Senior Problem

Methods Improvements For Oil and Gas Well Drilling

By: Homer J. Fulton

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9

Table of Contents

Oil and Gas Well Drilling

Introduction:

My reason for selecting the above topic is because I have been brought up around drilling wells just like a boy who has been born and raised on a farm. My father has been drilling oil and gas wells for the past 35 years. I spent much of my early youth performing the simpler tasks around a drilling rig as well as getting in the drilling mens road and asking questions. My father and his associates were always willing to answer my questions to the best of their knowledge. After I grew older I could see that the methods used in drilling with cable tools had not been changed or improved.

During my summer vacation from Michigan State College in 1947 I worked on a well in central Michigan acting in the capacity of tool dresser or second driller. I spent from 8 to 12 hours each day working on that well. The well was being drilled on a straight turnkey contract basis. The only time that money is being made on that basis is when the drill is doing work and the machinery is operating. There were many delays, some avoidable and some unavoidable.

Our nation needs new oil fields, as long as the cost of drilling wells is high, few new oil fields will be discovered because it requires so much capital to drill each well. The cost of labor and materials cannot be controlled here, but if the methods were improved the contract price wouldn't have to be so great, and more wells could be drilled to locate more new fields.

My intention is to introduce or suggest some ideas or new methods to be used to keep the drill working in the hole longer and at the same time decrease the shut down time. This will reduce the cost per foot of drilling.

The cable tool method of drilling is about 100 years old. Very few of the people engaged in this occupation have ever written books or papers on the methods they use in drilling oil wells. I have been unable to locate any material written on this subject in either the Michigan State College or State libraries. Much has been written on the production and geological aspects of the oil business but very little on the cable tool drilling methods. The Oil and Gas Journal and other industry periodicals contain new types of tools and machinery to be used in drilling wells with cable tools, but I have not been able to locate any articles concerned with new cable tool drilling methods.

A crew of two men is required to operate a drilling machine or rig. The driller is the boss and to my estimation requires as much skill as a die sinker or tool maker. He must be able to tell what the drill is doing 3 or 4 thousand feet in the earth merely by the touch or feel of the wire cable. If it is not drilling he must tell by this feel why it isn't drilling properly and must know what to do to correct this. In addition to the above the driller must be a skilled iron worker, carpenter, electrician and mechanic to erect a drilling machine. He must also be a proficient black-smith to make special tools and sharpen tools.

The tool dresser or second driller is really an apprentice driller. He must have had at least 4 years and on the average of 7 years as a tool dresser before he can become a driller. Essentially the job of tool dresser is a handy man and helper. Drilling tools and machinery are very heavy and because of its location the better methods of material handling such as conveyers and cranes cannot be used on a drilling rig economically. Therefore the physical effort required of a driller or tool dresser is exceptionally high. From my experience in the oil and other industries I would say that the jobs of driller and tool dresser are as hard and dirty as that of a coal miner and requires as much mental skill and effort as that of a tool maker or die sinker.

My project is dedicated to those men mentioned above, who have spent their lives swearing, sweating and worrying about holes in the ground so that we in other occupations can enjoy the benefits of petroleum products.

Conclusion:

1. Standard methods used by the various drilling crews are non existent.
2. Repetitive elements in the drilling operation constitute such a small percentage of drilling time that time study and motion analysis was not practicable and possible.
3. An estimated $1500 per well could be saved by using new proposed methods inPart IV.
4. From the present cost analysis it was found that factor of 1.5 is used by drilling contractors for allowing for unexpected trouble. This 1.5 is multiplied by the estimated cost to fix the contract price.

Senior Problem PLAN

Title: Oil and Gas Well Drilling

Objective: To reduce the cost per foot of drilling a 4,000 foot oil or gas well in the state of Michigan with cable tools.

Method:

I. Procure reference material for data.

   a. From experienced drilling contractors

   b. Books and manuals

      1. Petroleum Production Engineering
      2. 40 copies of Oil and Gas Journal
      3. National Supply Catalogue
      4. Oil Well Supply Catalogue
      5. Walsworth Supply Catalogue
      6. Drilling Equipment Directory
      7. Text on time, cost and motion study
      8. Petroleum drilling incentives
      9. Oil and Gas Well plugging directions
      10. Oil and Gas Field Labor Statistics

II. Make a preliminary report on the drilling operation.

III. Report on drilling methods and machinery.

IV. Determine the present cost per foot of drilling a well 4,000 feet deep.

   a. Combine the following data taken from contractors' records in drilling five wells.

      1. Labor costs

2. Taxes
3. Depreciation
4. Evacuation
5. Moving (trucking)
6. Construction
7. Fuel
8. Casing
9. Plugging
10. Interest on initial investment

V. From a time and motion study recommend new methods and machinery to reduce cost

a. Combine time and motion study for the following operations:

1. Driving pipe
2. Running and pulling casing 8", 6", 5", 2"
3. Drilling in 8", 6", and 5" holes
4. Moving
5. Plugging
6. Construction of equipment

VI. Study theory for the design of an automatic driller

a. Should such a mechanism be designed and constructed what would its save in cost per foot of drilling a well?

Conclusion: Discussion on new methods found to reduce costs. How much would the new methods reduce costs? Comparison of present cost with reduced costs.

The Current Oil Business In Brief

The United States needs new oil fields. The present reserve is enough to last until approximately 1980 at the present rate of consumption. Unless substitutes or synthetics and new oil fields are discovered before that time the United States will have to depend entirely on imports and we will have to pay upwards of 50¢ per gallon for gasoline.

The major oil companies are continually developing new methods of aiding geologists in locating new oil fields. Some of the new equipment includes radar sets and scesmagraph machines to find geological highes. A geological high is an anticline formation in the earths structure. Oil or gas is most likely to be found near or on these anticline formations. Unfortunately the major oil companies seldom drill a deep wildcat well unless they are thoroughly convinced from the results of their core test wells and geological calculations. They are not convinced that much very often.

At the present time it is fortunate that there are localities in the Western United States where oil and deposits can be found by drilling a series of core test and, after considerable expense, drill a deep test well and actually find oil.

In the Eastern United States the geological formations are much more complex. As a result many deep wells must be drilled in order to find a favorable anticline formation. It is a very interesting experience to watch these wild cat wells develop because one never knows which one will produce. Small independent promoters usually sell stock to successful business men after forming companies in order to finance these wildcat wells. These independent promoters usually have a good sales line and make the chances sound good of discovering oil. Remember that these old wildcat promoters seldom loose money in dry holes as do the investors. When oil is discovered the promoters usually become wealthy along with the investors by holding out leases for themselves.

Most of the discoveries that have been made in Michigan and other parts of the Eastern United States have been drilled by these small independent promoters. On the other hand, most of the hundreds of dry holes have been drilled by them also. Many of these men claim to be geologists, and some of them are graduate geologists but few oil men in the East accept their geological theories.

There have been many wildcat wells drilled in the state of Michigan for example. The State Department of Conservation requires a log and complete set of samples from each well drilled. From these logs are made maps to show where and when each well has been drilled. The maps also indicate the relative depths of the geological formations on a contour basis. This information is open to public inspection and if you should study these maps you would wonder where there would be room for a oil field amongst all of the dry holes. It is to the advantage of a perspective investor in a wildcat well to go to the Department and study those maps to determine the chances of finding a geological high at the location.

The promoter must secure the leases from the land owners. It is common practice to acquire from 4,000 to 7,000 acres of leases around the location of the wildcat well. The land owners do not invest money in the well. Leasing is the term used when the la d owner leases 7/8 of his oil rights usually at $1 per acre per year in wildcat territory. After the promoter acquires the leases and has sold the stock he lets out bids to contractors for the drilling of the well. The cost of drilling the well naturally depends on the locality and depth to be drilled. At present the cost averages $4 per foot to drill a wildcat well in Michigan. The promoter must sell enough stock in the enterprize to cover the cost of leasing the land, drilling the well and promotion costs. At present this cost is $20,000 per well on the average in Michigan. The stockholders are liable only for the amount of their investment, and during the drilling operation can sell their stock if they so desire.

These wildcat wells are usually drilled through all the formations that are likely to produce oil or has in the upper strata. There are huge possibilities of finding oil at depths from 9,000 to 12,000 feet in the state of Michigan but the cost amounts to millions of dollars and independent promoters usually do not undertake the job of financing such an enterprize when the risks are so great.

If no oil is discovered in these wildcat wells the well is plugged, the company dissolved and all investments lost. If oil is found the stock holders get together and hire an engineer to develop their leases. That is controlling the production and drilling the subsequent wells. The oil is sold to pipe line companies who transport the oil to the refining areas. The refineries purchase the oil fromthe pipe line company, refine the oil and sell the petroleum products to distributors and so on to the consumer.

Usually the stock holdersget together and sell their interests to a major oil company after they have made a huge profit.

DRILLING OF AN OIL WELL
(Cable Method)

Since Colonel Drake drilled the first oil well in 1859 there have been many improvements in drilling methods. About 1915 the rotary method was developed for drilling in soft rock formations. The principle involved in drilling a hole in the earth by rotary is similar to that of drilling a hole in a piece of steel with an ordinary bit.

My report is limited to drilling with cable tools, or the fundamental principle used by Colonel Drake on the first oil well. This method of drilling a hole in the earth is similar to that of drilling a hole in a piece of cement with a star drill and hammer. It is necessary to start with some economic or geological reasons for drilling a hole in the ground, and much could be said on both, but my project is related only to the physical process in drilling a hole in the ground. I will start by explaining the different developments in the hole as it gets deeper and later in this report I will explain about the machinery and tools used in drilling the hole.

In general, we can say that the size of the starting hole is directle proportional to the final depth that the hole is to be drilled. It is common practice in Michigan to start with an 8" hole for depths of 1800' and 10" hole to depths of 5000' and in the deeper wells sometimes use up to 24" pipe

In localities such as in Michigan where the prehistoric glaciers left a deposit of loose earth called drift over the bed rock, it is necessary to begin drilling by driving pipe along with drilling. This surface layer called drift, is loose and carries numerous water veins. To keep the drift from caving in the hole and also to keep the water out, pipe is driven into the hole. This cannot be done as the hole is drilled, but the process alternates by drilling about 15' or 20' and then driving pipe to the bottom of the hole, etc.

This so called drift formation deposited by the prehistoric glaciers is from 20' to 900' thick in Michigan and starts at the prese t earth's surface to the bed rock of the earth's prehistoric surface. The composition of the drift is mostly sand, gravel and clay with occasional limestone shells and coal. The bed rock is distinguished from drift in that it is firmer and will stand up without driving pipe along with drilling. The hardness of this bed rock varies directly as its depth. It would be difficult to mention all of the various formations from the bed rock to the earth's center throughout the world or even the U.S.A., however, since my report deals primarily with drilling in Michigan to the depth of 4,000 feet, I will mention some of the more important. From the bed rock to a depth of about 700 feet there is a strip of white sand stone bearing mineral water and gray shale. This formation is drilled with the 10" tools used for drilling through the drift but no drive pipe is required. Water from this and stone formation comes up the hole, sometimes overflowing and causing an artesion mineral water well.

The high density of water (relative to air) causes the dropping force exerted by the tools to decrease so much that the amount of hole that can be drilled in a 24 hour day decrease and it is necessary to shut off this water with 8" casing. The water is pumped out of the hole after the pipe is run to the bottom of the previously mentioned water bearing sand. The 8" drilling tools are used to drill from the bottom of the 8" pipe to the depth of about 1250 feet.

The drilling of this 550 feet of 8" hole is considered quite hazardous in the state of Michigan because of the Marshall sandstone formation. The first 200 feet of this 8" hole is comprised of shale, lime shells and streaks of sandstone with little or no water. The last 300 feet is Marshall sandstone which is divided into two parts, the upper Marshall or gray sandstone and lower Marshall or red sandstone (sometimes referred to as "red rock"). The danger in the Marshall comes from the danger of striking natural gas and water at the same time. Should this happen, the has pressure may cause a water gusher which would be very expensive to control and to continue drilling.

The Marshall formation is also full of crevices and acts similar to the drift formation or the water carries the sand into the hole and may cover up the tools during the drilling operation. Should the tools be lost while drilling in this Marshall formation due to breaking a tool joint or cable it would be difficult to remove the tools or (fish them out) should the sand cover the tools. There is also a danger of the drill to change its course should it hit a crevice in the Marshall. Should either of the above events happen it is often necessary to pull the 8" casing and 10" drive pipe and start all over on another hole.

The 6" casing is set about 30 feet below the bottom of the lower Marshall and 6" drilling tools are used to drill the next 2,000 feet or 3,000 feet depending on water zones confronted. From 1,250 feet to about 2,300 feet is almost solid blue shale and is easily drilled. Providing no mechanical difficulties are encountered 160 feet to 200 feet can be drilled in 24 hours in this blue shale formation. The drill then proceeds into a strip of a mixture of sandstone and limestone about 200 feet thick. This strip is comprised of formation known as the Berea and Coldwater Sandstone Formation. Geologists can predict possibilities of oil in lower zones by the distance between the top of the bed rock to the top of the Berea sandstone. If there is a general anticline in the area where the well is being drilled this distance would be less than it would be should there be no anticline in the general formation. Oil is usually found in areas where there is an anticline structure in the general formation.

Out of this sandstone, the drill goes into the brown shale which is about 400 feet thick. This formation does not usually carry any water veins and is soft like the blue shale drilled from 1,250 feet to 2,300 feet, but takes longer to drill through because of the time required to remove the tools from the lower depths.

When the hole is drilled through this brown shale preparations are usually made to control a flow of oil that may be found in the following limestone formations--Traverse and Dundee. The bottom of the brown or the top of the Traverse lime comes about 2,700 feet and is usually hard and drills up as very fine white grains of limestone. Oil or salt water is usually found in the first 100 feet of this rock. When salt water is found to be present, it is necessary to drill to the bottom of the Traverse with the hole filled with salt water. This is a slow process and costly because the limestone is hard and the driving force of the drill is decreased so much that only 30 feet to 50 feet can be drilled in a 24 hour period. It is not good practice to case the water off because the Traverse lime is up to 500 feet thick and may carry two or three water zones. Should the first water zone be cased off and the hole be drilled 200 feet deeper and another water zone encountered it would be necessary to pull all of the 5" casing and ream the hole down through the entire Traverse formation. This reaming operation is more expensive than drilling a full 6" hole.

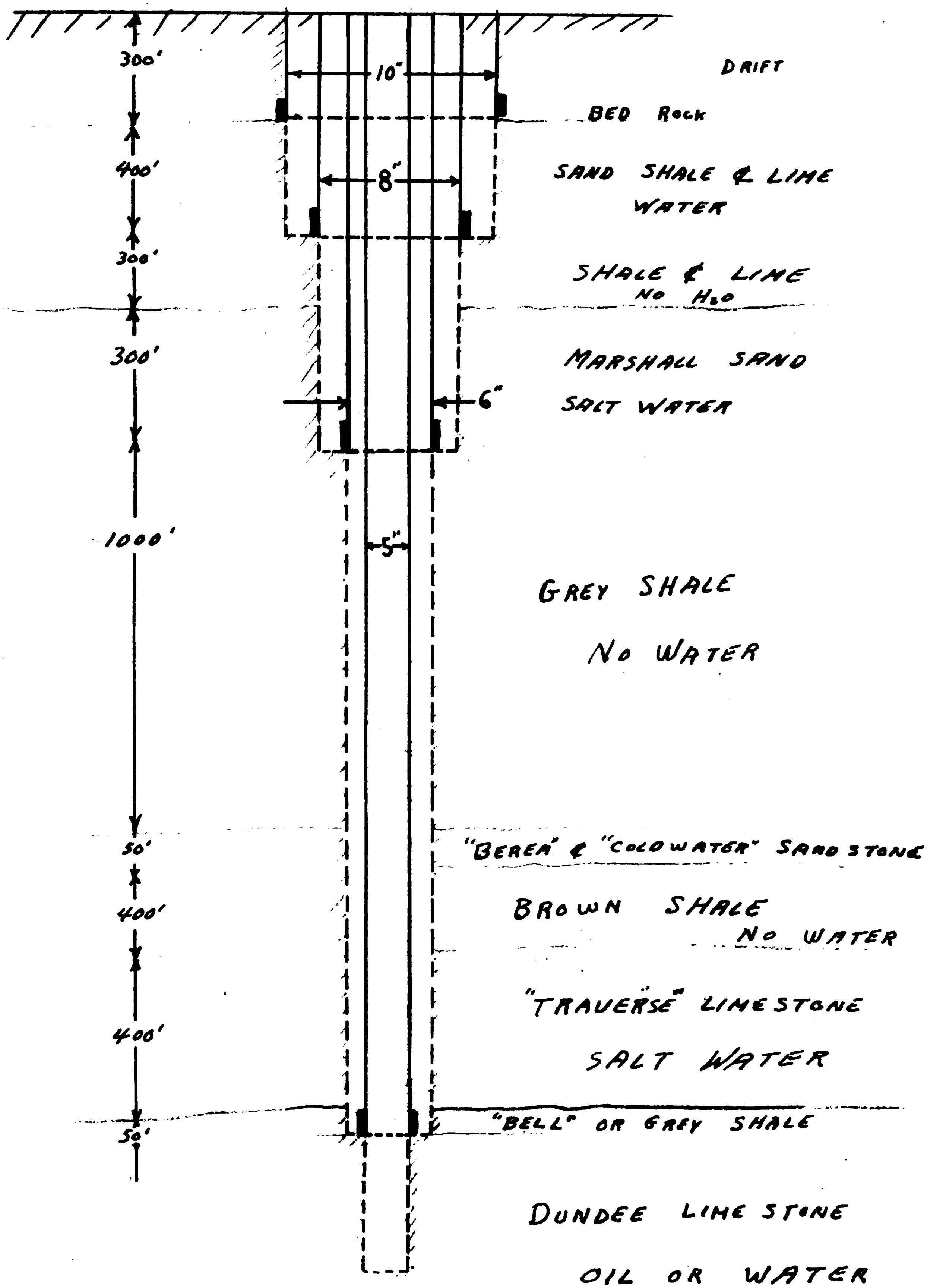
In Michigan the Dundee lime formation is usually the objective of drilling because it is more likely to bear oil than any other formation. There is a shale formation between the bottom of the Traverse and the top of the Dundee. This is only 50 to 150 feet thick and is quite soft compared to the Traverse and Dundee lime. This shale is known as the Bell Shale.

When drilling into the Dundee lime it is desirable to have a clean dry hole. Even if the open six inch hole is free from water zones it is necessary to set 5" casing on top of the Dundee because the various shale formations will cave to a certain extent. Should the Dundee lime bear oil and those cavings might seal the oil formation and decrease production.

After the 5" casing is set on top of the Dundee lime, a control valve is attached to the top joint for controlling any oil flow that may be encountered. The drilling is then proceeded as before and should any indication of oil be found, drilling is stopped and production tests are made. Should salt water be found and further drilling not desirable, the well is plugged and abandoned.

Well plugging procedure is decided by the State Conservation Department and presented by them to the driller. It consists of pulling the casing and placing bridges at various depths to hold the plugging material or the drillings that are put back in the hole at various depths to separate each water zone.

MICHIGAN WELL WITH FORMATIONS
(APPROXIMATE DEPTHS) Fig. I



PART III: REPORT ON DRILLING METHODS AND MACHINERY

The Drilling Tools:

First, I will explain the bit or the tool that actually does the drilling. As previously explained, this tool drills the rock similar to the way you would drill a hole in a piece of granite or concrete with a star drill. The bit is about 8 feet long and has a tapered screw pin at the upper end. The point is shaped as a wedge and can be dressed to any level desired. There is a grooved section on each side of the bit known as a water course - this allows room for the liquid or water and drillings during the drilling operation. The weight of the bit is not sufficient to produce the desired force at the end of the bit during the reciprocating. The bit is lifted and dropped a distance that is variable but is usually about 3½ feet.

The stem, or cylindrical piece of steel approximately 35 feet long and 3½" in diameter is used for two purposes. One is to provide the necessary weight or force to the bit and secondly to keep the hole in alignment. An internal tapered thread is on the bit end of the stem and is known as a box. A tapered male or external thread joint is at the top of the stem and is known as a pin.

During the drilling operation the tools get stuck and it is desirable to have a means of freeing them. This is accomplished by the use of a tool known as a jar. These jars are essentially are essentially two chain links interlocked with a pin joint at one end and a box joint at the other - they are made of steel approximately 7 feet long and weigh about 300 pounds. The stroke of the jars is about 2 feet and if the bit is stuck, reciprocating motion can continue with the steel cable stretching the remaining 1½ feet.

There are two methods of tying the wire cables to the tools mentioned above. The first and most common is the swival socket. This socket is a hollow cylindrical piece of steel with a box joint at the end that fastens to the jars. The upper end is necked and has a 1 inch I.D. The swivel is a separate piece made of tempered metal steel 2" O.D. Its I.D. is tapered from 1½ to one inch through its length of 8". The end of the wire cable is threaded through the top end or necked end of the socket to the box end then through the swivel. The strand s at the end of the cable are then unwound about 10" and tucked back into the solid cable and cut off. This tucked end is then pulled back into the I.D. of the swivel and the I.D. of the swivel may or may not be filled with babbit depending on the method of tucking the cable end. The swivel is then pulled back into the I.D. of the socket and the socket can be screwed onto the jars. I might add here that the cable wears quite fast at the socket end and for a safety measure the socket is refilled after each 24 hours of continuous drilling.

Common practice is to use a 6 x 10 x 7/8" plow steel wire rope but other sizes can be used. The wire rope is usually bought in 5,000 ' lengths at a present cost of about 22¢ per foot. The life of a wire rope in drilling varies with the amount of salt water and sand stone it comes into contact with. When the rope breaks it can be spliced but this is not advisable.

DRILLING MACHINERY

The drilling machine is mechanism to produce the reciprocating motion during the drilling operation and a means of admitting and removing pipe, tools and the bailer. Power is usually supplied to the machinery through gears, belts, friction and rope drives. Power requirements for a 4,000' hole would be 40 HP. The most economical power at present is the one cylinder horizontal diesel. For holes as shallow as 1,500' gasoline engines are the best because they are faster and more portable.

Three types of drilling machines can be used. The standard rig type is the least portable, heaviest and has been used the longest. It consists of a four legged derrick 80' high. Power is supplied from source to the band wheel which is 13' in diameter through a 12" belt. A crank is mounted on one end of the band wheel hub to produce the reciprocating motion to the walking beam. The tools are raised and lowered by the cable which goes over the pulley on top of the derrick and down to the spool of bull wheel shaft 10" in diameter mounted between two legs of the derrick. A brake wheel and a rope wheel each 10' in diameter are mounted at each end of the bull wheel shaft. Power is supplied to these wheels by means of a double crossed manila hemp rope from the band wheel. Distance between centers of these two wheels is about 30'. Advantage of the standard rig type drilling machine is that the tools can be pulled out of the hole

of the hole faster and casing arrangements are better. Disadvantages are that the spudding or pipe driving hook up is slower and the lack of portability.

The National Machine type has essentially the same parts as the standard rig type machine. The main difference is that instead of a bolted derrick it has a three section mast and the bull wheels are located between the mast and engine and are driven from a friction wheel mounted on the crank shaft between the band wheel and crank and is keyed to the same shaft. The sand reel is mounted on the steel machine frame and driven off the friction wheel. Advantage of the National Type machine is that it is more portable, lighter, more compact and requires less man hours to erect. Other advantages that the National type drilling machine has over the standard rig type are that it is more handy for spudding and driving pipe, easier to skid while erected if necessary and saves time in preparing to pull out of the hole because no ropes are involved.

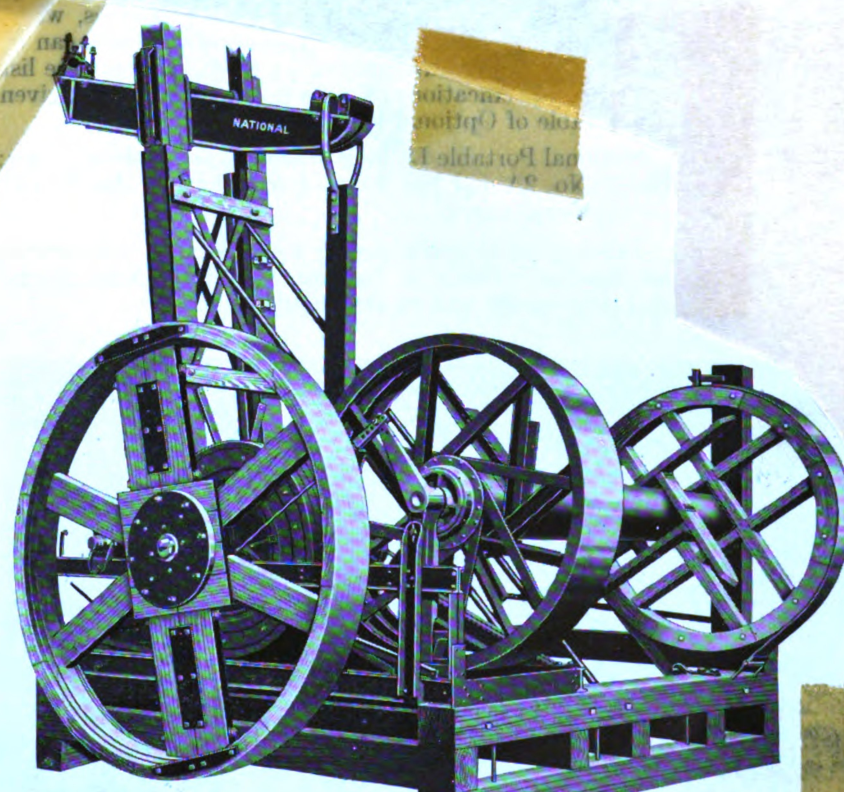
Disadvantages of this type machine are that, it is smaller and slower in pulling out of the hole, the mast will not stand high stresses and the initial cost is higher. If the well produces oil and a pumping rig is necessary, it is more economial to use a standard rig and leave it at the well to be used as a pumping rig. If a National Machine is used to drill the well and oil is found, it would have to be removed and replaced by a pumping rig. The bull wheels of a National Machine will not hold as much wire rope as a standard rig and that is one limiting factor of the maximum depth that can be drilled.

The standard rig can drill to 7,000 feet and maximum depth of the National Machine is 4,500 feet due also to the fact that the mast can't handle such heavy casing loads.

Maintenance costs are higher for National Machine than for standard rigs, but are lower than that of spudders which are chain and gear driven. Care must be taken in erecting a National Machine because it is very important, that the wood foundation will not be washed out by water used in the drilling operation.

NATIONAL DRILLING MACHINE

No. 2 Machine
Fig. H-1-A



No. 2A Illustrating Position and Method of Mounting Bull Wheels, Band Wheel and Friction Drum on Steel Frame
Fig. H-2-B

TYPE OF ENGINE USED WITH CABLE TOOLS

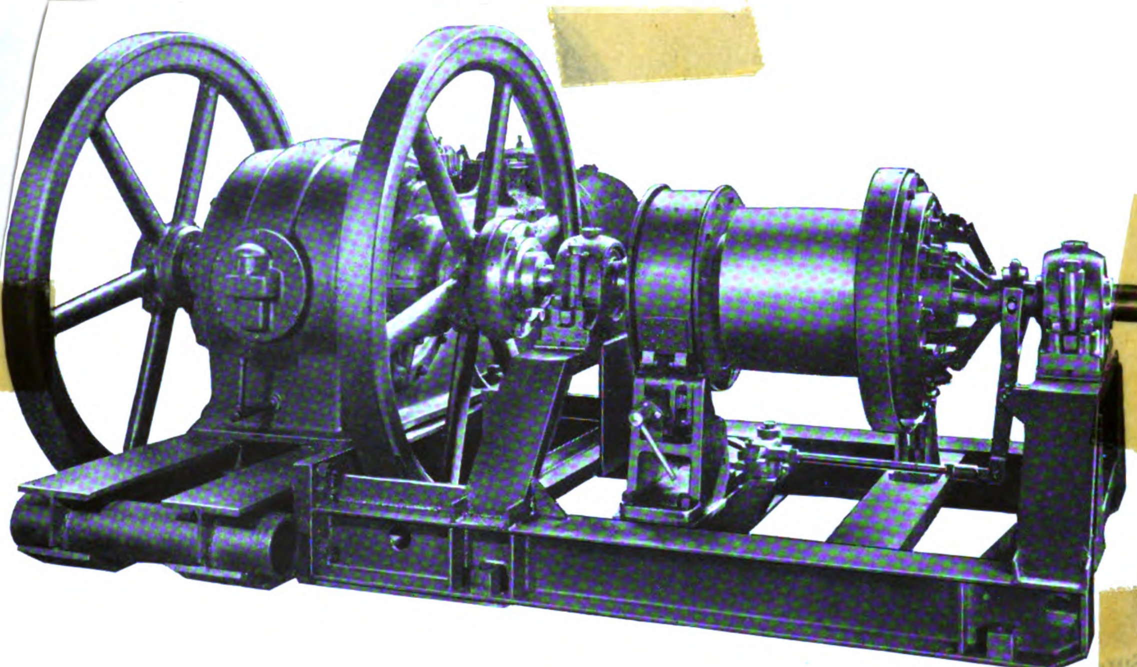


Fig. H-181-A

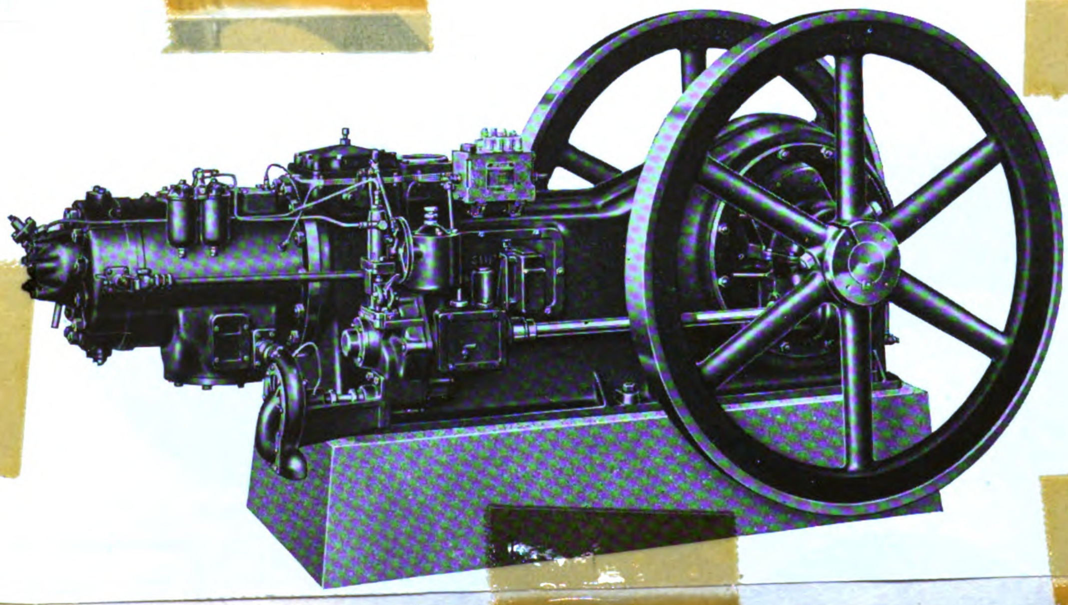
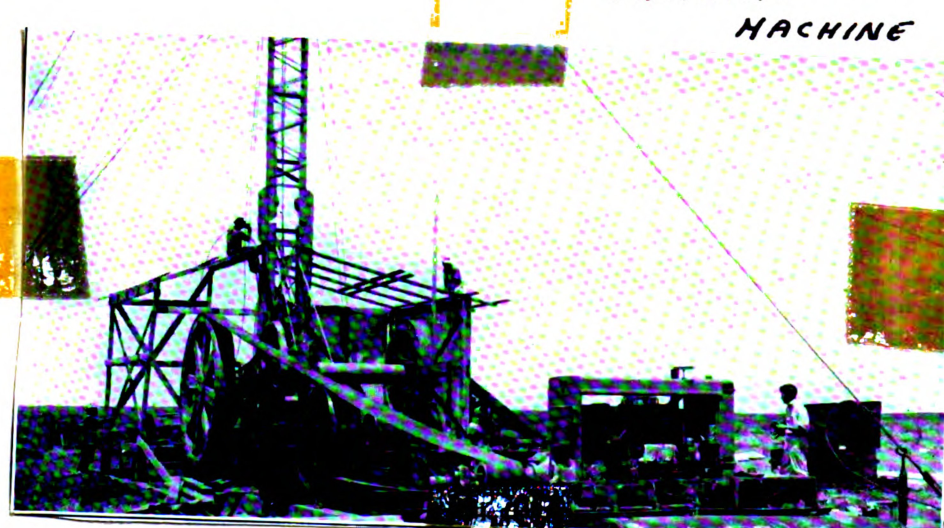


Fig. H-7-A

ROTARY DRILLING RIG.

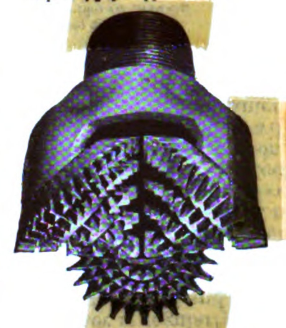
CABLE TOOL DRILLING RIG

NATIONAL MACHINE

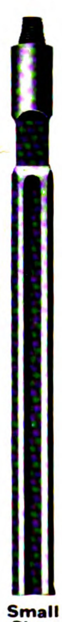


Fish Tail
Fig. H-146-A

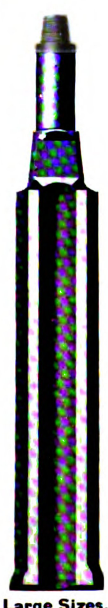
Diamond Point
Fig. H-146-B



ROTARY DRILLING BITS



Small Sizes
Fig. H-48-A



Large Sizes, except California
Fig. H-48-B

Large Sizes, California
Fig. H-48-C

CABLE TOOL DRILLING BITS

Part IV: Present Cost Analysis for Drilling a 4000' Hole

From interviews with contractors the following estimates are based on ideal conditions. About 150% is added for unexpected trouble.

1. 4 - 8 hour days required for moving and setting machinery with five men.
2. Two winch trucks are required to carry seven loads of equipment and aiding in setting machinery or 4 - 8 hour days at $10 per hour per truck = $640.
3. 400' - 10" open hole @ 200' per 24 hour day.
4. 300' - 10" drive pipe, 6 men required, @ 100'/24 hour day.
5. 8 hours for setting 8" casing and hitching on.
6. 600' - 8" open hole @ 150' per 24 hour day.
7. 8 hours for setting 6" casing, 7 men required.
8. 1900' - 6" open hole @ 140' per 24 hour day.
9. 8 hours for setting 5" casing and cementing, 8 men required.
10. 800' - 5" open hole, @ 45' per 24 hour day.
11. During drilling operation and driving pipe one driller required, @ $14 per day plus one tool dresser, @ $12 per day.
12. Continuous operation - 24 hours per day, 3 - 8 hour shifts.
13. Overall drilling, moving, erecting and dismantling estimated time is 52 days @ 6 working days per week or 8.66 weeks.
14. Operation requires one superintendent @ $460 per month.

I. Labor Cost

Description of Operation	No. of men req.	No. of 8 hr. da. per men req.	Cost per man per 8 hour da.	Total cost per operation
A. Moving & setting machinery				
1. Tool dressers & truck drivers	3	4	$12.00	$144.
2. Drillers	2	4	$14.00	112.
B. Driving pipe				
1. Tool dressers	3	3	12.00	108.
2. Drillers	3	3	14.00	120.
C. Drill 10" open hole				
1. Tool dressers	3	2	12.00	72.
2. Drillers	3	2	14.00	84.
D. Set 8" casing & hitch on				
1. Tool dressers	5	1	12.00	60.
2. Drillers	1	1	14.00	14.
E. Drill 8" hole				
1. Tool dressers	3	4	12.00	144.
2. Drillers	3	4	14.00	168.
F. Set 6" casing				
1. Tool dressers	6	1	12.00	72.
2. Drillers	1	1	14.00	14.
G. Drill 6" open hole				
1. Tool dressers	3	14	12.00	504.
2. Drillers	3	14	14.00	588.
H. Set 5" casing & cement				
1. Tool dressers	6	1	12.00	84.
2. Drillers	2	1	14.00	28.
I. Drill 5" hole				
1. Tool dressers	3	18	12.00	684.
2. Drillers	3	18	14.00	756.
J. Dismantling machinery & plugging hole				
1. Tool dressers	2	3	12.00	72.
2. Drillers	2	3	14.00	84.
K. Salary for Superintendent @ $460 per month	1		460.00	460.

Net Labor Cost	$4118.00
Workmen's Compensation Insurance @1%	41.18
Social Security @ 1%	41.18
Total Labor Cost	$4200.26
II. Depreciation	
A. Wire Cable	900.00
B. Tools and Machinery	500.00
Total Depreciation	$1400.00
III. Excavation	
A. Clearing location	5 0.00
B. Slush Pit 30' x 30' x 6'	100.00
C. Dead man holes 7 - 2' x 5' x 4'	15.00
Total excavation	$165.00
IV. Trucking	$640.00
V. Fuel Cost	
A. Fuel oil for engine @ 18¢ per gal. 36 gallons per day - 52 days	336.60
B. For forge 400 gallon @ 12¢ per gallon	48.00
C. Gasoline for electric generating unit 600 gallon @ 20¢ per gallon	120.00
Total fuel cost	$504.60
VI. Pipe cost	
A. 10" drive pipe 100% loss 300' @ $3.50 per foot	1050.00
B. Depreciation on 8", 6", and 5" casing	550.00
Total Pipe cost	1660.00

Summary of cost of Drilling 4,000 feet

1.	Labor	$4200.00
2.	Depreciation	1400.00
3.	Excavation	165.00
4.	Trucking	640.00
5.	Fuel	504.60
6.	Pipe	1600.00
7.	Interest on investment	900.00
	Total overall cost	$9409.60

Total cost per foot $= \frac{9409.60}{4000} =$ \$2.35 per foot

Part V.

Introduction:

It was found that the various drilling crews do not use enough standard methods to perform motion and time studies. The general method is the same in that the end results are the same, and the element time would be similar. My problem here is to improve on the general methods of operations, mainly to reduce avoidable delays. This should decrease costs. The main objection in reducing time and costs is to keep the machine at work drilling as much as possible. The avoidable delays that I will reduce by methods improvement are as follows:

1. Time spent changing bits - to sharpen and temper.
   a. How to reduce the number of changes.
   b. How to change the bits faster.
2. Time spent bailing the hole.
   a. Why make two trips in and out of the hole.
   b. Why not a longer bailer with change in design to clean hole in one run.
3. Time in resetting wire rope socket.
   a. Possible changes in socket design.
4. Better methods to reduce wear on wire rope.
5. Time lost in mudding up in the upper hole.
   a. How to prevent it.
   b. How to free the tools faster.
   c. How to detect indications of thick mud.

6. Time lost in machinery break down.

   a. Proper care of machinery.

   b. When to replace worn machinery.

7. Lost time in hole due to inefficient drilling.

   a. Dull bit - proper methods in bit dressing and tempering.

   b. Reduce run in and out time.

8. Setting or erecting machinery.

   a. Use wench trucks systematically.

   b. Have the proper hand tools at the right place at the right time.

9. Time lost in pulling and running casing.

   a. Use of work schedules to prepare for the casing operation.

   b. Ways to reduce the cost of casing operation.

   c. Proper care of casing (pipe).

Method:

A explanation of the various elements in the drilling operation will be explained and a proposed new method will follow. Conclusions will follow each of the proposed new methods and will include comparison of each.

I. To reduce the time spent changing bits, to sharpen and temper them.

a. The present method is to check the bit for wear with the bit gage each time the tools are removed from the hole in order to clean out the drillings. It is necessary that the bit does not wear to less than ¼ inch in diameter less than the nominal size. Two bits are used, that is while one is being used to drill, one is in reserve. After the bit is warn enough to change the wrenches are placed near the hole and the circle jack is assembled in place as the tools are pulled out of the hole. When the bit joint comes right to the top of the hole the tools are stopped and the joint loosened with the large tool wrenches and circle jack. The tools and loosened bit are then raised out of the hole and the bailer is then placed in the hole. While the bailer is being run in the hole by the driller, the tooldresser removes the bit from the tools. This is accomplished by completing the unscrewing of the bit from the stem by hand and dropping it on the derrick floor in an upright

position. The bit is then laid down on the anvil where it is cleaned for the sharpening operation.

After the driller raises the bailer out of the hole with the machine, the tooldresser pushes it away from the hole and steers it into a dump box where the drillings and water is removed by gravity through the valve in the bottom of the bailer. The bailer is then placed in the hole for another run. After the driller has started the bailer back up the hole with the machinery he chains the bailer lever down and goes to help the tooldresser get the reserve bit from the bit rack and place on the end of the stem. Previous to this the tooldresser has cleaned the pin of the reserve bit and box of the stem to insure a good tight joint.

With the aid of the swivel wrench and chain falls mounted on a swinging crane the reserve bit is screwed onto the stem. After the bailer is removed from the hole, emptied and placed back in tis rack the tools are placed in the hole. The tools are then lowered to the proper position and the joint is tightened with the large tool wrenches and circle jack.

After the tools are lowered to the bottom of the hole and started to drill again, the bit that was removed is sharpened. This is accomplished by heating the beveled end to a forging temperature and working the metal to the desired shape with 16 pound sledge hammers or a ram. From one to five heats are required to accomplish this, depending upon the size of the bit and the amount of work that has to be done on it.

An additional heat is required to bring the sharpened end to a cherry red color for tempering. The bit should be tempered hard enough so it won't break off or chip and soft enough so it won't batter. It is better to have it too hard than too soft, as a battered bit will be hard to remove from the hole.

b. Proposed method:

It has been found that proper methods of heat treating or tempering of bits are not generally used. My recommendation is that the drilling contractor get proper tempering methods from the bit manufacturer. From this data the contractor should make up a simple instruction shut to be followed exactly by the tool dressers while tempering the bits. It is my opinion that the bit manufacturer would gladly perform experiments to aid the man working in the field to detect the proper tempering temperatures with out the aid of any high priced instruments. If each bit were dressed properly to get the maximum wear the number of bit changes per well would be reduced.

In changing the bits, time could be saved by placing the bit in the celler 1½ feet from the hole and to the forge side, supplying a proper designed bracing set up and doing all the loosening and tightening of the bit joint out of the hole. This will increase machine time because the bailer could be operated during this saved time.

C. Conclusion:

At present bits must be changed on the average of one time for each three times the tools are removed from the hole for cleaning purposes. If each bit is sharpened properly giving maximum wearing surface and proper hardness this ratio could be increased to 4 to 1. Time spent changing bits is approximately 20 minutes. Often it is necessary to pull the tools out of the hole solely to change a dull bit: when that happens the time saved would be one hour.

My proposed method of changing bits would reduce bit changing time to 5 minutes while drilling at depths below 2000 feet. At shallower depths the time saved would range from 5 to 10 minutes per change. This is due to the fact that it does not require so long to pull out the bailor and machine time would be lost.

2. Reduction of time spent bailing or cleaning out the hole:

a. Present method:

It is necessary to remove all of the drillings after each drilling run. While drilling in a dry hole it is necessary that there is not excess water in the hole. Normally fifty feet of water in the bottom of the hole is sufficient for drilling.

To keep the hole free from excess drillings and water, the tools are removed from the holewhen the driller detects the tools dragging. That is the sign that the hole needs cleaning out. After the tools are removed it is common practice for the driller to make two runs or more with the bailer before continuing drilling.

b. Proposed method:

From discussion with many drillers, there is too much time lost bailing excess water. This is due to poor judgment on the part of many drilling superintendents. Pipe or casing is run into the hole for the primary purpose of shutting off water zones so the drilling tools will exert more force. It is found that many times there is not a complete water shut off. I propose that each drilling contractor should instruct his drilling superintendents to drill at least 40 feet into proceeding formation and add three barrels of gumbo clay to the holebefore running casing to insure a complete water shut off. This will reduce the number of times that the bailer must be run to remove excess water from the hole for dry hole drilling.

c. Conclusion

A complete water shut off will decrease the number of bailer runs. This decrease would be a variable amount but should save on the average of 16 hours per well.

3. Reduction of time spent resetting wire rope sockets.

a. Present method:

Wire rope sockets are reset periodically depending on the quality of the wire rope and the hardness of the rock being drilled. Many contractors require resetting every 72 hours of drilling to reduce the number of fishing jobs. The method of resetting the socket was described in the discussion on drilling tools.

b. Proposed method:

Each time the tools are removed from the hole the driller should inspect the wire cable for wear at the top of the rope socket. Since most of the wear on the wire rope occurs on the fifty feet directly above the tools, this should be inspected also each time the tools are removed from the hole. Cable that is worn to the point where wires are broken should be cut off.

c. Conclusion:

If proper cable and socket inspections are performed the number of lost tools or fishing jobs would be reduced. This would reduce the time drilling the well by one shift or eight hours.

4. Methods to reduce wire cable wear.

a. Present method:

Current practice is to cut the wire rope off as it is worn or a bad place is found in the center of the line. It is sometimes spliced but this is considered bad practice under normal circumstances. Many drillers use their good drilling cables for spudding in and driving pipe. This is considered good practice also, but it does save time in changing lines. Usually lines are removed from the bull wheels and wound directly on portable reels when the well is finished.

b. Proposed method:

Since wire line depreciation is a large expense in the drilling of the well, maximum care should be taken to decrease its wear. It should not be subjected to excessive strains, various types of abrasive formations, kinks and salt water. The proper amount of twist should be given a line each time it is clamped on the screw for drilling purposes to reduce kinks. The line should be washed off each time it is pulled out of a hole full of salt water. The line should be completely inspected each week and completely oiled after each well. When spudding or driving pipe at shallow depths an old line should be used. Any driller using excessive motion and slipping lines through cable clamps should be dismissed because those practices are the major cause for wire cables or lines to break and wear excessively.

c. Conclusion:

The above proposed methods should increase wire line wear by one-third. This should reduce time spent changing wire lines and reduce costs by $600 per well.

5. Reduction of lost time in pulling up in the upper hole.

a. Present method:

In Michigan there are stratas just below the drift that contain blue shale. This blue shale when drilled and mixed with water forms what is commonly called gumbo mud. When excessive drillings collect in the bottom of the hole, the mud forms in rings that collect around the stem and stick to the side of the hole. When the tools are removed from the hole, the bit won't clear these mud rings and as a result get caught. It is then necessary to drill up through these rings to free the tools. The process of drilling up through these mud rings takes from 20 to 40 minutes due, not to the hardness of the mud rings, but because of the time spent hitching on and unhitching to get the reciprocating motion for drilling.

b. Proposed method:

When the driller detects a slight indication of mud he should clean out the mud. Many drillers hesitate too long to do this because slight indications of mud are often detected after drilling only 2 or 3 feet on a run. From talks with many drillers who are experienced at getting out of these mud rings, it has been found that too many drillers try to pull too much on the tools and don't drill up through the rings far enough.

c. Conclusion:

It is advisable to drill up through the mud rings until the tools are absolutely free before tryingto pull on them. Naturally, many drillers hesitate to pull out when mud rings are detected because the shale is soft and drills so fast that he naturally has the feeling that he is making lots of hole, but in reality is losing time.

6. Reduce time lost due to machinery break down.

a. Present method:

It is the tool dressers job and the drillers responsibility to see that the machinery is constantly inspected and properly lucricated. Oil and gas well drilling machinery is designed to stand high stresses and shock loads but these stresses are often exceeded. When parts of the machinery break they are often replaced by makeshift parts that are not properly designed and add to more trouble. All bearings are of the babbit type and are lubricated frequently. The driller and tool dresser constantly must be on the look out for loose turn buckles and bolts.

b. Suggestions:

Worn machinery should be replaced before they break to insure the safety of workers and the related machinery. Proper care and constant inspection should be given to the guy wires or the wire cables that hold the mast up.

c. Conclusion:

It is important that drilling machinery be kept in constant repair. All worn machinery should be reported to the drilling superintendent and replaced immediately,

7. Reduce lost time due to inefficient drilling.

a. Present method:

Most drilling superintendents are experienced drillers and can tell when the drillers are using proper motion and methods of drilling. Now that there is a shortageof drillers there is a tendency to overlook many of the faults that the drillers have to keep them on the job. This fact has cost the contractors a lot of money and at present there hasn't been much done to improve drillers.

b. Proposed plan:

The drilling superintendent should use some tact and train the inexperienced driller by demonstrating the proper methods. The individual would benefit and more time and money could be saved. Any person not willing to learn and accept advice is not an asset to a contractor and should be dismissed. I propose that an incentive plan be enacted before the drilling of each well. The drilling superintendent should set the standards and make an attempt to help each crew participate in incentive pay by training aids and proper arrangements of crews.

8. Time saved by proper erection of machinery.

a. Present method:

Most contractors furnish a $1\frac{1}{2}$ ton winch truck with each drilling machine. This truck is very useful during the drilling to perform such tasks as hauling clay, gasoline, casing, tightening the belt and handling heavy tools. When the machine is to be dismantled and moved the truck is used extensively. When a full crew is available three men are used to dismantle the machine and the other three are used to prepare the next location by leveling off the foundation site, digging the dead man holes and slush pits. Many contractors overlook the importance of using sufficient footing for the foundation, because the mud for it varies with the kind of soil at the location.

b. Proposed method:

Hire two extra trucks from other jobs or trucking company. The one truck should be used only as a pole truck, that is, leave the derrick mounted on one of the trucks during the entire moving operation. The other two trucks should be loaded with the pole truck and carry the bulky parts of the machinery. The smaller parts of the machine can be easily loaded on the pole truck and quickly unloaded to free the pole truck to unload the other trucks at the new location. The machinery parts should be moved in such an order as to allow the pole truck to lift the machinery off the two other trucks and place it in the proper position for erection at the new location. The method may seem more expensive but it is believed that the cost of renting the trucks will save enough hand labor to justify its practice.

9. Reduce time lost in pulling and running casing.

a. Present method:

At the present time the practice of using hired casing crews to run long strings of casing and "pick up crews" for the short string is used. In Michigan the long strings consist of the 5" casing and varies from 2000' to 3700' depending on the depth of the top of the Dundee limestone. These hired casing crews are trained semi-skilled workers. "Pick up crews" are usually not trained but perform the simpler jobs. Part of the drilling crew is used to perform the semi-skilled jobs when pick up crews are used.

A special wire rope is used as a casing line. This wire rope is 1¼" in diameter. The rigging of the block and tackle and other casing tools is necessary before the pipe can be run or pulled. The internal and external threads of the casing is cleaned and oiled a day or so before the c casing operation. It is also necessary to inspect the casing before it is run in the hole.

When the casing is pulled out of a hole, the casing equipment is rigged and a casing crew is hired. Usually all of the casing is pulled in two successive days.

b. Proposed method:

Time can be saved when the number of lines are increased on the block and tackle to give a higher mechanical advantage as more casing is run in the hole. It takes approximately five minutesto add or decrease the number of lines. At the beginning of the casing operation, two lines should be used.

When 500 feet has been run in the hole, one more line should be added and one line added each 500' thereafter until the maximum of six lines are holding the pipe.

c. Conclusion:

The above method should reduce casing time by $\frac{1}{4}$ because the higher mechanical advantages are used only when necessary. The lower mechanical advantage being used will obviously speed up the operation.