DOE/CE/15553--T1

S-CAL RESEARCH CORPORATION

SYSTEM TO INJECT STEAM AND PRODUCE OIL FROM THE SAME WELLBORE THROUGH DOWNHOLE VALVE SWITCHING

DOE/CE/15553--T1

DE93 000914

Contract DE-FG01-92 CE 15553

OCT 0 5 1992

FIRST QUARTERLY REPORT

ABSTRACT:

Various Downhole Equipment systems have been designed for typical applications in three California Oilfields,based on well data gathered from three different Operating Companies (two Majors and one small Independent)

The first system,applicable to a 2,000 ft deep reservoir (Monarch) a highly underpressured,unconsolidated sand of 200 ft net pay,located in the Midway-Sunset field,is based on the use of a new well.It has been described in a recent article,co-authored with Pr.G.A.Cooper and S.Zeyrek,which has been submitted for publication in the Journal of Petroleum Technology,following its presentation at the SPE Regional Meeting in Bakersfield,CA,last Spring.

The second well configuration considered was the re-entry into an existing well equipped with a 7 in. casing and penetrating into two separate sandstone reservoirs,at normal pressures in the North Antelope Hills field.Only the bottom layer is presently in production through a gravel-packed 5.5 in.liner,while the upper zone is behind the cemented casing.

The third case studied was the re-entry into an existing well equipped with an 8 5/8 in. casing,presently unperforated,into a thin

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under-pressured sand reservoir (Weber) in the Midway-Sunset field.

All three California fields contain Heavy Oils of different but relatively high viscosities.

A new class of potential applications of our new technology has also been considered: the recovery of Light Oil (> 20 API) by steam injection in under-pressured Carbonate reservoirs which lay at depths beyond the economic limit for conventional steam injection technology.The possibility of including this application in a Field Test proposal to the DOE,under the Class II Oil Program,is now under review by various Operators.A drilling contractor experienced in drilling multiple horizontal wells in Carbonate reservoirs and a team of reservoir engineers experienced in the recovery of Light Oil by steam in fractured reservoirs have expressed their interest in participating in such a joint Field Project.

Laboratory tests on specific prototypes of Downhole Sealing Elements are underway.

1.DOWNHOLE EQUIPMENT-CASE 1 HEAVY OIL

In a new well drilled in soft formations,any reasonable casing diameter may be selected,if its cost is a relatively small fraction of the well cost.The main advantages of a larger diameter casing are:

- it allows the use of a relatively large-diameter (>=4.5 in. OD) Thermocase insulated steam tubing presenting a low wall thermal conductivity,in addition to another string of tubing.
- it allows a simple connection of two side by side intermediate liners cemented together inside the lower part of the casing.

Because of the likelihood of sand production problems in unconsolidated sands,a jet pump,which has no moving part,was selected

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for lifting the produced fluids from the base of the reservoir to the surface.The second tubing string carried the power fluid (water) to the jet pump.The produced fluid flowed through the annulus,thus surrounding the steam tubing for maximum heat exchange.

This case,studied for a Major Operator,assumed that minimizing Operating Expense was a major objective,justifying higher Capital Cost.For this reason,the operations required for switching from "huff" to "puff" were simplified as much as possible.No service unit rig was necessary,only an inexpensive conventional wireline unit was required.The downhole flow control devices were a pair of three-way valves controlled from the surface by hydraulic lines.

As shown in Appendix I,despite this rather generous Capital spending policy,the over-all cost of the completed well with two horizontal drainholes was only 1.936 times that of a single vertical well.The drastic increase in well productivity (a factor of about 7) easily justified such a policy.

The experimental work described in this Appendix confirms the technical feasibilty of building Downhole Valves including metal/metal seals.It demonstrates that a steam pressure difference of more than 1,200 psi across the seal can be maintained leak-tight. Suitable alloys are available for long-term operation in a corrosive environment at high steam temperature.

2.DOWNHOLE EQUIPMENT-CASE 2 HEAVY OIL

In Case 2,studied for a small Independent Operator,a totally different spending policy was used.Instead of drilling a new well,a work-over program was designed for an existing well already equipped with a 7 in. (23 #/ft) casing.The project planning was divided into

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two successive phases to provide pay-as-you-go financing of the operations.In the first phase,the Upper Zone,presently behind an unperforated casing,was put in production,with sequential "huff and puff" of both zones,using only the vertical well.In the second phase,the Lower Zone productivity was to be drastically increased by drilling a medium curvature horizontal drainhole operated in parallel with the existing gravel-packed vertical liner section.The drainhole would be drilled,gravel-packed and its liner cemented using only a coiled tubing unit,to further reduce Capital Cost.

For the same reason,the Downhole Flow Control System consisted of a set of plugs operated by wireline.For the same economic objective,a conventional rod pump was used,anchored in the vertical production tubing,above the Downhole Flow Control System.Both parallel tubings carrying hot fluids,steam in downward flow and produced oil and water in upward flow,the annulus was gas-filled at near atmospheric pressure.This configuration allows the use of an effective but inexpensive Silicate foam insulation on the steam tubing,instead of the much more costly and too bulky Thermocase used in Case 1.

Such a relatively primitive configuration is slightly more expensive to operate than in Case 1,because of the more complex wireline operations required.The small-diameter drainhole is also less productive than in Case 1,but probably sufficient,in view of the small thickness of each producing zone.

The Capital Cost of Phase 1 was estimated at $ 30,000 and that of Phase 2 at $ 40,000.The expected benefits were respectively a 20 % net increase in well productivity with Phase 1 and an additional 80 % increase with Phase 2.The pay-out of each Phase was less than six months.Despite acknowledging these economic benefits,this small

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Independent Operator could not proceed with the project.Indeed the economic situation faced presently by many small Independents in California is really grim.Prices paid for Heavy Oil at the refineries controlled mostly by International Majors remain very low and bank loans have pretty much dried-up for any project presenting a technical risk.In this context,it is difficult to convince anyone to try a new technology,regardless of its potential benefits.

3. DOWNHOLE EQUIPMENT-CASE 3 HEAVY OIL

In this case,studied for another Major Operator,a suitable work-over program was designed for re-entry into an existing 8 5/8 in. cased well,left unperforated.With this larger diameter,the plug-type Downhole Flow Control System used in Case 2 is applicable with two horizontal wells of medium curvature,connected through windows cut in the cemented casing,at two different depths,by means of two 3.5 in. liners.The upper part of each liner is cemented in the curved part of the borehole.The horizontal part of each drainhole is gravel-packed.A long-stroke pumping unit operates a rod pump successively in each drainhole.This allows switching from "huff" to "puff" without requiring a service unit rig.The only equipment brought to the well for this operation is a conventional wireline unit. This being an under-pressured reservoir,the pump is anchored near the bottom of the curved part of the drainhole.

Several variants to this basic configuration were also worked-out.For instance,if the drainholes are drilled with coiled tubing,the smaller hole must be equipped with a 2 7/8 in.liner. Instead of a long-stroke pumping unit,a conventional short-stroke jack pumping unit is then used.This,however,requires the use of a service

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unit rig each time that downhole switching is done.The relative economics of these variants have not yet been determined.

4. DOWNHOLE EQUIPMENT FOR LIGHT OIL RECOVERY IN UNDER-PRESSURED CARBONATE RESERVOIRS-LIGHT OIL

Light Oil recovery by steam injection has been recgnized as a viable option (Ref.1 and 2),especially in under-pressured reservoirs and it has been shown to be applicable to Carbonate reservoirs (Ref.3 and 4).Light OIl (API gravity > 20) has a price which is not subject to the heavy discount presently imposed by refiners and the forthcoming DOE Class II Oil program,with a relatively large budget,may offer to the Operators sufficient financial help to try a new technology.Although the DOE's emphasis appears to be on CO2 miscible floods in the Permian Basin,it has also recognized the potential impact of steam injection and of horizontal wells in slowing down the sharp decline of US Domestic Oil Production.There are many Carbonate reservoirs in the US which are too far from any CO2 source and too much under-pressured to achieve CO2 miscibility.This class of Carbonate reservoirs includes many fields which present favorable characteristics for Light Oil recovery by steam injection,but in which the reservoir depth exceeds the economic limit for conventional steam injection technology,because of excessive heat loss through the steam tubing.This limitation has been removed in our technology,so that wells of 2,000 to 5,000 ft could now be considered for steam injection.Multiple horizontal wells connected to a single vertical casing have already been drilled in Carbonates and their completion is usually in open hole,thus eliminating the costs and technical risks of a liner and gravel packing in the horizontal

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part of the well.These are the only changes which would be made to the well configurations studied for Cases 1,2 and 3.The use of steam for Light Oil recovery results from the same basic mechanisms as for Heavy Oil recovery,but the importance of steam distillation and of thermal expansion of the oil are much greater in the case of Light Oil.Useful screening guides have been presented in Ref.4 and two economically successful steam projects for the recovery of 22 to 24 API oils in fractured Carbonate reservoirs have been described in Ref.5 and 6. Work is underway to select a suitable reservoir and partners for responding to the DOE Class II Oil Program Solicitation.

5.EXPERIMENTAL TESTING OF PLUG-TYPE FLOW CONTROL DEVICES

A test program with protoype devices in a high pressure steam cell has been undertaken at the University of California,as a continuation of the work reported in Appendix 1.Preliminary results have shown the feasibility of achieving leak-tight status.Corrosion aspects are now under study to determine the best alloys and packings to be used for this type of device.

6.CONCLUSIONS:

A technical paper describing our technology and its potential application in a typical California Heavy Oil field was presented and has now been submitted for publication in the JPT.

Studies made for various California Operators for specific wells and reservoirs have confirmed the technical and economic feasibility of our new technology.

Specific well drilling or work-over programs developed for three different cases have shown the flexibility of the Downhole

Flow Control System being developed for a Field Demonstration.

The difficult economic situation faced by California Small Independent Operators and the exodus of many International Majors from California have so far delayed implementation of a Field Test in Heavy Oil fields.

The applicability of this technology to the recovery of Light Oil by steam injection in some of the under-pressured Carbonate reservoirs targeted by the DOE Class II Oil Program is now under study with prospective partners.

Preliminary tests of full-scale prototypes of plug-type Downhole Flow Control Devices are underway at the University of California-Berkeley.

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12 / 8 / 92