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* SEE LETTER DTD MAY 4, 1978

MULTI-PATTERN LOW-TENSION
DEMONSTRATION FLOOD
BIG MUDDY FIELD

TECHNICAL PROGRESS REPORT NO. 1
INCEPTION THROUGH APRIL, 1978

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DOE OFFICE OF PATENT
COUNSEL/LIVERMORE

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UNITED STATES DEPARTMENT OF ENERGY
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Revised Milestone Chart (Figure 2)

Water Injection for Reservoir Pressurizing (Figure 3)

Current Pressures in the Wall Creek (Figure 4)

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Drilling Memorandum for a Typical Well

Completion Memorandum for a Typical Well

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INTRODUCTION

The Big Muddy Low Tension Flood is a commercial size demonstration project involving nine 10-acre injection patterns in the heart of the Big Muddy oil field. It is located about 15 miles east of Casper, Wyoming. Figure 1 shows the layout of the site.

Project objectives relate to surfactant flooding in the low permeability, high fracture density, fresh water reservoirs typical of many fields in eastern Colorado and Wyoming. Design technology is based in part on a pilot test conducted previously at an adjacent site.

Work is divided into six steps. The first four are:

1. Preliminary studies to establish pattern orientation and to finalize construction plans.
2. Drill and complete all pattern wells, build the production facilities, complete enough of the injection plant to carry out the preflush step and select the formulation and size of the chemical slug.
3. Conduct a preflush to establish the oil production base line and to achieve the desired pattern balance. The injection plant will be completed during this step.
4. Inject the surfactant and polymer slug and taper off the polymer to the water flush.

The final two steps involve performance analysis. Step One, with the exception of some of the construction detail, has been completed at the time of the current monthly report.

The current report is the first to be submitted. It covers all work done since the start of the demonstration project.

SUMMARY

The contract for the Big Muddy Low-Tension Flood was approved in March 1978 and made effective January 1, 1978. The Milestone Chart has been revised to reflect the later than anticipated signing.

Work was completed on the study of preferential fracture direction in the area and the flood pattern reoriented N 05° E so that alternate rows of production and injection wells will coincide with the natural fracturing plane.

An environmental assessment was made by D.O.E. personnel with the conclusion that the environment would not be harmed by the proposed operation.

Well locations were staked and most of the twenty new wells can be drilled without undue problems at the surface. Old flow lines, automation cables and power lines must be moved in several cases and one major power line move is required. Only one well may have to be whipstocked to bring in to the pattern.

Major equipment and service requirements were bid out to responsible sources and vendors have been selected. Two drilling rigs will be used and drilling should be started by the end of May. The rigs will move off after setting casing and completion units will be used to perforate and stimulate.

Lost circulation is anticipated in the Second Wall Creek and water is currently being injected into selected wells to increase reservoir pressure prior to drilling. Other devices to reduce the lost circulation problem include the use of low weight mud and staged cement jobs.

The thief zone discovered in the pilot test and thought to be near the base of the Second Wall Creek has been located as suspected by an injectivity profile on R.B.W. No. 80. A primary objective during well completion will be to exclude this zone from the system. Pressure pulse tests have been designed to check the effectiveness of the completions.

Five existing wells will be worked over for use in the flood and data are now being gathered on these. A study has been completed of all existing wells to determine if any of the unused wells might effect the flood through loss of fluid to other zones.

Preliminary meetings have been held with the C&NW Railroad to discuss building a spur from their main line to the chemical injection plant to expedite chemical delivery. The spur is economically feasible and may even justify moving the plant location to a site closer to the rail.

A task force has been created to design the various sub-systems in the total process flow stream. Jobs have been assigned and much of the work has made considerable progress.

Sufficient disposal capacity has been identified for excess water produced by the flood. Solids from the back wash system on the plant filters will be buried in land-fill type pits. Two potential sites have been approved by the State.

Laboratory experimental work aimed at finalizing the surfactant selection is progressing on schedule. Three systems are being evaluated. So far all three show good oil displacement with low surfactant adsorption.

Other laboratory studies are evaluating the polymer type which will be most effective in the Big Muddy low-tension process. Preliminary screening indicates that both Dow P-500 and Kelco Xanflool give about the same mobility control. The Kelco polymer has better injectivity properties and produces the desired effect at lower concentrations. However, the Dow-500 costs less per pound which tends to equalize the cost advantage of the lower concentrations.

PROGRESS REPORT ON FIELD WORK
INCEPTION THROUGH APRIL 1978

CONTRACT DATE

The contract was signed by both parties in March 1978 retroactive to January 1, 1978.

MILESTONE CHART

Revisions were made in the Milestone Chart to reflect the later than anticipated signing of the contract. The major effect was a general four-month shift in time. A copy of the revised chart is attached (Figure 2).

OFFICIAL CONTACTS

Names and addresses of those most closely connected with the project are:

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TECHNICAL REPORT AND MEETING SCHEDULE

The monthly meeting with the Technical Project Officer has been scheduled for the second Thursday of each month. The Engineering Committee has been scheduled to meet concurrently, at least during the construction and start-up phases of the project.

Every reasonable effort will be made to have the monthly Technical Report distributed prior to the above meeting. Its contents should generally define the meeting agenda.

The Technical Status Report has been deleted for this project as has the Quarterly Technical Progress Report. A brief summary letter each three months will be substituted for the latter.

MEETINGS TO DATE

The following technical meetings have been held to date:

February 14, 1978 in Casper, Wyoming
Conoco and DOE personnel to discuss the environmental assessment.

February 23, 1978 in Casper, Wyoming
Project Engineering Committee to discuss details of the drilling and construction phase.

April 6, 1978 in Casper, Wyoming
Conoco matrix organization for engineering design to discuss plant construction and make design assignments.

April 10, 1978 in Casper, Wyoming
Conoco with Mr. Bill Howell and Mr. Rex Thomas to discuss project status and report scheduling.

April 17, 1978 in Tulsa, Oklahoma
Project Engineering Committee to discuss order of drilling, saturation determination and thief zone identification.

EQUIPMENT PURCHASING AND SERVICE CONTRACTING

Bids were requested from two or more suppliers on all but a few major items required in the early stages of the contract. The specific items and the winning suppliers are:

Well Location Surveys
Location and Road Construction
Drilling Rig (2)
Drilling Mud
Drilling Bits
Open Hole Logging
Coring
Cement Services Hardware

Powers Elevation Company
Thatcher and Sons
3-U Drilling and Burns Drilling
Pro-Mud and Imco
Reed
Schlumberger
Christensen
B-J Hughes

Completion Unit
Cased Hole Log and Perforating
Stimulation
Well Heads

Sing Well Service
Go-International
B-J Hughes
J & L Supply

PATTERN CONFIGURATION AND LOCATION PROBLEMS

The flooding pattern shown in Figure 1 was selected after all data on the directional nature of permeability in the 2nd Wall Creek had been evaluated. The N 05° E orientation aligns the injection wells so that the preferential direction of fracturing is between these wells and not toward producing wells. To do otherwise would severely reduce flooding efficiency.

Reorienting the pattern reduced the number of five-spots from ten to nine. This eliminated ten acres from the demonstration site initially proposed. Details were covered in a letter to Mr. Robert Johansen dated February 28, 1978, and the change was recognized when the contract was signed.

A geological study made by Casper based personnel showed no faulting of sufficient displacement to interfere with the movement of fluids in the reservoir. This conclusion is supported by earlier work involving pressure pulse tests that detected no significant barriers.

The new pattern has been surveyed and a revised map will be distributed during May. Figure 1 is a close approximation but there are several major differences. Perhaps the most significant is that the reported location for No. 64 has been in error and the well is actually only about 20 feet off the desired location for an injection well (No. 91). No. 64 is a shut-in Dakota well and logs are being obtained concerning the casing cement job near the Wall Creek sand and the well bore drift. The possibility of working this well over for injection to replace drilling No. 91 is being considered and will be discussed in a subsequent report.

Three wells have major location problems. One (No. 84) lies on the C&NW railroad right of way and probably must be moved. The most logical direction is north which will put the well about 150 foot off pattern. This may be undesirable because an injection well is involved and it can be necessary to whipstock the hole back near the correct bottom hole location.

No. 89 falls in the bottom of a large drainage ditch. This well is an internal producer and the bottom hole location must stay as close to pattern as practical. Whipstocking was considered, but the decision has been made to divert the flow in the ditch and build the location on pattern.

No. 94 will be on the Glenrock highway if located on pattern. It can be relocated about 90 feet south with a good chance of utilizing the natural well bore drift to force the hole northwest and perhaps make up a portion of the off-pattern distance. No. 94 is an outside producing well and the location of these wells is the least critical of all.

One well (No. 95) is too close to a major power line. Again an internal producer is involved and Pacific Power and Light will reroute the line. There are numerous other problems with old flow lines, automation cables and power lines to individual wells that can be handled routinely and present no special problems.

ENVIRONMENTAL ASSESSMENT

Conoco and DOE personnel from Oak Ridge met in Casper, Wyoming, February 14, 1978, to discuss the project insofar as it might affect the environment, either above or below ground. This included procedures for drilling wells, confinement of injected fluids to the demonstration zone and waste disposal from surface operations.

An archeological survey was made in March by the University of Wyoming with no finds relative to the project.

Results are being published with the conclusion that normal project operations should have no significant impact on the environment.

NEW WELL DRILLING

The initial 25-well demonstration site development plan called for drilling nine injection wells and eleven producing wells and for working over the five existing wells for production. These are indicated on Figure 1.

Drilling procedures are designed to minimize chances of lost circulation in the Wall Creek which is known to fracture at less than hydrostatic pressure. One approach is to inject water into selected wells to raise the rock pressure slightly above hydrostatic to help resist fluid invasion.

Other methods are built into the drilling procedure. These include restrictions on mud weight and pipe movement and the use of stage cementing techniques. A drilling memorandum for a "typical" well is attached. Individual well memos, with the exception of the injection well at the center of the pattern, will differ only in formation tops, total depth, and whether or not they are to be cored.

Two rigs will be moved in for the work. They will drill or core to total depth, log, set casing, and move off. A smaller completion unit will be moved on the hole to perforate and stimulate. This procedure not only reduces cost but also gets the wells finished earlier than otherwise possible.

Well No. 90 and No. 96 will be the first two drilled. These are outside producing wells on the east side of the pattern where attempts to raise the reservoir pressure will be effective earliest. There is no fixed order for the remainder of the drilling except that a core is desired from the northwestern part of the pattern as soon as possible and that the injection well in the center of the pattern (No. 92) will be drilled last. The special saturation tests and the mini-surfactant tests will be run on this well.

Contractors have been selected and drilling is expected to start by the end of May.

ANTICIPATED DRILLING PROBLEMS

Drilling will be relatively easy at Big Muddy with no anticipated problems above the target sand. Total time on the hole from spudding to the top of the 2nd Wall Creek should not exceed five days at the most.

Hole deviation should be minor and not cause individual wells to drift off pattern. Rotary drilled wells have been straighter than the older cable tool holes and the average drift of eight rotary holes surveyed recently is only 43 feet N 26° W.

The problems come in the 2nd Wall Creek with the lost circulation mentioned previously. This apparently occurs when the weight of the drilling mud and/or the cement breaks down and enters the east-west trending zone of weakness in the rock.

NEW WELL COMPLETIONS

Well completions will involve perforating and fracturing the upper part of the second bench of the Second Wall Creek sand by the limited entry technique. All wells will be treated similarly and the fracture stimulation has been found indispensable in these low permeability reservoirs.

Fracturing will follow the east-west trend and significantly shorten the effective distance between adjacent wells on this line. This was the basic concern in properly orienting the pattern.

The presence of a thief zone was discovered during the pilot test and its location was suspected to be at or below the bottom of the Second Wall Creek sand. This was later confirmed and a major objective of the completion effort will be to exclude this thief from the system. The limited entry fracture is one attempt at this by restricting the vertical extent of the crack, at least near the well bore.

A copy of a typical well completion memo is attached.

THE THIEF ZONE AND ITS DETECTION

The presence of a thief zone which permits inefficient and rapid migration of injected liquids from one well to another is undesirable in any case and particularly troublesome if in direct communication with the injection well itself. Such a zone is definitely known to be present near the bottom of the Second Wall Creek sand.

Its presence is detectable by pulse type pressure tests between a well known to be open to the thief zone and the well in question. This requires several weeks of testing but is quite definitive.

Concurrent pulse tests are planned for the first two wells (No. 90 and No. 96) to give an early evaluation of the effectiveness of the completion techniques in excluding the thief zone. Sensitive bottom hole pressure gauges will be installed in the two wells as soon as they have been completed and similar gauges already are installed in five surrounding wells. Water injection for building reservoir pressure must be stopped in the immediate area during the tests and drilling operations will be moved to the west side of the pattern.

Neither the proper conditions nor the required time will be available for similar tests on each well. Individual well pressure fall-off tests in conjunction with radio-active tagged frac sand will be used instead. The fall-off tests are not always reliable, but their interpretation can be guided by the presence or absence of a concentration radio activity in the vicinity of the suspected thief. This, at least, gives some degree of on-going testing while the drilling program is still active.

Finally, a reservoir wide pulse test is planned when the pattern is complete. This will involve injection pulses in selected wells surrounding the pattern with pressure responses noted in the twenty-five pattern wells. Pressure measurements will use down hole devices planned as permanent fixtures in the wells.

The thief, which was first detected in the pilot, was apparently shut off when a liner was cemented in the problem well. The liner was perforated and fractured in the upper part of the sand only which led to the guess that the thief was in the bottom of the sand section. The presence of higher than usual natural fracture density in cores taken near the bottom supported the guess.

An injectivity profile run in March 1978 in R.B.W. No. 80 with water and radio active iodine showed that 90 percent of the injected liquid entered the bottom of the sand. This confirmed the assumption. (No. 80 is completed open hole through the Second Wall Creek in the demonstration area.)

The location of the thief low in the productive section is fortunate since the chances of excluding it are much better than if it were present higher in this zone.

UTILIZATION OF EXISTING WELLS

Five wells were proposed originally for use in the flood. These were R. B. White-side Nos. 36-54-57-58 and 68. No. 57 is slightly off pattern for an internal producer. A decision either to use it or to drill a new hole will be made shortly.

Other existing wells shown near drilling well locations were considered but rejected because of poor mechanical conditions down hole.

Workover memos will be prepared for individual wells on the basis of individual conditions. All but one (No. 68) are open hole completions, however, and the objective will be to run and cement liners in a manner that excludes the thief zone. No. 68 has pipe set through and perforated. Previous tests show it still in communication with the thief. Working over this well requires cement squeezing, reperforating, and restimulating.

EFFECTS OF UNUSED EXISTING WELLS ON THE FLOOD

Many holes have been drilled in the area during the past 60 years. Most, however, were Shannon wells that did not penetrate the Wall Creek sands. All known wells that did penetrate the sand have been noted on the field map.

More recent wells are still open and leaks should be noticed as reservoir pressure is increased to the point where wells again would flow if permitted. Such was the case with No. 48 where parted casing was discovered when an attempt was made to inject water in the well.

Some of the more recent and all of the older wells were drilled with cable tools and have as many as five and six strings of pipe covering individual zones. Consequently, these zones have some protection even though a leak were present at the Wall Creek. Also, the multiple strings provide direct communication with the old well heads. These heads are prone to leak under pressure and should reveal a problem if one occurs.

WELL BORE LOGGING

Well bore deviation surveys will be run on all wells, old and new, that will be used in the project. Nos. 57 and 68 already have been surveyed and the other existing wells are scheduled for early in May. Single shot magnetic surveys will be run on the first few new wells while they are being drilled.

The open hole logging program on the new wells is designed to evaluate oil saturation and originally consisted of the following:

Gamma Caliper
Dual Laterolog
Micro Laterolog
Formation Density

A suggestion has been made recently to add the Sonic log in any case where the character of the gamma and density logs are substantially different from those run in R.B.W. No. 80. This could indicate a change in the shaliness of the sand in which case the Sonic log would aid in the interpretation of the others. The log will be run in at least one or two wells if the above condition occurs.

A Gamma log will be run in the new wells after casing is set to aid in perforating. A temperature survey will be run immediately after cementing to locate the cement tops for the primary and stage jobs. Gamma logs may be run again after fracturing as part of the thief zone identification.

The following logs will be run on all old wells:

Gamma for total well bore
Caliper in open hole section

In addition, we are considering running the Latero and Density logs for saturation determination if the open hole is in gauge, which is not likely.

CORING AND ANALYSIS

Cores are planned for all of the newly drilled injection wells. This number assures adequate volume for special laboratory testing and the injection wells provide scatter throughout the pattern.

The cored interval will start at or slightly above the top of the Second Wall Creek, continue into and through the second bench and stop at total depth about 20 feet below the second bench. Coring to T.D. should include the thief zone unless it is too fractured to recover. Total cored interval will be 110 to 120 feet. Cores will be four-inch diameter.

Cores will be packaged and preserved at the rig by the Casper branch of Core Lab. Routine analysis for porosity, permeability and saturation as well as a laboratory Gamma log will be run in Casper. The core will be shipped to Conoco's Research Laboratory in Ponca City, Oklahoma, for further work on fine tuning the chemical slug formulation.

Plans are to cut all the cores with the same drilling rig in an effort to improve coring and handling techniques.

PRESSURIZING THE RESERVOIR

Individual well pressures at the mid-point of the Wall Creek sand averaged 1220 psi in the demonstration area early in March 1978. Hydrostatic pressure would range from 1300 psi to 1370 psi in these wells, depending on depth.

A considerable number of wells were available for injecting water into the Wall Creek but nearly all are open hole completions and the sand in many of these is covered with cavings. Also, it was decided not to use any well that might be worked over later for use in the pattern.

Figure 3 shows the wells ultimately used for injection and the mid-sand pressures at the start of the project. Water from the production treaters in this area is being injected in all wells but R.B.W. No. 80. Sundance water from R.B.W. No. 60* is being injected into this well in case later plans call for its use as an observation point in the flood.

Injection was started and stopped several times as leaks were found and repaired in the old flow line system. These are now under control and injection should continue in a uniform manner unless new ones develop.

Figure 4 shows the most recent distribution of pressure across the pattern. These are building rapidly on the east side where injection points are plentiful and more slowly in the southwest corner. It may be necessary to augment injection in this area later although there still should be sufficient time to reach the desired levels with the current wells.

DELIVERY AND HANDLING OF CHEMICALS

As much as 30,000 tons of chemicals may be used in the flood. This includes surfactant, polymer, alcohol, caustic, salt and filter aids. Delivery of much of it by truck is impractical because of the size of some of the shipments. Receiving by rail on existing trackage and moving to the plant by pipe line and other means is also impractical because of the cost of duplicating certain special handling facilities necessary for the surfactant.

The main line of the Chicago and North Western Railroad passes within one-half mile of the existing injection plant and present plans are to lay a spur from this line to the plant with adequate room for spotting all cars that might be involved in a single delivery.

Preliminary discussions have been held with the railroad to determine feasibility of this approach and an on-site meeting is scheduled early in May to select possible routes for the spur and locate points for the main line switch.

There are two alternatives being considered. The first is to come to the existing chemical injection plant which was used for the pilot and can be expanded to meet the requirements of the demonstration project. The second is to build a much shorter and less costly spur to an area just south of the tracks and north of the Casper-Glenrock highway. Savings in the cost of the track and the elimination of the highway crossing would be used to rebuild the plant at the more centrally located position for the current project. The alternate plans are shown on Figure 5. State leases are involved in both cases.

The chemicals to be used at Big Muddy are not of the same hazardous nature as those that have made the news because of the recent train derailments. Spills would still be a problem, however, and Continental's legal staff has been asked for an opinion

*R. B. W. No. 60 is the water supply well used for the pilot and to be used for the demonstration project. Produced water from the treaters contains trace amounts of oil that eventually restricts water input in the low permeability Wall Creek sand.

as to where the project operator's liability would start in the event of a derailment related spill. Possible losses within the process area from broken lines and similar mishaps will be provided for by dikes and other containment facilities.

PLANT DESIGN

Conoco has set up a task group to complete the design for the entire project, from the inlet at the railroad spur through the outlet pipeline connection at the production battery. Personnel that are involved represent our engineering and operating facilities at Casper, Wyoming, Ponca City, Oklahoma, and Houston, Texas. Objectives of forming this matrix organization are not only to speed up the work but also to assure that maximum expertise is brought in.

The total project has been divided into several sub-systems for both design and operational purposes. These are shown on Figure 6. Future reporting on the project generally will be categorized by these sub-systems.

The alternatives of either expanding the existing plant or building new depends for the most part on relative costs for the railroad spur. Either way, however, there will be salvagable equipment from the present plant of appropriate specifications and adequate condition for potential use in the demonstration project. This equipment has been inventoried for consideration by the task group. Also, several scale-up and optimization tests have been run to better determine specifications required for expansion.

Over the past month considerable work has been done to optimize filter charge rate and the body feed rates for the precoat filter with the fluids anticipated for the demonstration project. A mini-filter test has been carried out in the plant using actual hydration and mixing equipment with the Sundance supply water. The small filter only requires small total volumes of fluid, thus reducing the cost of the optimization tests and allowing testing of several operating variables.

The mini-filter tests have been completed. These suggest that flow rates on the order of about 0.4 GPM/ft² with polymer solutions can be obtained. These throughput rates would allow the pilot filter to be reused in the demonstration project. The mini-filter tests also suggest that Perlite 436 will give an adequate filtrate quality. The Perlite is cheaper than diatomaceous earth which was used in the pilot. It now remains to determine the scale-up between the one square foot mini-filter and the 400 ft² pilot test filter. This work is planned for early May.

The task group has noted that super clean water aids the hydration and filtration of polymers. Consequently, the process design now calls for the addition of two precoat filters to highly polish both the polymer hydration water and the water used to dilute the polymer surfactant solutions.

Other improvements evolving from the process study to date are:

- (1) Use a viscometer control on the concentrated polymer stream. This step should reduce the cycle time and smooth out the blending operation.
- (2) Use "mini-bulk" container deliveries of polymer rather than bags as used in the pilot. This will result in better utilization of man time and reduce the dusting problem inherent with small bags.

- (3) Exchange heat from the hot supply water to warm the injection water and produced water.* Conservation of heat will amount to several million BTU's per day and will make the processing in the plant more efficient.

SOLID-LIQUID WASTE SEPARATION

There will be two principal waste streams off the project. One will be the water the production treaters. This is suitable for reinjection in existing water-flood operations but is not suitable for make-up water in the surfactant flood. The other stream is the solid-liquid mixture that occurs when the filters are backwashed at the chemical injection plant.

The solids off the plant will be nearly all Perlite type filter aids of very low density. These were separated using two concrete settling vats during the pilot. This system was workable but not satisfactory enough for use in the expanded plant.

The low density Perlite makes any gravity force separation system inefficient. Suggested alternatives included rotating vacuum leaf filtration such as is used for slimes removal in certain types of washer plants. It was also noted by the task group that late generation D.E. type filters use a "dry" backwash system so that the separation problem never arises in the first place.

The above and other alternatives are being considered.

SOLIDS WASTE DISPOSAL

The semi-dry filter aids from the plant will be trucked to a land-fill type disposal site under a yet-to-be-obtained permit from the state of Wyoming.

Two alternate sites have been selected. Both have the following in common:

1. Adequate but not excessive drainage to prevent surface water accumulation.
2. Sufficient clay in the soil to prevent leakage from the burial pits.
3. Outside the limits of any possible future Big Muddy expansion.
4. Good access without crossing main roads.
5. Reasonably well hidden from the nearby interstate highway.
6. A representative of the State Department of Environmental Quality visited both sites on April 27 and has given his general approval to either.

One site is closer to the plant but on State land where a third party holds the surface lease. The more distant site is fee land on which Conoco is a co-owner.

*The Sundance water well produced at a well head temperature of about 110° F during the pilot. The higher withdrawal rates for the demonstration project could result in 140° to 160° well head temperatures.

A formal application with the required Construction and Operating Plan will be submitted to the State in May. This will include a representative chemical analysis of the used filter aid as it exists in the semi-dry state.

LIQUID WASTE DISPOSAL

Produced water from the flood and the back wash water from the chemical injection plant may average as much as 6,000 barrels per day. Most of this can be injected into the Dakota reservoir which is under water flood. Any excess can be injected in Crary No. 40, a disposal well in the Wall Creek sand located over 1.5 miles west of the demonstration site.

PROGRESS REPORT ON LABORATORY TESTS
INCEPTION THROUGH APRIL 1978

SURFACTANT

The goal in surfactant selection for the Demonstration Project is to obtain a cost effective surfactant system which has a sufficient supply base to support full-scale commercial development. Three sulfonate types were selected for testing on the basis of feedstock availability, price estimates and preliminary core displacement tests. These are:

- (1) a synthetic sulfonate blended with a high molecular weight petroleum sulfonate
- (2) The same synthetic sulfonate except blended with a higher molecular weight synthetic sulfonate
- 3) a petroleum sulfonate manufactured from a single feedstream selected to give the appropriate molecular weight without additional blending.

The remainder of the surfactant system for any of the above will be alcohol (either isopropyl or isobutyl) plus salt water.

Mixtures of the sulfonate-alcohol blends were observed for phase stability over a range of:

- (1) sulfonate equivalent weights
- (2) types of alcohol cosurfactant
- (3) surfactant concentration
- (4) ratio of cosurfactant to surfactant
- (5) brine concentration.

As a first step, surfactant solutions which were a stable single phase were tested in core runs with large slugs. The step was intended as a rather coarse screening. Surfactant solutions which reduced the residual oil saturation to less than 10% and which exhibited adsorption less than 1 micro-equivalent per gram were further tested in Step 2 using smaller slugs but over a more narrow range centered around an apparent optimum in performance. In the third step, solutions showing the best performance in Step 2 were tested using small slugs which were equivalent in sulfonate usage to a slug of 10% pore volume containing 5 concentration percent surfactant. In Step 4 solutions which looked best in the small slug runs were selected for even more intensive work at attempted optimization over narrow ranges and with full viscosity control. The fourth step evaluation has been completed for two of the synthetic sulfonates and Step 3 is complete for the petroleum sulfonate.

The displacement tests through Steps 3 and 4 have been in Berea cores. All of the systems tested have indicated the ability to displace oil to a residual saturation less than 5% and have exhibited adsorption values in the range of 0.3 to 0.6 micro-equivalents per gram of rock. It appears that the active sulfonate concentration will be between 2 and 5% with a ratio of alcohol to active of between 1.0

and 1.5 to 1. In addition, all of the solutions tested have worked best in brine solutions between the 0.4 (salinity of the supply water) to about 1 percent.

MATERIAL IN PETROLEUM SULFONATE PLUGS FILTER

The petroleum sulfonate has demonstrated a plugging tendency with wax-like material. This finding has led to a research project aimed at wax removal. Attempts were made to filter the wax-like material with precoat filter, but the filter plugs quickly and the filtrate quality is poor. Filter tests were made on a petroleum sulfonate which was both untreated and deoiled by isopropyl extraction. Neither the extracted nor the untreated sample has been filtered successfully at temperatures below the reservoir temperature.

In an attempt to better understand the nature of the wax-like plugging material, the feed stream was dewaxed and deasphalted and sulfonated; however, filtration tests have not been completed yet.

POLYMER COST EFFECTIVENESS

Although Kelco Xanflood (polysaccharide) was used in the pilot flood, a study was undertaken to determine the most cost effective polymer for the demonstration project. Screening tests comparing Kelco's Xanflood polymer to the following polyacrylamides has been completed: Dow P-500, Visco 222-X, Amoco, Betz, Calgon and Cyanamid 930.

All of the candidates were hydrated in synthetic Sundance brine with a pH adjusted by caustic addition to 12. In each case the manufacturer's recommendation for best hydrating and mixing was followed. The polymer solutions were all adjusted to 8.5 centipoise at 12 rpm on a Brookfield viscometer. The polymer solutions were evaluated by flowing with 1 and 10 psi pressure drop through a 0.8 millipore filter, a 4-6 micron glass frit, 1 1/2" in diameter and approximately 1/2" thick, and a 1/2" by 1 1/2" disc of fired Berea core. Three processing conditions for each polymer were tested as follows:

- (1) unsheared and unfiltered
- (2) unsheared but filtered through a precoat filter using Perlite (Dicalite 436)
- (3) sheared at 500 psi pressure drop through a spray nozzle and filtered.

Dow P-500 and Kelco Xanflood polymer showed the best flow performance in the screening tests and were further studied in a two foot long Berea core. Two cores were saturated with an 8.5 centipoise glycerine water solution and each was displaced with a different polymer. Tracers were used in the glycerine and polymer solutions to observe the elution profiles. Flow rates in both were 1 ft/D and maintained with a constant rate pump. Pressure drop during the flow test was monitored at points along the core inside a differential pressure transducer.

Results indicated about equal pressure drop with the Dow or Kelco polymer and almost identical glycerine elution profiles. The mobility of the two polymers was equal but about one third more Dow P-500 was needed to obtain the same displacement characteristics as observed with Xanflood. Following the polymer,

8.5 centipoise glycerine solution was used to displace the polymer. The glycerine solution in the core in which polyacrylamide had been used had a resistance of almost 70% greater than resistance of glycerine solution in the core where polysaccharide had been used.

Figure 3

Well Number
Surface Location — Subsurface Location of Top of Wall Creek Formation (From Directional Survey)

- DRILL FOR PRODUCTION (11)
- FOR PRODUCTION (5)
- △ FOR INJECTION (9)

- Producing Well - Leased
- Producing Well - Owned
- Producing Well - Wall Creek
- ✕ Shut-In Well
- ✕ Abandoned Well
- ✕ Dry Hole
- ✕ Water Injection Well
- ✕ Surfactant Injection Well

REVISIONS	
By	Date

CONTINENTAL OIL COMPANY
PRODUCTION DEPARTMENT
Casper, Wyoming

BIG MUDDY

Wall Creek Pressure Before Injection

Contour Interval - 20 psi

County: Converse

State: Wyoming

Engineer: J.G. Davis

Draftsman: B.S.

Date: 1-31-7

= Pressuring Wells

LEGEND

Well Number 56
 Surface Location Subsurface Location of Top of Wall Creek Formation (From Directional Survey)

- DRILL FOR PRODUCTION (11)
- FOR PRODUCTION (5)
- △ FOR INJECTION (9)

- Producing Well - Lakota
- Producing Well - Dakota
- Producing Well - Wall Creek
- ✕ Shut-In Well
- ✕ Abandoned Well
- ✕ Dry Hole
- ✕ Water Injection Well
- ✕ Surfactant Injection Well

REVISIONS	
By	Date

CONTINENTAL OIL COMPANY
 PRODUCTION DEPARTMENT
 Casper, Wyoming

BIG MUDDY

Wall Creek Pressure 4/26-27

County: Converse State: Wyoming

Engineer: J G Davis

Draftsman: B.S

Date: 1-31-7

REVISIONS		By		Date	

CONTINENTAL OIL COMPANY
 PRODUCTION DEPARTMENT
 Casper, Wyoming

BIG MUDDY

FLOOD SUB-SYSTEMS

County: Converse State: Wyoming

Engineer: J.G. Davis

Draftsman: B.S. Scale: None

Date: 5-3-78

FIG 6

DRILLING MEMORANDUM
R. B. WHITESIDE NO. _____
BIG MUDDY SURFACTANT
(Typical Well)

Location: _____ Section 9, T33N, R76W,
Converse County, Wyoming

Interest: Continental Oil Company - 100%

Elevation: 5060' GLM (approximate)

Objective: Second Wall Creek

Estimated Formation Tops:

<u>Formation</u>	<u>Depth (RBM)</u>	<u>Datum</u>
Shannon	910'	+4160'
Niobrara	2370'	+2700'
1st Wall Creek	3025'	+2045'
2nd Wall Creek (1st Bench)	3075'	+1995'
2nd Wall Creek (2nd Bench)	3095'	+1975'
Total Depth	3190'	+1880'

Note: T.D. to be approximately 20' below base of 2nd Wall Creek but in no event closer than 10' to the top of the 3rd Wall Creek.

Hole Diameter and Capacity:

<u>Diameter</u>	<u>Interval</u>	<u>Capacity (Bbls./100')</u>
12 1/4"	0' - 250'	14.58
7 7/8"	250' - 3190'	6.02

Drilling Fluid:

O-T.D. Water and bentonite low solids gel. Light weight mud is essential in the Wall Creek. Add flake type lost circulation material at about 2500 feet.

No ligno-sulfonates, phosphates or oils to be used under any circumstance. pH should not exceed 10.

The Casper office must approve the final mud make-up.

Surface Location: Surface location should be picked so that the normal drift at Big Muddy will bottom the hole in a 100' circle about the regular pattern location.

CC: Well File AMY LRT JRG JMG CKB(2) OEA(4) LAH(2) Uranium HJK HWP AFE File.

Drilling Memorandum

R. B. Whiteside No. ____

Page Two

Hole Deviation and Surveys:

Deviation is not to exceed the equivalent of 3° at total depth. Rate of change should not exceed 1.5°/100'. Run a Monel collar from 250' to at least the top of the Wall Creek. Take magnetic directional surveys every 500' to the top of the Wall Creek.

Coring: (Injection wells only)

Take 4" core from the top of the 1st Bench of the 2nd Wall Creek to T.D. (115'). Cores will be transported immediately to the laboratory for analysis. PRD will provide direction on core handling and analysis.

Use full hole (7 7/8") core head with 3-point stabilization on core barrel. Condition mud prior to coring to

Plastic visc = 5-10

Yield point = 10-15

Drilling Problems:

The breakdown pressure for the Wall Creek is less than hydrostatic and lost circulation may be encountered both while drilling (or coring) and while cementing. Also, fractures in the Wall Creek may jam the core barrel.

Special Precautions:

1. Lost circulation

- a. The reservoir pressure will be increased to at least 1400 psi (hydrostatic) in the area of the well prior to drilling.
- b. Mud weight will be kept as low as possible with the type mud specified.
- c. Movement of drill pipe, core barrel and casing will be restricted after the Wall Creek is penetrated. Normally, this should apply only to the trip in and out on the second core run and to running in the 5 1/2" casing.
- d. Self fill-up equipment will be used during cementing.
- e. Flake type lost circulation material will be used in mud and in primary cement.
- f. Maintain equivalent circulating density as low as possible in the Wall Creek.

Special Precautions: (Continued)

2. Wall Creek sand contamination.
 - a. Drilling mud composition will be closely controlled.
 - b. Steel mud tanks will be used and these will be steam cleaned.
 - c. A biocide, as recommended by PRD, will be added to the drilling mud prior to penetrating the Wall Creek and to the cement pre-flush for the Wall Creek.

Drill Stem Tests: None.

Geological Assistance:

Assistance will be helpful to pick coring point, to describe core and to pick T.D.

Logging:

<u>Log</u>	<u>Interval</u>
FDC-GR-CAL	TD to Surface
Dual Laterolog	TD to 250'
Micro Latero Log	TD to 250'
SP (selected wells)	TD to 250'

Special Tools and Services: (All 250' to TD)

One foot drilling time recorder
Mud level recorder
Mud cleaner
Monel collar
Mild stabilization (3 Points)

Drilling Samples:

Catch and bag samples every 30' from surface to 2000' and every 10' from 2000' to TD. Tag with field name, well number and sample interval.

Fuel and Water:

Fuel will be furnished by contractor and water by company (Sundance water supply Well R.B.W No. 60).

Drilling Memorandum

R. B. Whiteside No. _____

Page Four

Casing and Capacity:

Surface: 8 5/8", 24 lb., K-55, ST&C set at 250'. (6.36 bbls./100')

Production: 5 1/2", 15.5 lb., K-55, ST&C set at 3190'. (2.38 bbls./100')

Sand blast 5 1/2" to cover intervals

TD to 3050' (2nd Wall Creek)
2440' to 2340' (Niobrara)
1070' to 870' (Shannon)
Also across Crary if present.

Cement and Cementing Equipment:

Surface: Cement to surface with 160 sacks Class "G" with 2% CaCl_2 (100% excess).
0-250'

Displacement volume = 15.8 bbls.
Water for cement = 12 bbls.
Pumping time @ 60°F = 2 hrs.
24 hr. compressive strength = 2000 psi min.

8 5/8" guide shoe with baffle plate
Top plug only
1 - centralizer on shoe joint
1 - centralizer up 60'

Primary: Cement out shoe with double plugs and with 60 sacks Class "G" 2875'-TD with mica flake and friction loss reducer (125% of gauge hole). Adjust volume to conform to Caliper log but use not less than 60 sacks.

Run 1,000 gallons mud flush followed by 10 barrels fresh water ahead of cement. Do not attempt turbulent flow.

Displacement volume = 76 bbls.
Water for cement = 7 bbls.
Pumping time @ 115°F = 4 hrs.
24 hr. compressive strength = 2000 psi
Slurry weight = 15.8 lbs./gal.

1 - 5 1/2" poppet type float collar with self-fill attachment and a guide shoe with a steel stop ring.
2 - cementing plugs
1 - centralizer on shoe joint
4 - centralizers at 60' intervals picked from Caliper log.

Cement and Cementing Equipment: (Continued)

Stage: Drop bomb and open stage collar. Cement out stage collar at 900-2500' 2500' with 275 sacks Class "G" with 2% gel, 50% pozzolan and friction loss reducer. (25% excess.) Adjust volume as above.

Use 1,000 gallons mud flush and maintain turbulent flow after cement reaches stage collar (60 barrels pumped).

Displacement volume	= 60 bbls.
Water for cement	= 38 bbls.
Pumping time @ 90°F	= 4 hrs. min.
24 hr. compressive strength	= 1000 psi
Slurry weight	= 14.2 lbs./gal.

5 1/2" stage collar with bomb and top closing plug.

2 - centralizers across Niobrara
2 - centralizers across Crary (if present)
2 - centralizers across Shannon

Drilling Procedure:

1. Drill 12 1/4" hole to 250'
2. Run and cement 8 5/8" casing.
3. Begin nipples up at six hours. WOC 12-hour total.
4. Pressure test BOP to 1000 psi for 15 minutes.
5. Drill 7 7/8" hole to top of 1st bench of 2nd Wall Creek sand.
 - a. Condition mud and core to T.D. if well is for injection.
 - b. Add biocide and drill to T.D. if well is for production.
6. Condition mud and run logs. Calculate cement volumes and pick centralizer points. Stage collar at 2500'.
7. Run 5 1/2" casing to T.D. Conform to pipe movement restrictions.
8. Run mud flush and primary cement job over Wall Creek sands.
9. Drop bomb and open stage collar. Circulate annulus to give total of six hour initial set on primary cement.
10. Run mud flush and stage cement job over upper sands.

Drilling Memorandum
R. B. Whiteside No. ____
Page Six

Drilling Procedure: (Continued)

11. Set slips on casing.
12. Release rig and clean up location.

Prepared by: J. G. Davis
Senior Staff Engineer

Approved by: John R. Kemp
Division Engineer

[Signature]
Drilling Superintendent

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COMPLETION MEMORANDUM

R. B. WHITESIDE NO.
BIG MUDDY SURFACTANT
(Typical Well)

Location: _____, _____, Section 9, T33N, R76W,
Converse County, Wyoming

Elevations: _____ KBM
5060' GLM

Depths (GLM): 3180' TD
3150' Differential Fill Collar
2500' Stage Collar

Casing: Surface: 8 5/8", 24 lbs./ft., K-55,
ST&C set at 250'

Production: 5 1/2", 15.5 lbs./ft., K-55,
LT&C set at T.D.

Burst: 4810 psig
Collapse: 4040 psig
Capacity: 0.0238 bbl./ft.
Drift Diameter: 4.825"

Tubing: 2 7/8", 6.5 lbs./ft., J-55, EUE

Burst: 7260 psig
Collapse: 7680 psig
Capacity: .00579 bbl./ft.
Drift Diameter: 2.347"

Casing-Tubing Annulus: Capacity: .0158 bbl./ft.

Procedure:

1. Move in a completion unit, two steam cleaned 400-barrel tanks, a power swivel, and circulating equipment.
2. Pick up a 4 3/4" bit and casing scraper. Clean out to the steel plate in the casing shoe. Circulate hole clean.
3. Run a CBL-VDL-GR with Casing Collar log from T.D. to 2600'. If the bond is not satisfactory, contact the Casper office for a squeeze procedure.
4. Swab hole dry and dump in 3% KCl water to 2600'.
5. Perforate the Second Wall Creek with one shot in each 4 foot interval from 10' below the top of the 2nd bench to 46' below. Total of 10 shots.

CC: Well File AMY LRT JMG CKB(2) LAH(2) Uranium HJK HWP EA AFE File

Procedure: (Continued)

6. Set the tubing open ended 50' above the top perforation.

7. Rig up service company and stimulate as follows:

All frac fluid will consist of clean 3% KCl water containing 30 pounds of HEC gelling agent per 1,000 gallons of water, but no fluid loss control additives. All sand is 20-40 mesh. Radioactive tagged sand will be run in all wells.

A.) Pressure test tubing and surface piping to 3500 psi. Set maximum treating pressure to 3000 psi.

B.) Break down the formation as follows:

1. Pump 2,500 gallons of frac fluid at 15 BPM.

2. If pressure at 15 BPM does not exceed 2250 psi, at least 6 perforations are open. Continue with stimulation.

3. If pressure exceeds 2250 psi, isolate blank pipe with a packer and bridge plug. Reperforate as required.

C.) Pump 2,000 gallons (48 barrels) of frac fluid containing 1/2 pound of sand per gallon at 15 BPM.

D.) Pump 3,000 gallons (7 barrels) of frac fluid containing 1 pound of sand per gallon. Start 1 lb./gal. sand at 15 BPM and gradually reduce the rate to 10 BPM.

E.) Pump 5,500 gallons (131 barrels) of frac fluid containing 1 1/2 pound of sand per gallon at 10 BPM.

F.) Displace the sand to the bottom of the tubing at 10 BPM. Displacement volume is ____ barrels.

G.) Allow the pressure to bleed into the formation.

8. Pull the tubing and clean out with a sand pump to T.D.

9. Run Gamma-Ray log in selected wells.

10. On production wells:

A.) Run tubing, rods, and pump for productivity test and to clean fracture of residual gels.

B.) Hook up to test tank or to battery as necessary for pumping. Anticipated rate is about 350 BPD total fluid.

Completion Memorandum
R. B. Whiteside No. ____
Page Three

Procedure: (Continued)

11. On injection wells:

- A.) Run plastic tubing and packer.
- B.) Swab well for gel cleanup and test as above.

Prepared by: J. G. Davis
Senior Staff Engineer

Approved by: John R. Kemp
Division Engineer

Tom Galovich
Production Superintendent

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