A COMPARISON OF THE INVESTMENT AND OPERATING COSTS FOR WATER PRODUCTION BY AIR LIFT PUMPING AND BY DEEP WELL TURBINE PUMPING

THESIS FOR THE DEGREE OF C. E.

Marshall Edwin Snider

1933

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Pumping machinery
Water-supply

Civil engineering Sanitary engineering

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Before a municipality, or an industrial group, can install new or expand existing water production facilities, there are several factors which should be considered. Principal among these factors is the source of water supply and means of pumping the water.

Lacking a suitable source of surface water supply, such as lakes or rivers, it becomes necessary to resort to a supply derived from either shallow gravel wells or deep rock wells. When deep rock wells are chosen as a source of supply, a further choice must be made with regard to the means of pumping the water from the wells.

There are three principal methods of pumping wells:-

1. By suction lift plunger pumps.
2. By deep well turbine pumps.
3. By air lift pumps.

Suction lift pumps are being rapidly supplanted by the other types and will not be considered in this paper. The six following combinations for the production and pumpage of well water are to be discussed. All of the plans are based on the same general conditions as detailed later.

Plan I - Air lift pumps - Purchased power.

This plan contemplates the production of water by means of air lift pumps, using air from synchronous motor driven compressors. As is usual in air lift installations, the water flows by gravity from the air separator at the well to a reservoir from which the high lift pumps take suction. All power used is to be purchased from a power utility at the prevailing rate.

Plan II - Air lift pumps - Diesel engine power.

The only difference between Plan I and Plan II is that the air compressors and high lift pumps are driven by direct connected Diesel engines in Plan II.

Plan III - Air lift pumps - Steam power.

This plan varies from Plans I and II in that the compressors are steam engine driven and the high lift pumps are driven by steam turbines. A boiler plant is also included for the generation of steam.

Plan IV - Deep Well Turbine Pumps - Purchased Power

In Plan IV, and likewise in Plans V and VI, the deep well turbine pumps are located in underground vaults and discharge directly to the distribution system. Plan IV uses purchased power for driving the pumps. Power is secured from the same source and at the same rate as in Plan I. An outdoor substation is used to step the voltage down to 440 volts for pump motors.

Plan V - Deep Well Turbine Pumps - Diesel engine power.

Under Plan V, Diesel engine driven generators located at a central station supply energy for driving the deep well pumps.

Plan VI - Deep Well Turbine Pumps - Steam Power

Plan VI includes a boiler plant for the generation of steam to supply steam for steam engine driven generators which in turn supply energy to the deep well turbine pumps.

It is not the purpose of this paper to express a definite final opinion as to the relative merits of the various ways of pumping water from wells, but rather to suggest a general opinion and suggest a method of comparison which can be readily applied to any given set of conditions. For purposes of illustration of the method, a set of conditions is assumed and is used throughout the calculations. The assumed conditions follow:

General Conditions

Producing capacity of development - 8 million gallons per day.
Static water level - 20 feet below grade
Specific capacity - 3 gallons per foot of draw-down
Load Factor - 65%
Average daily production to mains - 5,200,000 gallons or 3,610 g.p.m.

Power Rate Schedule

Demand charge:	\$ 2.50 per kw. per month for the first 100 kw. of maximum demand (15 minutes).
	\$ 1.50 per kw. per month for all over 100 kw. of maximum demand.
Energy charge:	1.15¢ per kw.-hr. for first 250 hours use of maximum demand per month.
	0.95¢ per kw.-hr. for all over 250 hours use of maximum demand.
Power Factor Correction:	The actual demand and measured energy are multiplied by the constant given below and the result is the billed demand and billed kilowatt hours:

100% Power Factor	0.9330
90% Power Factor	0.9610
80% Power Factor	1.0000

Discount:	A discount of 5% is allowed for prompt payment.

Cost of Fuel Oil - 6¢ per gallon

Cost of Coal - \$4.25 per ton in bunker.

Conditions Common to Plans I, II and III

Draw-down - 140 feet

Production capacity of each well - 420 g.p.m.

Fourteen 12" diameter wells will be required to supply the 8 m.g.d. demand; two additional wells are added to provide reserve capacity, making a total of sixteen. These wells are assumed to be cased for the first 60 feet, and to have a depth of 425 feet. Wells spaced 500 feet apart.

Height of discharge above grade - 10 feet

Average submergence - 255 feet

Per Cent submergence - 60%

Length of eduction pipe - 425 feet

High lift pumping head - 150 feet

Conditions Common to Plans IV, V and VI

Top of pump bowls - 200 feet below grade

Total pumping head - 330 feet above pumping water level in well (160 foot draw-down)

Production capacity of each well - 480 g.p.m.

Twelve 14" diameter wells will be required to supply the 8 m.g.d. demand; two additional wells are added to provide reserve capacity, making a total of 14 wells. Wells cased 60 feet, with a 425 foot total depth and spaced 550 feet.

Power Requirements - Plan I

Air Lift - Purchased Power

According to standard empirical formula:-

$$\text{Air Required} = \frac{255}{335 \log \frac{255 + 34}{34}}$$

= 0.85 cu.ft. free air per gal.of water

Total air required is:-

3610 g.p.m. x 0.85 = 3068 cu.ft. air per minute

Synchronous motor driven compressors will require

20.25 horsepower input per 100 cubic feet of air compressed. 20.25 x 30.68 = 621 horsepower required to bring water from wells to the separating tank, from where it will flow by gravity to the reservoir (low lift).

Assuming an overall efficiency of 70% for horizontal motor driven centrifugal high lift pumps, the power input will be:-

$$\frac{3610 \text{ g.p.m.} \times 150 \text{ ft.head} \times 8.34 \text{ lb.per gal.}}{33{,}000 \text{ ft. lb.per hp.} \times 70 \text{ eff.}} = 195 \text{ hp.}$$

The total horsepower required will be the sum of the low and high lifts (621 + 195) or 816 hp. which is equivalent to 610 kw.

An average load of 610 kw. will require 445,605 kw.-hr. per month. A 550 hour use of the demand will result in a demand of 810 kw. Assuming a 100% power factor for the synchronous motors, the above quantities will be reduced as a bonus for high power factor by multiplying by 0.933.

Application of the rates given above results in a power charge of $64,309.65 per year for Plan I.

Fuel Requirements - Plan II

Air Lift Pump - Diesel Engine Power

The fuel required for the Diesel engines used to drive the air compressors and high lift pumps may be calculated in the following manner.

The conditions as to water produced and air required, are the same in both Plan I and II, viz., average daily production 5,200,000 gallons of water and 3,068 cubic feet of free air per minute.

Diesel engine driven compressors will require 20.75 brake horsepower per 100 cubic feet of compressed air.

20.75 x 30.68 = 637 b.hp. required to bring water from the wells to the reservoir (low lift).

Assuming the same pump efficiencies as in Plan I, 195 b.hp. will be required for high lift pumping.

The total brake horsepower will be the sum of low and high lifts or 832 b.hp.

The overall economy of a Diesel engine is assumed as 0.6 pounds of fuel per brake horsepower, and cost of fuel as 6 cents per gallon, resulting in an annual fuel cost of $33,900 as follows:

$$\frac{832 \text{ hp.} \times 24 \text{ hrs.} \times 365\tfrac{1}{4} \text{ day} \times 0.6 \text{ lb.} \times 7.48 \times 6¢}{58 \text{ lbs. (cost of Oil per cu.ft.)}} = \$33,900$$

Fuel Requirements - Plan III

Air Lift Pumps - Steam Power

The same conditions of water produced and air required are used as in Plans I and II.

Steam driven compressors will require $20\frac{1}{2}$ indicated horsepower per 100 cubic feet of compressed air.

20.5 x 30.68 = 629 i.hp. required to bring the water from the wells to the reservoirs (low lift).

Assuming the same high lift pump horsepower as in Plan II, 195 i.hp. will be required.

The total indicated horsepower will be the sum of the low and high lifts or 824 i.hp.

The overall economy of a steam plant operating condensing is taken as 20 pounds of steam per indicated horsepower. With an overall evaporation of 8 pounds of steam per pound of coal, and a cost of coal of $4.25 per ton in bunkers, the annual fuel cost is $38,400, as follows:-

$$\frac{824 \text{ i.hp.} \times 24 \text{ hrs.} \times 365\tfrac{1}{4} \text{ da.} \times 20\# \text{ econ.} \times \$4.25 \text{ per ton}}{8\# \text{ evap.} \times 2000\#} = \$38{,}400$$

Power Requirements - Plan IV

Deep Well Turbine Pumps - Purchased Power

The power requirements for Plan IV may be determined as follows:-

Assuming the same production demands as for the air lift systems, a static level of 20 feet and pumps operating with 160 feet of draw-down and and 150 feet discharge pressure, the water horsepower to be developed equals:

$$\frac{3610 \text{ g.p.m. x } 330 \text{ ft.head x } 8.34 \text{ lbs.per gallon}}{33{,}000 \text{ ft. lb. per hp.}} = 301 \text{ w.hp.}$$

Assuming an overall pump efficiency of 60 per cent, 502 hp. input is required for the motors, or 375 kw. With a 2% loss in electric secondary demand and a 3% transformation loss from 4,400 volts to 440 volts, this becomes 393 kw. measured energy required.

Using the same rate schedule for purchased power as in Plan I the annual electric energy charges are $42,553, as follows:

An average load of 393 kw. will require 3,450,000 kw.-hr. per year or 287,500 kw.-hr. per month. A 550 hour use of the demand (as in Plan I) will result in a demand of 523 kw.

Assuming a 90% power factor for the induction motors, the demand and energy are multiplied by 0.9610 resulting in a demand of 503 kw. and 276,500 kw.-hr. for energy.

Demand charge:-

100 kw. @ $2.50 =	$ 250.00
403 kw. @ $1.50 =	604.50

Engergy charge:-

250 x 503 x 1.15¢ =	1,446.12
150,750 x 0.95¢ =	1,432.13
Total Gross charges	3,732.75

Total Gross charges	$3,732.75
Less 5%	186.64
Monthly Power Cost	$3,546.11
Annual Power Cost	$42,553.32

Fuel Requirements - Plan V

Deep Well Turbine Pumps - Diesel Engine Power

Under this plan the energy required at the switchboard is the same as in Plan IV or 382 kw. which is equivalent to 570 brake horsepower of Diesel engine capacity (90% conversion efficiency).

Using the same economy and oil costs as in Plan II, the annual fuel costs are $23,250.

$$\frac{570 \times 24 \times 365.25 \times 0.6 \times 7.48 \times .06}{58} = \$23,250$$

Fuel Requirements - Plan VI

Deep Well Turbine Pumps - Steam Power

The switchboard energy requirements of Plan VI are the same as for Plans IV and V, 382 kw. or 570 hp.

Using the same economies and costs as in Plan III, 20 lb. per i.hp. overall economy, 8 lb. evaporation and coal at $4.25 in the bunkers, an annual fuel cost of $26,800.

$$\frac{570 \times 24 \times 365.25 \times 20 \times 4.25}{8 \times 2000} = \$26,800$$

The labor and maintenance charges to be applied to each of the various plans are subject to a considerable variation, but the following estimates are believed to be reasonable and serve to demonstrate this method of comparison.

Plan	Annual Labor Cost	Annual Maintenance Cost
I Air Lift		
Purchased Power	$ 8,400	$ 3,000
II Air Lift		
Diesel Power	8,400	4,000
III Air Lift		
Steam Power	12,900	5,000
IV Deep Well Turbines		
Purchased Power	4,800	4,000
V Deep Well Turbines		
Diesel Power	8,400	4,000
VI Deep Well Turbines		
Steam Power	12,900	5,000

Fixed charges for all plans are taken at the same rate, 15%, as any attempt to differentiate between plans as to percentage of fixed charges would involve controversial discussion which would be very difficult of proper solution.

Estimated costs of the initial investment are necessary to the determination of the most economical system of producing water. No explanation of these estimates is necessary. The estimates submitted are indicative of firstclass practice in each of the items. The prices used have been accumulated over a period of several years and represent fair market values. Manufacturers and contractors who have contributed estimates used herein include the following:

William H. Cater
Pomona Pump Co.
Indiana Air Pump Co.
Fairbanks-Morse
Wickes Boiler Co.
Chicago Pneumatic Tool Co.
Allis Chalmers Mfg. Co.
C. H. Wheeler Mfg. Co.

Plan I, II or III

Estimated Cost - Well Field Installation

Air Lift Pumping System

(8 Million gallons per day capacity)

16 - 12" Wells - 425 ft. deep -	$ 40,500
16 - Air Lift Pumps -	2,400
16 - Piping installations -	
Eduction pipe and air line -	6,400
16 - Air separator tanks and towers -	3,200
Air lines from compressing station	
to wells -	10,000
Discharge Piping - Wells to reservoir -	30,000
Real Estate -	20,000
Overhead and Miscellaneous 10% -	11,250
Engineering and Supervision 5% -	6,060
Interest during Construction 1½% -	2,075
Total cost of Well Field Development -	$131,885

Plan IV, V or VI

Estimated Cost - Well Field Installation

Deep Well Turbine Pump System

(8 Million gallons per day capacity)

14 - 14" Wells - 425 ft. deep -	$ 42,000
14 - Deep Well Turbine Pumps -	46,200
14 - Pump vaults -	4,900
14 - Meter Installations -	5,600
14 - Piping Installations -	2,800
Electric Distribution Lines -	2,700
Discharge piping from wells to point of transmission -	30,000
Real Estate -	20,000
Overhead and Miscellaneous 10% -	15,420
Engineering and Supervision 5% -	8,480
Interest during Construction 1½% -	2,670
Total cost of Well Field Development -	$180,770

Plan I

Estimated Cost - Station Installation

Motor Driven Compressors

3 - 1800 cu.ft. synchronous motor air compressor -	$ 45,000
Building and Foundations -	37,800
Reservoir - one million gallon capacity -	20,000
Piping and meters -	5,000
Auxilliaries -	1,000
Switchboard -	4,000
Wiring -	4,000
Overhead Crane -	1,500
3 - 3000 g.p.m. synchronous motor driven centrifugal high lift pump -	12,000
Chlorinator - low pressure -	1,200
Air receiver tanks -	700
Real Estate -	5,000
Overhead and Miscellaneous 10% -	13,720
Engineering and Supervision 5% -	7,550
Interest during Construction 1½% -	2,380
Total Station Cost -	$160,850

Plan II

Estimated Cost - Station Installation

Diesel Driven Compressors

3 - 1800 cu. ft. Diesel engine driven air compressors -	$ 85,500
Building and Foundations -	53,000
Reservoir - one million gallon capacity -	20,000
Piping and meters -	15,500
Auxiliaries -	6,500
Wiring -	2,000
Overhead Crane -	1,500
3 - 3000 g.p.m. Diesel driven centrifugal high lift pumps -	22,000
Chlorinator - low pressure -	1,200
Air Receivers -	700
Cooling water supply -	6,000
Fuel Oil Tanks -	6,500
Railroad siding -	2,000
Real Estate -	5,000
Overhead and Miscellaneous - 10% -	22,740
Engineering and Supervision - 5% -	12,510
Interest during Construction - 1½% -	3,940
Total Station Cost -	$266,590

Plan III

Estimated Cost - Station Installation

Steam Driven Compressors

3 - 1800 cu.ft. Steam Engine driven air compressors -	$ 47,000
Building and Foundations -	81,900
Reservoir - one million gallon capacity -	20,000
Piping and meters -	20,000
Auxiliaries -	4,000
Wiring -	3,000
Overhead Crane -	1,500
3 - 3000 g.p.m. turbine driven high lift pumps -	14,000
Chlorinator -	1,200
Air Receiver Tanks -	700
Cooling water supply -	4,000
Boilers and settings -	21,000
Stokers -	8,500
Chimney and Breeching -	7,500
Forced Draft fans and ducts -	3,000
Coal and Ash Handling equipment -	9,000
Oil Filters and tanks -	1,000
Condensers -	13,000
Railroad siding -	2,000

Real Estate -	$ 8,000
Overhead and Miscellaneous - 10% -	27,030
Engineering and Supervision - 5% -	14,865
Interest during Construction - 1½% -	4,680
Total Station Cost -	$316,875

Plan IV

Estimated Cost - Outdoor Substation Installation

Deep Well Turbine Pumps driven Purchased Power

3 - 200 Kv-a. Transformers -	$ 3,500
Foundations and Enclosure -	1,000
Wiring -	1,300
Chlorinator (high pressure) -	1,800
Real Estate -	500
Overhead and Miscellaneous - 10% -	810
Engineering and Supervision - 5% -	450
Interest during Construction - 1½% -	140
Total Sub-Station Cost	$ 9,500

Plan V

Estimated Cost - Station Installation

Diesel Engine Driven Generators

3 - 400 b.hp. Diesel Engines direct connected to 375 kv-a. generators -	$ 87,000
Building and Foundations -	42,500
Piping and meters -	13,000
Auxiliaries -	6,500
Switchboards -	4,000
Wiring -	4,000
Overhead Crane -	1,500
Chlorinator (high pressure) -	1,800
Cooling water supply -	6,000
Fuel Oil storage -	5,000
Railroad siding -	2,000
Real Estate -	5,000
Overhead and Miscellaneous 10% -	17,830
Engineering and Supervision 5% -	9,810
Interest during Construction 1½% -	3,090
Total Station Cost	$209,030

Plan VI

Estimated Cost - Station Installation

Steam Engine Driven Generators

3 - 400 i.hp. Vertical Uniflow Engines direct connected to 375 kv-a. generators -	$ 48,000
Building and Foundations -	69,500
Piping and meters -	20,000
Auxiliaries -	4,500
Switchboard -	5,000
Wiring -	4,000
Crane -	1,500
Chlorinator (high pressure) -	1,800
Cooling water supply -	4,000
Boilers and settings -	16,000
Stokers -	7,000
Chimney and Breeching -	6,500
Forced draft fans and duct -	7,500
Coal and Ash handling equipment -	9,000
Oil Filters and Tanks -	1,000
Condensers -	7,000
Railroad siding -	2,000
Real Estate -	8,000

Overhead and Miscellaneous 10% -	$ 21,730
Engineering and Supervision 5% -	11,950
Interest during Construction 1½% -	3,765
Total Station Cost	$254,745

Using the foregoing estimates as a basis, a reasonably close estimate of the total cost of operation under each plan may be prepared. These total costs of operation are readily reduced to unit costs by considering the total annual production.

A tabulation of the cost of operation for each of the six plans being considered has been made and is now submitted in the following six estimates. The fixed charges shown in each case are the sum of these items on the corresponding station and well field installations.

Plan I

Annual Cost of Operation

Air Lift System Using Purchased Power

Power -	$ 64,310
Labor -	8,400
Lubricants -	300
Supplies -	300
Maintenance -	3,000
Total Production Expense -	$ 76,310
Fixed Charges @ 15% -	43,910
Total Annual Cost of Operation -	$120,220

Unit Cost Per Million Gallons Produced

Production Expense -	$ 40.14
Fixed Charges -	23.10
Total -	$ 63.24

Plan II

Annual Cost of Operation

Air Lift System - Diesel Engine Driven Compressors

Fuel -	$ 33,900
Labor -	8,400
Lubricants -	2,600
Supplies -	1,200
Cooling water -	1,400
Maintenance -	4,000
Total Production Expense -	$ 51,500
Fixed Charges @ 15% -	59,770
Total Annual Cost of Operation -	$111,270

Unit Cost Per Million Gallons Produced

Production Expense -	$ 27.09
Fixed Charges -	31.44
Total -	$ 58.53

Plan III

Annual Cost of Operation

Air Lift System - Steam Driven Compressors

Fuel -	$ 38,400
Labor -	12,900
Lubricants -	600
Supplies -	500
Maintenance -	5,000
Total Production Expense -	$ 57,400
Fixed Charges @ 15% -	67,314
Total Annual Cost of Operation -	$124,714

Unit Cost Per Million Gallons Produced

Production Expense -	$ 30.19
Fixed Charges -	35.46
Total -	$ 65.65

Plan IV

Annual Cost of Operation

Deep Well Turbine Pumps - Purchased Power

Power -	$ 42,553
Labor -	4,800
Lubricants -	300
Supplies -	600
Maintenance -	4,000
Total Production Expense -	$ 52,253
Fixed Charges @ 15% -	28,540
Total Annual Cost of Operation -	$ 80,793

Unit Cost Per Million Gallons Produced

Production Expense -	$ 27.49
Fixed Charges -	15.01
Total -	$ 42.50

Plan V

Annual Cost of Operation

Deep Well Turbine Pumps - Diesel Driven Generators

Fuel -	$ 23,250
Labor -	8,400
Lubricants -	2,000
Supplies -	800
Cooling Water -	1,400
Maintenance -	4,000
Total Production Expense -	$ 39,850
Fixed Charges @ 15% -	58,470
Total Annual Cost of Operation -	$ 98,320

Unit Cost Per Million Gallons Produced

Production Expense -	$ 20.96
Fixed Charges -	30.76
Total -	$ 51.72

Plan VI

Annual Cost of Operation

Deep Well Turbine Pumps - Steam Driven Generators

Fuel -	$ 26,800
Labor -	12,900
Lubricants -	900
Supplies -	700
Maintenance -	5,000
Total Production Expense -	$ 46,300
Fixed Charges @ 15% -	65,327
Total Annual Cost of Operation -	$111,627

Unit Cost Per Million Gallons Produced

Production Expense -	$ 24.35
Fixed Charges -	34.37
Total -	$ 58.72

For purposes of easy comparison the resultant data obtained in the last six tabulations is shown below:

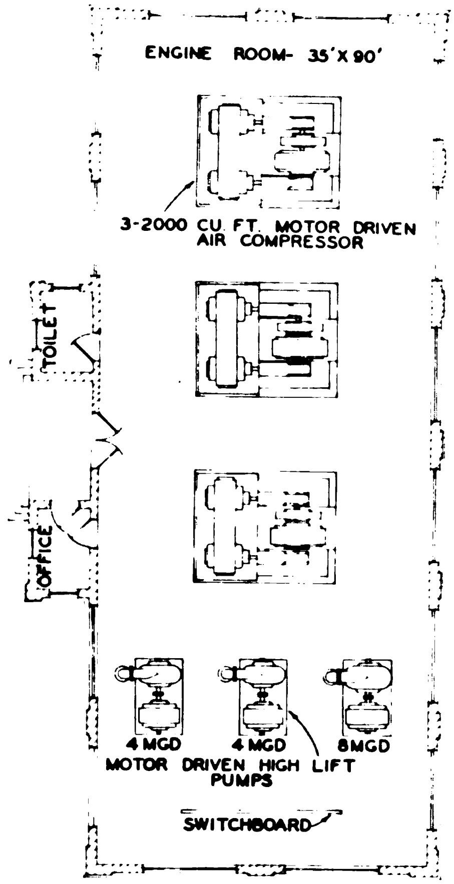
Unit Costs Per Million Gallons Produced

Plan	Production Expense	Fixed Charges	Total Expense
I - Air Lift			
Purchased Power	$ 40.14	$ 23.10	$ 63.24
II - Air Lift			
Diesel Power	27.09	31.44	58.53
III - Air Lift			
Steam Power	30.19	35.46	65.65
IV - Deep Well Turbines			
Purchased Power	27.49	15.01	42.50
V - Deep Well Turbines			
Diesel Power	20.96	30.76	51.72
VI - Deep Well Turbines			
Steam Power	24.35	34.37	58.72

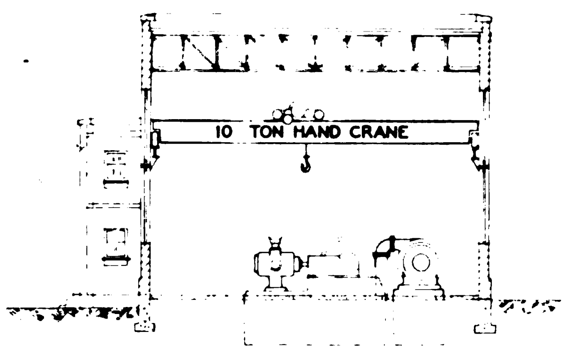
Explanation of the above tabulation will show that the cost of producing water by means of deep well turbine pumps driven by purchased power is decidedly lower than in any of the other five methods discussed.

A definite statement concerning the relative economies of the various plans can only be made after a detailed study has been prepared of the case in question. This is true because of the wide variation possible in each of the factors effecting the problem. A favorable market in which machinery might be purchased would have a correspondingly favorable effect on the fixed charges, but it is very doubtful if this effect would be sufficient to overcome the decided advantage indicated for Plan IV (Deep Well Turbines and Purchased Power). The relative cost of fuel or electric energy will also have a decided effect on "Total Production Costs", but it is probable that the cost of coal, fuel oil or electric energy will fluctuate similarily and the net result will be approximately as indicated.

In view of the above, the general statement may therefore be made that water may be most economically produced, and pumped to the water distribution system, by means of deep well turbine pumps driven by purchased power.



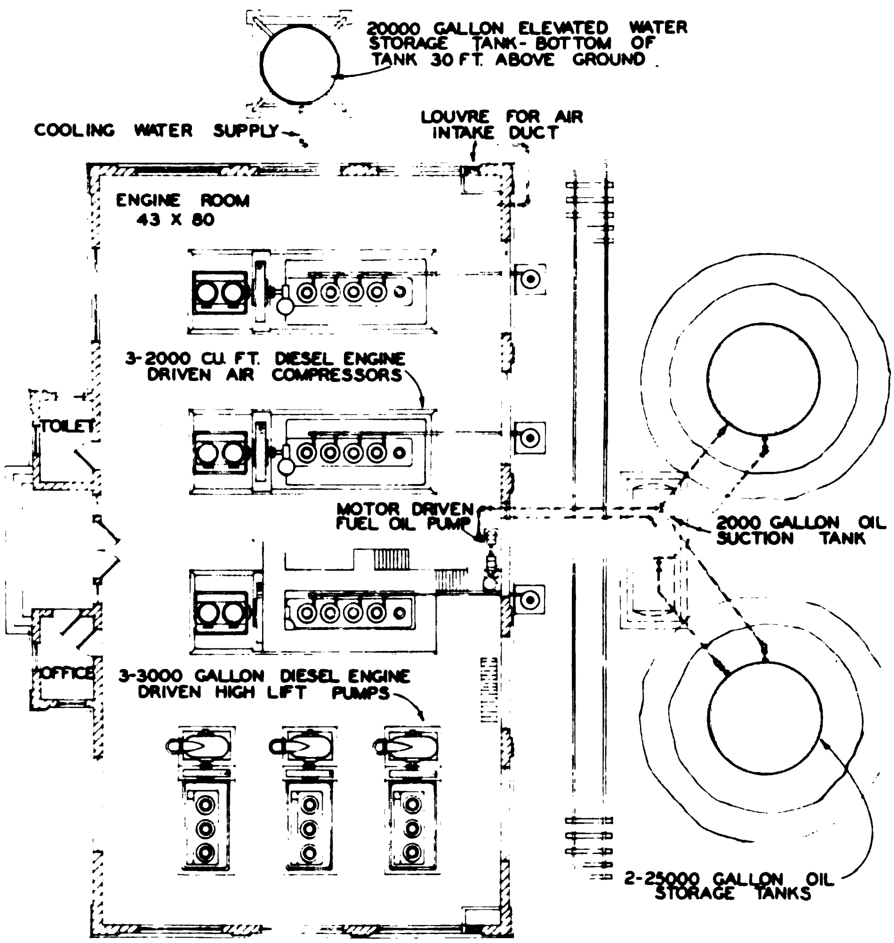
PLAN

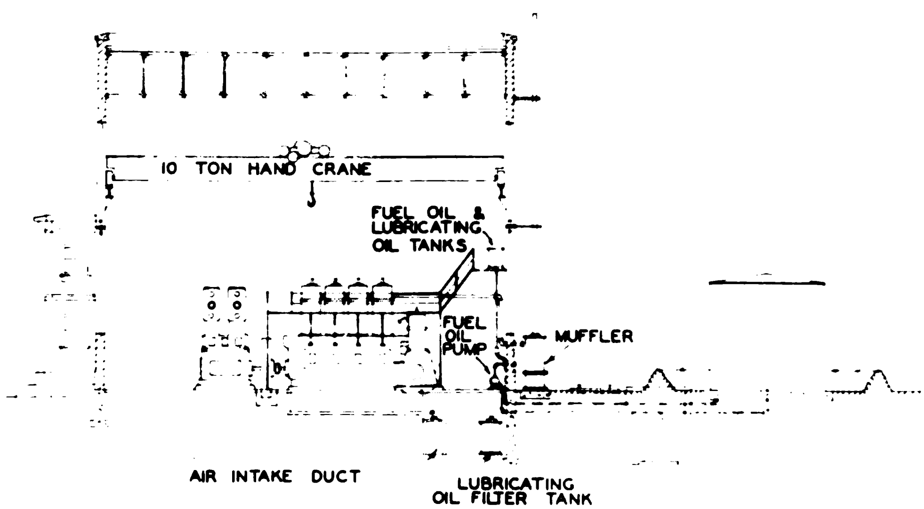


ELEVATION

PLAN № 1

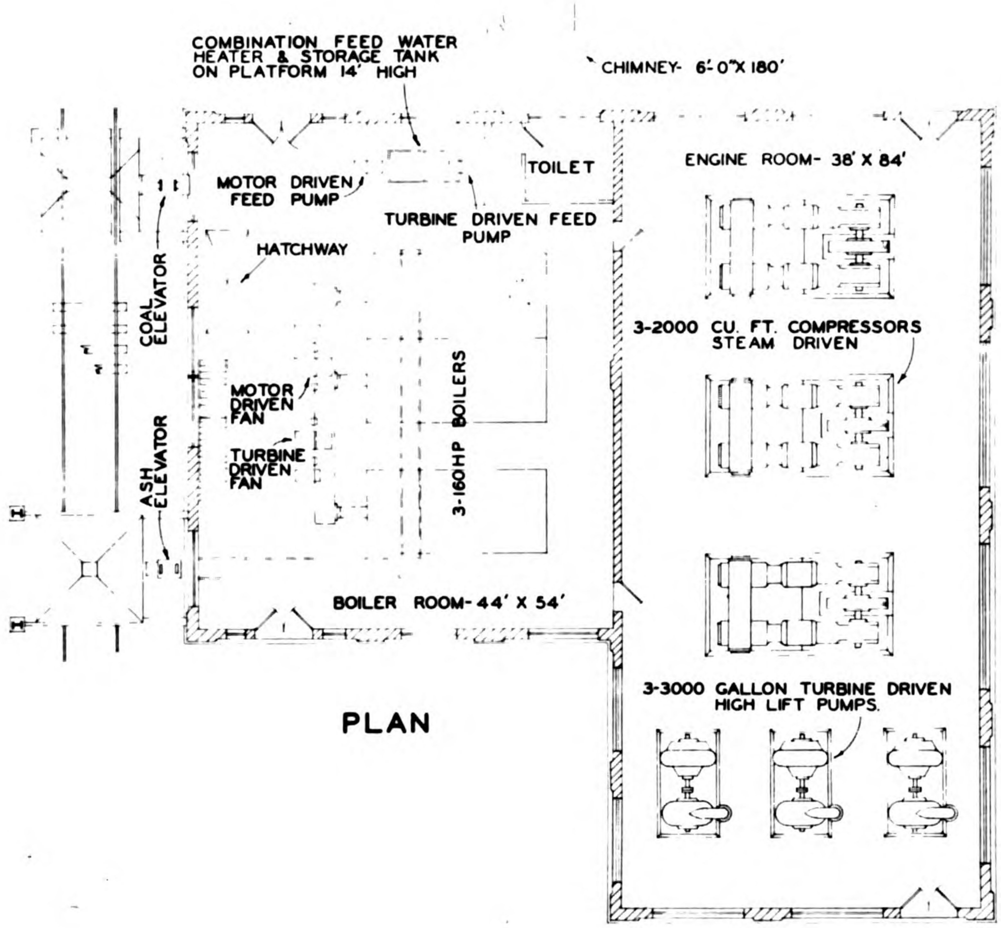
LAYOUT OF PURCHASED POWER DRIVEN AIR COMPRESSORS & HIGH LIFT PUMPS



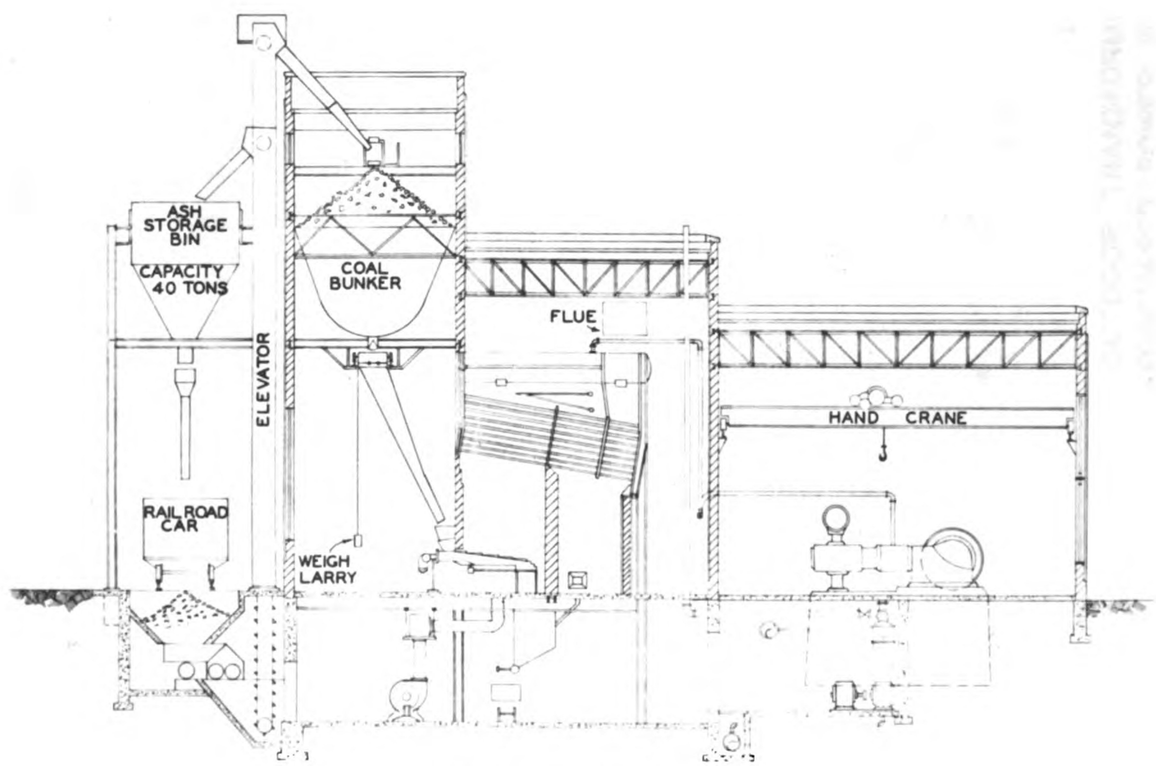


PLAN № 2

LAYOUT OF DIESEL ENGINE DRIVEN COMPRESSING AND HIGH LIFT PUMPING PLANT



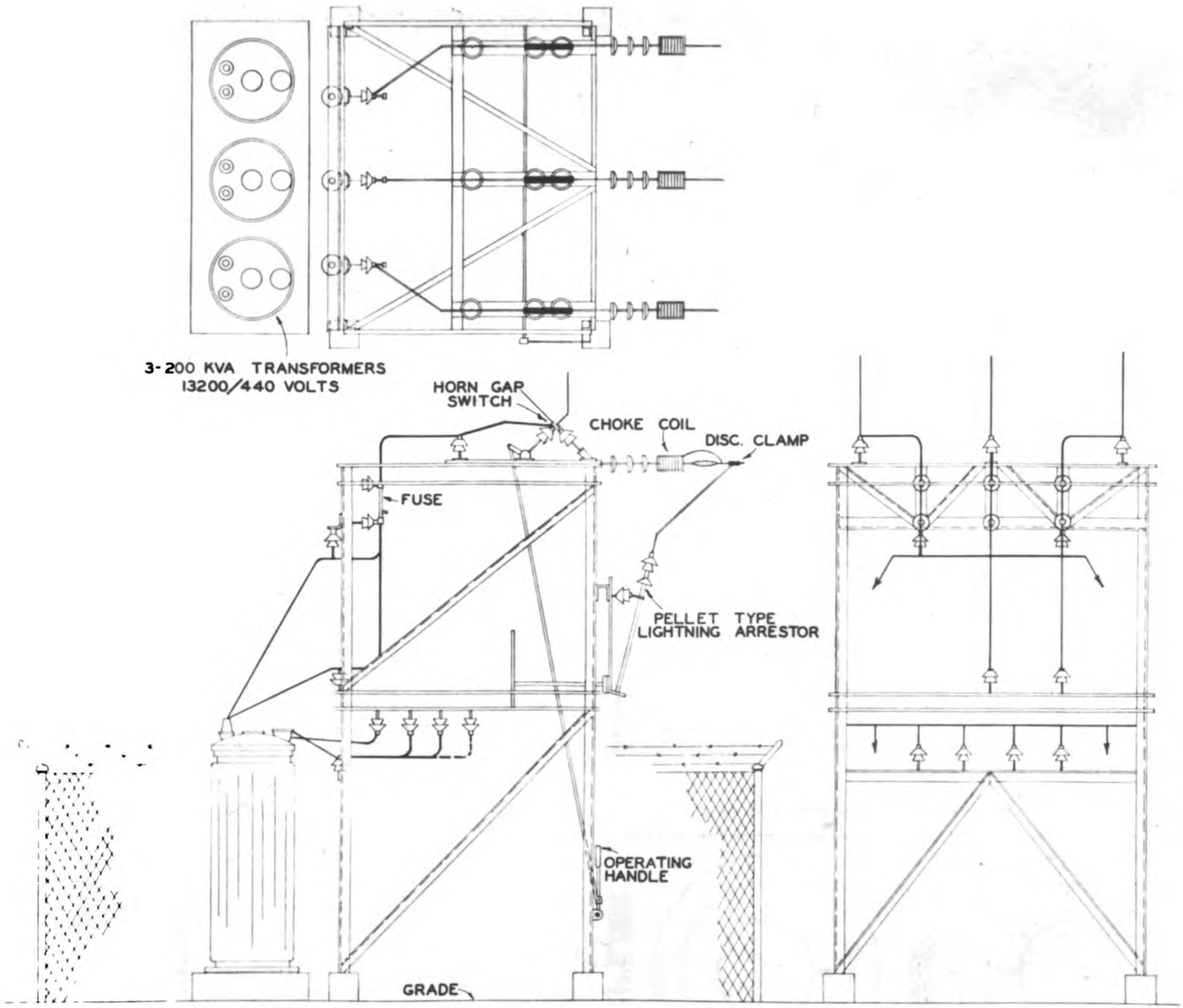
PLAN



ELEVATION

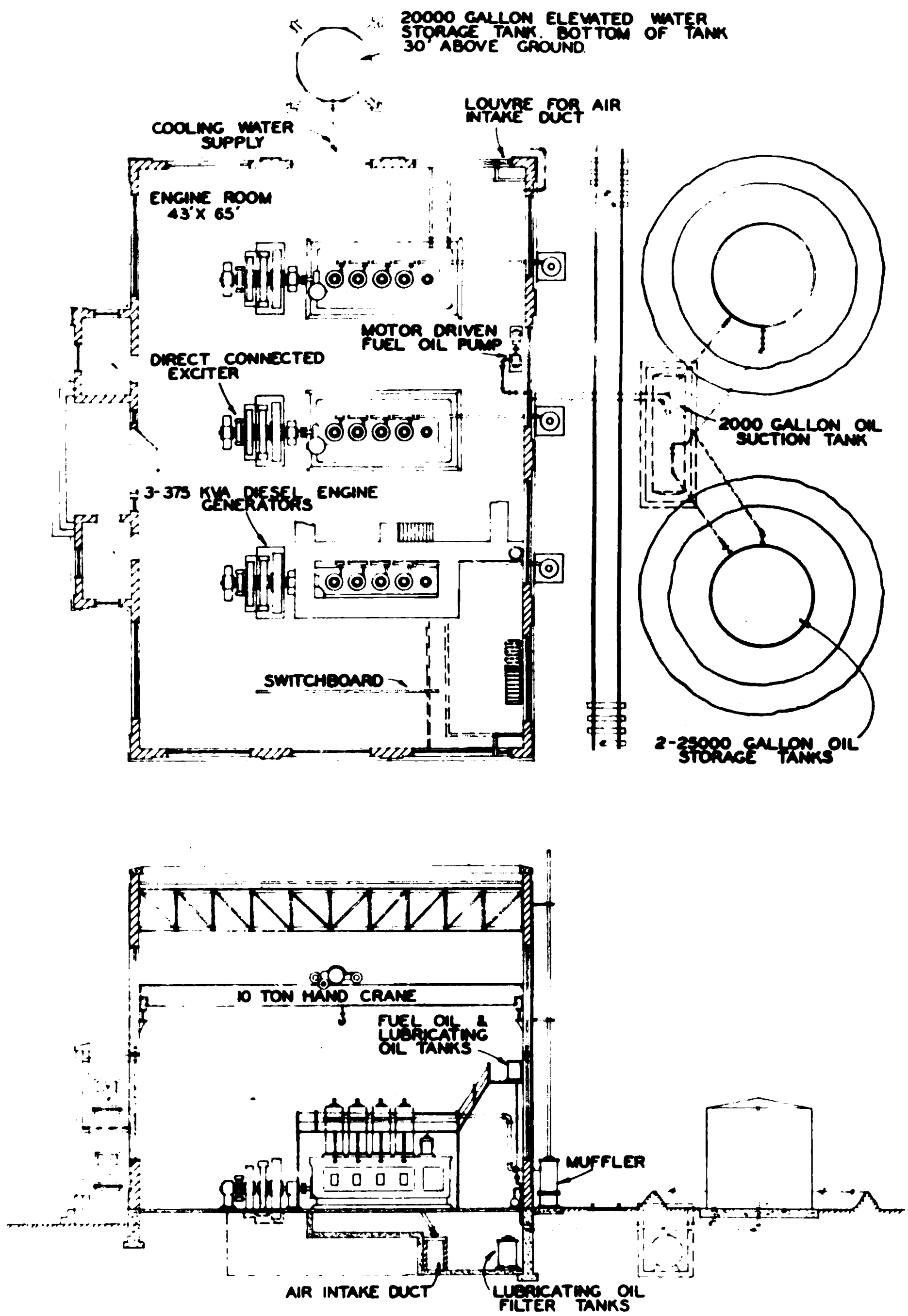
PLAN Nº 3

LAYOUT OF STEAM DRIVEN AIR COMPRESSORS & HIGH LIFT PUMPS



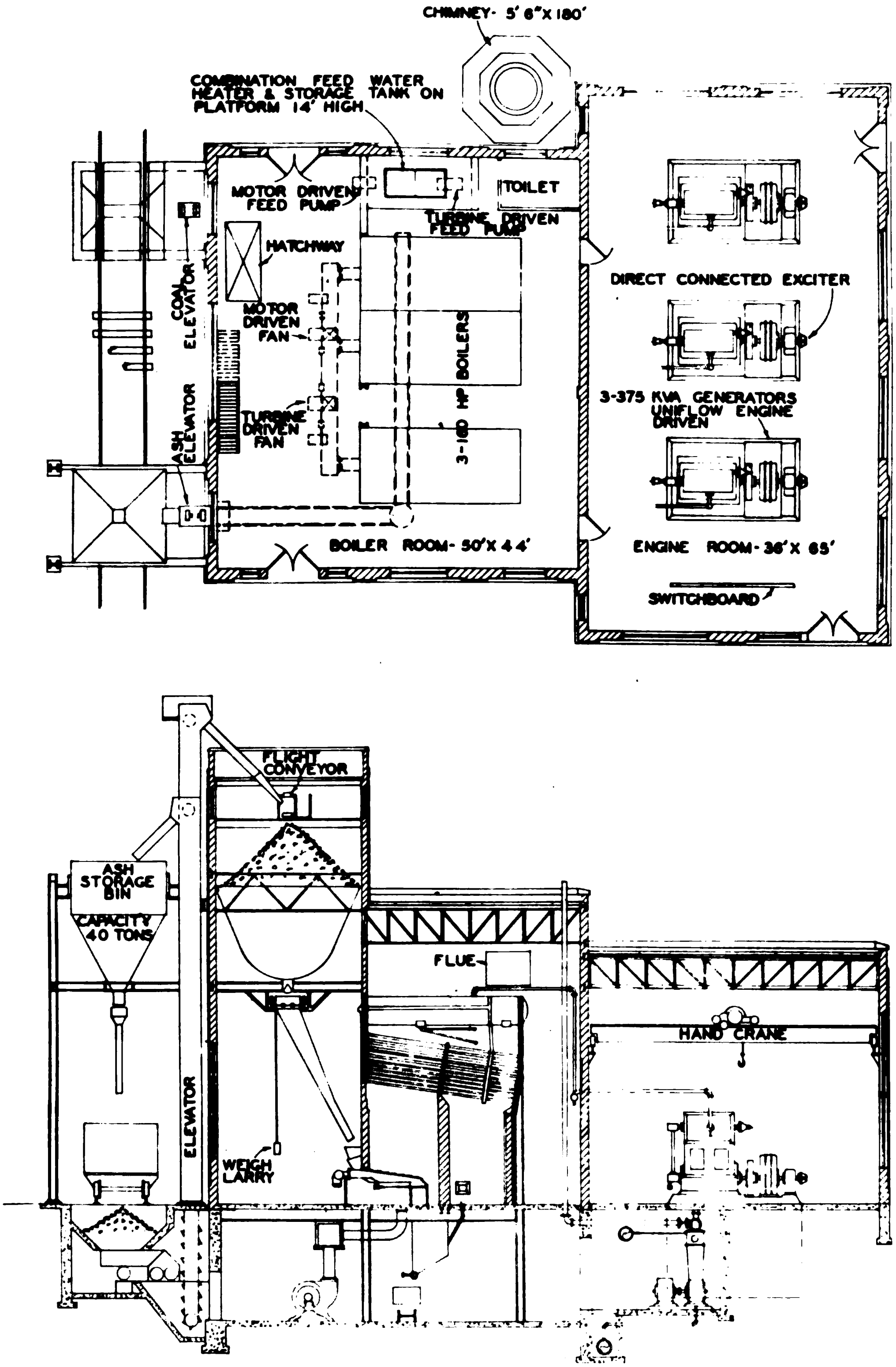
PLAN № 4

OUTDOOR TRANSFORMER STATION FOR FURNISHING PURCHASED POWER FOR DEEP WELL TURBINE PUMPS

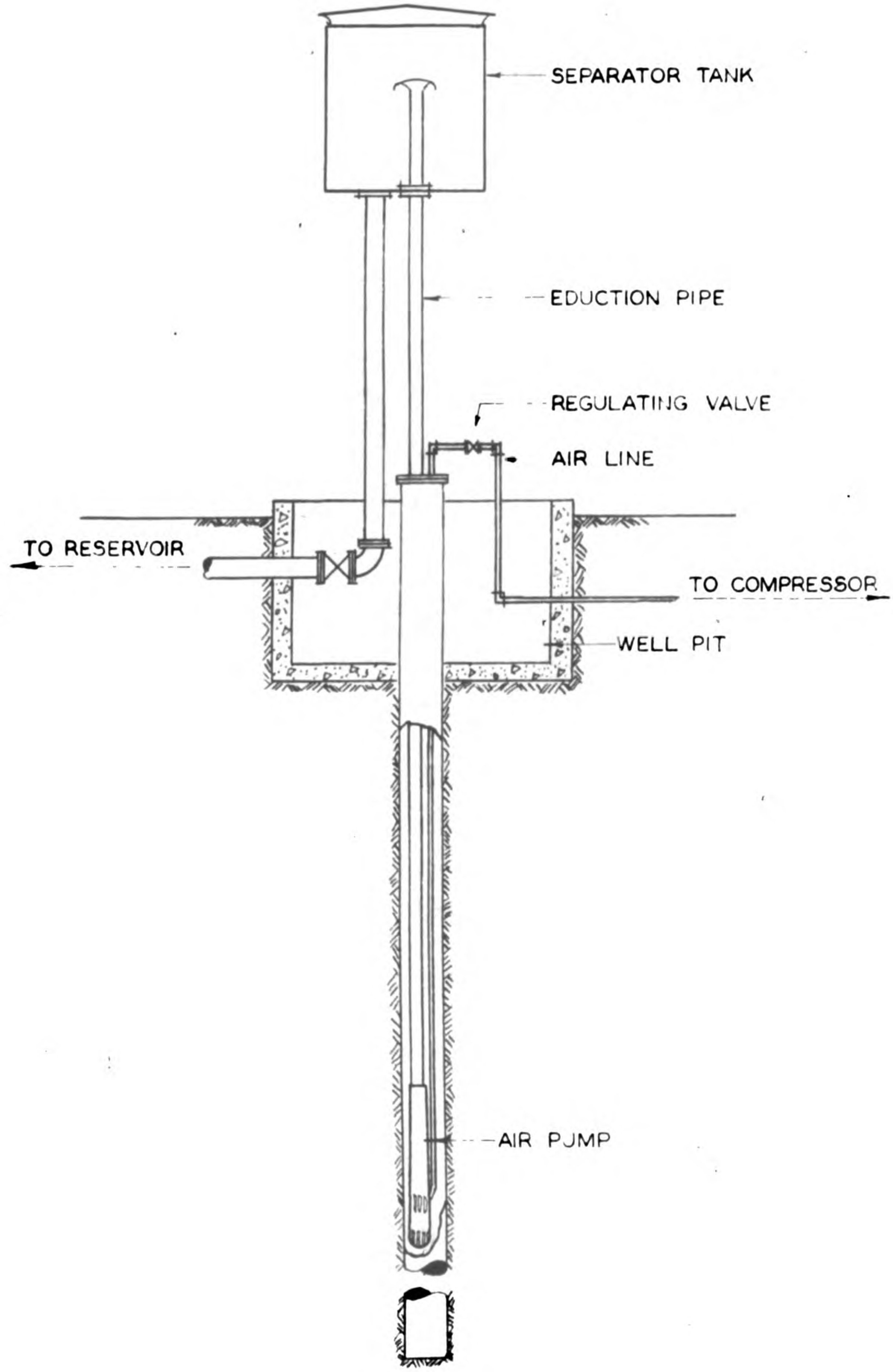


PLAN Nº 5

LAYOUT OF DIESEL ENGINE GENERATING PLANT



PLAN № 6
LAYOUT OF UNIFLOW ENGINE GENERATING PLANT
FOR GENERATING POWER FOR DEEP WELL PUMPS



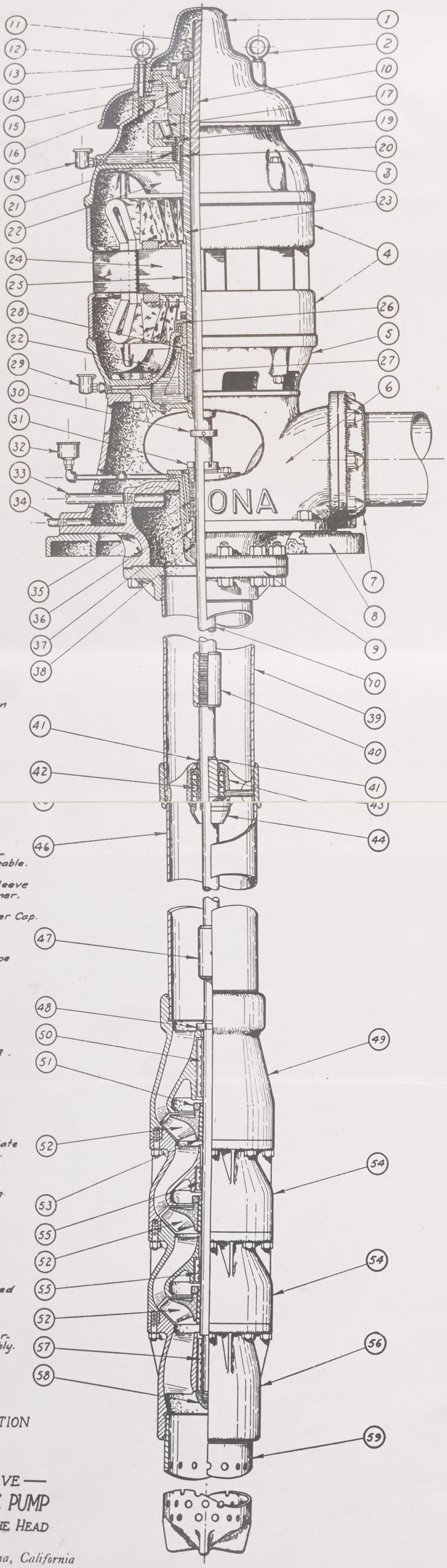
AIR LIFT PUMP
INSTALLATION

1 Motor Cover
2 Motor Cover Eyebolts
3 Top Bearing Mounting
4 Standard Induction Motor-Rotor & Stator
5 Motor Mounting
6 Discharge Head
7 Discharge Flange
8 Foundation Plate
9 Column Flange
10 Head Shaft
11 Adjusting Nut
12 Drive Plate Key
13 Drive Plate
14 Non-Reverse Ratchet
15 Ratchet Ring.
16 Drive Hub
17 Timken Roller Bearing.
18. Upper Oil Cup
19. Oil Pump.
20 Upper Oil Sleeve
21 Oil Pump Sleeve
22. Air Deflector
23. Rotor Hollow Shaft.
24. Rotor.
25. Rotor Key
26. Sealing Ring.
27. Lower Oil Sleeve
28. Sleeve Bearing Bushing
29. Lower Oil Cup.
30 Water Slinger.
31. Packing Gland
32 Packing Grease Cup
33 Priming Water Inlet Connection
34. Drain Pipe Connection.
35 Upper Packing
36. Packing Box.
37 Packing Gland Bearing.
39. Discharge Column Top Pipe.
40. Drive Shaft Coupling.
41. Bearing Sleeve-Non-Corrosive-Replaceable.
42 Pomona Patented Revolvable Rubber Sleeve
43 Discharge Column Brg. Retainer.
44 Discharge Column Brg. Retainer Cap.
45. Discharge Column Coupling
46. Discharge Column Bottom Pipe
47. Pump Shaft Coupling.
48. Sand Slinger.
49. Discharge Bowl
50. Water Lubricated Discharge Bowl Bearing.
51. Impeller Lock Nut
52. Impeller.
53. Impeller Bushing
54. Intermediate Bowl.
55. Water Lubricated Intermediate Bowl Bearing.
56. Suction Bowl.
57. Water Lubricated Suction Bowl Bearing.
58. Pump Shaft Cap.
59. Suction Strainer.

42-43-44, Pomona Water Lubricated Line Shaft Guide Bearing Patented Oct. 20, 1925.

49-51-52-53-54-56, Pomona Water-Lubricated Turbine Pump Assembly. Patented Sept. 22, 1925.

— Other Patents Pending. —



SECTIONAL ILLUSTRATION OF TYPE "H3"

POMONA

— ELECTRIC UNIDRIVE —

DEEP WELL TURBINE PUMP

WATER LUBRICATED BELOW THE HEAD

Pomona Pump Co., Pomona, California