximum belt horsepower output. See Extension Bulletin E338 "Tractor Power for Power-Take-Off-Driven Pumps," for suggestions for certain tractors.

Used Engines

Same irrigators have bought used gasoline engines for their system power plant. *Be very careful when making this choice!* The horsepower requirement for a system is based upon the amount of water to be pumped, and the total head against which the water is to be forced. This cannot be figured until *after* you have decided the acreage to be irrigated, the depth of application, and the pumping time. A supplemental irrigation system built around a power unit or pump you have already bought, usually covers less land than it should, or wastes fuel in inefficient operation.

If you are considering a used engine, be sure to study two things. First of all, check the mechanical condition of the engine. If it is in poor condition, it may need a complete overhaul. An automobile engine usually needs a larger cooling system (when operated in a stationary position) to maintain a reasonable horsepower output.

The second consideration is the manufacturer's original rating of the engine. Used automobile engines often can develop only 25 to 40 per cent of their original maximum performance rating.

Safety Devices

Since irrigation engines are often left alone for long periods of time, it is a good idea to install safety devices to shut them off when unsafe operating conditions develop, such as: (1) oil pressure drops, (2) engine overheats, (3) pump loses its prime, and (4) discharge pressure drops.

Completely shield the power-take-off shaft or belts connecting the engine to the pump.

EQUIPMENT MAINTENANCE

Keeping your irrigation equipment in good working order is highly important. A failure during a frost protection run, or a shutdown for several days during an extreme drouth period can cause complete or partial loss of crop.

Check the following parts often:

(1) Applicators
- Replace worn nozzles, weak springs, and worn bearings.
- Do not use a lubricant unless it is suggested by the manufacturer.

(2) Pipe
- Inspect coupler gaskets and replace when they are deeply checked.
- Remove sediment from around the gasket in the coupler.

- Inspect the valves and lubricate them as the manufacturer suggests.
- Flush system thoroughly after applying fertilizer.
- Inspect pipe for dents and crushed areas. You may have to replace seriously damaged pipe, or cut out the crushed section and replace it with a coupler.
- Use special trailers or racks built for the tractor when transporting pipe. Using them will speed up pipe moving as well as reduce damage to pipe, risers, and sprinklers.
- Drain all pipe lines before freezing weather. There should be a way for buried lines to drain (by gravity or pumping out).
- Store pipe above the ground on racks and cover it to keep out debris.

(3) Pumps

Horizontal Centrifugal

- Lubricate it, as suggested by the manufacturer, during the operating season.
- Have your equipment dealer inspect it and make needed repairs when it doesn't seem to be pumping well.
- Tighten packing gland and replace packing as needed.
- Drain the impeller housing of the horizontal centrifugal pump before freezing weather.
- **Seal intake and discharge openings** when not in use to keep out debris and rodent nests.

Deep Well Turbine

- Contact your pump dealer to inspect, adjust, or repair the pump when it seems to pump less than it should.
- If the deep well turbine is water lubricated, drain the water reservoir next to the pump head before freezing weather.
- If the gear head lubricant is water cooled, drain the cooling coils before freezing weather.
- Follow the manufacturer's suggestion for lubricating the gear head and pump.
- It's a good idea to check on the distance from the ground surface to the water level from time to time.

(4) Power Units

Electric Motors

- Protect electric motor power units with the right size fuses and/or safety devices. A safety switch is good, to stop the motor if the discharge pressure drops.
- Lubricate the motor according to manufacturer's suggestions.
- Check the motor for dust, dirt, debris, and rodent damage to insulation. Cover openings with hardware cloth to keep out mice and other rodents.
- Check manufacturer's recommendations for other needed maintenance, such as brushes, if used, etc.
- Unless the motor has a weather-proof case, protect it with a small building.
- Provide enough ventilation for cooling the motor.

Internal Combustion

- Internal combustion engines should have daily and other periodic maintenance as recommended by the manufacturer.
- Overhaul it during the winter season to keep the engine in top condition. This will help lessen the chance of failure during the operating season.

(5) Engine Storage

Engines, left idle during the winter, can have a much shorter life unless they are well cared for. Be sure to prepare them properly for inactive duty, and for service again after storage. Manufacturers give complete information on storing engines and starting engines that have been in storage. It takes only a few minutes to care for an engine properly. Too often the switch is turned off at the end of the season and the engine left idle until next season. Sometimes batteries are removed.

The following simple procedure is suggested for storing gasoline engines:

1. Clean the engine and accessories, including radiator and air cleaner, of all external grease, dirt, and corrosion. Use a solvent.

2. Clean out engines which have been operating on leaded gasoline. Run them on unleaded or white gasoline for at least 10 minutes

after running the leaded gasoline out of the lines and carburetor. (See item 5 below.)

3. Drain and flush the cooling system unless it has a permanent anti-freeze with non-rust additives.

4. With the engine oil hot, as at the end of a day's run, drain the oil from the crankcase. If equipped with oil filter, drain and clean, or change the element.

5. Fill the crankcase with rust-proofing oil meeting Ordnance Specification No. 2-166, and operate the engine for the non-leaded gasoline run. (See item 2 above.)

6. After the non-leaded gasoline run and with the engine running at a fast idle (about half speed), slowly start pouring a small stream of flushing oil into the carburetor intake. Gradually add more until about 1 pint is used up. Pour in the last part of the oil rapidly enough to stall or stop the engine. Shut off the ignition switch.

7. Remove spark plugs and pour (or spray) rust-proofing oil into the combustion chambers through each hole while the engine is being turned by starter or hand crank. Use 6 to 10 tablespoons of oil per cylinder to insure cylinder walls, pistons, rings, valve stems, and other parts against rust.

8. Remove valve tappet cover and spray or coat springs, tappets, and valve stems with rust-proofing oil (while turning the engine).

9. Seal all openings, such as breather, air cleaner intake openings, and exhaust with moisture proof tape or plugs.

10. Do not disturb the engine until it is needed for regular duty. Rust-proofing oil is not fluid after standing 24 hours.

11. If the engine has battery ignition, remove the battery and store it. Store batteries on a rack or bench (not on concrete) in a cool, dry place, warmer than freezing. Check at least once a month for water level and specific gravity, and keep charged to about 1.250.

12. When the engine is needed again, service it in the regular manner. Rust-proofing oil is very soluble in regular lubricating oil. Therefore, you do not need to remove any parts to remove it.

Diesel Engines

Procedures for preparing Diesel engines for storage may vary according to the certain makes. Check carefully with your dealer or manufacturer.

Some Diesel makers recommend using rust-proofing oil the same way it is used in a gasoline engine. By this method, the combustion chambers, piston tops, fuel pump, injectors, governor, etc., are protected against corrosion.

Other makers of Diesels recommend pouring a small quantity of lubricating oil through the injection valve openings each month, then turning the engine a few turns each week to distribute the oil. Set the engine in the **start** position or the compression of oil into the small space might damage the engine.

Starting Gasoline Engines That Have Not Been Properly Placed In Storage

It often happens that an engine is left idle which did not get serviced for storage. An engine which has remained idle for a few weeks will probably have dry cylinder walls and starting it will cause damage —if it will start.

- Remove the spark plugs and pour or spray in each cylinder 2 tablespoons of a mixture of one-half gasoline and one-half light lubricating oil.
- Remove the valve cover and flush the valve mechanism with the same mixture.
- Crank the engine rapidly to blow the excess oil out the spark plug holes.
- Drain the crankcase and flush with kerosene or flushing oil. Refill with lubricating oil. Service the oil filter and replace the element.
- Service the rest of the engine for fuel, cooling solution, grease, etc.
- Clean the air cleaner and service it as needed.
- Clean the spark plugs, adjust gaps and install them.
- Start the engine and let it run slowly. Notice if any valves are sticking; if so, pour a little kerosene on the valve stem until it is loose. Replace valve cover.
- Gum will form in fuel tanks, lines and carburetor if the engine is not used. Gum can be dissolved with acetone or a 50-50 mixture of alcohol and benzol.

SELECTING AN EQUIPMENT DEALER

Many technical factors of a hydraulic nature go into the design of an efficient irrigation system for your farm. Because of these factors, it is nearly impossible to buy a packaged system of one general design that will do the job. In most cases it is best not to try to design your own system.

Any reputable irrigation equipment dealer should provide engineering service for planning an irrigation installation. The dealer should stock a supply of replacement parts and fixtures.

When the irrigation system is designed by and purchased from one dealer, he should take responsibility for its performance. He should also advise you on operating and maintaining the system.

If the irrigator plans his own system, or buys his equipment from several different dealers, obviously, he must take the responsibility for overall performance himself.

ANNUAL COSTS

Increased yields produced by supplemental irrigation should be enough to cover the investment in equipment, the operating costs and repairs, and a fair profit for the owner. You can divide the cost of irrigating into fixed costs and variable costs.

Fixed Costs

Take 10 to 15 years as an average life for the equipment when figuring depreciation. You might use an itemized list of annual fixed costs such as the following:

Depreciation	7.5 to 10 percent
Interest on total investment	2½ percent*
Repair	1 percent

The total annual fixed-cost of irrigation equipment is 11 to 13.5 percent of the first cost.

Variable Costs

Every irrigation installation requires a specific size of engine, and has a minimum labor requirement. Such variable costs must be determined in each individual case.

*Interest charge at 5 percent on one-half of the investment.

However, you can use the following rates for a guide in figuring these variable costs:

Gasoline—0.1 gallon per horsepower-hour

Oil—crankcase capacity, plus 1 quart every 10 operating-hours; oil change every 100 hours

Labor—1 to 1¾ man-hours per acre per irrigation.

Total Cost

Study of a number of systems shows a total cost of $3.50 to $10.00 each year per acre-inch of water applied. The cost of water application must be near $3.50 per acre-inch if the irrigation of forage and corn is to be profitable. High return crops, such as strawberries and truck crops, can use more expensive water and still be profitable. For more complete information on costs see Michigan Agricultural Experiment Station Quarterly Bulletin Article No. 39-19, "The Economics of Irrigating in Michigan."

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