H. E. GREENWELL
Consulting Engineer
[illegible] ROYAL SPRINGS DRIVE
DALLAS, TEXAS

November 9, 1964

Mr. T. C. Carlson
Guyer Oil Company
P. O. Box 223
Midland, Texas

Dear Mr. Carlson:

The following report is concerned with plant design criteria for maintenance of suitable water quality in the Many Rocks Field waterflood.

Results indicate that conditions favor trouble-free operation and that little processing of the water will be required. Measures to keep abreast of any changes that occur in water handling requirements are suggested in the report. Critical features of using the water are discussed in some detail.

Yours very truly,

H. E. Greenwell

H. E. Greenwell

HEG:cg

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ENGINEERING STUDY

DESIGN CRITERIA FOR MAINTENANCE
OF WATER QUALITY
MANY ROCKS FIELD

November 9, 1964

PREPARED FOR

GUYER OIL COMPANY

BY

H. E. GREENWELL
CONSULTING ENGINEERS

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INTRODUCTION

This report presents results of a study to determine plant design criteria for maintenance of suitable water quality in the Many Rocks Field water injection project. Conclusions and recommendations are based on tests run to determine the actual condition of the water, as produced by the Source Well. The report also covers test and control work that will be useful in helping to assure that trouble-free operations result throughout the life of the project.

At the time field work was done, a Source Well had been completed, and approximately 9,000 barrels of water had been produced to waste. The well was equipped with a 3-3/4 inch casing pump set in 5-1/2 inch pipe, which serves as the tubing in 9-5/8 inch casing. The pump was reported to be set at approximately 1,200 feet. Producing rate of the well was approximately 1,050 BWPD.

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CONCLUSIONS

1.

The water is only moderately corrosive, such that an injection system constructed of internally bare steel pipe will afford the most economical installation. Actual corrosion rate should be monitored so that appropriate chemical treatment can be adopted later, if needed.

2.

The water has a low content of plugging solids under actual in-line conditions. Filtration will not be required.

3.

The water must be handled under air-free conditions at all times.

4.

The water contains sulfate reducing bacteria at an intermediate level of activity. Bactericide treatment will not be required initially, but this factor will require periodic re-evaluation.

Any recompletion work done on the Source Well may change the content of filterable solids of the water. The need for filtration must be re-evaluated if any such work is done.

RECOMMENDATIONS

A. Plant Design

1.

Construct the system so as to provide minimum retention of the water, consistent with hydraulic and mechanical requirements of operation.

2.

Install and maintain a minimum six inch "oil seal" of diesel fuel on any tank used in the system.

3.

Provide a liquid seal for the polished rod of the Source Well. Keep the annulus of the Source Well closed at all times.

4.

It would be desirable to maintain a 50 foot "oil seal" of diesel fuel in the annulus of the Source Well. The well presently is believed to be "pumping off", which condition would make maintenance of the oil seal impossible. If feasible, well operating conditions should be changed to permit use of an oil seal.

Source Well withdrawal and injection rate should be balanced as closely as possible. Best operation from the standpoint of water quality will result if the Source Well operates continuously.

B. Measures of Water Quality Control

1.

On-location tests must be run at the Source Well to determine the condition of the water under system conditions if any re-completion work is done on the well. Tests would be of the same type done in this study.

2.

Operation of the system as a whole should be determined by suitable on-location tests within two to four weeks after system start-up. Interpretation of the results will determine if all design goals are being met properly and will indicate if any adjustments of procedure are necessary.

3.

System performance should be determined approximately each six months thereafter to keep abreast of the changing requirements of trouble-free operation. Specific factors that require monitoring include the following:

a. Content of plugging solids of the water at the Source Well.

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b. Precipitation of iron and calcium compounds from the water.

c. Entry of air.

d. Activity of sulfate reducing bacteria.

e. Corrosion rate.

DISCUSSION

Properties of the water and characteristics of the Source Well generally are favorable to trouble-free injection operations. Certain potential problems are present, but suitable measures can be adopted to overcome them. The basic principle that should be followed in designing the plant and operating the system should be to preserve the naturally favorable conditions that exist. A limited amount of periodic test work will be sufficient to detect any changes in requirements that might occur.

Tests to determine actual in-line conditions show that the well has cleaned up satisfactorily. Under steady operation, content of plugging solids of the water being produced lies just slightly above the level that could be secured by effective filtration. It is probable that the well will clean up additionally with continued withdrawal and that water of excellent physical quality will be available. Stopping and starting the well indicated that the wellbore is free of solids and that only a minor residue on the pipe still is present.

Significant chemical properties of the water include its content of dissolved calcium and of iron and its slightly alkaline pH. Calculations show that the water will not be prone to form calcium carbonate scale under air-free conditions. The content of dissolved iron is sufficient to create significant plugging solids if this iron were allowed to precipitate. The most likely cause of precipitation would be reaction with oxygen if air were allowed to enter the system. Means of keeping an air-free system are relatively certain, and chances are very good that this potential problem can be avoided. The pH of the water will tend to remain alkaline so long as the water is not disturbed by aeration and it may be expected, qualitatively, that such corrosion as does occur will not be severe.

Tests also show the water to contain sulfate reducing bacteria at an intermediate level of activity. Sulfate reducing bacteria can be found in most waters and this does not represent an unusual occurrence. In the majority of cases, the bacteria present do not cause significant operational problems. It is only when activity of the bacteria exceeds a critical level that countermeasures have to be taken. When activity of sulfate reducing bacteria is high, the bacteria are capable of causing a significant rate of corrosion and large increases in the content of plugging solids. These effects result from metabolic processes in wh[illegible] the bacteria d[illegible] the iron, causing it to corrode, and generate hydrogen sulfide, which precipitates dissolved iron. Reliable methods have been developed for following the activity of sulfate reducing bacteria, and it will be possible to undertake effective countermeasures, should they be required.

It is understood that the Source Well is operating with a low fluid level relative to the pump setting depth. Under these conditions it will be difficult to assure complete freedom from aeration. Since the well was producing less than the desired volume of water, it is assumed that means of increasing productive capability will be considered. If an increase can be accomplished by setting the pump deeper, it then may become possible to maintain an oil seal in the annulus of the well. This measure will assure that no aeration occurs in the well and will greatly enhance maintenance of air-free conditions throughout the system. In the event that reperforation or other recompletion work is done, the well will have to be re-tested to determine the content of plugging solids in the water being produced. Since present plant design recommendations do not provide filtration, this consideration will be fundamental.

With filters not being used, the plant design should provide minimum retention of the water between Source Well and the injection pump. Only that volume necessary for hydraulic and mechanical reasons should be provided. Any tank used for this purpose should carry an oil seal, as suggested. Experience has shown that a six inch layer of diesel fuel is adequate to prevent aeration of water in tanks.

From a water quality standpoint, operation of any water system is enhanced by smooth, continuous operation of each component. It is desirable to minimize fluctuation of level in all vessels and it is particularly beneficial to operate rod pumps on a continuous basis. Source Well withdrawal and injection rate should be balanced as closely as possible. Other measures should be taken as necessary to give continuous operation of the Source Well and of the injection pump.

Data resulting from the field test work and subsequent laboratory analysis are attached. They reflect the content of plugging materials as they exist under system conditions, the chemical composition of the water produced by the Source Well and the activity of sulfate reducing bacteria. Run 1 was made after a relatively lengthy period of continuous operation of the Source Well. The Source Well pump then was stopped and the Well was idle for one hour. Pumping was resumed and Run 2 was made very shortly thereafter. The purpose of this procedure was to determine if the Source Well had cleaned up and stabilized.

The analyses of actual plugging solids show little difference between Run 1 and Run 2, indicating that the well had cleaned up. The minor difference between plugging solids found on Run 2 and Run 1 was made up of a small increase in precipitated iron compounds and a slight increase in sand production. (Sand appears as "silica" in the process of chemical analysis and is so reported.) The small increase in iron compounds is believed to have been caused by corrosion products being dislodged from the pipe because of the disturbance occasioned in stopping and starting the well. The magnitude of this increase is such that it has only limited significance, at most. Under conditions of air-free operation, this material will disappear from the well. Most of the "silica" constituent of Run 2 is believed to be a drilling mud constituent. The amount of this material present in the water also will decline with extended withdrawal. As the well continues to clean up, it is believed that the content of plugging solids will fall somewhat below that determined in Run 1. This concentration of plugging materials will approach the value that can be obtained by effective filtration, and it is concluded that filter equipment will not be needed.

A sample of drilling mud was analyzed to determine if any relationships existed between composition of the mud and composition of the plugging solids being produced by the Source Well. Results show that the two materials are quite different in overall composition. It is concluded that virtually all drilling mud left in the well has been produced out. The trace remaining is reflected in the "organic" constituent of the actual plugging solids. In both runs, this constituent was present in a proportion sufficient to color the samples of solids obtained. The fact that a slight decrease in organic was obtained upon stopping and re-starting the well indicates that most of it was present as a thin coating on pipe in the well. In any case, there is no evidence that the well now is producing significant quantities of mud, and it may be concluded that the completion is stable.

Routine test needs of this system will be relatively simple. Factors that do require periodic evaluation include properties of the raw water at the Source Well, checks to verify that air is not entering the system, measurement of the amount of precipitation that actually is occurring in the system, activity of sulfate reducing bacteria and corrosion rate. It is expected that all of these requirements can be satisfied adequately by determining actual system performance at approximate six month intervals. In this way, any detrimental changes that occur will be detected and suitable steps then can be taken. This procedure should yield optimum operating economy, since measures will be taken only as the need is demonstrated.

CORE [illegible] INC.
[illegible]
[illegible]
WATER AN[illegible]

File [illegible]

Company Guyer Oil Company	Well Name	Sample No. 1
Formation	Depth	Sampled From [illegible]ter Source Well
Location	Field [illegible]	County State
Date Sampled 10-21-64	Date Analyzed 10-[illegible]-64	Engineer [illegible]

Total Dissolved Solids 22143 mg/L calculated

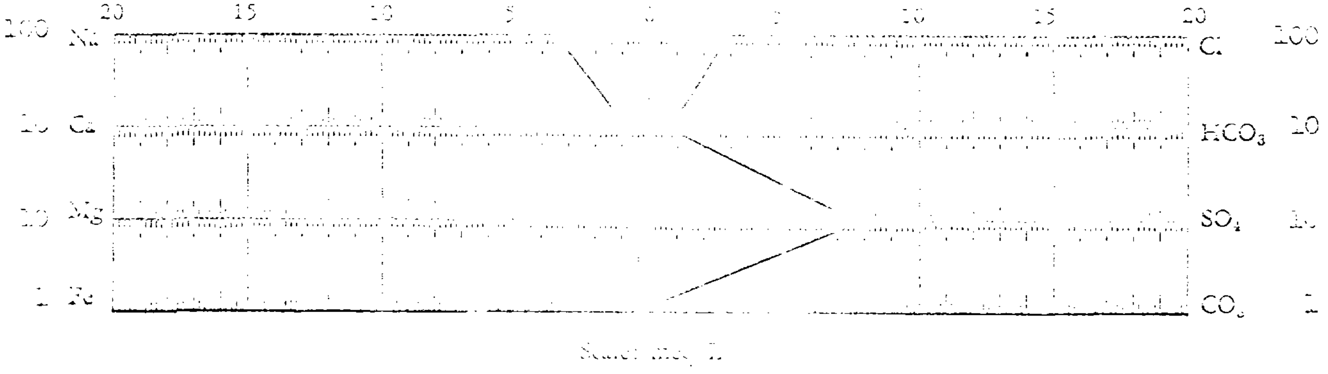
Sp. Gr. 1.015 @ 75 °F.

Resistivity 0.346 ohm-meters @ 74 °F. measured

Hydrogen Sulfide 0.0

pH 7.5

Constituents	meq/L	mg/L	Constituents	meq/L	mg/L
Sodium	346	7966	Chloride	276.73	9815
Calcium	8.68	[illegible]	Bicarbonate	6.72	409.9
Magnesium	5.50	[illegible]	Sulfate	77.13	3718 (Grav.)
Iron	0.093	2.[illegible]	Carbonate	0.0	0.0
Barium	0.0	0.0 (Grav.)	Hydroxide	0.0	0.0



Scale: meq/L

All analyses except iron determination performed on a filtered sample.

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CORE LABORATORIES, INC.
Petroleum Reservoir Engineering
DALLAS, TEXAS
WATER ANALYSIS

File [illegible]

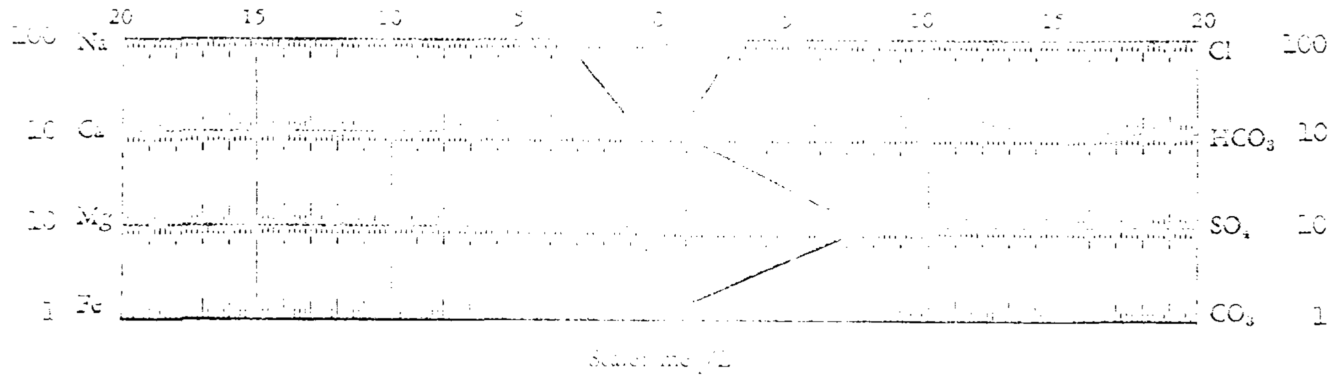
Company [illegible] Oil Company	Well Name	Sample No. 2
Formation	Depth	Sampled From [illegible] Source Well
Location	Field [illegible]	County / State
Date Sampled 10-21-64	Date Analyzed [illegible]	Engineer [illegible]

Total Dissolved Solids 22192 mg/L calculated — Sp. Gr. 1.017 @ 77 °F.

Resistivity 0.340 ohm-meters @ 74 °F. measured — Hydrogen Sulfide 0.0

pH [illegible]

Constituents	meq/L	mg/L	Constituents	meq/L	mg/L
Sodium	345	[illegible]	Chloride	275.8	9780
Calcium	6.80	[illegible]	Bicarbonate	6.8	426
Magnesium	5.42	[illegible]	Sulfate	77.[illegible]	3713 (Grav.)
Iron	0.25	7.0	Carbonate	0.0	0.0
Barium	0.0	0.0 (Grav.)	Hydroxide	0.0	0.0



Scale: meq/L

All analyses except iron determination performed on a filtered sample.

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[illegible]
DALLAS, TEXAS

November 10, 1964

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Sampled 10-21-64

Drilling Mud Sample
Many Rocks No. 2

Organic	6.34%
Ironoxide (hydrated)	0.73%
$CaSO_4 \cdot 2H_2O$	6.11%
$CaCO_3$	43.10%
$MgCO_3$	0.64%
Acid insoluble (Silica)	43.08%
Total solids	100.00%

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Petroleum Reservoir Engineering
DALLAS, TEXAS

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Analysis of Actual Plugging Solids
Many Rocks Field

Sample No. 1

Total Solids	0.71 mg/l
Iron Oxide (hydrated)	0.07 mg/l
Organic	0.45 mg/l
Silica	0.19 gm/l

Sample No. 2

Total Solids	1.13 mg/l
Iron Oxide (hydrated)	0.35 mg/l
Organic	0.38 gm/l
Silica	0.40 gm/l

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Sampled 10-21-64

[illegible]

Location	Activity Index
Water Source Well Run No. 1	7
Water Source Well Run No. 2	<5

Note: Activity Index is an arbitrary scale in which 100 represents the highest possible activity of sulfate reducing bacterial. Generally, activity indices greater than 20 signify appreciable contamination.

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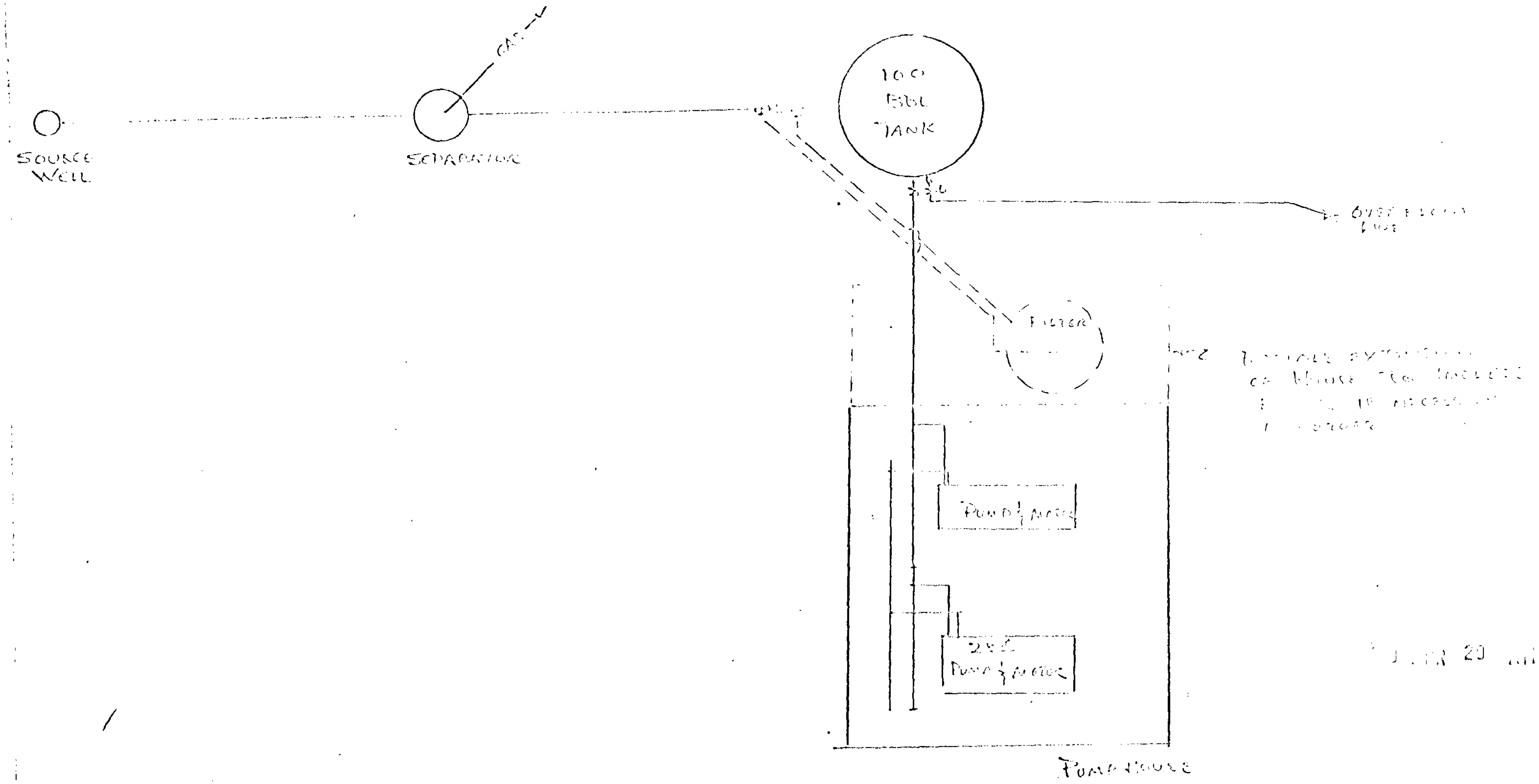
MANY ROCKS WATERFLOOD UNIT
SYSTEM SCHEMATIC



03/11/65

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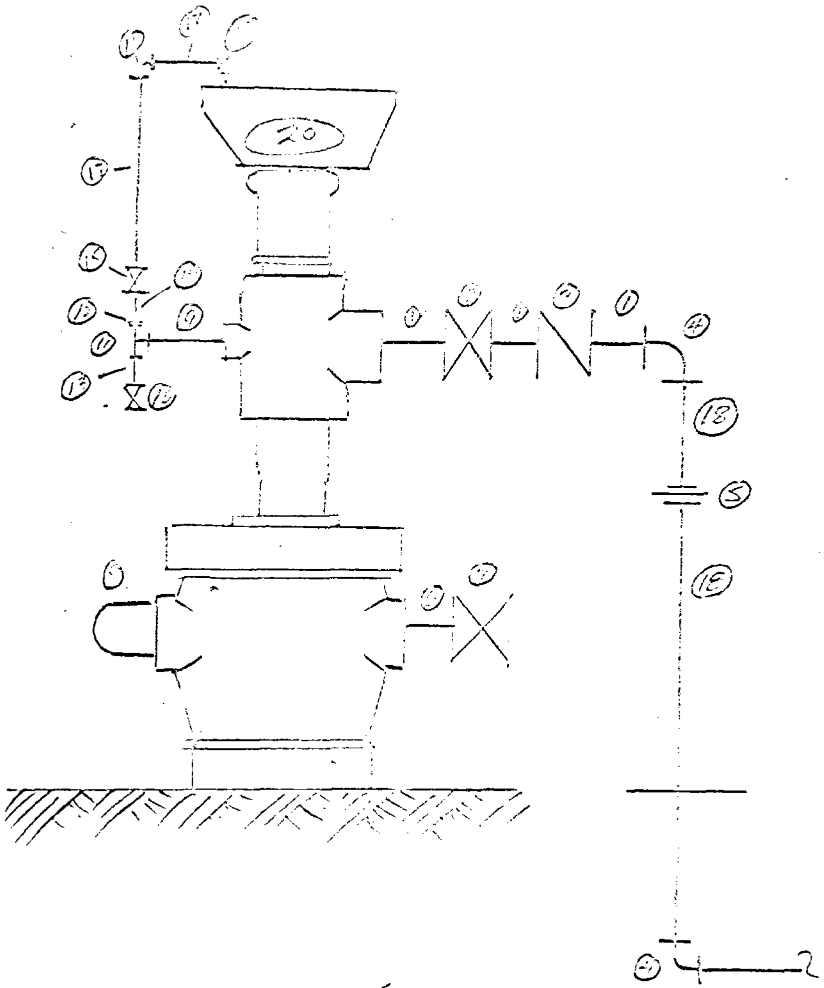
[illegible]
WATERFLOOD



WELLHEAD PIPING RQ'D

No.	No. RQ'D	ITEM
1	3	3"X6" NIPPLE
2	1	3" PLUG VALVE, 125 PSI } OR [illegible] COMBINATION —
3	1	3" CHECK VALVE, 125 } PLUG-CHECK ASSY.
4	2	3" STD ELL
5	1	3" UNION, 125 PSI
6	1	2" X 6" NIPPLE
7	1	2" PLUG VALVE, 125 PSI
8	1	2" BULL PLUG
9	1	1" X 6" NIPPLE
10	1	1" GATE VALVE, 125 PSI
11	1	1" STD TEE
12	1	1" X 1/4" BUSHING
13	1	1" X 2" NIPPLE
14	1	1/4 X 3" NIPPLE
15	1	1/4" NEEDLE VALVE
16	2	1/4" ELL
17		1/4 NIPPLE(S) VARIOUS LENGTHS TO MAKE CONNECTION TO STUFFING BOX
18		3" NIPPLES NECESSARY TO GO DOWN FROM PUMPING TEE TO FOUR FEET BELOW SURFACE.
19	1	STUFFING BOX LIQUID RESERVOIR

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03/11/64 CF

LARGE FORMAT
EXHIBIT HAS
BEEN REMOVED
AND IS LOCATED
IN THE NEXT FILE