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DESIGNS FOR OIL FIELD TOOLS
TO AID IN
WATER FLOODING

By
FREDERICK SQUIRES

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DESIGNS FOR OIL FIELD TOOLS

TO AID IN Water Flooding

THIS is a description of proposed designs for three new oil field tools to solve problems presented by water flooding. They are the shot-hole caliper, the shot-hole core-drill, and the rotor valve. The first two tools supplement each other in the process of finding permeabilities of the sand in old wells in the absence of original core analyses. The last is for measuring and regulating the flow of water from an upper into a lower sand.

The suitability of old oil fields for water flooding may be determined in part by studying lease histories of their initial, cumulative, and present productions of oil and water, their sand thickness, structure, and past responses to vacuum or gas repressuring. Such information usually is available, but data on permeability, porosity, sand grain size, clay content and cementing material of the oil sand are rarely known. These characteristics may be determined best by examination of cores, but in many old fields and some new ones, no cores have been taken. The relative permeabilities of equal vertical sections of the sand may be found, without drilling, by measuring in the well the rate of water or gas intake, under uniform pressure, as the well bore through the sand is filled up, in equal vertical amounts, by a self-removable seal. But in order to know how much of the seal material it will take to fill up to each desired height, it is necessary to know the diameters of the shot hole, which can be determined only with a caliper.

The same is true if the relative permeabilities from bottom to top are determined by means of injecting two liquids of different densities and conductivities, the interface between which is located by an electric pilot, and which interface is lowered by pumping in more of the lighter liquid under uniform pressure throughout the thickness of the sand while timing the descent of the interface¹. (A simple float may take the place of the electric pilot.) Here again it is necessary to know the diameter of all cylinders of equal length exposed to the water in order to correct the intakes of such units to the intake of a standard sized area of exposed surface.

The distance between any two cores taken by the shot-hole core drill, when the bottom of the drill is raised by equal unit distances, depends on the radii of the shot hole at the points where the cores are taken. This also requires a caliper picture of the shot hole.

The third tool is necessitated by the relatively new practice of flooding lower oil sands with water supplied directly from the upper water sands in individual

By **FREDERICK' SQUIRES**
Petroleum Engineer, Illinois State
Geological Survey

wells. The present method is to perforate the casing opposite the water sand with the number and size of shots estimated to be sufficient to admit just the proper volume of water. But in the absence of accurate information as to the permeability of the oil sand and the degree of pressure in the water sand, there is no basis for determining the best number and size of casing perforations. In many cases at Allendale and in the McClosky (Illinois) areas the amount of water admitted is too great and its travel from water well to oil well is too fast. The measuring and regulating rotor-operated valve is intended to overcome this difficulty.

Shot-Hole Caliper

The shot-hole caliper is shown by a sketch of the method of using the caliper in a shot hole and a section of the caliper itself, drawn to scale, in Figure 1.

The caliper has a long body, cross-formed in section, made up of four cornering angles, one face of each angle of which has been painted or covered by a thin sheet of aluminum. At the upper end of each of the four angles, an arm is attached to a slide and held against the center member by a hook at the bottom but under outward pressure from a spring while the tool is being lowered through the well on a wire line from a pulling machine. When the caliper hits the bottom of the shot hole the momentum of the slides unhook and releases the arms, and the springs force their free ends against the walls of the shot hole.

On each arm, contracting the stationary body of the caliper, is a sharp-pointed marker, held forcibly against the aluminum or painted side of the angle, on which the upward motion of the marker leaves a scratch which bears a one-tenth relation to the profile of the shot hole.

While hooked to the bottom of the caliper the arms carry the whole weight of the tool by means of rods from the top of each arm, running the length of the tool and attached, above the tool, to the pulling-machine wire line. When the arms are released by contact with the bottom of the shot hole, the main body of the caliper is temporarily left resting on bottom. Then the arms, hav-

ing spread to the sides of the shot hole, are raised by reeling up the pulling machine wire line. In their travel, the upward moving pins on the arms mark the sides of the stationary angles. The radius of the mark on the angle is one-tenth of the corresponding radius of the shot hole. When the top of the slides to which the arms are attached reaches the top of the cross-formed main body of the caliper, the tops of the slides are stopped against a solid circular cap which forms the upper end of the tool, and the pulling machine raises the whole assembly to the surface. The scratch marks on the painted or aluminum covered angles are then measured and the outline of the shot hole is drawn by increasing ten times the radii of the outline marked on the angles. If aluminum strips are used they may be detached, rolled up and sent to the office for enlarging by drafting into the accurate outlines of the shot hole.

The advantage of this mechanical caliper is in its simplicity. Any lease man can operate and read it after it has brought its evidence to the surface. The shot-hole caliper provides approximate data on the shape of the shot hole, information needed in the method of determining permeability by the introduction of liquids, and useful when selective shooting is to be done. The original shooting which made the shot hole was for a purpose opposite to that now required, because the first shot was placed in the section of greatest permeability whereas the new shots must be placed in the least previous parts of the sand. The first shot was intended to increase oil production, the later shots to increase water intake of denser sections.

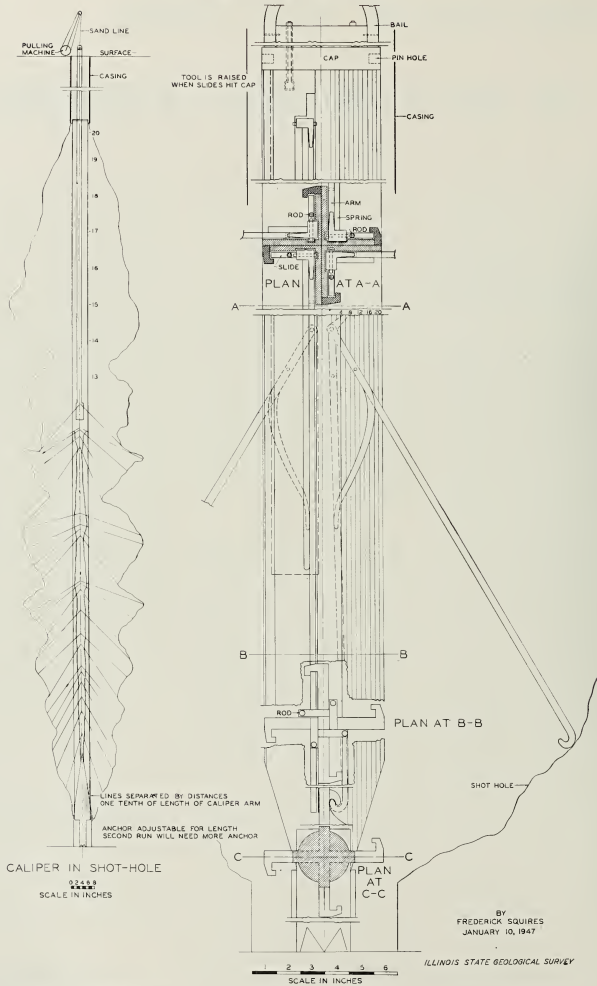
In the writer's opinion the present-day oil well caliper does not check exactly with the spot in the hole at which it



Figure 1. This tool marks outlines proportional to the profiles of the shot hole by means of movable arms traversing a stationary body. It is intended to be run with a standard pulling machine and the results are easily understood by the oil field worker. Shot hole profiles are needed to give information necessary in obtaining permeability profiles in old wells. It is proposed to build this tool and operate it in the field after which the results obtained and refinements made will be described in a later article.



SHOT-HOLE CALIPER



CALIPER IN SHOT-HOLE

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SCALE IN INCHES

2 3 4 5 6
SCALE IN INCHES

BY
FREDERICK SQUIRES
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SHOT-HOLE CORE DRILL

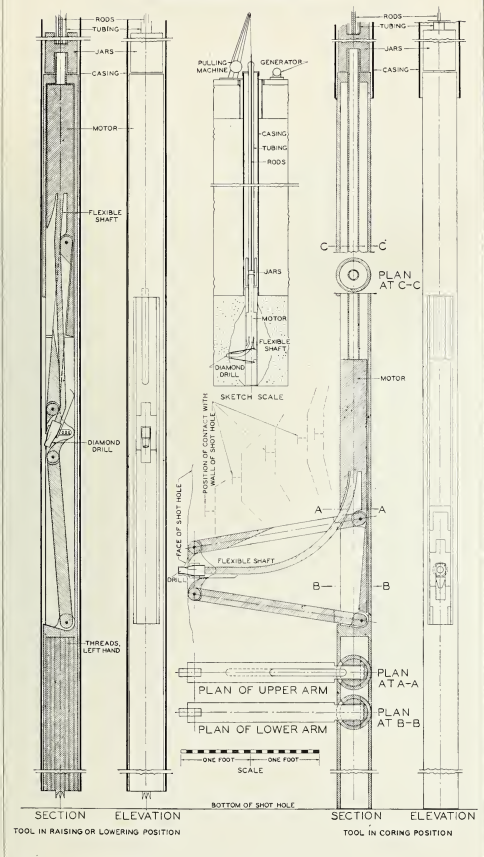


Figure 2. This tool is to obtain cores from the sides of shot holes in old wells. It employs the devices of telescoping cylinders which project the drill to the side of the shot hole, and the use of a high-speed diamond drill operated by an electric or air-driven or turbine motor to rotate the diamond drill. It is designed to cut a number of cores without withdrawing from the well. The tool can be run on a standard pulling machine and operated by oil field workers. Pressure on the drill may be regulated by hanging the tubing on a temper-screw or by a spring behind the drill itself attached to the contact member, in which case the temper screw would not be needed. This tool will be built and operated and the results described.

was taken and it cannot measure under-cutting. These imperfections are due to the fact that the arms always point downward. An accurate picture never can be made until someone invents a caliper with arms which can be projected outward horizontally.

Shot-Hole Core Drill

With the shot-hole core drill, cores may be taken in old shot holes to supplement permeability tests made by fluid injections or as an alternative to them.

The tool is shown in the sketch in Figure 2. It is a long tube which looks, on the outside, like a bailer, and the assembly is lowered into the well on tubing with a standard pulling machine.

Inside, slidable within the outer shell, is a second cylinder to which the well tubing is attached. The outer and inner tubes are connected by arms which lie in nearly vertical line while the tool is being lowered into the well but which are forced outward by the telescoping action of the tubes when the outer tube stops on bottom, and the weight of the tubing forces the inner tube into it, in much the same way that one opens an umbrella. The weight of the tubing, which has moved the inner tube downward into the stationary outer tube, forces the ends of the arms outward until they contact the wall of the shot hole. The inner tube contains an electric motor connected to a generator at the surface. The motor actuates, by means of a flexible shaft, a diamond drill mounted at the junction of the outer ends of the arms. The arms force and hold the outer ring of the diamond drill against the shot hole wall while the rotation of the diamond drill cuts out a core. The drill can penetrate only a predetermined distance, being stopped by a guard at the end of the arms. Just before complete penetration is reached the core contacts a sloping member inside and at the back of the drill which breaks the core loose from the shot-hole wall. Two springs on the inner surface of the drill tube hold the core until the succeeding core drives it farther back in the body of the drill.

The tool is then raised enough to retract the arms, the tubing is turned, left to right, which causes the left-hand threaded members in the bottom of the outer casing to screw out in the manner of a compound jack, raising the drill to a point at which a second core may be taken. As the tool is now designed this process can be repeated four times before the core drill has to be raised out of the hole for lengthening. An anchor is then inserted and the operation repeated until the shot hole is cored at predetermined equal intervals from bottom to top. Drills of later design will recover more than four cores without re-anchoring.

These cores are suitable for determinations of permeability, porosity, grain sizes, clay content, and cementing material. For these reasons they are a valuable aid in determining which old fields are suitable for water-flooding.

Rotor Measuring and Regulating Valve

Years ago the conditions at Allendale were studied where water from an upper formation was flooding the Biehl oil sand through holes in the casing and producing startling increases in oil. The amount of water entering the oil sand

was unknown and could not be controlled, and it was obvious that, in some instances, the volume was far too great so that wells were flooded out before they had time to make their production. The need of some means to measure and control the rate of water input became obvious.

At present the same kind of thing is happening in some of the McClosky fields, although the upper water has been let in purposely by gun-perforating the casing. As at Allendale, the volume of water is unknown.

Flooding in these fields has been profitable and justifies an effort to improve the technique. The design of the rotor valve assembly, shown in Figure 3, is such an effort.

Description of Process

In general the process consists of perforating the casing in an oil well opposite an upper water sand and running tubing on a packer. At some point in the tubing string, preferably above the water sand, the stationary part of the valve is placed. After tubing is completed the inner part of the rotor valve assembly is run into the tubing on rods and landed on a seat provided in the stationary body.

The valve is regulated by a ball governor actuated by a rotor, the number of revolutions of which is recorded at the surface by means of a make-and-break device in a two-wire circuit. Instead of governor-operated valves, stationary valves may be used, the proper water intake resulting by changing the size of the orifice.

With the automatic valve open, water flows through the rotor, the turning of which operates the ball governor. This in turn operates the opening in the slide valve by raising or lowering it proportionally to the speed of the rotor, causing it to cut off more or less of the water inlet through the tubing. By a proper choice of valve orifice, an equilibrium will be set up, in which the governor keeps the valve open just enough to admit the desired amount of water.

The valve may be let in and pulled out through the tubing by a pulling machine in the way an inserted working barrel is handled.

Summary

These three tools are offered in the hope of solving problems in water-flooding. It is intended to build and try them out under field conditions. No one of them will be expensive, and each can be operated by oil field workers. They will supplement the information now available through electric logging and production histories. The caliper and core drill, by providing cores for permeability tests, will aid in selecting areas suitable for water-flooding in territory, which, because of past successes, is now being investigated for secondary recovery possibilities.

Acknowledgments

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- ¹ Leo Courter's Patent No. 2,413,435.

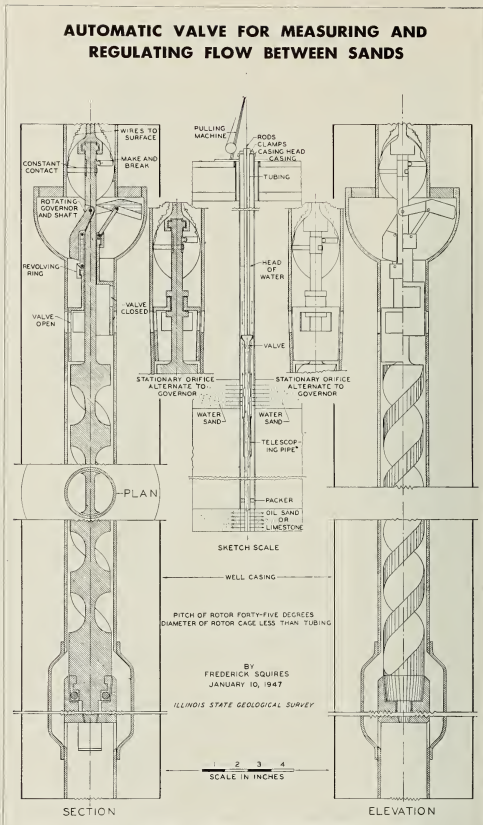



Figure 3. An automatic and a "fit-and-try" valve. The tool is designed to be let into the well and withdrawn as would be done with an inserted working barrel. The position of the outer body may be changed to vary the water head by means of telescoping joints of pipe below the valve. The speed of the rotor may be indicated by electric make-and-break circuit, or by the sound of the make-and-break mechanism conducted by a column of water filling the tubing from the valve to the surface and read at the surface by a water-proof contact microphone fed into an audio-amplifier connected to a head phone.



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