TEXAS AGRICULTURAL EXPERIMENT STATION
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letin 745 February 1952

Cost of Water for Irrigation on the High Plains

in cooperation with the
UNITED STATES DEPARTMENT OF AGRICULTURE

The TEXAS AGRICULTURAL AND MECHANICAL COLLEGE SYSTEM
GIBB GILCHRIST, Chancellor

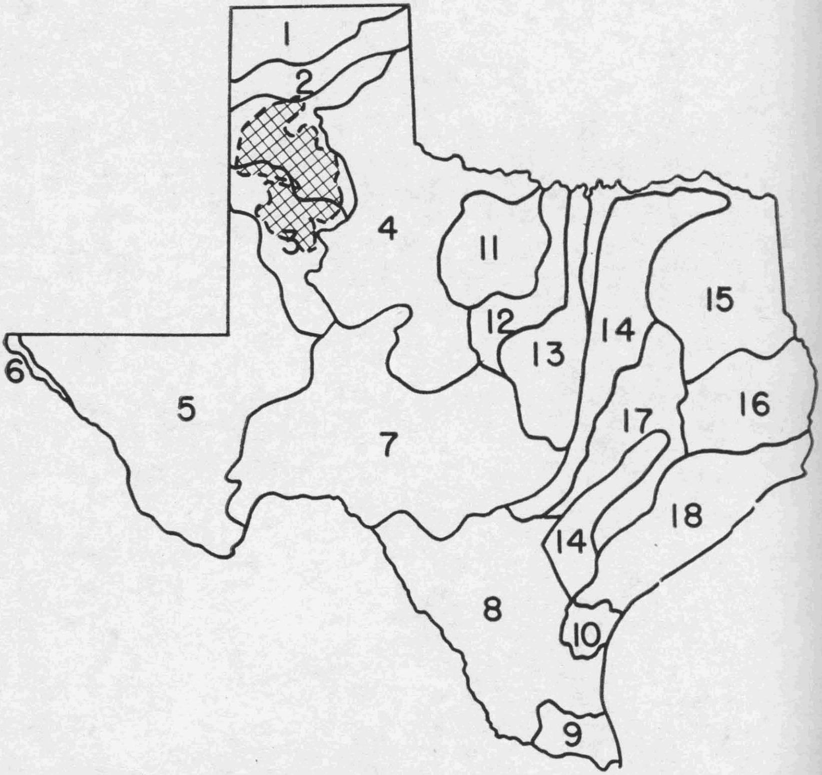

Figure 1. The shaded area shows the approximate boundary of the High Plains irrigated from wells. From Progress Report No. 7, Texas Board of Water Engineers, March 1949.

DIGEST

Approximately 1,860,000 acres of the Texas High Plains were irrigated from about 14,000 wells in 1950. All but a very small part of this irrigation development has taken place since 1934, with the greatest expansion occurring since World War II. Drilling of wells continued at a rapid rate during 1951.

Such a rapid expansion of irrigation has caused many questions to be raised as to the costs of pumping irrigation water. This bulletin reports data concerning pumping costs gained during 1947, 1948 and 1949 in a study of a yearly average of 176 wells in Lubbock, Hockley, Hale, Floyd and Swisher counties. Included are the costs for installation and for operation.

During this study, the cost of developing and equipping a new irrigation well in this area usually ranged between $4,000 and $5,000. The average cost varied with the size and type of motor used and may be broken down as follows:

	Cost of motor	Total cost
Drilling, casing and spillway	$1,272	
Pump	2,155	
Power unit of which the common types are:		
Electric motor	$ 720	$4,147
Auto engines rated 100 h.p. or less	485	3,912
Auto engines rated more than 100 h.p.	782	4,209
Industrial engines	1,320	4,747

An average of 126 acre-feet of water was pumped per well each year of the study. The average cost per acre-foot of water pumped by the type of power and kind of fuel used was as follows for pumping plants operated with:

Electric motors	$6.58
Auto engines rated 100 h.p. or less:	
Using butane	7.53
Using gasoline	8.70
Using natural gas	5.15
Auto engines rated more than 100 h.p.:	
Using butane	8.46
Using gasoline	9.85
Using natural gas	5.94
Industrial engines:	
Using butane	8.77
Using gasoline	9.13

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BULLETIN 745 FEBRUARY 1952

COST OF WATER FOR IRRIGATION ON THE HIGH PLAINS

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IRRIGATION HAS BECOME an important factor in crop production on the High Plains of Texas.

According to reports issued by the State Board of Water Engineers, only minor irrigation development took place on the High Plains during the first 25 years after the first well was drilled in 1911. Only 300 wells and 35,000 acres of irrigated land were reported in 1934. By 1940, the number of irrigated wells had increased to 2,180 and the acreage irrigated to 250,000. At the end of World War II in 1945, the number of wells had increased to 4,300 and the acres irrigated to 550,000. Wells reported for 1950 numbered approximately 14,000, with 1,860,000 acres irrigated. Drilling of wells continued at a rapid rate during 1951.

Figure 1 shows the area in which irrigation wells are concentrated.

The rapid shift from dryland to irrigation farming has caused farmers of this area to raise many questions as to the cost of pumping irrigation water, the water needs of various crops, production and production requirements and practices with irrigated crops, and adjustments in farm organization that facilitate the best use of ground water resources. To assist in answering such questions, a study of all phases of the organization and management of farms as affected by the use of irrigation water was made during the 3-year period 1947-49. In making this study, the cooperation of 150 to 190 farmers with irrigation wells was obtained each year.

Pumping costs are reported for an average of 176 wells during 1947-49. The wells studied are in Lubbock, Hockley, Hale, Floyd and Swisher counties and are about equally divided between the sandy loam soils and the clay and clay loam soils.

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PERFORMANCE OF WELLS

Measurements of pumping lift, static water level and the well yield were obtained each year for a large number of wells. Measurements of the static or undisturbed water level were made by personnel of the U. S. Geological Survey during the winter or early spring and before the pumping season started. After pumping was underway, the water level while pumping and the well yield were measured. Pumping levels were measured from the water surface, while the pump was in operation, to a fixed point—usually the pump base. This measurement is easily obtained and closely approximates the pumping lift.

The pumping lift increases during long periods of heavy pumping. An effort was made in this study to measure each well during a time of general pumping when measurements are more representative of seasonal water levels and yield rates.

A summary of the pumping level measurements is shown in Table 1. The range in pumping level was from approximately 42 to 194.5 feet. However, only a few of the wells were near either of these extremes. Water was pumped between 75 and 150 feet in approximately 88 percent of the wells. Nearly 70 percent of the pumping levels measured were over 100 feet.

Table 1. Measurements of water level while pumping, 1947-49

Item	Wells grouped according to water level while pumping					
	75 ft. or less	75.01 to 100 ft.	100.01 to 125 ft.	125.01 to 150 ft.	150.01 ft. and over	All wells
No. wells measured	9	45	78	33	13	178
Percent of total	5.1	25.3	43.8	18.5	7.3	100
Water level while pumping (group average) feet	65	88	114	136	162	112

The yield of a well is measured in terms of the gallons of water pumped per minute and is referred to as G.P.M. Such measurements usually were made with a portable flow meter attached to the discharge pipe. In a few cases a current meter was used to measure the amount of water being pumped. When making well measurements, each pump was run at its normal operating speed. With few exceptions, measurements were made after several hours of continuous pumping. Thus, yield rates were obtained under conditions of normal operation and are considered representative of the pumping season for that year. Yield measurements for the 3 years of the study are summarized in Table 2. Yield rates for individual wells ranged from a little under 250 to nearly

1,400 G.P.M. In general, there was relatively little variation in the yield for a particular well from year to year.

Data for the wells studied were divided into four groups according to G.P.M. When grouped as in Table 2, 80 percent of the wells were in the two groups that yielded from 501 to 1,000 G.P.M. The 3-year average for all wells was 739 G.P.M.

Wide differences in the rate of yield and in hours of plant operation resulted in large differences in the acre-feet of water pumped per year, Table 2. For instance, in 1947, with a medium amount of pumping, an average of 197 acre-feet of water was pumped from the wells yielding more than 1,000 G.P.M. This was nearly three times the amount pumped the same year from wells discharging 500 G.P.M. or less. A similar situation occurred during the other years of the study.

During a season of low rainfall, there is a marked tendency for heavy pumping of all wells, and most wells are pumped a relatively small number of hours during a season of high rainfall. Consequently, wide differences in hours of pumping may occur, particularly between years.

Table 2. Summary of yield measurements, 1947-49

Item	Grouping of wells based on measured discharge in gallons per minute					Hours pumped, average all wells
	500 and less	501 to 750	751 to 1,000	1,001 and over	All wells	
No. wells measured	20	75	68	13	176	
Yield-average 3-year period (G.P.M.)	395	647	861	1,148	739	
Acre-feet pumped:						
1947	67	110	145	197	121	925
1948	89	148	198	262	168	1,245
1949	47	75	100	132	89	625
Average	70	112	144	190	126	930

COST OF WELLS

Irrigation wells were drilled by either rotary rigs or cable-tool rigs. Drilling cost was based on a per-foot charge for the depth to which a well was drilled. This charge varied with changes in the general price level and with the influence of other factors. Wells established during the 1930's cost considerably less than those drilled later.

When drilling was completed, the usual practice was to install perforated steel casing. Most of the casing was 16 inches in diameter, although smaller sizes were sometimes used. In some instances, casing was installed the entire depth of the well. However, in most wells the casing lacked a few feet of reaching the bottom. Casing was priced by the foot and could be purchased in odd lengths as needed.

Most wells are equipped with a concrete spillway to receive water as it is discharged from the well. The power unit usually was mounted on the spillway. About one-fourth of the cooperating farmers had a small, inexpensive house over the well and power unit.

Installation costs for 55 new wells established during 1947-49 are shown in Table 3. Wells established prior to 1947 were developed at a much lower cost. The data shown are more nearly representative of current costs of installation.

The cost of drilling and for casing varies with the depth of the well. In general, wells in the same locality are drilled to about the same depth. There is, however, considerable variation in the depth of wells located in different parts of the High Plains. Table 3 gives the average of the wells studied.

Drilling costs in 1948 were higher than in the other 2 years. On the other hand, the cost of casing increased during each year of the study. For the 3-year period, the average expense of drilling and casing a well plus the cost of a spillway amounted to $1,272. The addition of a well house would increase the average cost about $150.

Table 3. Costs of irrigation wells, 1947-49

Item	Year			
	1947	1948	1949	Average
No. of wells	25	20	10	18
Depth drilled—feet	212	215	173	206
Drilling cost—dollars per ft.	2.53	3.01	2.80	2.75
Total drilling cost—average dollars per well	536	647	484	566
Depth cased—feet	203	207	173	199
Cost of steel casing[1]—dollars per ft.	2.92	3.57	3.62	3.28
Casing cost—dollars per well (installed)	593	739	626	653
Spillway cost—dollars per well	54	58	43	53
Total cost for drilling, casing and spillway—dollars per well	1,183	1,444	1,153	1,272

[1]Includes cost of perforations and welding.

COST OF PUMPS

Numerous makes of pumps are used but all are multi-stage deep-well turbine types. Water is lifted by turbine centrifugal action of a series of impellers enclosed within their respective bowls. Each bowl is commonly referred to as a stage. The number of stages needed for a particular well depends on the impeller design, the G.P.M. pumped and on the lift. About 50 percent were three-stage pumps and the remainder were about equally divided between two and four-stage installations. Only one of the wells studied was equipped with a five-stage pump. Twelve-inch bowls were the predominating size. The depth at which pumps were set ranged from 68 feet to 220 feet, and 10 to 20 feet of suction pipe extended below the pump setting. A few of the pumps used on the High Plains are 6-inch and a few are 10-inch size but most of those in use are 8-inch pumps.

A summary of the cost of new pumps purchased during 1947, 1948 and 1949 is shown in Table 4.

Table 4. Costs for irrigation pumps, 1947-49

Item	Year			
	1947	1948	1949	Average
No. of pumps	25	20	10	18
Depth pump setting—feet	136	144	141	140
No. of stages—average	3	3	3	3
Cost per pump—dollars	2,035	2,248	2,279	2,155

Irrigation pumps were very much in demand during the period of the study. In practically all cases, the new pump was purchased before the well driller started to work. Under these conditions, there was little opportunity to buy the size of pump best suited to the lift and the yield of the well that was later developed. Although no efficiency tests were made, it seems evident from this study that numerous pumps now in use were not designed to give maximum efficiency under present operating conditions.

The cost of new pumps purchased ranged from less than $2,000 to $2,800, and averaged $2,155 for the 55 pumps.

COST OF PUMP POWER UNITS

Irrigation pumps are powered by electric motors and internal combustion engines. In this study, the latter group was further sub-divided into automobile engines and industrial engines.

An average of 28 wells on cooperating farms were pumped with electricity. Most of the motors were either 30 or 40 h.p. (horsepower) size. However, a few larger electric motors were in use. Electric motors require very little attention, run at a steady speed, seldom need repairs and seldom break down. Some operators state that an electric motor cannot be slowed down to keep a weak well from breaking suction. Also, electric motors are likely to "cut out" during an electrical storm. A failure in power during the pumping season may stop pumping at a time crops need irrigation and result in loss of production.

An average of 144 of the wells studied were powered with an automobile or truck engine of one kind or another.

During the period that irrigation was being rapidly expanded, automobile engines were available and were relatively cheap. These were high-speed engines. In many cases, the gear ratio between the pump and the engine was 1 to 1, which indicates that the engine and the pump run at the same speed. Recommendations for most pumps are that they be run at 1,760 r.p.m. (revolutions per minute). With a 1 to 1 gear ratio, 1,760 r.p.m. also would be the normal engine speed. However, some use a 1 to 1.1 or 1 to 1.2 gear ratio. In such cases, the engine is speeded up to run at 1,900 to 2,100 r.p.m. to get the desired pump speed.

Automobile engines vary greatly in horsepower but, for the purpose of this study, all such engines were divided into two groups. Engines rated at 100 h.p. or less were included in the first group. Ford and Chevrolet are typical of the engines in this class. An average of 58 power units were in this group. This power unit is commonly used for wells of relatively shallow lift or of low to medium yields. These small automobile engines are seldom used for wells that yield as much as 1,000 gallons per minute.

Automobile or truck engines rated at more than 100 h.p. are included in the second group. An average of 86 power units are in this grouping. Although the larger automotive

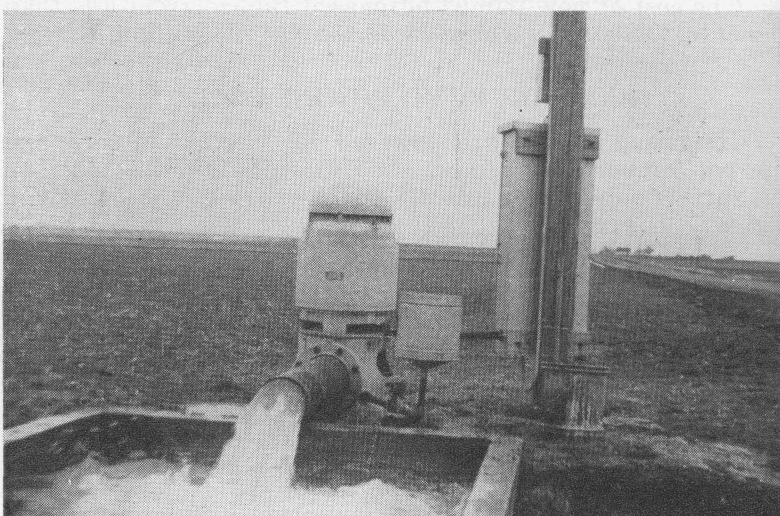

Figure 2. A pump installation equipped with an electric motor for pumping irrigation water. Most of the motors used were either 30 or 40 horsepower size.

engines were used under a wide variety of conditions, they were used mostly with wells of greater-than-average lift or with those of greater-than-average rate of yield.

The present trend seems to be away from the small automobile engines and toward more powerful units. Many farmers wish to have a greater reserve of power than is available with the small automotive engines. The necessity for lowering the pump setting on many wells has increased the demand for the large type engines. Also, some of the companies that made 85 to 100 h.p. engines are now manufacturing engines with a higher horsepower rating.

Another power unit frequently used is the industrial engine. Cooperating farmers used an average of 20 such units during each year of the study. These engines run slower than do automobile engines and are capable of developing a large amount of power. Most industrial engines run at 1,300 to 1,400 r.p.m. and are geared to operate the pump at about 1,760 r.p.m. They are suitable for pumping wells with either a high yield rate or a large lift, or both.

A few wells on the High Plains are equipped with Diesel engines. However, there are so few Diesels in operation that the data obtained were inadequate for comparative purposes and are not included.

Three kinds of fuel—butane, gasoline and natural gas—were used with automobile and industrial engines. The use of natural gas is limited to a few wells that are relatively close to a gas line. The high cost of pipe limits laying a line to a relatively short distance. Butane was used more extensively than gasoline.

Dealers deliver butane or gasoline to the irrigation well as needed. Gasoline is ordinarily used from barrels. However, the farmer needs storage for several days' supply of butane, and storage tanks of 500 to 1,000-gallon capacity are usually purchased.

Tables 8, 9 and 10 give the number of engines of each type and the number using the different kinds of fuel.

A total of 178 new power units were purchased by cooperating farmers while the study was in progress. Cost data obtained for these power units are shown in Table 5. Fifty-five of these were for newly developed wells and the remainder were to replace power units for wells already in use. An average of 7 industrial engines were bought each year and were the most expensive of those purchased. More than half of all the units purchased were automobile engines with a horsepower rating greater than 100. The purchase price averaged about 60 percent of that of an industrial engine. The average electric motor cost a few dollars less than the large automobile engine. The least expensive power unit was the small auto engine.

Cooperating farmers paid an average of approximately $275 for a tank in which to store butane. It is also necessary to have a special carburetor or to equip the engine with a conversion unit to use butane or natural gas.

Table 5. Costs for power units commonly used in pumping irrigation wells, 1947-49

Item		Year			
		1947	1948	1949	Average
No. new power units purchased:					
Electric		5	11	6	7
Automobile:					
Rated 100 h.p. or less		18	8	5	10
Rated more than 100 h.p.		41	41	23	35
Industrial		7	3	10	7
Average cost:					
Electric	(Dollars)	729	693	764	720
Automobile:					
Rated 100 h.p. or less	(Do.)	468	490	540	485
Rated more than 100 h.p.	(Do.)	792	778	771	782
Industrial	(Do.)	1,114	1,373	1,447	1,320
No. fuel tanks purchased for engines using butane		13	8	7	9
Cost fuel tanks	(Do.)	288	274	253	276

Farmers who use natural gas also have to provide the line for piping gas to the well. Among cooperating farmers, the amount of pipe needed for this purpose varied from a few to a few hundred feet. Pipe for the gas line cost an average of 38 cents per foot and the welding necessary to install the line averaged about 5 cents per foot of pipe. Power unit costs shown in Table 5 do not include the cost of pipe for those units that use natural gas. This is not an important item when only a small amount of pipe is used, as was the case on most cooperating farms.

ANNUAL OVERHEAD COSTS

The chief items of overhead costs were depreciation, interest and taxes. Depreciation and interest were calculated from the investment. Data concerning the investment in the different items making up the irrigation plant are summarized in Table 6. On the farms studied, the investment ranged from an average of $3,900 for a plant equipped with a small automobile engine to $4,750 for a similar plant operated with an industrial engine. The outlay for the pump amounted to from 45 to 55 percent of the total investment. Differences in the power unit selected accounted for a large part of the variation in investment between newly installed irrigation systems.

Depreciation varied with the different items of equipment, Table 6. The amount of depreciation for each item was calculated on the basis of the years of service it was expected to give. Information for early installations indicates that a well, including the casing, will be serviceable for about 25 years. An irrigation pump can be expected to last about 14 to 15 years with normal repairs. Cooperating farmers reported that electric motors gave the longest period of service —an average of between 14 and 15 years. Combustion engines normally have to be replaced after 6 to 8 years of service. As a general rule, industrial engines will last a little longer than automobile engines.

In this study, interest is calculated at 5 percent of a depreciated value, or 2.5 percent of the cost new. Stated differently, the average investment in the irrigation system over the lifetime of the plant would be only half of the initial cost.

Even though there are a few exceptions, taxes are ordinarily increased as a result of irrigation farming. An irrigation system is treated as an improvement in assessing taxes. In calculating state and county taxes, a common practice is to increase the farm valuation by $500 for each irrigation well. For school tax purposes, such an improvement is valued at about $750. Due to variations in tax rates, the amount of taxes paid per well differs from county to county and from one school district to another.

Table 6. Overhead costs for the well, pump and four commonly used power units, 1947-49

Item	Investment	Percent depreciation	Depreciation cost	Interest cost	Total overhead cost
Well[1]	$1,272	4	$ 50.88	$ 31.80	$ 82.68
Pump	2,155	7	150.85	53.87	204.72
Power unit:					
Electric motor	720	7	50.40	18.00	68.40
Automobile engine:					
100 h.p. or less	485	15	72.75	12.13	84.88
More than 100 h.p.	782	15	117.30	19.55	136.85
Industrial engine	1,320	13	171.60	33.00	204.60
Taxes—entire system					17.00
Total per irrigation system with:					
Electric motor	4,147		252.13	103.67	372.80
Auto engine:					
100 h.p. or less	3,912		274.48	97.80	389.28
More than 100 h.p.	4,209		319.03	105.22	441.25
Industrial engine	4,747		373.33	118.67	509.00

[1]Includes cost of drilling, casing and spillway.

On the farms studied, the increase in farm taxes resulting from irrigation averaged approximately $17 per well.

On an average, the lowest overhead cost was among pumping installations equipped with electric motors. However, the overhead cost for such an installation was only a few dollars less than for one run by an automobile engine of 100 h.p. or less. The relatively large investment and high rate of depreciation for industrial engines resulted in a comparatively high overhead cost.

A fuel tank and a special carburetor for engines operated with butane will add approximately $20 to the annual overhead cost of the irrigation system.

ANNUAL OPERATING COSTS

Operating costs include fuel or energy, lubricants of various kinds, repairs of both the power unit and the pump and the labor used in servicing the pumping plant. The operating cost of an individual well or of a group of wells varies greatly from year to year as the amount of pumping varies.

High Plains irrigation farmers state they did an average amount of pumping in 1947. Heavy pumping was done in 1948, and was followed by a light season's pumping in 1949.

During each year of the study, operating costs were obtained for an average of 176 irrigation plants. Detailed records were obtained on both the quantities of fuel, lubricants and similar materials used, and on the unit price and the cost. The amounts of turbine and gear-head oil used with the pump in 1948 and 1949 and its cost were kept separate from the engine lubricants. Repair expenses for each engine and each pump were included. Also included was a record of the hours each well was pumped during the year. In addition, information was obtained as to the number of hours the operator spent servicing each pumping plant. A charge of 75 cents per hour was made for the time used in calculating operating costs.

Cost information for each type of power unit was grouped separately in making an analysis of the data obtained. Summaries are shown in Tables 7, 8, 9 and 10. Cost data for combustion engines were further sub-divided within these tables according to the fuel used. In each instance, the average operating cost per hour of plant operation was shown.

The type of power or the kind of fuel has little or no effect on pump repairs. A pump may be run several years before major repairs are necessary. But any repairs that involve pulling the pump are expensive to make. Over a period of years, the amount of pump repairs depends on the hours of pumping.

Electric Motors

Electric rates were not uniform among farmers with irrigation wells. The rate per kilowatt hour (K.W.H.) varied from 1.25 to 1.5 cents. The average rate paid by cooperating farmers was 1.33 cents per K.W.H. A farmer paid a minimum annual charge for electricity whether or not the current was used. Consequently, the hourly cost for pumping went up when less than the minimum amount of current was used during a pumping season.

Table 7. Operating costs for irrigation pumping plants with electric motors, 1947-49

Item		1947		1948		1949		Average	
No. studied		37		20		26		28	
No. hours pumped during year		1,009		1,457		646		1,037	
		Amt.	Cost	Amt.	Cost	Amt.	Cost	Amt.	Cost
Electricity—total per motor	(K.W.H.)	30,085	$401.97	43,938	$586.35	25,700	$344.13	33,241	$444.15
Lubricants:									
Oil	(Gal.)	3.9	2.68	.6	.63	.1	.12	1.5	1.15
Grease	(Lbs.)	.2	.02	.1	.02	.7	.06	.3	.03
Total fuel, oil and grease			404.67		587.00		344.31		445.33
Motor repairs			2.03		1.05		3.50		2.19
Pump lubricants:[1]									
Turbine oil	(Gal.)			4.9	3.57	6.0	4.03	5.4	3.80
Pump repairs			50.45		72.85		32.20		51.85
Labor[2]	(Hours)	5	3.75	7	5.25	4	3.00	5	3.75
Total cost per well			460.90		669.72		387.04		506.92
Total cost per hour pumped			.46		.46		.60		.49

[1]Included in motor lubricants in 1947.
[2]Servicing pump plant.

Data for the electric motors included in the study are grouped together in the summary of operating costs shown in Table 7. With this type of power, electricity and pump repairs are the only large cost items for pump plant operation and make up 98 percent of the average operating costs. Electric motors seldom require attention and may run several seasons before repairs are necessary. Consequently, repair costs are relatively small. Also, very little of the operator's time is needed for servicing the pump plant. Electric motors operate with only small quantities of lubricants.

With medium to heavy pumping, as was common during 1947 and 1948, hourly operating costs averaged 46 cents. Because of a light pumping season in 1949, some wells did not use the minimum amount of current. Consequently, the cost of electricity per K.W.H. used was more than during the 2 previous years. Likewise, operating cost increased to 60 cents per hour of pump plant operation during 1949. For the 3 years of the study, the average cost of operating a pumping plant with an electric motor was 49 cents per hour.

Automobile Engines

More automobile engines were used than any other type of power for pumping irrigation wells. Here fuel costs averaged 50 to 70 percent of total operating costs. However, lubricants, engine repairs and pump repairs were all sizable items of expense. An automobile engine requires frequent attention while in operation. Otherwise a breakdown at a critical time during the watering season may occur. This could mean an expensive repair bill as well as some loss of the use of the well.

To determine cost differences, data for pumping plants with relatively small automobile engines (those rated at 100 h.p. and less) were studied separately from those equipped with automotive engines rated at more than 100 h.p.

Automobile Engines Rated at 100 h.p. or Less

An average of 58 of the pumping plants studied were equipped with Ford, Chevrolet or other automobile engines rated at 100 h.p. or less. Operating costs are summarized in Table 8.

To illustrate the influence of different fuels on cost, irrigation pumping plants equipped to use butane, gasoline and natural gas are summarized separately.

Engines Using Butane

Approximately two-thirds of the pumping plants equipped with small automobile engines were run with butane. Fuel consumption fluctuates within a fairly narrow range between individual engines. An average of 4.4 gallons of butane were used per hour of pumping. About one quart of crank-case oil is used per 10 hours of running.

Since the cost of butane made up about 70 percent of the total operating expense, changes in the price of fuel greatly affect operating cost. In 1947, most farmers paid 8 cents

Table 8. Operating costs for irrigation pumping plants with automobile engines rated at 100 h.p. or less, 1947-49

Item		1947		1948		1949		Average	
Engines using butane									
No. studied		51		32		34		39	
No. hours pumped		879		1,120		572		857	
		Amt.	Cost	Amt.	Cost	Amt.	Cost	Amt.	Cost
Butane used per engine	(Gal.)	3,729	$310.21	5,084	$558.84	2,526	$197.33	3,781	$355.46
Crank-case oil	(Do.)	20	16.73	24	20.71	13	11.36	19	16.27
Other motor oil	(Do.)	3.2	2.82	1.5	2.96	.6	.74	1.8	2.17
Grease	(Lbs.)	1.7	.32	1.0	.21	1.1	.19	1.3	.24
Total fuel, oil and grease			330.08		582.72		209.62		374.14
Engine repairs			55.12		96.17		37.33		62.87
Turbine oil[1]	(Gal.)			7.6	6.86	4.1	3.58	5.8	5.22
Gear-head oil[1]	(Do.)			.8	.83	.3	.36	.6	.58
Pump repairs			43.95		56.00		28.60		42.85
Labor[2]	(Hours)	13	9.75	43	32.25	17	12.75	18	13.50
Total cost per well			438.90		774.83		292.24		499.16
Total cost per hour pumped			.50		.69		.51		.58
Engines using gasoline									
No. studied		27		16		5		16	
No. hours pumped		640		939		428		669	
		Amt.	Cost	Amt.	Cost	Amt.	Cost	Amt.	Cost
Gasoline used per engine	(Gal.)	2,561	$287.77	3,552	$528.49	1,681	$243.77	2,665	$353.34
Crank-case oil	(Do.)	15	10.63	19	16.62	12	10.61	15	12.62
Other motor oil	(Do.)	1.5	.91	1	1.35	1.6	1.60	1.4	1.29
Grease	(Lbs.)	1.3	.22	15	.11	.4	.07	.7	.13
Total fuel, oil and grease			299.53		546.57		256.05		367.38
Engine repairs			77.38		90.86		70.10		79.45
Turbine oil[1]	(Gal.)			8	6.47	3.4	2.72	5.7	5.59
Gear-head oil[1]	(Do.)			.5	.50	.4	.94	.4	.72
Pump repairs			32.00		46.95		21.40		33.45
Labor[2]	(Hours)	12	9.00	45	33.75	17	12.75	25	18.75
Total cost per well			417.91		725.10		363.96		505.34
Cost per hour pumped			.65		.77		.85		.76
Engines using natural gas									
No. studied		3		4		2		3	
No. hours pumped		1,698		1,566		937		1,400	
		Amt.	Cost	Amt.	Cost	Amt.	Cost	Amt.	Cost
Natural gas used per engine			$241.04		$220.30		$146.36		$202.56
Crank-case oil	(Gal.)	39	31.85	22	17.02	24	22.10	28	23.66
Other motor oil	(Do.)	8.3	8.33	4.1	4.12			4.1	4.15
Grease	(Lbs.)	1.0	.17	.4	.07	2.1	.36	1.2	.20
Total fuel, oil and grease			281.39		241.51		168.82		230.57
Engine repairs			78.32		73.53		44.35		65.40
Turbine oil[1]	(Gal.)			7.5	5.56	7.0	6.15	7.3	5.85
Gear-head oil[1]	(Do.)			2	1.75	.6	1.80	1.3	1.77
Pump repairs			84.90		78.30		46.85		70.00
Labor[2]	(Hours)	17	12.75	39	29.25	31	23.25	29	21.75
Total cost per well			457.36		429.90		291.22		395.34
Cost per hour pumped			.27		.27		.31		.28

[1]Included with motor oil in 1947.
[2]Servicing pump plant.

per gallon for butane and the hourly cost of pump plant operation averaged 50 cents. The butane price advanced to about 11 cents per gallon during 1948 and pumping costs increased to 69 cents per hour. With the butane price back to approximately 8 cents per gallon in 1949, pump plant operating costs dropped to 51 cents per hour.

The second largest item of operating expense was for engine repairs. Minor repairs or replacements were relatively inexpensive and were made by the farmer. Major repair costs were for overhauling engines. Engines were usually dismounted and taken to a repair shop in town for overhauling. The usual plan was to start the season of heavy pumping with the engine in good running order. In some cases, this requires an annual overhaul job. By careful attention, the operator can frequently avoid, or at least reduce, repair costs.

Average repair expenses for automobile engines rated at 100 h.p. or less were the highest among the engine types studied. This seemed to hold true regardless of whether the fuel was butane, gasoline or natural gas. It is believed that in numerous cases the pumping load under which these engines operate was more of a strain than was the pumping load of larger, more powerful engines.

Engines Using Gasoline

An average of 16 automobile engines rated at 100 h.p. or less were fueled with gasoline. As in the case of engines run with butane, fuel was by far the major operating cost. Gasoline consumption averaged four gallons per hour of operation, or about 90 percent as much as used by similar engines burning butane. However, the advantage of lower gasoline consumption was more than offset by the lower price per gallon for butane. During the study, gasoline averaged 3 to 6.5 cents per gallon more than butane.

In 1947, when gasoline cost 11 cents per gallon, the average cost per hour to operate a pumping plant with a small auto engine was 65 cents. This was 15 cents more per hour than for similar power units using butane. The following year, with gasoline at 14.5 cents per gallon, the hourly cost was 77 cents, or 8 cents higher than the cost with butane at 11 cents per gallon. Gasoline remained at 14 to 15 cents in 1949 and operating costs averaged 85 cents per hour. This was 34 cents more per hour than for power units operated with butane costing 8 cents per gallon. Unusually high repair expense for the five engines using gasoline in 1949 contributed to the relatively high operating cost of this group. Other things being equal, repair expenses for engines run with gasoline and with butane are normally about the same.

Engines Using Natural Gas

Of the engines in the study rated at 100 h.p. or less, an average of only three burned natural gas. These engines used between 450 and 500 cubic feet of natural gas per hour of operation. Fuel made up about half the total cost of operation.

Gas bills were rendered monthly. If there had been no pumping, a flat rate, usually $1.50, was charged. Otherwise, a graduated scale was used in calculating the farmer's bill for natural gas. The more gas used, the lower was the cost per 1,000 cubic feet. Monthly gas consumption varied according to the amount of pumping. For the wells studied, it ranged from a few thousand to as much as 230,000 cubic feet in a single month. In the latter case, the unit price paid for the natural gas used during the month averaged 28 cents per 1,000 cu. ft. At the other extreme, the cost was nearly 50 cents per 1,000 cu. ft. Thus, there was a decided advantage to the user of large quantities of this kind of fuel.

Cooperators who used natural gas did much more than the average amount of pumping, Table 8. Several of them irrigated relatively large acreages of wheat during the winter and early spring. Some rather large acreages of alfalfa—a crop with high water requirements—also were included. Under these conditions, there was quite an advantage in using natural gas when available. Some advantages of using natural gas are indicated in the bottom section of Table 8. As shown here, the hourly cost of operating a pumping plant with natural gas ranged from 27 to 31 cents during the study. The 3-year average cost of 28 cents per hour was approximately half the operating cost when butane was used and about one-third of the cost for pumping plants operated with gasoline. Of all the pumping plants studied, the lowest hourly operating costs were obtained with the small automobile engines that used natural gas.

Many farmers consider that automobile engines rated at 100 h.p. or less have insufficient power for wells with a high rate of yield or for those with a deep lift. Seldom is an engine of this type and size used in pumping wells of 1,000 G.P.M. or more. For such wells and for very deep wells,

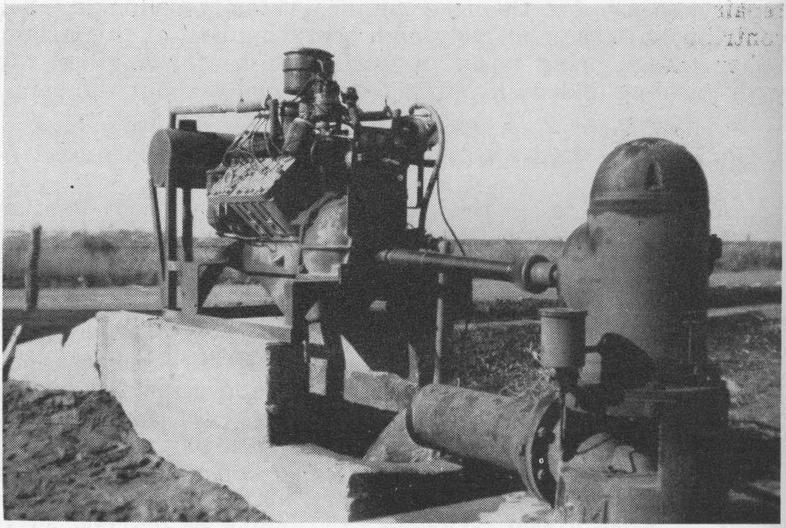

Figure 3. Irrigation well operated with an automobile engine. Approximately 75 percent of the wells studied were equipped with this type of power unit.

the common practice is to use more powerful units, either large automobile engines or another type of power plant.

Automobile Engines Rated at More Than 100 h.p.

An average of 86 pumping plants were equipped with automobile engines having a horsepower rating of more than 100. This was the most common size of engine studied. Some of the cooperating farmers preferred this power unit even on wells with low yield rates or with a short lift. Such farmers usually contend that a light load is easy on the engine and is conducive to more years of service than for an engine working more nearly at capacity.

A summary of the operating cost of plants using large automobile engines is shown in Table 9. These data also are grouped according to the fuel used.

Engines Using Butane

Butane was used with about 75 percent of the automobile engines rated at more than 100 h.p. These engines used an average of 5.1 gallons of fuel per hour of pumping. This was about 15 percent more butane than was used by automobile engines rated at 100 h.p. or less. Approximately one quart of crank-case oil was needed for 10 hours of running, which was the same rate of consumption among the small automotive engines. With the large automobile engines, fuel made up about 70 percent of all operating costs. Here again, changes in the price of fuel greatly affected operating costs.

The expense of engine repairs for the 3-year period averaged $67 per engine with butane, Table 9. This was 6.8 cents per hour of operation, or only a little less than was reported for auto engines rated at 100 h.p. or less.

Total operating cost for the 3-year period averaged 65 cents per hour. This was 7 cents per hour more than the average for automobile engines rated at 100 h.p. and less. Greater fuel consumption largely accounted for this difference.

Engines Using Gasoline

An average of 11 records were obtained each year for the large automobile engines using gasoline. The hourly fuel consumption averaged 4.9 gallons. Fuel was 76 percent of all operating costs. As a general rule, year-to-year variations in operating cost follow the pattern of fuel prices. The gasoline price in 1948 was approximately 25 percent higher than in 1947. At the same time, the cost of operating the large automobile engines increased from 72 cents to 90 cents per hour, or a 25 percent increase. In 1949, the hourly operating cost was 99 cents, and for the 3-year period it averaged 86 cents. These costs were higher than the operating costs of any of the other groups studied, regardless of the type or size of engine or the kind of fuel.

Engines Using Natural Gas

Of the automobile engines rated at more than 100 h.p., an average of 10 used natural gas, Table 9. Natural gas consumption for these engines averaged about 650 cu. ft. per hour of operation. For the period of study, the cost of natural gas made up 56 percent of total operating cost for these pumping plants.

Here again the tendency was for heavy use of the pumping plants using natural gas. This was particularly true in 1947 and 1948. Above average rainfall during the summer of 1949 greatly reduced the need for irrigation. As a result, the hourly operating cost in 1949 was 44 cents, as compared with 34 cents the year previous and 27 cents in 1947.

Table 9. Operating costs for irrigation pumping plants with automobile engines rated at more than 100 h.p., 1947-49

Item		1947		1948		1949		Average	
Engines using butane									
No. studied		49		68		78		65	
No. hours pumped		969		1,291		681		980	
		Amt.	Cost	Amt.	Cost	Amt.	Cost	Amt.	Cost
Butane used per engine	(Gal.)	4,961	$416.26	6,409	$698.04	3,640	$285.76	5,003	$466.68
Crank-case oil	(Do.)	27	21.11	37	31.72	18	14.88	27	22.57
Other motor oil	(Do.)	2.7	2.78	3.4	4.54	1.4	1.73	2.5	3.02
Grease	(Lbs.)	1.7	.31	1.3	.27	1.3	.35	1.4	.31
Total fuel, oil and grease			440.46		734.57		302.72		492.58
Engine repair			71.09		76.94		52.19		66.74
Turbine oil[1]	(Gal.)			9.1	7.72	5.7	4.77	7.4	6.25
Gear-head oil[1]	(Do.)			.7	.85	.6	.61	.6	.73
Pump repairs			48.45		64.55		34.05		49.00
Labor[2]	(Hours)	15	11.25	50	37.50	16	12.00	27	20.25
Total cost per well			571.25		922.13		406.34		635.55
Cost per hour pumped			.59		.71		.60		.65
Engines using gasoline									
No. studied		17		11		6		11	
No. hours pumped		705		1,158		367		743	
		Amt.	Cost	Amt.	Cost	Amt.	Cost	Amt.	Cost
Gasoline used per engine	(Gal.)	3,398	$386.57	5,901	$830.61	1,724	$249.93	3,674	$489.04
Crank-case oil	(Do.)	20	15.13	32	26.80	8	6.65	20	16.19
Other motor oil	(Do.)	1.9	1.03	1.8	1.36	1	1.67	1.6	1.35
Grease	(Lbs.)	1.8	.32	1.3	.21	1	.18	1.4	.24
Total fuel, oil and grease			403.05		858.98		258.43		506.82
Engine repair			56.14		67.72		69.95		64.60
Turbine oil[1]	(Gal.)			12.8	9.61	1.7	1.48	8.8	6.74
Gear-head oil[1]	(Do.)			.9	.84	.9	.84	.9	.84
Pump repairs			35.25		57.90		18.35		37.15
Labor[2]	(Hours)	18	13.50	62	46.50	19	14.25	32	24.00
Total cost per well			507.94		1,041.55		363.30		640.15
Cost per hour pumped			.72		.90		.99		.86
Engines using natural gas									
No. studied		5		12		12		10	
No. hours pumped		1,259		1,754		534		1,182	
		Amt.	Cost	Amt.	Cost	Amt.	Cost	Amt.	Cost
Natural gas used per engine			$198.93		$325.40		$141.04		$221.79
Crank-case oil	(Gal.)	32	26.74	38	31.69	15	12.51	28	23.65
Other motor oil	(Do.)	1.8	1.80	4.5	9.52	1.4	1.59	2.6	4.30
Grease	(Lbs.)	1.5	.25	.9	.23	1.2	.19	1.2	.22
Total fuel, oil and grease			227.72		366.84		155.33		249.96
Engine repairs			27.00		93.66		40.29		53.65
Turbine oil[1]	(Gal.)			11.3	8.52	4.5	3.14	7.9	5.83
Gear-head oil[1]	(Do.)			.4	.90	.4	.72	.4	.81
Pump repairs			62.95		87.70		26.70		59.10
Labor[2]	(Hours)	22	16.50	60	45.00	15	11.25	32	24.00
Total cost per well			334.17		602.62		237.43		393.35
Cost per hour pumped			.27		.34		.44		.33

[1]Included with motor oil in 1947.

[2]Servicing pump plant.

Industrial Engines

Industrial engines were among the more powerful units used for pumping irrigation water. Consequently, they were more commonly used on wells with deep pump settings or with large yield. Industrial engines run at a relatively low speed and develop the necessary power for pumping without indication of engine strain.

Farmers planning to use a combustion type engine, and needing more power than is provided by the small automobile engines, may choose between one of the large automotive engines or an industrial type engine.

There were numerous minor differences among the industrial engines used. They varied in horsepower rating, in speed of operation and in other ways. However, the small number of engines of the industrial type included in the study did not permit groupings according to engine differences. The industrial engines studied were operated with either butane or gasoline. As shown in Table 10, costs for those using butane are summarized separately from those fueled with gasoline. Data are not available for industrial engines burning natural gas.

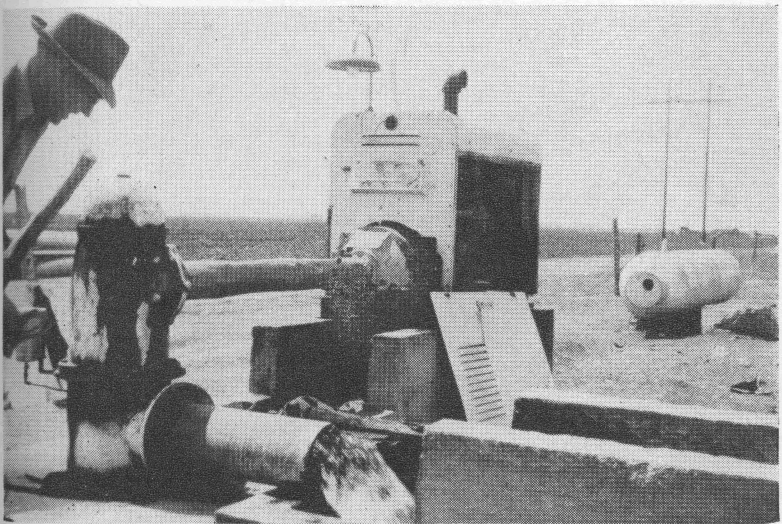

Figure 4. Irrigation well operated with an industrial engine. This type is among the more powerful units used for pumping irrigation water.

Engines Using Butane

During the 3-year period, 17 industrial engines using butane consumed an average of 5.1 gallons per hour of operation. This was the same rate of consumption as found among automobile engines rated at more than 100 h.p. Also, the consumption of lubricants was very nearly the same in both cases.

Industrial engines had the advantage of the lowest repair costs of all combustion engines studied.

The total cost of operating these industrial engines was 58 cents per hour in 1947, 65 cents in 1948, 60 cents in 1949, and averaged 62 cents per hour, Table 10. These year-to-year variations were largely the result of differences in fuel prices since fuel made up about 75 percent of the total operating cost.

Table 10. Operating costs for irrigation pumping plants with industrial engines, 1947-49

Item		1947		1948		1949		Average	
Engines using butane									
No. studied		29		10		13		17	
No. hours pumped		943		937		703		861	
		Amt.	Cost	Amt.	Cost	Amt.	Cost	Amt.	Cost
Butane used per engine	(Gal.)	4,973	$418.81	4,604	$500.20	3,744	$296.80	4,440	$405.27
Crank-case oil	(Do.)	34	26.78	27	20.65	19	15.53	27	20.98
Other motor oil	(Do.)	3	2.55	3	3.00	1.5	2.93	2.5	2.83
Grease	(Lbs.)	2.6	.44	1.4	.28	1.1	.20	1.7	.31
Total fuel, oil and grease			448.58		524.13		315.46		429.39
Engine repairs			44.92		16.26		54.05		38.41
Turbine oil[1]	(Gal.)			7.2	4.40	7.3	6.19	7.3	5.30
Gear-head oil[1]	(Do.)			.8	.63	.3	.27	.5	.45
Pump repairs			47.15		46.85		35.15		43.05
Labor[2]	(Hours)	9	6.75	27	20.25	18	13.50	18	13.50
Total cost per well			547.40		612.52		424.62		530.10
Cost per hour pumped			.58		.65		.60		.62
Engines using gasoline									
No. studied		5		3		2		3	
No. hours pumped		525		588		293		469	
		Amt.	Cost	Amt.	Cost	Amt.	Cost	Amt.	Cost
Gasoline used per engine	(Gal.)	2,215	$249.11	2,187	$305.52	1,052	$152.62	1,818	$235.75
Crank-case oil	(Do.)	20	13.83	19	18.23	5	4.22	15	12.10
Other motor oil	(Do.)	2.8	4.22	2.3	2.93			1.7	2.38
Grease	(Lbs.)	1.3	.19	2.7	.39	6	1.50	3.3	.69
Total fuel, oil and grease			267.35		327.07		158.34		250.92
Engine repairs			22.02		29.80		60.02		37.28
Turbine oil[1]	(Gal.)			1	1.03	5.5	4.75	3.2	2.89
Gear-head oil[1]	(Do.)			.3	.27			.2	.18
Pump repairs			26.25		29.40		14.65		23.45
Labor[2]	(Hours)	11	8.25	19	14.25	6	4.50	12	9.00
Total cost per well			323.87		401.82		242.26		323.72
Cost per hour pumped			.62		.68		.83		.69

[1]Included with motor oil in 1947.
[2]Servicing pump plant.

Engines Using Gasoline

Only a small number of the industrial engines studied used gasoline for fuel. Consequently, Table 10 is based on a comparatively small sample.

Gasoline consumption for industrial engines averaged about four gallons per hour of operation, which was somewhat less than that reported for the large automobile engines.

The average cost of operating pumping plants with gasoline-driven industrial engines was 69 cents per hour. This was somewhat more than the hourly cost with butane-driven industrial engines but considerably less than the cost involved with the large gasoline-driven automobile engines, Table 9.

TOTAL COST OF IRRIGATION WATER

In the previous discussion, overhead and operating costs have been treated separately. The total cost of irrigation water is obtained by combining the two, Table 11. Also included are the cost per hour of pumping and per acre-foot of water pumped for a well of average yield.

The average total cost of 126 acre-feet of irrigation water ranged from $650 to nearly $1,250. The lower cost was obtained with the small automobile engines that used natural gas. Here the lowest operating cost of any of the groups studied is combined with a relatively low overhead.

Table 11. Total cost of pumping irrigation water, 1947-49

Item	Annual overhead cost per irrigation system[1]	Average operating costs[2]	Total cost of irrigation water		
			Per pumping plant	Per hour of plant operation[3]	Per acre foot pumped[4]
Power units by type and kind of fuel used:					
Electric	$372.80	$455.70	$828.50	$ .89	$6.58
Automobile engines rated at 100 h.p. and less:					
Using butane	409.28	539.40	948.68	1.02	7.53
Using gasoline	389.28	706.80	1,096.08	1.18	8.70
Using natural gas	389.28	260.40	649.68	.70	5.15
Automobile engines rated at more than 100 h.p.:					
Using butane	461.25	604.50	1,065.75	1.15	8.46
Using gasoline	441.25	799.80	1,241.05	1.33	9.85
Using natural gas	441.26	306.90	748.15	.80	5.94
Industrial engines:					
Using butane	529.00	576.60	1,105.60	1.19	8.77
Using gasoline	509.00	641.70	1,150.70	1.24	9.13

[1]Table 6.
[2]Based on 930 hours of pumping (3-year average all wells, Table 2) and cost data shown in Tables 7, 8, 9 and 10.
[3]For 930 hours of pumping.
[4]Based on 126 acre-feet (3-year average pumped all wells), Table 2.

The second lowest cost is with automobile engines rated at more than 100 h.p. and using natural gas. Yet, the highest cost is for the same type of engine using gasoline. This indicates something of the influence of various kinds of fuel on the cost of irrigation water.

For farmers not having access to natural gas, electricity provided the cheapest source of power for pumping. Water pumped with electricity averaged only 5 to 12 cents more per acre-inch than water pumped with natural gas.

The highest average water costs are obtained with gasoline, regardless of the type of engine. Of those using gasoline, the cost of water pumped with automobile engines rated at more than 100 h.p. was the highest. This is largely because of relatively high fuel costs.

With automobile engines rated at more than 100 h.p. and using gasoline, the average cost of irrigation water per acre-foot was $3.27 more than with the electric motor. Expressed differently, it costs an average of $81.00 less to pump a three-acre-inch application of water for 100 acres with electricity than with the average large automobile engine using gasoline.

Most pumping systems run with butane operated at a cost of about 15 percent less than similar systems operated with gasoline.

Pumping plants equipped with industrial engines had a relatively high initial cost and high overhead, but these were partially offset by low repair costs.

In general, fuel cost was the most important single item affecting the cost of irrigation water for wells of similar capacity and pumped a comparable number of hours per season.

Before a new pumping plant is installed, farmers have some opportunity to adapt the entire pumping system to the pumping lift and yield of the well. But with facilities already established, the operator seldom has an opportunity to make changes in either the well or the pump. When a power unit is replaced, the operator should consider the possibilities of lowering water costs. It is well to consider the advantages and disadvantages of the different power units. If a combustion type engine is preferred to an electric motor, a comparison of prospective fuel costs should be made. At prices prevailing during 1947-49, butane was more economical than gasoline. When available, natural gas was the least expensive of all.

Electric and natural gas rates remained the same throughout this study. There was considerable year-to-year variation in the prices paid for both butane and gasoline. During periods of rising prices, rates charged for electricity and natural gas go up much more slowly than the prices of other items. When prices generally are on the decline, there is the same tendency for utility rates to lag behind in the downward adjustment of prices.

Data in Table 11 show that, with the same fuel, the large combustion engines were more expensive to operate than the small automobile engines. Ample power should be provided, but a power unit larger than necessary adds to the expense of pumping water. Automobile engines rated at 100 h.p. or less do not furnish enough power to pump some wells. However, where they are adequate this study indicates that the small automobile engines supply irrigation water at lower cost than large combustion engines.

Costly repairs may be avoided by careful attention to the pumping plant.

FACTORS AFFECTING COSTS

Yield Rate

To determine the influence that rate of yield has on pumping costs, the wells studied were divided into four groups on the basis of the gallons of water discharged per minute. In general, such a division represents differences in the capacity of the various wells studied. No effort was made in this study to group irrigation systems according to the efficiency of their operation. Based on the grouping made, the cost of irrigation was then calculated for each group according to the type of power unit and the kind of fuel used, Table 12. These costs were figured for an average pumping season of 930 hours.

High cost per acre-foot was associated with a weak well, regardless of the type of power or the kind of fuel used. As the rate of yield increased, there was a marked tendency for the cost per acre-foot to decrease. For instance, with wells operated with electricity and supplying 500 G.P.M. or less, the cost per acre-foot of water pumped averaged $11.84, compared with $4.36 per acre-foot for electrically-pumped wells discharging more than 1,000 G.P.M. This latter cost is

Table 12. Effect of rate of yield, G.P.M., on the cost of irrigation water, 1947-49

Kind of power unit	Cost per acre-foot of water pumped by wells grouped according to rate of yield			
	500 G.P.M. and less	501-750 G.P.M.	751-1,000 G.P.M.	1,001 G.P.M. and over
Electric motor	$11.84	$ 7.40	$ 5.75	$ 4.36
Auto engines rated at 100 h.p. or less:				
Using butane	13.55	8.47	6.59	
Using gasoline	15.66	9.79	7.61	
Using natural gas	9.28	5.80	4.51	
Auto engines rated at more than 100 h.p.:				
Using butane	15.22	9.52	7.40	5.61
Using gasoline	17.33	11.08	8.62	6.53
Using natural gas	10.69	6.68	5.20	3.94
Industrial engines:				
Using butane	15.79	9.87	7.68	5.82
Using gasoline	16.44	10.27	7.99	6.06

only about 36 percent of that of the low-yielding group. A similar relationship exists for the other types of power and kinds of fuel.

Hourly pumping cost for low-yielding wells was about the same as for those with a considerably higher rate of yield. Little difference was found in either the investment or the rate of depreciation for wells of different yield rates.

In most cases, there is very little that can be done to increase the yield of a well that is in a low water-yielding formation. It is important with any well that the pump operate efficiently in order to obtain the optimum yield the well is capable of producing. Several cooperating farmers greatly increased the yield of their wells by making much needed repairs.

Costs can be lowered to some extent by adjusting the power unit to the pumping load. For instance, some of the wells yielding 500 G.P.M. or less were equipped with industrial engines. For these low-yielding wells using butane, the average cost per acre-foot of water was $15.79. The per-acre-foot cost of water in wells of similar capacity, but operated with small automobile engines, averaged $13.55. This was $2.24 per acre-foot in favor of pumping relatively low-yielding wells with automobile engines rated at 100 h.p. or less rather than in using industrial engines. For wells in the 751-1,000 G.P.M. group that were equipped with these two kinds of engines and using butane, the difference averaged only $1.09 per acre-foot in favor of the small automotive engine. Thus, the advantage in favor of the small automobile engine was substantially greater in the case of low-yielding wells than with strong wells.

Hours of Pumping

Water costs per acre-foot were not as high for wells given a large amount of pumping as for similar wells given light usage. Special groupings of wells were made each year to study this relationship. To make these groupings, the wells studied were arrayed according to the number of hours pumped. The entire number then was divided into three groups of equal size. The wells with the fewest pumping hours were in one group, those with a medium amount of pumping in another and those with the most pumping hours in the third group. Because of year-to-year variations in the amount of use, individual wells were not always in the same group each year.

The cost of irrigation water for wells in each group was then calculated. Such data were also subgrouped by type of power and by kind of fuel.

In all cases, the average cost per acre-foot of water was highest for the group of wells pumped the fewest number of hours. Here, relatively high overhead costs were an important factor. Likewise, the lowest average cost was for the wells pumped the most hours. A typical relationship between cost of water and hours of pumping is illustrated in Table 13 by an average of 65 records obtained for each year of the study for wells equipped with automobile engines rated at more than 100 h.p. and fueled with butane.

A third of these wells were pumped an average of 463 hours per season and produced irrigation water at an average cost of $12.10 per acre-foot. At the other extreme, wells pumped 1,463 hours produced water at an average cost of $7.10 per acre-foot. In between was a group of wells pumped an average of 865 hours per season which produced irrigation water at an average cost of $8.67 per acre-foot.

Although annual repairs for pumps and for power units increased with a large amount of pumping, there was a tendency for the hourly cost of these items to decrease with heavy usage. For butane and gasoline, hourly fuel consumption with a particular power unit was approximately the same regardless of the hours run. With natural gas, much pumping invariably resulted in a lower fuel cost. With electricity, the rate per K.W.H. was the same regardless of the amount taken. But there was a minimum charge for current regardless of how little electricity was used. It was to the farmers advantage to plan the use of at least the minimum amount of current. Overhead expenses do not increase in proportion as the number of hours of pumping increases.

The wells were further subdivided on the basis of rate of yield. Costs for each of these subgroups are summarized in the last four columns of Table 13.

Table 13. Cost per acre-foot of water related to hours of pumping and differences in G.P.M. yield, 1947-49

Item	Automobile engines rated at more than 100 h.p. and using butane					
	Average hours pumped, all wells	Average cost per acre-foot of water				
		All wells	Wells grouped according to G.P.M.			
			500 G.P.M. and less	501-750 G.P.M.	751-1,000 G.P.M.	1,001 G.P.M. and over
Average yield (G.P.M.)		740	397	647	860	1,148
All wells grouped according to number hours pumped:						
Lower 1/3	463	$12.10	$22.42	$13.86	$10.44	$ 7.78
Middle 1/3	865	8.67	16.24	9.94	7.47	5.59
Upper 1/3	1,463	7.10	13.21	8.12	6.09	4.57

In the case of each subgroup, the wells given the heaviest pumping provided water at about 60 percent of the cost of those pumped the least number of hours.

The high water cost resulting from light pumping of low-yielding wells is also shown. For instance, the wells that yielded 500 G.P.M. or less and were pumped relatively few hours, produced water at an average cost of $22.42 per acre-foot. At the other extreme, wells that yielded more than 1,000 G.P.M. and were given a large amount of pumping, produced water for only $4.57 per acre-foot.

These data suggest that a farmer should plan for the maximum efficient use of existing wells before putting down additional wells.

The period of time during which irrigation water is normally applied is limited. Preseasonal irrigation for crops, such as cotton, and watering winter-growing crops are means of lengthening the pumping season.

This wide difference illustrates something of the combined effect that heavy pumping and a high rate of yield have on water costs. Here also is indicated the cost advantage enjoyed by farmers fortunate enough to have high-yielding wells. Such differences can be very important during periods of relatively low prices.

SUMMARY

The total cost of developing and equipping a new irrigation well on the High Plains of Texas during 1947, 1948 and 1949 usually ranged between $4,000 and $5,000.

Such installation costs included the drilling, the casing and the spillway for the well, all of which averaged $1,272. The cost of drilling and casing varied with the depth of the well. Although the pump cost also varied with the depth of the well and the depth of the pump setting, 55 new pumps installed on the farms studied averaged $2,155. The average pump setting for these installations was 140 feet. The power unit was the other major item in equipping a well.

For purposes of this study, power units used to pump irrigation wells were divided into four groups — electric motors, automobile engines rated at 100 h.p. and less, automobile engines rated at more than 100 h.p. and industrial engines. During the study, the average purchase price paid for each of these four types was $720, $485, $782 and $1,320, respectively. For these four types, the respective total cost of the pumping plant averaged $4,147, $3,912, $4,209 and $4,747.

Overhead costs of the pumping plant and operating expenses make up the total cost of pumping irrigation water. Overhead items include interest on the investment, depreciation and taxes. Fuel, oil, other lubricants, labor servicing the plant and repairs for the pump and the power unit make up operating expenses.

Installations equipped with electric motors had the lowest annual overhead cost and those with industrial engines the highest of those studied. Fuel made up a major part of total operating expenses. Repairs for the power unit were a minor item with electrically-run plants but were an important item with combustion engines. Over a period of years, the amount of pump repairs was closely associated with the hours of pumping.

The lowest average cost per acre-foot of water pumped was for units operated with natural gas. Units operated with electricity had the second lowest cost. During this study, butane was cheaper for pumping water than gasoline.

On the basis of the grouping of combustion engines as used in this study, the total cost of pumping irrigation water

averaged lower with automobile engines rated at 100 h.p. or less than with either large automobile or industrial engines.

The common practice has been for farmers to purchase the pump, then have the well drilled and the pump installed, without considering the pumping efficiency expected of the equipment. Often, similar pumps are in use in wells that differ greatly in yield of water and in lift. Although this study does not attempt to evaluate pump efficiency, it indicated that in many cases much greater efficiency would be obtained if the lift and the yield of the well are considered when the pump is purchased.

The cost per acre-foot of irrigation water was greatly affected by the yield of the well. High pumping costs were associated with low-yielding wells regardless of the type of power or the kind of fuel used. A farmer can influence costs to some extent by using a power unit well suited to the pumping load of his well.

When the wells studied were grouped according to the number of hours pumped, the average cost per acre-foot of water was highest for the group pumped the fewest hours. The lowest cost was for those pumped the most hours.

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ACKNOWLEDGMENTS

The authors acknowledge the assistance of D. L. Jones, superintendent of Substation No. 8, Lubbock, in planning the study and for helpful suggestions throughout. John Box, assistant irrigation engineer, Substation No. 8, was a valued advisor. Appreciation is also expressed to the county agents and other Extension Service personnel who were helpful in planning and getting the study under way. Personnel of the U. S. Geological Survey gave much valuable help in making well measurements. Other Federal agencies in the area were particularly helpful in planning the study.

This study was made possible with the cooperation of many farmers who gave freely of their time in furnishing the information reported.

This study was conducted cooperatively by the Texas Agricultural Experiment Station and the Bureau of Agricultural Economics, U. S. Department of Agriculture.