ENGINEERING REPORT

# THE APPLICATION OF ELECTRICITY TO THE OIL INDUSTRY

By

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# THE APPLICATION OF ELECTRICITY TO THE OIL INDUSTRY

**Statement of Problem**

There are two purposes to be accomplished in this report: first to ascertain whether or not the electric drilling, pumping, and cleaning of oil wells can be made a commercial success; second to make recommendations as to the type of electrical equipment, and its installation, best suited to the oil industry on the Pacific Slope.

The first part of the present report is divided into two groups: (a) The oil well owner and producer must be convinced that the electrification of his wells is to his advantage; he must be convinced that the electric motor will handle his operating conditions as well as the time-honored steam engine. (b) It is desired to find wherein the present manufactured electrical equipment, and its installation, fail to meet these requirements.

**Previous Electrification**

The use of the electric motor for drilling and pumping oil wells is not a new thing. The electrification of oil wells was started in the Baku fields of Russia during the year 1900, when several wells were pumped by motors. In 1906 occurred the first electrification of oil fields in this country, when the South

Penn Oil Company extensively utilized this process in their fields at Folsom, West Virginia. Five years later this company successfully completed the first oil well drilled entirely by electric power in this country. To-day there are approximately two thousand wells being operated by electric motors; the general tendency is to electrify the proven fields, and to drill by electricity wherever possible. This rapid development and success of the oil well motor is largely due to the numerous advantages, the ease and reliability of operation, of the polyphase, variable speed, induction motor.

Scope of Investigation

When this investigation was first undertaken the writer thought that it would be possible to obtain the use of a well upon which he could carry out his experimental work. It was his original intention to study the equipment for drilling and pumping oil wells at the present time, and then to build an entire new set; to install this new apparatus, and to keep accurate data upon the drilling of the well. However, conditions arose which made this work impossible, and so the problem was attacked from another standpoint. The purpose now was to collect all available data and information pertaining to the present manufactured electrical equipment for drilling and pumping oil wells. Most of the printed data that was found was "ancient history" in the oil industry; therefore actual data had to be obtained directly from the fields and offices of different oil companies,

Order of Presenting Results of Investigation

Data and information will be presented in the order in which they were obtained, as follows:

(1) Drilling with standard cable tools

(2) Drilling by the rotary method

(3) Comparison between electric and steam drilling

(4) Individual pumping on the beam

(5) Comparison between electric, steam, and gas pumping.

(6) Auxiliary equipment used

(7) Recommendations

Conclusions

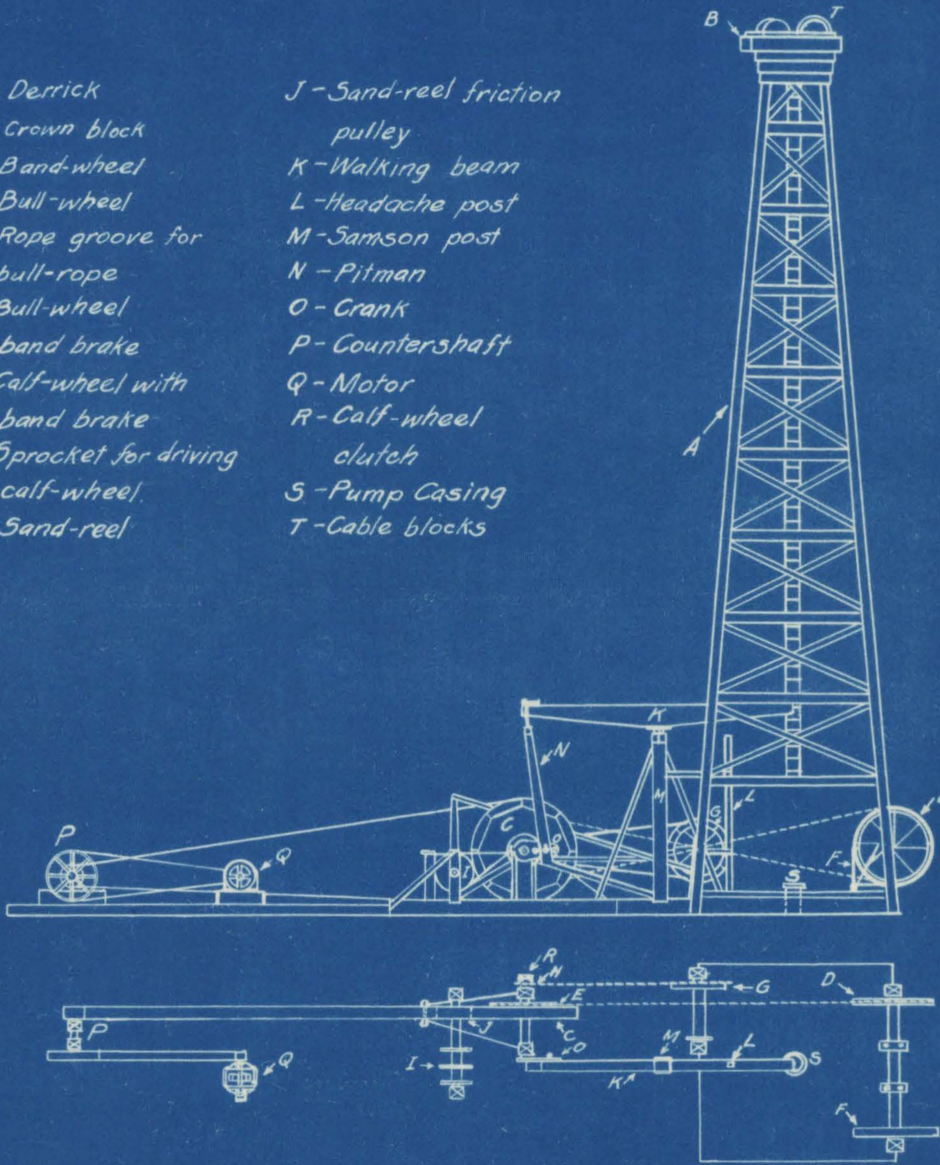
The conclusions at which the investigator arrived may be stated briefly as follows:

(1) The induction type motor is especially adapted to the oil industry on the Pacific Slope, and has been used from the first, not only because of the fact that alternating current power is available in practically all of the fields, but also because the induction motor has the mechanical strength and the necessary overload capacity required to withstand the oil field service.

(2) The Pacific Slope is especially adapted to the use of electricity in the oil industry.

(3) The electrification of all the proven fields

A - Derrick
B - Crown block
C - Band-wheel
D - Bull-wheel
E - Rope groove for bull-rope
F - Bull-wheel band brake
G - Calf-wheel with band brake
H - Sprocket for driving calf-wheel
I - Sand-reel
J - Sand-reel friction pulley
K - Walking beam
L - Headache post
M - Samson post
N - Pitman
O - Crank
P - Countershaft
Q - Motor
R - Calf-wheel clutch
S - Pump Casing
T - Cable blocks




ELEVATION AND PLAN OF MOTOR-OPERATED
OIL WELL RIG

PLATE 1
G.L.C.

on the Pacific Slope will be realized in the near future, and practically all new drilling will be done electrically; with this will come a demand for electric drilling and pumping equipment.

(4) The electric drilling and pumping of oil wells is a decided commercial success for both the oil producer and the electrical manufacturer.

Drilling With Standard Cable Tools

The use of the electric motor for drilling with standard cable tools does not require any special rig construction other than that of the ordinary type, except in the arrangement and size of the motor house. With an old installation the addition of a motor base is necessary.

On account of the heavy strain to which oil well equipment is subjected, back-geared motors have not proven a success and are not found in general use. The best layout for electric drilling (and for pumping on the beam) is shown on Plate 1; this is a belted type installation, using a countershaft P to reduce the speed of the band wheel. If the installation is an old one, the countershaft may be fastened on the engine block. (In some cases it has been found more economical to use the original steam engine itself for the countershaft.) "All the operations of drilling are handled by a machine installed at the time of erection of the rig, which is replaced by one of smaller capacity when the well is 'brought in' as a producer and is put 'on the beam' or equipped with a pumping-jack."[1]

Plate 2 shows the mechanical arrangement and electrical setup of an electrically operated standard cable tool drilling equipment, installed for the San Fernando Oil Company, near Pacoima, California. This equipment (manufactured and installed by the General Electric Company) consists of a 75 h.p., variable speed, delta connected, 440 volt, induction motor; a main and an auxiliary controller and resistor, providing eighty-eight possible motor speeds between standstill and full-load speed; an oil circuit breaker provided with under voltage and overload releases; and a countershaft with pulleys to give the correct drilling speed. The two controllers and resistors are operated independently from the headache post by means of wire ropes; the main controller and resistor allow ten possible speed variations between full-load and half-load speeds; the auxiliary controller and resistor divides each of the main controller speeds into eight additional speed variations. The two controllers, the entire control resistance, and the protective oil circuit breakers, are mounted as a unit upon a movable engine block in the engine house. In this way practically all of the motor control connections can be made

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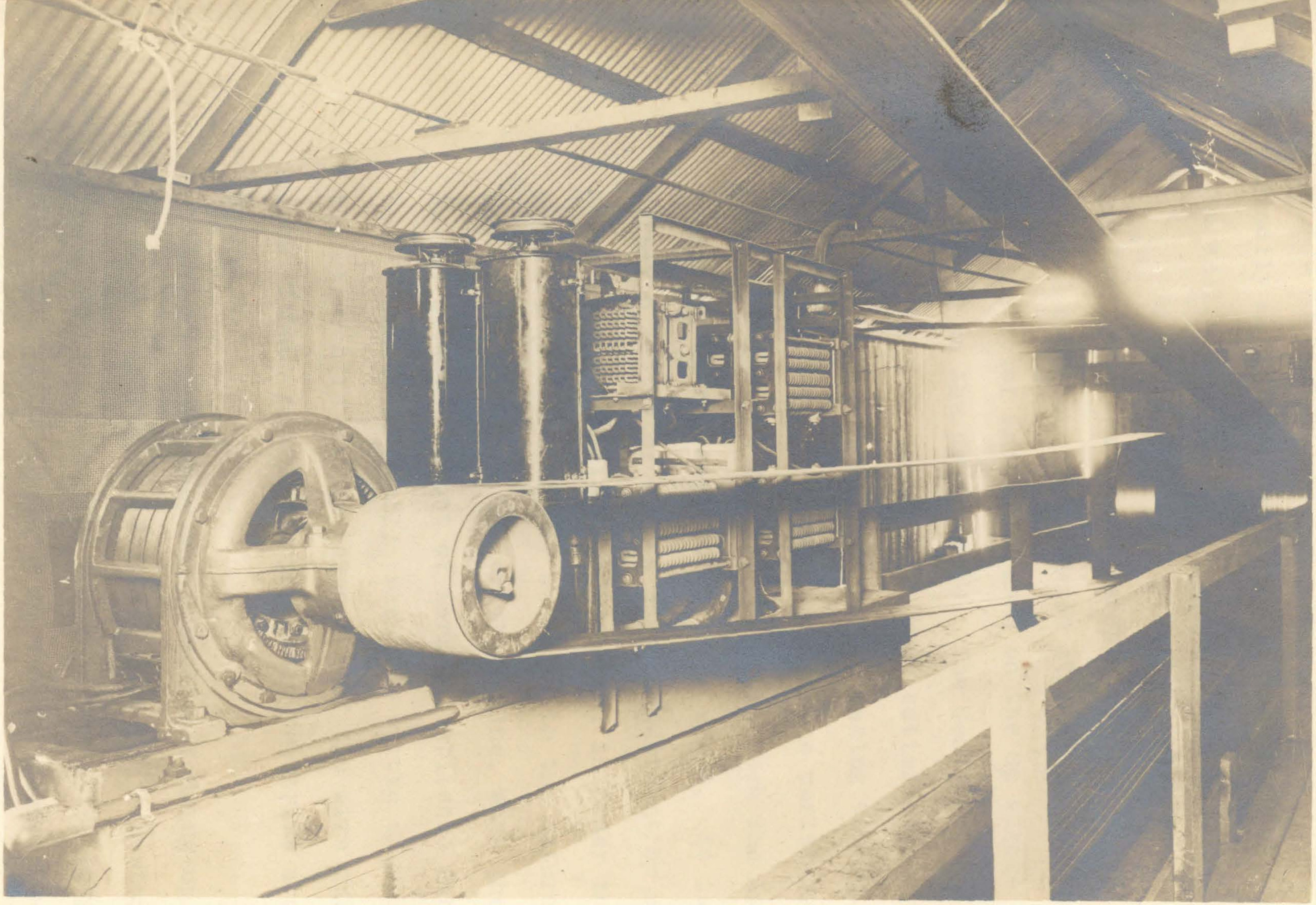
[1] General Electric Co., Bulletin No. 48013 August 1914.



326999 OIL WELL DRILLING MOTOR EQUIPMENT AT THE SAN FERNANDO OIL CO. PACOIMA CAL. USING 75 HP. 900 RPM. 440 V. MOTOR OPERATING ON 50 CYCLE CIRCUIT.

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PLATE 2

in the shop; also the equipment, as a unit, may be readily moved to a new location upon completion of the well.

To obtain the most effective blow in cable drilling, the beam must overspeed to allow the tools a "free drop" on the downward stroke; to accomplish this the motor must slow down on the up stroke and speed up on the down stroke. The General Electric Co. obtains this characteristic very satisfactorily with the induction motor by so proportioning the motor and countershaft pulleys that some of the resistance will always be left in the rotor circuit when the motor is operating at the correct drilling speed. It is then merely a matter of minute speed adjustment by means of the main and auxiliary controllers, in order that the movement of the beam may accord with the natural period of vibration of the drilling line. When the stroke is too slow the amount of work accomplished for the time consumed is small; when the stroke is too fast the stretch is merely taken out of the wire drilling line without permitting the tools to strike a cutting blow.

For slow, easy work, such as tonging up a joint of pipe, the 75 h.p. drilling motor is too strong and too fast; consequently, for this work, its output must be considerably curbed. This may be accomplished by inserting a third controller and resistor in the circuit in series with the other two resistors; it will then, under ordinary running conditions, be shunted out, and should be used only when a small output is demanded. It has been found by actual test that the resistance should be equally divided in the three phases to give a maximum decrease in motor speed.

The use of standard cable tools for drilling sometimes requires that the cuttings be taken away with a circulating or slush pump. Common practice in the oil fields points to the use of a separate single, variable speed motor ranging in capacity from 35 to 50 h.p. The motor may be either belted or geared directly to the mud pump. The variable speed required by the pump may be obtained by the use of a single main controller and resistor. An ammeter is sometimes inserted in the motor circuit and mounted on the Samson post; at all times it can be easily seen by the driller. This gives him an accurate indication at all times of the amount of strain he is putting on his casing.

Drilling By Rotary Method

The use of electricity for drilling by the rotary method is comparatively new. The trouble experienced in the past has lain in getting a quick reversal of the rotary table. If the rotary drill strikes a rock and cannot crush or dislodge it upon repeated trials, the drill may hold solid and if the power is not shut off, the drill rod will be twisted. The driller must therefore be able to reverse the motion immediately and "unwind" the drill rod. Heavy, cumbersome chains and moving parts must therefore be avoided as much as possible; also, all parts of the equipment should be fastened to one soild frame in order to resist the tremendous shock and strain upon reversal. A very good example of the necessity of this was found at the Smiley #1 Well, Whittier, California.' Here a heavy silent chain was used from the motor to the countershaft, and a link chain was used to connect the countershaft to the rotary table and draw-works. When a rock was struck which could not be broken or dislodged the power was reversed, but instead of the rotary table's reversing immediately, as it should have done, the heavy silent chain had inertia enough to make the slowing down and reversal a gradual process. Three drills were twisted off in less than a week. At the same well the motor for drilling was mounted on a base separate from the countershaft, which was mounted on a separate concrete base; the result was that the countershaft and base were torn out by the tremendous reversal strain. A new base of timbers about 24 inches square was built up, making the countershaft and motor solid; the silent chain was taken off and replaced by a much lighter link chain. Since then the entire equipment has been working very successfully.

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'Owned by The Western Union Oil Co., Los Angeles, Cal.

The same electrical equipment is used for drilling by the rotary method as with the standard cable tools with the exception that the motor has three bearings, an outboard bearing being supplied to take the strain of the long motor shaft which is required to accommodate the gear for the countershaft chain. Also a single controller usually provides sufficient speed variation to drive the rotary table and draw-works. The slush pump used with the rotary drill requires an additional motor similar to that used on the mud pump for cable tool drilling. However, it might be found profitable to install, at first, equipment suitable for both rotary and standard cable tool drilling; then after having driven the hole to the oil sands by the rotary method, the well could be finished with standard cable tools in the customary manner.

Comparison Between Electric and Steam Drilling

A few actual facts as to the initial cost of equipment and the cost of drilling with electricity will probably do most to convince the driller who has never used anything but steam, that the electric motor will serve him equally as well.

The following costs, which to represent a fair average for the various fields of Southern California, are quoted on equipment manufactured by the General Electric Company:

A standard cable tool drilling equipment, including a 75 h.p. variable speed, 440 volt induction motor; controllers and resistors complete; speed reduction countershaft and pulleys, may be installed complete, ready to run, "exclusive of all belts, buildings, or foundations," and without a circulating pump for about $2500. The equipment described above, including a circulating pump, would cost about $3500, installed complete, ready to run, "exclussive of all belts, buildings, or foundations." This equipment will cost about $200 more in the fields of Northern California as opposed to the southern fields; the difference in price being due to the higher frequency of the available power, necessitating a motor with a greater number of poles. This cost is about one-third the cost of the same equipment required for steam operation, and does the same work. However, the saving in the initial cost of drilling equipment is relatively small as compared with the saving in operating expenses. The actual cost of energy for well drilling, of course, increases with the depth of the well, for as the hole goes down it takes longer to bail and more pipe must be handled, and consequently the weight on the beam is constantly increasing.

The data in Table 1, which was obtained from two wells drilled with General Electric Co. equipment using standard cable tools, in Ventura County, California, illustrates the gradual increase in the cost of drilling with the increase in depth of the well:

TABLE 1

| Well No.1 Cost of Power | Well No.1 Depth of Well | Date of Operation | Well No.2 Cost of Power | Well No.2 Depth of Well |
|---|---|---|---|---|
| $132.85 | 1096 ft. | 5/1 - 7/26 | $192.15 | 869 ft. |
| 163.50 | 1407 | 7/26- 8/26 | 163.50 | 1194 |
| 201.25 | 1952 | 8/26- 9/25 | 201.25 | 1412 |
| 202.20 | 2129 | 9/25-10/31 | 202.20 | 1550 |
| 212.15 | 2274 | 10/31-11/26 | 212.15 | 1744 |
| 217.88 | 2581 | 11/26-12/27 | 217.88 | 2202 |
| 94.20' | 2987 | 12/27- 1/27 | 94.20' | 2435 |
| | | 1/27- 2/26 | 77.40' | 2829 |
| | | 2/26- 3/26 | 7.20' | 2973 |

The Western Union Oil Company, Los Angeles, Calif., drilled a well on the Harris Lease at Orcutt, using rotary equipment. This well was drilled to a depth of 4300 ft., and the average cost of power for the entire well was $8.44 per day. Other wells nearby were being drilled at that time by steam equipment; the average fuel consumption on these was 50 bbls. of oil per day, the cost of fuel oil was $1.50 per bbl.(present cost $2.25 per bbl.), delivered at the well, making the fuel

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'Actual period of operation was less, as the casing was cemented off and allowed to stand for several days.

expense $75 per day, and to this was added the cost of the water used. It was estimated that the saving on the one well, due to the use of electrical equipment, was $25,000.

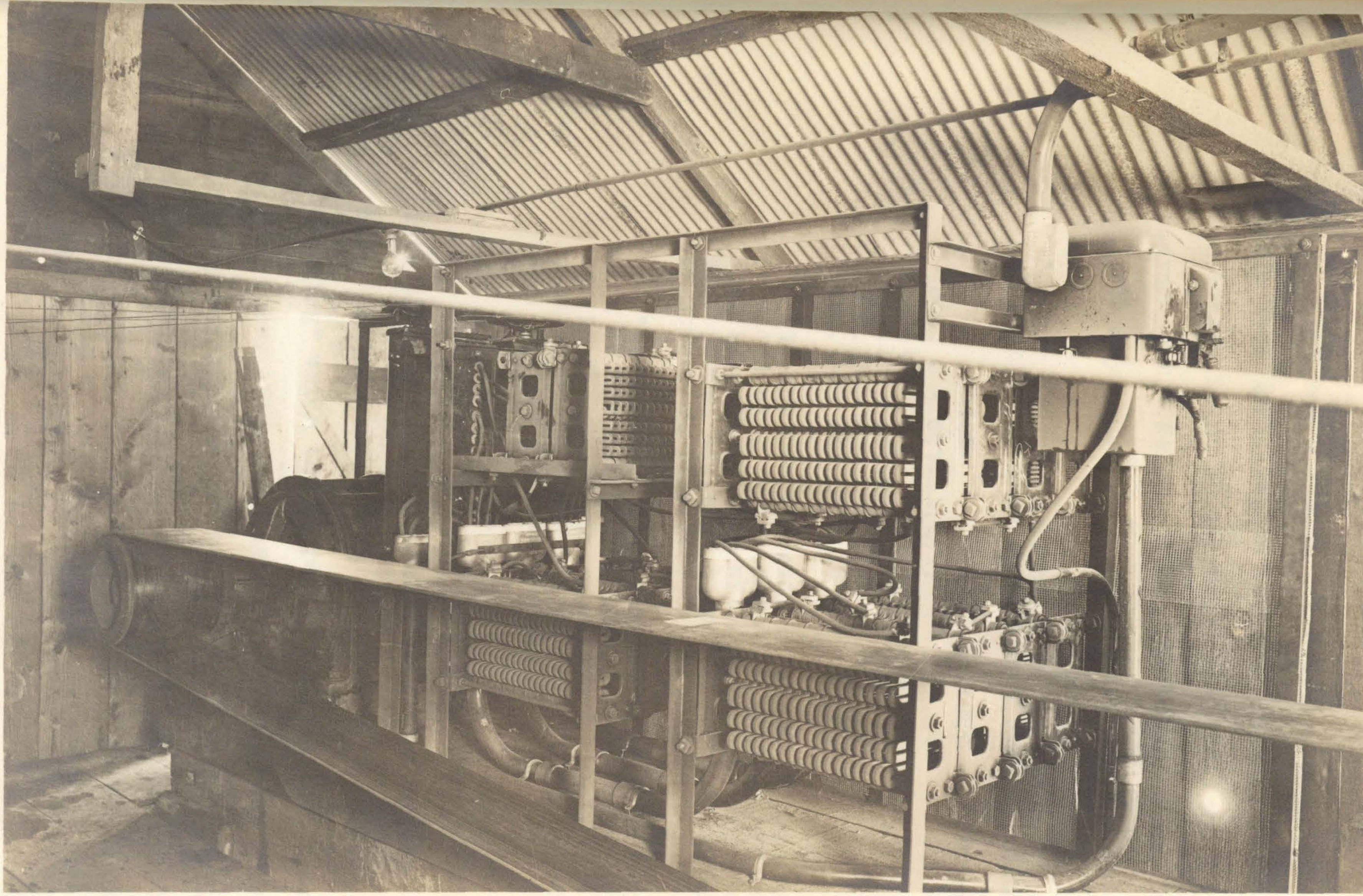
In a letter to the General Electric Company, the superintendent of the Beatty Oil and Development Co., Los Angeles, California, says of a well which they drilled with electrical equipment, using standard cable tools:

> "...Our motor as installed by you operates the tools beautifully, we can get almost any speed desired, and the tools drop as freely as with steam, we can pull the tools faster with the motor, and we at all times have steam up and have no delays waiting for the tooley to get up steam, cleaning the flues, or any of the dozen delays that go with the average steam plant, and if someone burns a boiler it is no bother to us.
>
> "...As to the cost of operating our motor, in January we drilled 22 days and used 'juice' for 5 days more, the total power bill was $93.70 or about $3.34 per day; in February for 29 days our bill was $92.03 or about $3.17 per day. Our lighting bill for January and February was $36.62 this was for the rig lights, cook house, bunk house lights, and also for running a 1 h.p. electric water pump, and for the forge fan.
>
> "...I am confident that the Electric Equipment on this lease shows a saving of 75% over the cost of operating a steam plant, and at least 15% in the efficiency of men, as they are where they are needed, on the derrick floor."

This shows a very low operating cost and a high efficiency in labor and equipment. In practically all cases the users of electrical equipment are more than satisfied with the results and are the real "boosters" for its use.

The Shell Company of California has done a considerable amount of drilling, using a standard 75 h.p. motor on the cable tools, and a 35 h.p. motor on the circulating pump. On well "A", in the Montebello fields, their total power bills for the twelve months of 1919 amounted to $3936.44, or an average of $328 per month. On the Turnbull Canyon well, their total cost of power for drilling for 4½ months was $1221.24, or an average of $271 per month. The McGonigle #1 well, drilled by the Shell Company, in Ventura County, is the deepest well that has been bored electrically. It is 4412 feet deep, and was drilled with a 75 h.p. motor on the cable tools, and a 40 h.p. motor on the circulating pump. The McGonigle #2 well was drilled to a depth of 4200 feet.

The Western Union Oil Company drilled the Smiley #1 well at Whittier, to a depth of 2520 feet. This well was equipped with a standard rotary equipment (General Electric Co.), using a 75 h.p. drilling motor on the draw-works and rotary table, and a 50 h.p. variable speed motor on the circulating pumps. The time elapsed during operations was 45 days, of which 16 days were required for the actual drilling. The total light and power cost was $325.



326978 OIL WELL DRILLING MOTOR EQUIFMENT AT THE SAN FERNANDO OIL CO., PACOIMA, CAL., USING 75 HP 900 RPM. 440 V. MOTOR OPERATING ON 50 CYCLE CIRCUIT.

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PLATE 3

The San Fernando Oil Company, used a standard cable tool installation (General Electric Co. equipment, See Plates 2 and 3) in drilling a well in the Pacoima Canyon. Mr.W.Nelson Shell, president of the San Fernando Oil Company, submitted the following statement:

"...Our power and lighting bills since the installation of this system, has been as follows:

| PERIOD | LIGHT | POWER |
|---|---|---|
| Oct. 2 - Oct.11,1919 | $1.04 | $27.60 |
| Oct.11 - Nov.12,1919 | 42.79 | 184.36 |
| Nov.12 - Dec.13,1919 | 43.76 | 287.18 |
| Dec.13 - Jan.13,1920 | 37.46 | 163.24 |
| Jan.13 - Feb.13,1920 | 29.21 | 182.16 |

"To the above costs, of course, there has to be added expense for coke for heating bits which work is usually done with oil and we think would be a proper addition to power cost. Coke has cost us something like $75.00 per month.

"We estimate that the use of fuel oil for the work we are doing, including transportation to our lease, would run about eight hundred to nine hundred dollars per month, indicating, as you will see, quite a material saving."

The power bill for the period Nov.12 to Dec.13, 1919 shows a marked increase over that of any of the other months, this being due to a long period of "fishing" which the company was compelled to do at that time. After the cost of coke has been added to the power expense, making the maximum monthly power cost $250, we find that the drilling cost is only one-third as much as it would have been with the use of steam.

Mr.E.W.Klein, secretary of the San Fernando Oil and Gas Company, Los Angeles, California, referring to their electrical equipment, says:

> "...our operation expense to date (April 14,1920) has not exceeded $200.00 per month for power and lights running full capacity 24 hours daily.
>
> "We consider electric power the best and most economical as well as the cleanest of any power for oil well drilling and will gladly recommend the same."

**Advantages of Electric Drilling Over Steam**

The advantages of electric drilling over steam may be briefly summarized as follows:

(1) Operating expenses are minimized.

(2) There are no standby losses for idle equipment and the equipment is always ready for use.

(3) Maximum saving of time is gained in all operations.

(4) Full power may be developed at any speed.

(5) Momentary overload of about 300 per cent may be carried by the equipment.

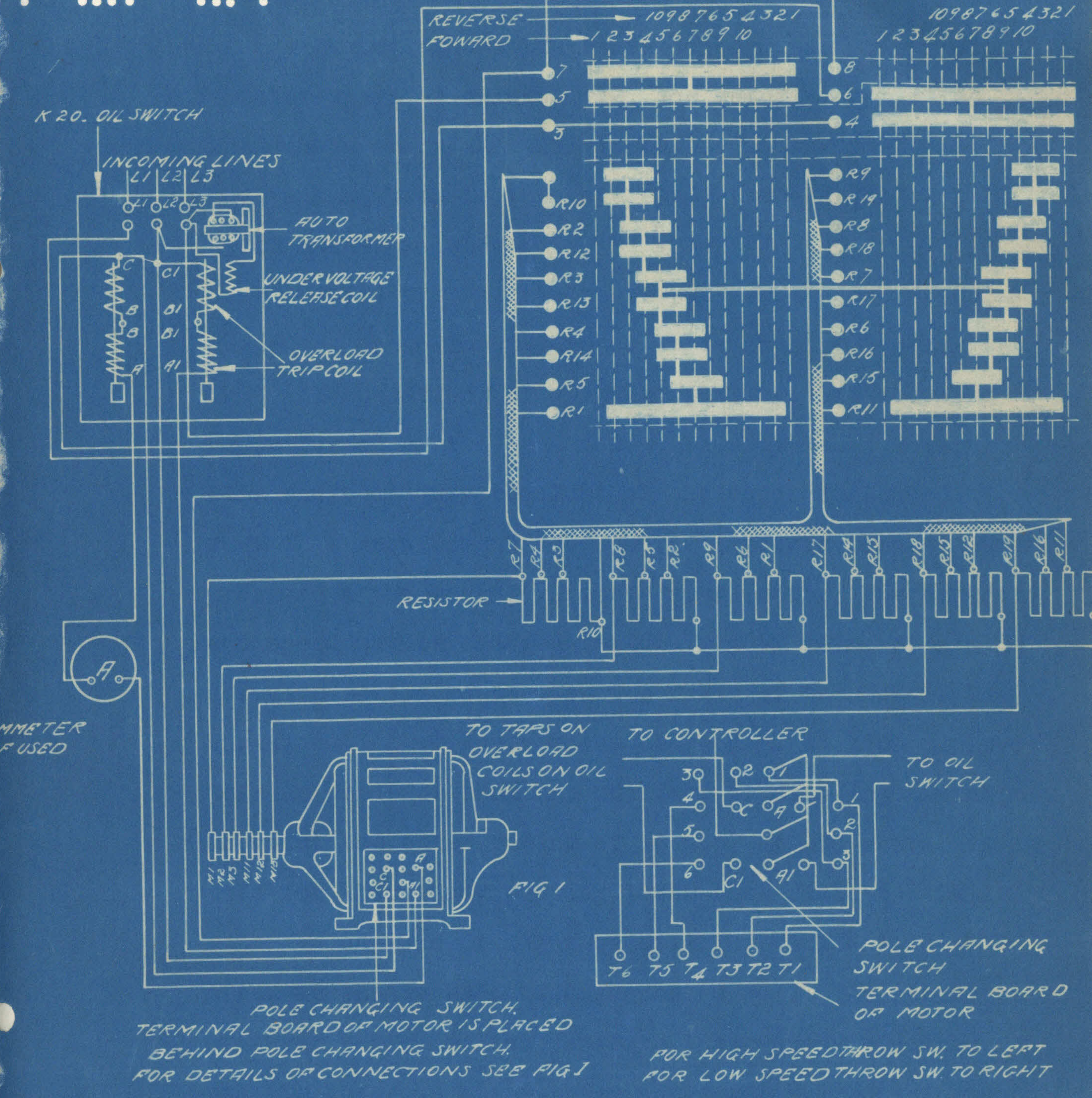
(6) Exact speed control is realized at all times.

(7) Explosions and fire are sources of danger and are minimized.

(8) Maximum safety of operation is gained.

**Pumping on the Beam**

The two speed, variable speed, induction motor has become the standard type of motor used for pumping, pulling, and cleaning purposes; it is usually of much smaller horsepower than the drilling motor.




(1) RETRACED JUNE 11, 1918

CONNECTIONS OF TWO SPEED VARIABLE SPEED OIL WELL MOTORS T52G AND P CONTROLLERS (CR3202) AND K20 OIL SWITCH WITH OVERLOAD TRIP ON LOW SPEED ONLY.

K/920353

CHECKED A.C. Prescott APPROVED IND. CON. DEPT.

GENERAL ELECTRIC COMPANY, SCHENECTADY, N.Y.

IC DRAWN BY O.L. BROWN APR. 19, 1918 RE INSPECTED JUNE 11, 1918

PLATE 4

Plate 1 shows the elevation and plan views of a motor-operated oilwell rig. The motor is belted to the countershaft and this is belted to the band-wheel; the walking beam is then operated by the crank in the usual manner as shown.

Where the well is to be put "on the beam" and pumped by an individual motor it is usually preferable that all operations of pumping, pulling, and cleaning be performed by the same motor. Thus there is a very wide range of duty required of the motor installed. To meet this requirement the General Electric Company has produced a two speed, variable speed motor; the capacity and speed may be changed immediately by means of a pole changing switch mounted on the frame of the motor. The normal rating of their motor is 30 h.p. at 1200 r.p.m.; this is used for shaking, bailing, or handling tubing or rods; the other rating of 15 h.p. at 600 r.p.m. is used for the steady pumping load. (See Plate 6) This motor is capable of light re-drilling work which is often necessary when cleaning out a well. The stator of their motor has two separate three-phase windings, and the rotor is a six-phase wound rotor, requiring six collector rings. The two controllers (see Plate 2) are equipped with rope wheels so that the motor may be controlled from the headache post by means of telegraph cords in the same way as for drilling. An oil circuit breaker providing for undervoltage and overload protection is connected in the circuit as shown in the diagram.'

Plate 5 shows the installation at the T.F. Gilmore Oil Company, Los Angeles, California. It shows the arrangement for the individual pumping of wells on the beam, with a small horsepower squirrel cage motor with a larger motor for pulling and cleaning purposes.

In a few cases where the depth of tubing has exceeded 4000 feet, or where extra heavy gravity oil is pumped, it has been found necessary to install equipment rated at 20 h.p. for pumping purposes and 50 h.p. for pulling and cleaning; these motors have a momentary maximum capacity of 75 h.p..

Counter-balances

The economy of pumping has been materially increased by the addition of a weight to counterbalance the rods on the beam. The counterbalance, which is hung from the back end of the walking beam, relieves the motor of the necessity of lifting the full weight of the rods on each stroke. Actual tests have shown a saving of from 8 to 22 per cent in the power required to pump the well, the amount depending upon the depth of the well, the weight of the rods, and the speed and length of the stroke.

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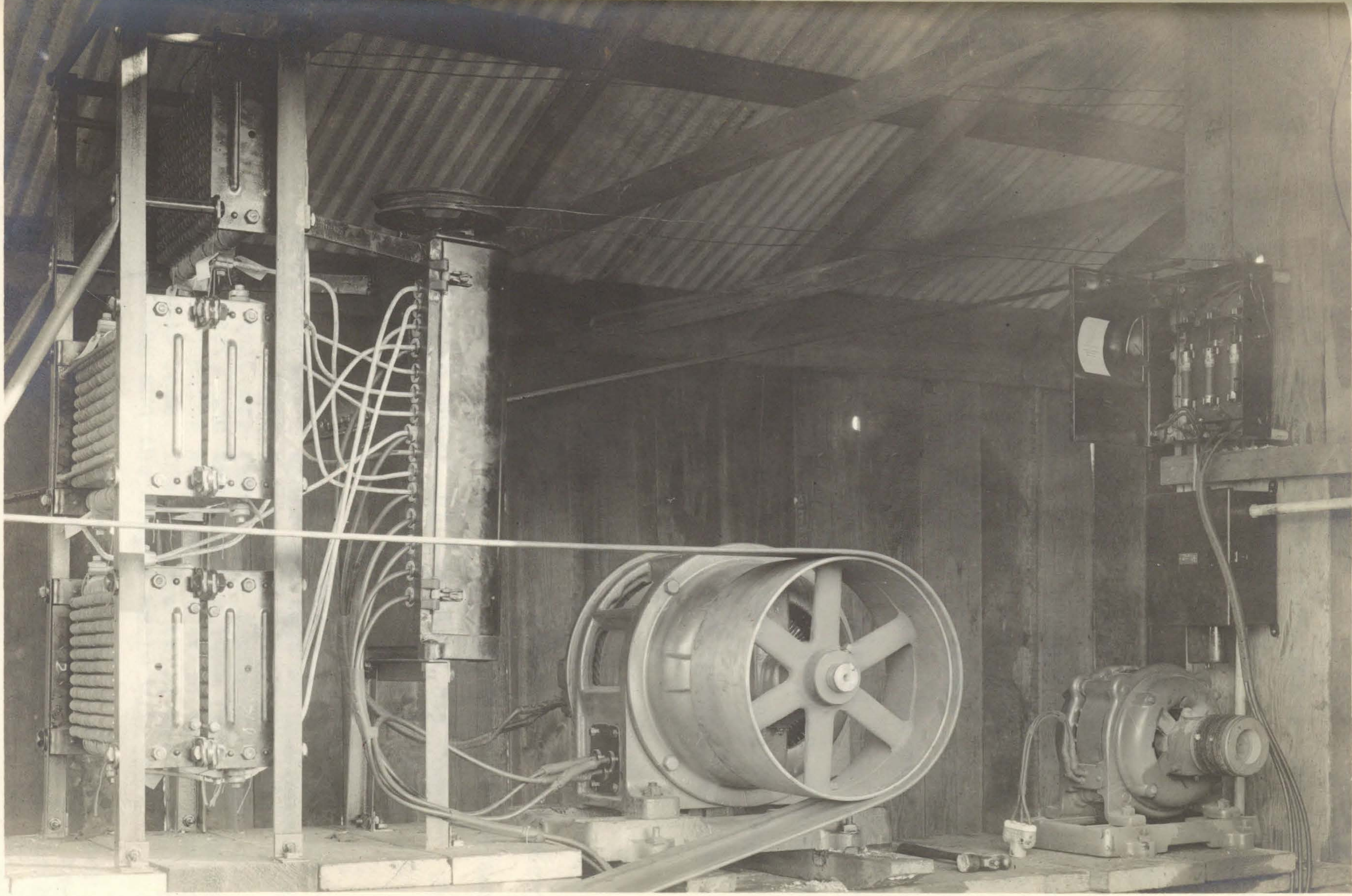
'See Plate 4, Blueprints furnished by the General Electric Co., Schenectady, N.Y.



326979 SEPARATE MOTORS FOR OIL WELL PUMPING AND PULLING AT THE A. F. GILMORE OIL CO., LOS ANGLES, CAL., THE PUMPING MOTOR BEING TYPE KT-7 5 HP - 1800 RPM 440 V AND THE PORTABLE PULLING MOTOR BEING TYPE MT-40HP - 1200 RPM -440V WITH T-10-J CONTROLLER. MOTORS OPERATE ON A 50 CYCLE CIRCUIT.

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PLATE 5

Pumping by Jack-Power

If the pulling and cleaning of several wells in the same territory is infrequent, and the wells are well balanced against each other, and if the gravity of the oil, the diameter of the tubing, and the general conditions of the well are approximately the same, the pumping may be done from a central power head or jack, which may be electrified at a comparatively low cost per well. A standard constant speed, squirrel cage motor is suitable for practically all operating conditions met with. The motor is belted to a countershaft, which is in turn belted with a quarter turn belt to the power head. When the wells are pumped by jack-power all "shaking up", pulling, and cleaning must be done by some type of portable outfit.

Power Consumption for Pumping Operations

The simplicity and flexibility of operation, aside from the all-round efficiency of the electrical pumping equipment, appeals to the average oil man.

Mr.J.H.Royer, of the Birch Oil Company, Fullerton, California, says:

"...regarding our motor installation for oil well pumping I would say that we are operating ten 30/15 h.p. oil well pumping motors on our wells that are tubed to a depth of 2500 to 3900 feet, and the gravity runs from 19° Baume on the shallow wells to 21.5° to 28.5° Baume on the deep ones. The shallow wells are tubed with 2" tubing and the deeper wells with 2½".

"...Our power cost averages about $90.00 per month per well, and the rate is 1 cent per kw-hr. with a standby charge of $1.00 per month per h.p. and a surcharge of .001 per kw-hr."

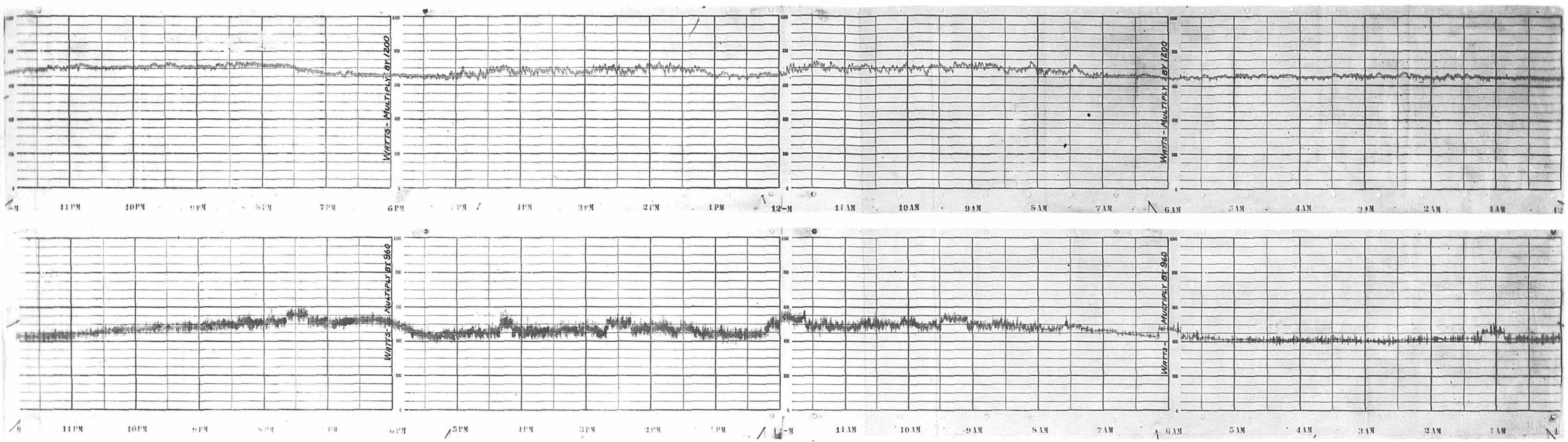
The "cleaning gang" at this well, using a 30/15 h.p. motor for pulling and cleaning, pulled sixty, 60-ft. stands of $\frac{3}{4}$ in. rods in 55 minutes.

From Mr. Royer's statements we see that the cost of power for pumping does not depend upon the depth of the well to any great extent, because the gravity of the oil pumped offsets the increased depth of pumping. The power cost, however, is regulated to a large extent by the viscosity of the oil and the gas pressure, speed of the rods and the length of the pumping stroke.

The significance of these statements is further shown by the subjoined report of the Fullerton Oil Co.:

| | |
|---|---|
| No. of wells pumped by motor | 6 |
| Average minimum pumping depth | 2581 ft. |
| Average maximum pumping depth | 3220 ft. |
| Size of tubing used | 2" - $2\frac{1}{2}$" |
| Gravity of oil | 17° - 22° B. |
| Average power cost per well per month | $80.00 |

The load in an oil field is almost of an ideal nature as is well shown by Plate 6, the actual curve-drawing wattmeter records of sub-stations serving typical California oil fields. The load is practically constant twenty-four hours a day, throughout the year, without any material variation. The slight rise shown in these curves at night is due to the lighting load.




320112 TYPICAL 24 HOUR OIL FIELD LOAD CURVES. UPPER RECORD FROM SUBSTATION OF SAN JOAQUIN LIGHT AND POWER CORPORATION SERVING A PORTION OF THE MIDWAY OIL FIELD, AT TAFT, CALIFORNIA. LOWER RECORD FROM SUBSTATION OF MIDLAND COUNTIES PUBLIC SERVICE CORPORATION SERVING A PORTION OF THE COALINGA OIL FIELD IN CALIFORNIA.

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PLATE 6

The Pan American Petroleum Corp., Los Alomos, California, using a 30/15 h.p. General Electric motor, is pumping a 4,000 ft., 3 in. tubed well at the rate of 20 strokes per minute, using the first hole of the crank. This is the deepest well that has been pumped with a motor of this capacity.

The Coalinga Mohawk Oil Co. is pumping a 3,800 ft. well at 30 strokes per minute, using the third hole of the crank, with a 50/20 h.p. General Electric motor. However, the actual measured input on this motor is only 26 h.p.

The Petroleum Midway Co. is operating the Mulholland Lease in the Montebello fields on a 30/15 h.p. General Electric Co. motor at an average cost of $65 to $70 per month, consuming an average of 3640 kw-hr. per month. The P.& D. Lease, operated by the same company, consumes an average of 8240 kw-hr. per month for two wells. The power rate at this field is 1.2 cents per kw-hr. plus a maximum demand standby charge of $22.50 per month. These wells are all pumped on the beam by individual motors.

Table 2' shows the comparative power consumption of selected groups of electrically operated oilwells in California.

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' See page 8, "Electric Power in the Oil Fields", by W.G.Taylor, Power and Mining Engineering Department, General Electric Co., Schenectady, N.Y.

TABLE NO.2

| | Case 1 | Case 2 | Case 3 | Case 4 | Case 5 |
|---|---|---|---|---|---|
| No. of wells ...... | 50 | 5 | 6 | 4 | 6 |
| Location (Calif.).. | Kern | Casmalia | Casmalia | Cat Canyon | Santa Maria |
| Av. depth, feet ... | 1000 to 1100 | 1800 | 2000 | 2900 | 2800 3000 |
| Pumping speed ..... | 27 | 18 | 20 | 22 | 20 |
| Hole in crank used for pumping ...... | 1st. 2nd.&3rd. | 1st. | 1st. | 1st. | 1st. |
| Gravity of oil °B.. | 12.5°to 14.9° | 10°to 11° | 12° | 15° | 19°to 21° |
| Size of tubing .... | ... | $4\frac{1}{2}$" | $2\frac{1}{2}$"- 3" | ... | $2\frac{1}{2}$" |
| Water ............ | Much | Much | ... | ... | ... |
| Gas ............... | ... | ... | Very Little | Some | Yes |
| No. of months ave'd | 4 | 3 | 3 | 3 | 3 |
| Av. kw-hr. per well per month.. | 5252 | 4403 | 3927 | 4229 | 3941 |

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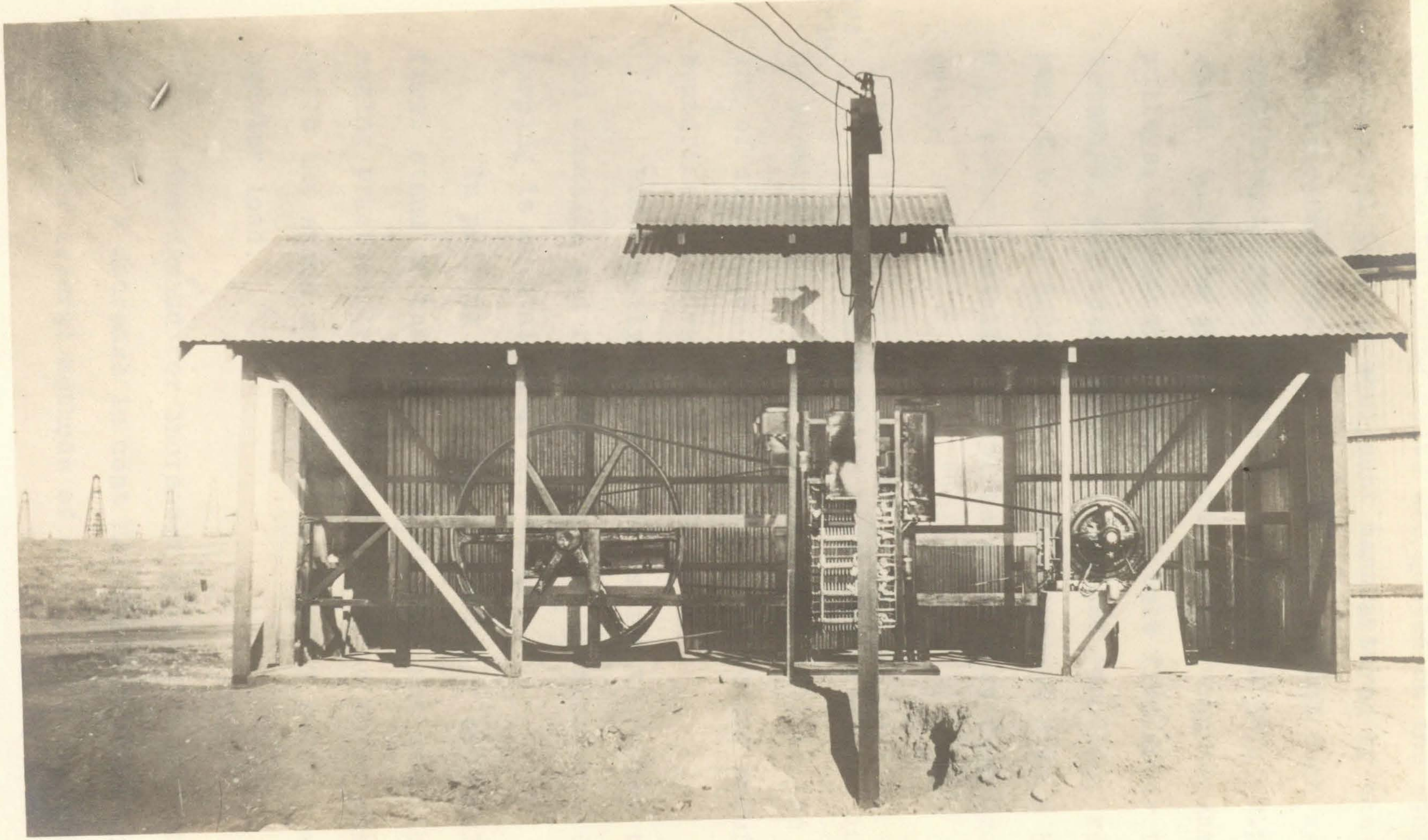
It is interesting to note in the above table that the kilo-watt hour consumption of the deep wells is no more in many cases than that of shallow wells. This table shows that the most influential factors are the length of the stroke, the speed of pumping, the diameter of the pump barrel, the gravity of the oil and the fluid level in the wells.



320324 TYPE OMT-336-6/12 POLE. 30/15 HP-1200/600 RPM 440 VOLT TWO-SPEED VARYING-SPEED OIL WELL MOTOR AS INSTALLED BY THE ASSOCIATED OIL CO.. IN THE COALINGA OIL FIELDS IN CALIFORNIA.

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PLATE 7

Cost of Pumping Equipment

The following costs are quoted on the standard electrical pumping equipment manufactured by the General Electric Company. This standard equipment such as shown in the photograph (Plate 7) includes: A 30/15 h.p.two speed, variable speed induction motor, countershaft and pulleys, all control equipment, belt from motor to countershaft, and motor house, installed complete, ready to run, $1600 to $2000. The same equipment with a 50/20 h.p. motor installed complete would cost from $2000 to $2500.

Advantages of Electric Pumping

The arguments which have been presented in favor of electrical drilling apply equally well to the pumping of oil wells. Further than this we may briefly summarize the advantages as follows:

Practically all shut-downs due to engine trouble; rod breakage and repairs, etc. are eliminated. Steady pumping is maintained at all times.

In pulling and cleaning, the motor will pull the first stand of tubing as fast as the last one, the load making practically no difference in the motor speed, while the steam engine speed is greatly reduced with the heavier load.

Auxiliary Electrical Equipment

The demand for increased production and at the same time a decrease in cost has brought about the perfection of several methods of electric de-hydration within the last few years. Having electrical energy at the oil well makes electric de-hydration possible, and so in the future the electrical manufacturer will be obliged to consider equipment for this work. It is a very significant fact that at the present time more than one million barrels of oil per month are being electrically de-hydrated in California, the average power consumption per barrel of clean oil ranging from 22 to 65 watthours.

If the well is located in a "pocket" and is a "gasser" it is advisable to use oil switches throughout the entire equipment, for this prevents any chance of the igniting of the gas from the well by the make or break spark of an open knife switch. In one particular case where the gas is unusually strong and may come on at any time, the oil company has asked the electrical manufacturer to provide against sparking at the collector rings. This, however, is a very extreme case such as is not often met.

Portable pulling and cleaning equipment should be provided for if the wells are pumped on the beam by jack-power, or if the individual motor is too small for that purpose. Any standard type hoist may be connected to an electric motor and mounted upon a movable frame; such a portable motor driven hoist may be transported from well to well and connected by plug connectors at each place.

Transformers are usually furnished and installed at the fields by the power companies. However, when the oil company purchases its own transformers, the cost of electrification per well will be lower if a group of wells can be equipped with motors and all operated from the one bank of transformers.

For drilling work a separate bank of transformers should be used for each motor.

Advantages of Electrification

During the investigation many advantages of the electric motor over the steam or gas engine have been found. These may be summed up as follows:

(1) Motor drive is the most economical and therefore minimizes the operating expenses. Where the price of boiler feed water is high and the quality poor the saving in water alone has amounted to more than the cost of the electric power. The reduction in the number of boilers or their complete elimination, increases the oil production. This saving is an item of considerable value, particularly where high gravity oil is produced.

(2) As has been cited in this article, the steam or gas engine does not allow a steady pumping motion, whereas the electric motor gives a very constant motion, thus increasing the oil production.

(3) Valves, cylinder heads, and steam piping are bound to leak and are thus the cause of well known losses in the oil fields. The corresponding losses of

electric power due to transmission are low and have a fixed percentage throughout the life of the equipment.

(4) No fuel is required to get up steam; no power is consumed with idle equipment.

(5) Accurate control is essential and may be obtained with the electric motor to a higher degree than for any other method of drive, whether for drilling, pumping, or cleaning.

(6) Time is valuable. The delays due to motor trouble are much less than the delays due to engine and boiler trouble. In pulling a well the first stand of tubing may be pulled as fast as the last one, practically without regard to the load lifted.

(7) The motor is always ready to start at the turn of the controller, and will always give the same speed upon the same controller point under similar operating conditions.

(8) The control is simple and accurate; there is no reverse lever.

(9) The speed of the motor is practically independent of the voltage fluctuations but may be varied at will by the controller.

(10) There is less danger of rod breakage with the motor drive than with the steam or gas engine, since the motor does not pick up the rod with a jerk; the speed of the band-wheel is practically constant during the entire revolution, thus reducing the tendency for the rods to crystallize.

(11) The fire risk is reduced, and the danger from explosions is practically eliminated. Insurance rates are therefore lower.

(12) Greater safety of operation is obtained with the motor, as it cannot "run away" when the rods part or the hoisting cable breaks under the heavy load.

(13) Boiler depreciation (which is usually high in the oil fields) is greatly reduced or entirely eliminated.

(14) Power consumption can be measured at all times and thus an accurate cost of operation can be kept for each well.

(15) The motor house, belts and machinery, can be kept cleaner , with a consequent less rapid deterioration of machinery and rig.

Recommendations

From the results of the foregoing investigation we find that the electrification of oil wells is a commercial success for both the oil producer and the electrical manufacturer. With the electrification of future wells and of proven territory must come a demand for standard electrical equipment, for which the following recommendations may be made:

DRILLING MOTOR AND EQUIPMENT.- A variable speed induction motor, with a main and auxiliary controller and resistors complete, protected by a triple-pole oil circuit breaker with an automatic under-voltage release and an overload trip is recommended. The motors should be built in two sizes, 50 h.p. and 75 h.p. for 440 volts.

PUMPING EQUIPMENT.- Pumping motors should be two speed, variable speed induction motors, and should be built in at least two different capacities; 30/15 h.p and 50/20 h.p. A convenient method for obtaining the change in speed is by means of a pole changing switch (which may be mounted on the frame), one position connecting the stator windings for six-pole operation and the other position for twelve-pole operation. The rotor which has been found most satisfactory is a six-phase wound rotor, requiring six collector rings. This equipment should be protected by a triple pole oil circuit breaker equipped with an automatic under-voltage release and a two-coil series-inverse-time-limit overload trip. The two coils should be electrically interconnected with the motor pole changing switch in such a manner that whenever the latter is thrown to either the high-speed or the low-speed positions the coils will be connected to trip the switch at an overload corresponding to the motor rating in use.

CONTROL APPARATUS.- The controllers should be provided with rope wheels in place of the standard industrial handles, so that they may be operated independently from the headache post by means of telegraph cords, which should govern both the forward and reverse operations as well as all speed variations.

TRANSFORMERS.- For drilling work a separate bank of transformers should be used with each motor. For pumping purposes the cost of electrification per well will be lower if an entire group of wells equipped with motors is put on one transformer bank.

Standard outdoor-type oil cooled transformers are best suited for oil field service.

INSTALLATION.- For drilling purposes separate concrete bases are not satisfactory; the equipment should be mounted upon a fabricated "I" beam base.

Excessively heavy chains from the motor to the countershaft should be avoided so as to reduce the moment of inertia and thereby allow a quick reversal of the motor and rotary table.

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Bibliography

Electrical Equipment of Oil Wells ....... G.E.Co.

General Electric Co. Bulletin No.48013, Aug.1914

"Applying Motors to Oil Well Pumping"...... W.G.Taylor

Electrical World, Jan.3,1920

"The Operation of Oil Wells by Electric Power and the Resulting Gain to the Oil Producer."

General Electric Review, May, 1919...W.G.Taylor

"Electric Power in the Oil Fields" .........W.G.Taylor

Presented at the Forty-third Convention of the National Electric Light Association Pasadena, California, May 18-22,1920

"The Application of Electricity to the Production of Crude Oil. .....................W.G.Lane

The Oil Age, Jan.,1920