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SEALING AEC #1 WELL
LYONS, KANSAS
FINAL REPORT

October 1, 1973 - January 30, 1974

February 11, 1974

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DOWELL DIVISION OF THE DOW CHEMICAL COMPANY

Tulsa, Oklahoma
Research Report

DL 9018-6
February 11, 1974

SEALING AEC NO. 1 WELL AT LYONS, KANSAS

L. H. Eilers

Summary

AEC #1 well, Rice County, Kansas, has been sealed with expanding (Chem Comp) Portland cement and epoxy resin. This exploratory well drilled through the Hutchinson salt was to be abandoned when it was decided not to place a pilot radioactive waste depository near Lyons, Kansas. It was therefore selected as a logical borehole to demonstrate permanent sealing techniques reported in Sub-contract Report No. 78X-15966C.

This borehole was cleaned and then sealed in six stages. Three stages were salt saturated Chem Comp (expanding) cement, one stage below the salt, one stage through the salt, and one stage above the salt. Small epoxy plugs were placed at the top and bottom intervals of the salt zone. The surface section was sealed with fresh water neat Chem Comp cement after removal of surface casing. All operations proceeded satisfactorily except the washover removal of surface casing. This proceeded slowly with ultimate sticking of washover pipe with about 30 feet of casing remaining to be released. This final section of casing was removed by milling. This portion cost about double the estimated amount.

This report includes observations and discussions of each operation. Following these are comments on the overall sealing and recommendations for future boreholes including possible elimination of the epoxy resin plug. Finally, there are tables, photographs, and daily logs on which this report is based.

Introduction

AEC hole #1 is located NE NE NE NW Sec. 26, T19S, R8W, Rice County, Kansas. The hole was completed in October 1970 to a total depth of 1300.8 feet. This area was originally considered as a site for possible depository for radioactive wastes in the competent salt section. This hole was drilled (cored) to investigate the formations above and below the salt as well as the salt section. The upper 71 feet is of the Quaternary and Cretaceous periods and consists of clay and soft shale. The remaining portion from 71 feet to 1300 feet is Permian formation. From 71 to 315 feet it consists chiefly of siltstone and shale. There are possible aquifers in a sandstone from 106 to 127 feet and another in the Dolomite section of the Stone Coral 296 to 315 feet. From 315 to 815 feet the composition is chiefly shale. The salt section extends from 815 to 1084 feet. The section from 1084 to 1300 feet is chiefly shale and anhydrite with some dolomite in the lower portion. The surface casing was set to 309.5 feet (apparently 306 feet from ground level) with 8 5/8 inch casing which was cemented to surface. The remainder was completed open hole.

Many other boreholes have been drilled through the salt section in the vicinity of Lyons, Kansas, in search of petroleum bearing formations. These have not been carefully sealed. For this and other reasons, a decision was made not to place a pilot radioactive waste depository at Lyons, Kansas. AEC #1 well was then selected as a logical borehole to demonstrate the permanent sealing techniques suggested in Subcontract Report No. 78X-15966C.

The recommendations made in final report on Subcontract 78X-19566C were that the following steps be taken where long term seals were desired:

1. Characterize the well by checking all available records and running any new logs or surveys required.
2. Prepare the well for sealing by grouting any porous zones, remove the casing if present through the salt zone, and clean the formation face.
3. Seal the well using Portland cement as the primary sealing material and set a short epoxy plug at the top and bottom of the salt zone.
4. Place a detecting device in the well and monitor for leaks if such is required.

Cleaning the Wellbore

Discussions were started in July and August on sealing AEC #1 borehole at Lyons, Kansas. During this time, a drilling rig was selected and a study made of the drilling record and numerous logs available on this well. These indicated that the formation would be chiefly shale except for the salt section. Since the predominant formation material is shale, it was feared that some might have sloughed into the hole in the three years the well had been standing full of salt water.

The actual work toward plugging the well was started November 14, 1973. A Sterling Drilling Company rig was moved on location. The well was cleaned to bottom by running a 6 5/8 inch bit on drill pipe to the bottom. There were 92 feet of sludge and solids at the bottom of the well. The fluids and solids were circulated to surface with saturated salt water. Samples were taken and analyzed for starch and clay content. Results of these tests are given in Table I. No starch and only a trace of clay (less than 0.2 pound per barrel of water or 0.06%) was found in the water. In this report, a barrel is 42 gallon oil field barrel. Sample 4 of the washed out bottom sludge was found to contain both a trace of starch and considerable clay (or shale) materials. X-Ray analysis confirmed that the material was high in clay minerals. The shale was dark in color indicating it had originated in the lower section of the well. The shale above the salt bed was mostly red in color.

A caliper log was then run by the Wellex Division of Halliburton Services and compared with earlier logs. A summary covering 50 foot averages is given in Table II.

It will be noted that the caliper logs compare quite well above the salt zone. Through the salt zone and slightly below, from about 860 feet to 1140 feet by visual comparison of the logs, the wellbore has enlarged by dissolving the salt and allowing the shale bands and specks inter-spaced in the salt to deposit on the bottom. The section between 1084 and 1140 apparently enlarged by sloughing solids to the bottom of the well. If all these solids including the salt had sloughed to the bottom of the well, this would account for the 92 feet of non-compacted solids in the bottom. However, the salt apparently dissolved so a small amount of solids must have settled from above the salt section.

It had previously been decided to seal the lower portion of the well before removing the surface casing. Following the caliper survey of the well, the walls of the wellbore were cleaned by acidizing. One thousand gallons of salt saturated 15% hydrochloric acid followed by 1000 gallons of salt saturated 13% hydrochloric-3% hydrofluoric acid (Mud Acid) were pumped slowly into the well at 1.2 BPM (50 gpm) in order to give each acid about 20 minutes contact time. Hydrochloric acid was pumped first to remove any easily soluble materials. The more costly Mud Acid was then allowed to react on any clayey materials. Excessive soaking time was not desired as the acid might loosen shale along the sides of the borehole. A sample of the discharge about halfway through the acid returns was checked and determined to be 8% acid. This indicated some reaction and/or dilution of the acid with salt water. There was some dilution with salt water since 100 barrels (one hole volume) extra salt water was required to clear the acid from the wellbore. No starch and only a trace of clays (or shale solids) was found in the acid returns.

Sealing the Wellbore

The lower portion of the wellbore was sealed in steps. The first step was to seal the wellbore up to the salt zone with expanding Portland cement (Chem Comp). The Wellex caliper survey was used to estimate the volume fill-up from 1300 feet to 1070 feet which was 14 feet into the salt zone. The estimate was 15 barrels (630 gallons) of cement. A 2.5 barrel excess was used. Because of the small amount to be placed, a paddle mixer was used to prepare the cement slurry. This gave a more uniform mixture than would be obtained with a continuous mixer. The correct amount of salt water (11 barrels) was added to the blender, then 0.1% of citric acid (to reduce gelation) was added and Chem Comp cement was blown in to produce a slurry of desired consistency. This slurry was then pumped at a rate of 2.5 to 3 BPM down the drill string which was positioned three feet off bottom. The cement slurry was followed by six barrels salt water which were pumped behind it to balance cement inside and outside the drill string. Samples of the Chem Comp cement broke pint and quart glass jars. This is shown in Photographs 9 and 10.

There are two flow regions in which cement is normally pumped. One is slow laminar flow in which the cement moves upward in straight lines displacing all the lighter materials ahead of it. The other is turbulent (agitated) flow in which the cement is in rapid swirling motion. The lead cement removes thickened materials (muds) from the formation wall by actually mixing with them. About 10 minutes turbulent flow past an area is required to get good cleaning of the

formation walls. The thinner cements are easier to pump and enter turbulent flow at a lower pump rate. Calculations for turbulent and laminar flow of Chem Comp cements are shown in Table III.

The slurry was pumped at laminar flow (Sloflo®) speeds of less than five barrels (210 gallons) per minute since greater than eight barrels per minute would have been required to place the slurry in turbulent flow. The slurry would have been in contact with the bottom section for only two minutes and in contact with the top for only seconds. The salt water in the wellbore was in turbulent flow, however. We were displacing low density salt water (10 pounds per gallon) with cement (15.7 pounds per gallon) instead of a mud which might have a density very near that of the cement. By the very nature of turbulent flow, 20 feet or more of the lead cement would have mixed with salt water if the cement had been in turbulent flow.

A 17% excess cement was used in this first stage since we wanted to be sure we would have good cement for coring a specimen. The bottom of the drill pipe was raised to about 1070 feet and the two barrels excess cement was removed by reverse circulation. That is, salt water was forced down the annulus between the drill pipe and casing or wellbore and out the opening in the drill string. There are several reasons for this. The volume of the annulus was about 85 barrels and that of the drill pipe six barrels, so a ten barrel reverse circulation was sufficient to remove all the cement from the drill pipe. Also reverse circulation produced a flat upper surface on the remaining cement with undisturbed slurry beneath, while pumping down the drill string would have jetted salt water several feet into this slurry producing a weak contaminated interface. Finally pumping the excess cement up the annulus would have allowed diluted and possibly contaminated cement slurry to contact the formation which would partly offset the cleaning (acidizing) step. Set cement particles loosened by drilling would not adhere to the formation walls.

This cement stage was allowed to set for two days and was then cored from 1068 to 1078 feet. These cores varied from six inches to 12 inches long. They were labeled and wrapped in a vinyl plastic and preserved for further testing. The core barrel was laid down and a 7 7/8 bit attached to the drill pipe and a 7 7/8 hole drilled from 1068 to 1085 feet to remove residual cement from the wellbore.

The wrapped cores were stored at the well site for about two weeks and then at Tulsa for over a month. The results of strength and permeability tests on core sections are given in Table IV. These strengths of 6000 to 7000 psi and permeabilities of 0.001 to 0.007 millidarcies are quite acceptable, I believe, in view of the fact that these cores (though wrapped) were subject to mild drying conditions and repeated freeze-thaw cycles. One core taken at 1068 feet and cut for permeability, fractured during drilling. No flaw was noted in the original core although one might have existed.

The well was swabbed dry or nearly so after the cement coring operations was completed. This was accomplished by placing a valve on the bottom of the tubing (drill pipe). A weighted steel rod containing rubber swab cups on the

end of a wire line was raised and lowered inside the tubing to raise the salt water to the surface. This is shown in Illustration 1 and Photographs 7 and 8. The action is similar to the deep well lift pumps. All but about 10 feet of salt water was removed by this method. We did not attempt to remove the residual with a bailer since we felt four or five feet of fluid plus some drainage would remain anyhow. About 70 runs of the swab were required to remove the 80 to 85 barrels water in the wellbore. About a handful of black solids was returned with each pull of the swab. This analyzed to be magnetite with a trace of anhydrite and salt. The magnetite probably was scale from the drill pipe. There was concern that the shale formations might slough when the fluid was removed from the wellbore but this did not occur.

An epoxy resin seal was placed on top of the Portland cement after the water had been bailed from the hole. Seventy-five gallons of epoxy liquid resin was mixed in two 37.5 gallon batches and placed on bottom using a glass bottom dump bailer. A diagram of the bailer is given as Illustration 2. The epoxy resin was mixed in a 55 gallon open top drum with an electric mixer. Since the catalyst was thinner, it was added first, then the thicker resin and finely powdered silica (sand) as a weighting agent was added to make certain that the mix would be more dense than any salt water in the hole and would displace it. The resin was poured into the bailer (positioned in the casing) and the bailer was run to bottom on a wire line. The glass bottom was broken upon tagging bottom and the resin flowed into the wellbore. The glass bottom bailer seems to be the most dependable dump bailer. Samples of the resin taken to the hotel room set to a hard competent mass in the expected 7-8 hours. Samples left at the well site near freezing temperatures set within 24 to 30 hours. The placement of the epoxy resin was more difficult because of the small volumes handled. A larger volume could have been handled with a mechanical blender and pump and displaced down tubing. The placement losses would have been exceptionally high, however, with the small volume used. It was desired to use only a very small plug to act as an exceptionally strong seal and shock absorber. It may be possible to eliminate this step in future work. This is discussed at the end of this report as elimination of epoxy plugs.

A second stage of cement was placed through the salt zone and capped by a second epoxy plug in approximately the same manner and the same amounts as the first stage. However, this section of cement was not cored. A small amount of salt water preceded and followed the second cement stage to flush the tubing before it was pulled. This was not removed from the wellbore so the second epoxy plug was placed under 100 to 150 feet of salt water. This confirmed that the epoxy plug could be placed under salt water although it was more convenient to place the plug with a bailer when very little water was in the wellbore. About 20 hours after the epoxy plug was placed, the well was scheduled to be filled with salt water. This was delayed to 40 hours because of a shortage of salt water. No sloughing of shale was noted at any time while the salt water was removed from the wellbore.

The section of wellbore above the salt (808 feet) and below the casing (310 feet) was cemented with salt saturated Chem Comp mixed with a conventional cementer. This was a longer section of wellbore with a larger diameter which required more cement slurry. The volume calculated to be 48.5 barrels with

10% extra and one barrel extra for contamination. Fifty-four barrels were used. The cement was continuously mixed by blowing cement into a stream of salt water in a jet type mixer. This was at 3 to 3.5 barrels per minute in laminar flow rather than turbulent flow since we still did not have sufficient time and volume to pump at greater than nine barrels per minute for ten minutes. The larger wellbore above the salt would have required an extra barrel per minute flow to place it in turbulence. Following the cementing, the drill pipe was raised to 316 feet and the excess cement removed by circulating fresh water down the drill pipe and up the annulus. Reverse circulation was not used because the annular volume was now only about 25 barrels and also we desired to replace all the salt water with fresh water. There was no worry about contamination of the formation above the cement area since this was behind casing which was to be removed. A 7 7/8 bit was run to 315 feet to make sure all sections were clear.

This completed the plugging up to the possible fresh water zones behind the casing. This portion of the project was ahead of schedule with no major problems encountered.

Grouting Fresh Water Zones

The remaining portion of the contract was to grout the fresh water zones, remove the casing and cement to the surface. This was started by perforating two intervals using Wellex Super Dynajet at two shots per foot between 295 to 310 and 106 to 126 feet. The water level dropped four to six inches per hour (1 to 1.5 gallon per hour). A packer was to be set just above the lower perforations and below the collar at 266 feet. However, the packer would not go below about 110 feet. The bottom of the packer element was believed to be catching on burrs from perforations at 106 feet. There was no ream tool for 8 5/8 pipe closer than Enid, Oklahoma. A milling tool of 7 7/8 inches O.D. was available at Great Bend, Kansas. The packer was 7 3/4 inches O.D., the milling tool was used to clear burrs from the pipe at 106 to 126 feet in about one hour. The tool then lowered rapidly to a collar at 133 feet but was apparently milling on steel at the collar. The milling tool was an oval ridged chunk of steel with tungsten carbide studs in the ridges and an opening through the center for circulation, somewhat like a large hollow centered pineapple. (This is shown in Photograph 11.) This was screwed onto the bottom of the drill collars (very thick walled drill pipe) for added weight. It was assumed the mill would not go below the collar at 133 feet because the mill and drill collars were rigid and the casing might have a slight bend at this point. It was felt we might mill through the wall of the casing if we continued. Also the packer being 1/8 inch smaller and more flexible might make the bend. The mill was removed and an attempt made to lower the packer. It refused to go below 134 feet, the same point that milling stopped. It was therefore set at 130 feet. When the casing was later removed, there was no apparent bend or out of round portion of the pipe although there was slight milling into the pipe at the 133 foot collar. The inside of the pipe was too dark to obtain this on film.

The reason for setting the packer in the casing was to isolate the upper perforations at 106 to 126 feet from the lower perforations below 295 feet. The lower perforations were to be grouted with Zonelock 150 (silicate) grout followed by a Portland cement squeeze. The mixing of the first Zonelock was begun

before it was found that we could not originally get the packer beyond the perforations at 106 feet. Since this mix would gel in four to five hours, the 1500 gallons in the paddle tanks were dumped and the tanks cleaned. It was desired to complete the grouting the following day so each section received half the remaining Zonelock (750 gallons) because additional silicate was not available at Lyons, Kansas, on such short notice.

The second attempt to grout the possible water zones was successful. The packer was set at 130 feet and water pumped slowly into the zone at 295 to 315 feet to make certain it was open. The Zonelock 150 was then mixed and pumped at 1.5-2 barrels or 75 gallons per minute. A pressure of 350 to 400 psi was required to displace this. This would be fracture pressure or slightly over one psi per foot depth. This was followed by two barrels fresh water to clear the tubing followed by 50 sacks (12 barrels) Class A cement slurry made with fresh water. This was pumped at 2 to 2.5 barrels per minute. This was followed by sufficient fresh water to displace the cement to about 270 feet. About 25 feet of cement (1.5 barrels) remained in the casing for safety. We did not wish to channel fresh water through the perforations at 295 feet. The pressure reached 400 to 450 psi at this stage indicating some resistance to pushing the cement through the perforations and into the fracture. The pressure dropped to zero in 30 minutes and there was no flow back. The packer was then removed.

The top zone could have been treated down the annulus on top of the packer but this would have allowed for a possibility of sticking the packer in the casing with cement above it. The packer was removed instead and coarse sand was added to the casing to bridge off above the cement already in the casing at 270 feet. Fifty-five gallons (about 25 feet) were added. Once sand has settled in a casing it will bridge and it cannot be moved at normal pressures. One hour was allowed for the sand to settle.

An injection test was taken on the formation after one hour. The pressure increased to 200 psi then rapidly broke back to 100 indicating we had injected into the upper zone. Three hundred to 400 psi had been required for the lower zone. The Zonelock 150 was then mixed and 750 gallons pumped away (3 BPM) at 75 psi. This was followed by two barrels fresh water to clear the lines and 50 sacks (12 barrels) Class A cement slurry also pumped at 75 psi. The pressure rose to 100 psi as the cement was being displaced from the casing with fresh water. Approximately 10 minutes after the flush was completed, it was noted that fluid had broken through to the surface 30 to 35 feet from the casing point. This is shown in Photograph 12. It was theorized that this might have been a previous seismic shot hole area. The fluid appeared to be water, from the initial fluid injection, rather than Zonelock 150. It disappeared, soaked into the ground, within 20 to 30 minutes. It seems that 750 gallons of Zonelock was sufficient at least for the upper zone since more would have been lost to the surface.

The day after the grouting, the well was cleaned to bottom with a 7 7/8 bit. The following is the log of what was found:

<u>Depth</u>	<u>Found</u>	<u>Remarks</u>
0- 90 ft	Flush water	As expected
90-140 ft	Good cement	As expected
140-150 ft	Packed sand	Expected to find Zonelock or flush water
150-250 ft	Sand and weak cement	Expected 20 to 30 feet packed sand
250-315 ft	Good cement	As expected
315 ft	Hard aged cement	As expected

The light cement drilled at 315 was obviously Chem Comp, not the grey-green Class A cement found above.

Removal of Surface Casing

It was desired to use a large drilling rig to remove the casing. One would not be available locally for at least a month which would have placed the removal in mid-winter. It was felt that the cost would be excessive to move a rig in from more than 25 miles. The small rig on the well was therefore converted to handle large washover pipe with a power swivel to rotate the washover pipe. Regardless of the type drilling rig on the well the first 100 feet or so of washover would be made with a power swivel to rotate the large washover pipe. The washover pipe used was 30 foot sections of about 10 3/4 inch O.D. by 9 7/8 inch I.D. with internal square thread. This made a smooth joint between sections both inside and outside which could not readily be distinguished from the solid pipe. The washover shoe was approximately 11 1/2 inch outside and 9 7/8 inch inside. The bit is tipped with "Cutrite", a brass alloy containing chunks of tungsten carbide to cut the formation (Photographs 13 and 14) Surface pipe in the wellbore consisted of 8 5/8 casing and 9 5/8 inch O.D. collars leaving a 1/4 inch total clearance between the inside of the washover pipe and the outside of the collar or an average of one-eighth inch all around. On the outside of the washover pipe, the clearance was 3/4 inch overall or an average of 3/8 inch all around between the pipe and the formation wall. The casing had originally been forced into a slim hole 10 7/8 to 11 inches in diameter indicating that at some points it was wedged against the formation. The washover shoe (cutting bit) was therefore cutting at least 1/2 inch of new hole. This seemed to be a new experience for all involved. They did not know how well the formation would cut with the washover shoe.

We were required to choose a tool company to supply the washover equipment, the power swivel, and a man to operate the equipment. We choose a larger tool company, Rucker Acme, over a local company, Atlas, both of Great Bend, Kansas, because Acme had readily available 30 foot joints of washover pipe rather than the usual 40 foot joints and a larger power swivel to rotate the pipe. I felt the larger unit would produce more steady power and less strain on the small rig. The costs would be about 5% higher but this would be offset if we saved one day rig up time on the estimated eight day washover time.

The rigging up for washover was accomplished in one and one-half days in reasonable weather. Just as we started the washover operation, an ice and sleet

storm arrived and from this time on, we had rather poor weather conditions. This slowed drilling operations since it became more difficult to make pipe connections. It also required using some salt water in the drilling fluid to prevent freeze up. The equipment operated in a satisfactory manner except for two hose breakages on hydraulic lines which I believe were caused from occasional flexing under cold and icy conditions. Starting motors, removing ice and frost from controls, and beginning circulation generally required less than one-half hour but on two occasions required over one hour.

The washover operation was started using clear water drilling fluid. A pressure of 600 to 800 psi on the torque converter gave 60 RPM on the washover pipe the first afternoon and the drilling proceeded at about 10 feet per hour. However, when the pipe was raised to place a spider (steel ring with supporting arms) over the hole, about three feet of cavings entered the hole in 25 minutes. The circulating fluid was also tending to freeze so salt water and salt water gel (a clay) was added to stabilize the hole and prevent freezing. The spider was necessary to hold slips (toothed wedges) which gripped the washover pipe in the wellbore when additional pipe was added. The spider is shown in Photograph 18. The second and third days the washover rate was about 6.6 feet per hour. Data on washover rate is given in Table IV. The fourth day the washover operation reached the vicinity of 110 to 136 feet where the milling operation had been required to set the packer. The drilling rate dropped to 4.5 and then to 1.8 feet per hour. It is not known whether this indicated we were binding against the 8 5/8 inch casing or not. There was no evidence of greatly increased torque since 800 to 1000 psi on the torque converter still gave 60 to 65 RPM on the drill pipe. When we were well past this collar, the drilling rate increased to 3.6 feet per hour before we removed the upper section of casing. We were now at 177 feet which was the limit of the 180 feet of washover casing on hand. The washover pipe was then removed and laid down.

An inquiry was made as to whether the collars on the casing were welded in place or not. No one seemed to know for sure but did not think they were. We therefore attempted to unscrew the casing by placing a high torque on the casing and springing the collar at 166 feet with a primacord charge inside the pipe. This failed to release the pipe so a circular jet charge was lowered to 144 feet to shoot off the pipe (Photographs 19 and 20). This was successful and the upper section of casing was removed. The collars were found to be tack welded into place so they would not unscrew.

An alternate method of cutting the casing was available. This was a Rucker Acme inside casing cutter. This cutter could be lowered into the well and set onto the casing. Tungsten carbide knives then would spring out and cut a groove into the casing. According to the Acme tool man, six or more hours would be required to cut the casing. He therefore recommended it would be cheaper to shoot the pipe off. This tool might have been better to use had we been at a greater depth so we could have put weight on the cut off tool.

The lower section of casing removed from the well was expanded and split by the shot. It was later shown that the top of the remaining section was also belled out (Photographs 21 and 22). This was probably due to the shallow depth. About two feet of the top of the casing was milled when the washover pipe was returned to the hole. The washover pipe then slipped over the casing

(fish) into the original cut. A new washover shoe with a toothed rather than a flat bottom was used on the second part of the washover. It did not speed up the washover process. However, the washover also reached a tougher portion of the shale formation. Oil was added to the drilling fluid to lubricate and reduce friction downhole and sodium carbonate was added to give better solids carrying. It was felt the shale was probably balling up on the bit to reduce penetration. The penetration rate was slowly improving until the day the pipe stuck.

The washover pipe stuck at a depth of 272 to 273 feet. A pull of 45,000 to 50,000 pounds raised the wash pipe 1.5 to 2 feet but it would not raise further. At this pull, the blocks on which the rig was setting began to sink into the ground. A torque of 2000 psi on the power swivel failed to rotate the pipe. The information was conveyed to various people. The consensus of recommendations from the rig owner, Mr. Meade, the consultant, Mr. Walters, and the Dowell area manager, Mr. Law, was that our best hope for unsticking the washover pipe was to hook in pressure pipe, spot oil across the face of the shale, to lubricate it, followed by acid to weaken and partly dissolve any cement, limestone, or shale to be followed by more oil. If this did not show help, then to pump oily mud as rapidly as possible with all pumps.

A high volume pump was obtained from Dowell with 1000 gallons of acid. A load of crude oil was obtained from a local hauler. High pressure piping was attached to the drill pipe and while the Dowell pump was being hooked into the system drilling fluid was circulated with rig pumps as rapidly as possible (about five barrels per minute). The fluid movement between the casing and washover pipe was about 210 feet per minute and outside between the washover pipe and formation was about 310 feet per minute. No effect was noted on freeing the stuck pipe.

The Dowell pump was used to pump 8-9 barrels of oil followed by acid. We intended to spot five barrels of acid inside the washover pipe and the eight barrels of oil outside and let it soak. As the acid was being spotted the pipe suddenly came free and began to rise out of the hole. No sudden rise in pressure was noted. The pipe finally could be rotated and after some rotating time circulation was re-established. The pipe then moved freely up and down and no solids or other reason for sticking could be found.

However, when an attempt was made to start washover drilling again, the pipe again stuck but was released at 35,000 pounds pull. The washover drilling operation was then suspended and the pipe removed. Mr. Blevins, the Acme tool operator, said it seemed the washover shoe was cutting steel.

The remaining casing was shot off at 268 feet. This was two feet below the collar and as near the bottom of the washover section as we dared go. This section of casing was found to have a two foot wedge section milled off at the top. This is shown in Photograph 23. The bottom collar had been cross-threaded and screwed in about five threads. This is shown in Photograph 25.

There seems to be little doubt that we were cutting into the casing below the last collar after viewing the collar. The 8 5/8 inch casing has eight threads

per inch. A cross-thread of one thread would bend the pipe $1/8$ inch for each $8\ 5/8$ inches. This collar appeared to have a two thread offset or $1/4$ inch for each $8\ 5/8$ inches. With the welding and milling produced by the washover bit the exact offset was difficult to determine. If the washover pipe was against the collar on one side there would be one-fourth inch space on the other side. There was an additional $1/2$ inch offset between the collar and the casing. Thus when the casing bent $3/4$ inch the washover shoe would contact the casing and begin to mill into it. The offset in the pipe is shown in Photographs 27 and 28. If the offset at the collar was one thread, contact would occur in about four and one-half feet. If it was offset two threads, contact would occur in about two and one-half feet. All indications are that we milled into the casing sufficiently to cut through about six or seven feet below the collar and stuck the pipe by catching the washover shoe in the slot. It might have been possible to start a new cut and finish the washover after all the loose casing had been removed. In all probability the washover pipe would have followed the old grooves and continued cutting into the casing.

The last 40 feet of casing was removed by milling. An example of the milling tool used is shown in Photographs 29 and 30. Two mills were used, one to cut the portion of casing already loosened by the washover operation and another to mill from there to bottom. The casing milled out at about one foot per hour except for the very bottom collars and cement shoe which were slightly slower. The drill rig rather than the power swivel was used for milling. About 800 to 1000 pounds of steel shavings were deposited in the mud pit.

The borehole contained a salty oil emulsion mud at this point. Although it looked like almost pure crude oil, it analyzed to be only 27% oil by weight or about 33% by volume. This was flushed from the wellbore with fresh water containing a nonionic soap solution somewhat like a dishwashing soap concentrate. The wellbore was then cemented to surface with expanding cement slurry made with fresh water. The first four barrels of cement were used as scavenger cement to remove any residues in the wellbore and were flushed into the mud pit. When the drill pipe was removed the cement level was down about 21 feet. About five feet of this could be accounted for by removal of the drill pipe but the other 16 feet of fall back could not be accounted for unless some water was lost from the slurry into the formation.

The oily mud containing traces of iron was disposed of by hauling to a large dump pit. The surface around the well containing sand and salt water was bulldozed into the reserve pit. The box around the wellbore was removed. The ground was then leveled with some dirt being dumped into the upper 21 feet of wellbore. Unless the ground around the well was much more salt water contaminated than it appeared to be, the ground surface should be back to normal by summer.

Comments on Sealing AEC #1

A. Use of Small Rig for Washover

It has already been noted that all portions of the wellbore sealing proceeded quite well except for the casing removal. There is room for argument as to whether we should have used the small rig or waited for a large rig to move in. The following should be considered:

1. The first 100 to 150 feet of washover would have proceeded in much the same manner with either a small or large rig. A power swivel would have been used to rotate the washover pipe and no auxiliary weight could have been added. A large rig with larger pump might have removed solids slightly faster. The handling of large pipe by a big rig would have been easier. The use of shifts to get 24 hour drilling would have saved the time required for start up each morning when the engines were cold. This would have applied to small or large rigs. We would have used additional crews if they had been available. The energy crisis has resulted in a shortage of competent crews.
2. Below 150 feet, we undoubtedly could have drilled somewhat faster with a large rig and added weight on the washover pipe. A larger pump might also have aided by washing out some shale. Offsetting this is the possibility we might have drilled further into the casing at 270 feet or even have gone completely through the pipe and become stuck even more than we did.
3. A third consideration is the weather which became progressively worse as we proceeded into December. We could not have gotten a large rig in until after Christmas. It is doubtful if we would have finished by December 29, as we did by this method. On December 30, a severe storm hit the area with heavy snow and below zero temperatures for more than a week. This weather might have produced more delay than we experienced with the small rig. An account of estimated versus actual time for each step is given in Table VII. Following this is a log of the daily progress.

B. Uncertainties of Casing Removal

I feel that removal of casing through the critical salt zone is necessary for a complete seal. One can never be certain of the condition of the casing or the seal behind the casing. This well is a good example. Although good records were kept, we did not know whether the collars were welded or whether there was a centralizer on the bottom of the casing. We definitely did not expect to find the last collar to be cross-threaded.

C. Elimination of Epoxy Plug

A controversial part of this sealing is the epoxy plug. It is organic in nature and of uncertain durability. I now believe the epoxy seal can be eliminated with a different type seal at the top and bottom of the salt

zone. The replacement seal would be a shale or clay filled Portland cement which could be emplaced during or following a regular cement operation without requiring a separate stage.

The idea occurred when we considered that shale might slough as we removed the water from the wellbore for placement of the epoxy plug. I considered the result of the sloughing of a small amount of shale would be to place a layer of shale mixed with epoxy or Portland cement and solidified in place. This would produce a weak spot in the seal but should not be extremely detrimental. A fracture occurring in this section should be partly resealed by expansion of the shale if it contacted water. It is known that fractures in many shale sections will heal on contact with water.

Expanding (Chem Comp) slurries containing as much shale as cement were tested on the return to the lab. The results of these preliminary tests are given in Table V. Two shales were tested. One was a fissle (high clay) shale from Kansas known to be very water sensitive and causing much trouble in drilling. The other was a red bed shale from this AEC #1 well which was much less water sensitive.

The tests were conducted by mixing salt saturated Chem Comp slurries, adding the shales and pouring into molds which were cured under 100°F temperature and 3000 psi pressure. The sample containing fissle shale began to gel before pressure could be applied. The samples were cured for three days before pressure was released. The small one inch cores were then fractured lengthwise of the cylinder by placing them on a sharp knife blade and striking another sharp knife blade above with a hammer. The ends were then sanded off and the cores placed in a Ruska type permeameter. The procedure for the permeameter is given in the final report for Subcontract 78X-15966C dated October 31, 1973. Water was used as the pressuring fluid.

It was found that the fractured one inch cores had an immediate permeability of 1.5 to 1.7 Darcys (1500 millidarcys). The core containing fissle shale reduced in permeability much more rapidly than the one containing red bed shale on contact with water. Whether it would be possible to emplace the cement containing the fissle shale would depend on the equipment available.

I believe the placement of such a sealing plug might be done as follows: Mix a standard salt saturated cement slurry and place it across the entire section to be sealed with pipe on bottom. This could be Chem Comp, Type V, or whatever slurry was to be used, and could be placed in turbulent or plug flow depending on circumstances. The tubing would then be raised to a few feet below the salt section and a couple of barrels of slurry containing the maximum pumpable amount of graded shale emplaced. The tubing would be raised again to the top of the salt section and a second quantity of shale filled cement emplaced. The shale-cement would produce a weaker sealant at these points but should not seriously change the bond strength since non-filled cement was placed across the section first. The weaker shale filled cement should be the point of fracture if stresses occur such as settling of the formation. This fracture would then reduce in permeability by expansion of the shale if water encroachment occurred.

If the original cement sets too rapidly for emplacement by the technique described then the neat cement could be brought up to or slightly above the lower salt zone, the tubing raised to the salt zone and the shale filled cement emplaced, the tubing raised slightly again to above the shale filled cement and more neat cement pumped to above the top of the salt. The procedure for emplacement of the shale filled cement would then be repeated at the top of the salt with neat cement again above. Although this would require some staging and movement of pipe, it would not require any long periods of waiting on cement to set. The shale filled cement should not swap places with neat cement if both slurries have near the same composition and density.

The completion of data and field testing of such a system would require time much beyond the scope of this subcontract. I do feel that Dr. Tamura might want to investigate this further since he has a permeability apparatus. I cannot recommend a source for the water swellable shales since I have almost used up that on hand. The state highway engineers usually know where these water reactive shales outcrop to the surface since they cause problems in road building. I know that one occurs on Interstate 70, west of Grand Junction, Colorado, but others should occur in New Mexico.

D. Lack of Cement Around Surface Casing

There was almost no cement found around the casing when it was removed from the well. This was even true of the area below the collars where the washover shoe could not have contacted the pipe. This seemed to worry Mr. Walters as to the bonding between the casing and cement. I believe the original pipe probably had a considerable mill scale or varnish coating. This coupled with the vibration produced during coring operations probably jarred the pipe and loosened the cement to some degree. The shock produced by perforating the pipe at 110 and 300 feet also would probably loosen the cement.

What to me seems more remarkable was the fact that the last section of casing remained in place. The bend (dog leg) produced by cross-threading this collar undoubtedly resulted in considerable whipping of the core barrel and drill string against the casing at this point. If this portion of casing or the drill collar below had come loose during coring, it would undoubtedly have been attributed to a bad cement job.

During the washover operation, it was obvious that the casing was either not straight or not centered in the hole. On several occasions, the washover pipe leaned sideways in the hole as far as the rig would allow. Although the washover hole started at 11 5/8 inch size, the top was an oval of 14 by 21 inches at the end due to the rubbing of the washover pipe against one side. This hole is shown in Photographs 31 and 32.

E. Changes in Sealing Procedure

If a similar well were to be sealed, I would recommend only a few changes which have already been discussed in this section. I would cement through the salt zone as a single stage with emplacements of shale filled cement at the top and bottom of the salt zone. Additional shale filled cement above the salt zone might be considered if reduced strength and higher permeability would not be a detriment.

I would also suggest that the removal of any casing be on a bid for completed job or turnkey contract type operation with the method of removal being left to the contractor as long as proof of removal was furnished. This is the one part of sealing in which it is difficult to estimate costs.

I would also recommend that a ream or mill of the correct diameter for the casing be available in the area if any critical sized tools such as packers are to be introduced into the well. A tool company should be willing to have one available on a standby basis for a small fee if contacted in advance. This would be much less costly than standby rig time if a tool has to be brought in.

F. Visitors for the Project

We had few visitors for the project considering the publicity given by the AEC and articles appearing in the Wichita, Kansas, Eagle and Lyons Daily News newspapers. This probably was caused by the adverse weather. We would probably have had considerable more visitors in late spring or early fall months.

We did have several visits from Mr. G. J. Toman, Kansas State Plugging Inspector, and from Hank Nauor and Larry Schultz of American Salt at Lyons, Kansas. We also had Mr. Normal Biegler of Kansas State Board of Health present during one of the cementing stages. Mr. M. L. Klein of Halliburton Company, Wichita, Kansas, was present during the milling operation to set packer. Mr. W. Knowles and Mr. J. J. Schreiber of the AEC were present for a portion of the washover operation. Miss Martha Ketelle and Dr. T. Tamura of Union Carbide also visited location during portions of the sealing operation. Mr. Pete Stubbs or Mr. R. F. Walters of Walters Drilling Company, Wichita, Kansas, were observers on most of the operation.

G. Records and Photographs

The records of daily progress at the end of this report are a summation only of those taken during the time work was being done. A more complete record can be found in Dowell Record Book 1357. Likewise, a number of photographs were taken which are not included in this report. They will be attached to a supplement of Dowell Notebook 1357.

TABLE I

Composition of Fluids from AEC #1

These fluids were removed from the well during the initial cleanout and during the acid clean-up the next day. Procedures taken from API RP 10B given in Attachment I.

No.	Volume Circulated	Approx. Depth	% Solids	Type Sample	Pounds per Barrel		% Acid
					Starch	Clay	
1A	30	400	1	Water	0	0.1	0
1B				Composite	0	0.3	0
2A	60	800	1	Water	0	0.2	0
2B				Composite	0	0.3	0
3A	90	1200	2	Water	0	0.2	0
3B				Composite	0	0.5	0
4A	100	1250?	10	Water	Trace	2.0	0
4B				Composite	0.1	4.0	0
5	250	Clean bottom	T*	Composite	0	0.1	0
6	Input salt water		T*	Composite	0	0.1	0
Acidizing Samples							
7	100	Bottom	0	Acid	0	0.1	8
8	150	Bottom	1	Acid	0	0.2	0.5
9	200	Bottom	1	Brine	0	0.1	0.003
10	250	Bottom	0	Brine	0	0	0**

* Trace

** This last sample was pH 5.2.

TABLE II

Caliper Size of AEC #1 Borehole

Depth (ft)	Caliper Surveys by			Approximate Change (inches)
	Schlumberger 1970	Birdwell 1970	Welex 1973	
325	11.6	>10	11.7	+0.1
375	11.5	>10	11.3	-0.2
425	11.3	>10	11.3	0
475	11.2	>10	11.1	-0.1
525	10.2	>10	10.2	0
575	9.8	9.7	9.7	0
625	9.4	9.3	9.3	0
675	9.1	9.2	9.3	+0.1
725	8.4	8.4	8.7	+0.3
775	8.4	8.1	8.3	0
825	8.4	8.3	8.4	0
875	8.3	8.6	9.3	+0.8
925	8.5	8.7	9.1	+0.5
975	8.3	8.5	8.8	+0.4
1025	8.3	8.5	8.9	+0.5
1075	8.3	8.4	8.8	+0.4
1125	8.0	7.8	8.2	+0.3
1175	8.0	7.9	8.0	0
1225	7.8	7.8	7.8	0
1275	7.8	7.7	7.6	-0.1

TABLE III

Cement Flow Calculations

Cement A - Chem Comp Cement - 67% sodium chloride saturated brine by weight of cement (56% by volume)

Cement B - Chem Comp Cement - 67% sodium chloride saturated brine by weight of cement (56% by volume) and 0.1% citric acid viscosity reducer

Cement Mix	Fann Readings			
	600 RPM	300 RPM	200 RPM	100 RPM
A	88	60	49	37
B	49	29	22	13

	Viscosity Parameters			
	Bingham Plastic		Power Law	
	K	ty	K	n'
A	6.2717×10^{-4}	0.29983	3.0716×10^{-2}	0.48433
B	4.4035×10^{-4}	0.07458	3.0728×10^{-3}	0.73766

(For the 287 feet of fill through the salt section)

Cement A - Bingham Plastic Model:

Turbulent flow - 24.94 barrels per minute - 3600 psi maximum pressure - 2050 horsepower to pump - 0.2 minutes time

Sloflo - 5.2 barrels per minute maximum

Cement B - Bingham Plastic or Power Law Model:

Turbulent flow - 8.1 barrels per minute - 500 psi maximum pressure - 97 horsepower to pump - 2.7 minutes to pump

Sloflo - 5.2 barrels per minute maximum

Salt Water - Bingham Plastic or Power Law Model:

Turbulent flow - 0.3 barrels per minute (minimum)

(No further calculations on salt water since all pumping would be far in excess of 0.3 barrels per minutes.)

TABLE IV

Strengths and Permeabilities of Sealants

The following strengths and permeabilities were determined for the set samples of cement and epoxy resin obtained from AEC #1.

<u>Sample from</u>	<u>Time Aged (days)</u>	<u>Strength (psi)</u>	<u>Permeability (md)</u>
Cement - cored 1068 feet - Stage 1	48	6389	No test
Cement - cored 1069 feet	48	6430	0.007
Cement - cored 1072 feet	48	5984	0.005
Cement - cored 1074 feet	48	6748	0.001
Cement - cored 1076 feet	48	6175	0.003
Cement - cored 1078 feet	48	7257	0.006
Second core - 1078 feet (bottom)	48	--	0.003
Cement - Stage 1 - Surface set	42	4025	0.013
Epoxy - Stage 2 - Surface set	37	10700	0.000
Cement - Stage 3 - Surface set	35	6050	0.004
Epoxy - Stage 4 - Surface set	34	10450	0.000
Cement - Stage 5 - Surface set	32	7025	0.005
Cement - Stage 6 - Surface set	6	3775	0.006

TABLE V

Water Healing of Fracture in Shale Filled Cement

A slurry was prepared by mixing the ratio of 100 gms TXI Chem Comp cement, 67 grams (57 mls) saturated salt water and then blending in 100 gms graded* shale solids. Cured three days at 100°F and 3000 psi, fracture lengthwise and permeabilities determined using deionized water. Seven day cement properties: with fissile shale - 950 psi, 0.027 md perm; with red bed shale - 1700 psi, 0.004 md perm

<u>Time in Contact with Water</u>	<u>Cement with Fissile Shale</u>	<u>Cement with Red Bed Shale</u>
Initial	1510 md	1700 md
30 min	625	1600
1 hr	380	1500
4 hr	290	--
1 day	140	1320
2 days	38	1260
3 days	--	566
5 days	7.0	--
7 days	5.2	364
9 days	7.1	302
14 days	5.1	260

* Graded shale was 50% 8-20 mesh, 25% 20-60 mesh, 15% 60-200 mesh and 10% slate flour (-150 mesh)

TABLE VI

Washover Rates on Surface Casing

The actual rotating time is estimated for each day, omitting start up, mud mixing and pipe handling time.

<u>Day</u>	<u>Estimated Rotating Time (hrs)</u>	<u>Total Depth (ft)</u>	<u>Feet per Hour</u>
December 4	2.75	28	10
December 5	5.0	61	6.6
December 6	6.7	105	6.6
December 7	7.0	136	4.5
December 10	6.5	148	1.8
December 11	7.5	177	3.6
December 12	Removed casing		
December 13	4.0	184	1.7
December 14	7.0	198	2.0
December 15	6.5	215	2.6
December 17	7.0	237	3.1
December 18	6.0	265	4.7
December 19	4.0	273	2.0

Pipe stuck - shot off 268.5 ft

December 26	12 hrs milling	268-278 ft	1
December 27	20 hrs milling	299	1
December 28	11 hrs milling	307	0.7
	0.5	309+	No casing

TABLE VII

Sealing AEC #1 - Lyons, Kansas

The estimated versus actual time required for various steps in sealing well.

No.	Steps to be Taken	Time (days)	
		Estimated	Required
1-a	Locate well		
-b	Spot tanks or dig pits	2	1
2	Mobilize small rotary rig (\$40 per 8 hr day)	1	1/2
3-a	Check total depth with drill pipe; clean out if necessary	1-3	1/2
-b	Salt water for rig		
4	Run directional survey for permanent borehole record (not recommended)	1	Not done
5	Run caliper survey	1/2	1/2
6	Install head for stripper plug	-	-
7-a	Acidize hole - 1000 gal 15X SS + 1000 gal MA - SS	1	1/2
-b	Check returns for starch and bentonite to determine if second acid job required	-	-
-c	Salt water displacement fluid	-	-
8	Spot salt saturated Chem Comp 1300 to 1080 ft Reverse circulate any excess - 100 sacks	1	1
9	Core, drill and underream 10 ft section of cement at end of WOC time	1	1
10	Install back-pressure valve and swab salt water from well	1/2	1
11	Run epoxy cement 1090 to 1070 ft - 75 gal	1 1/2	1
12	Spot salt saturated Chem Comp 1070 to 820 ft into open hole if possible - 110 sacks	2	1
13	Run epoxy cement 820 to 800 ft - 75 gal	1 1/2	1
14	Load salt water	1/2	0
15	Spot salt saturated Chem Comp 800 to 315 feet. Reverse circulate any excess - 250 sacks	2	1

TABLE VII (cont'd)

<u>No.</u>	<u>Steps to be Taken</u>	<u>Time (days)</u>	
		<u>Estimated</u>	<u>Required</u>
16	Perforate 106 to 126 ft and 296 to 310 ft	1/2	1
17-a	Set packer. Check lower zone injection	1/2	1
-b	1500 gal Zonelock - 50 sacks cement if required	1	1/2
-c	Wait on cement	1	-
18-a	Set bridge plug and packer. Check upper zone injection	1	} 1/2
-b	1500 gal Zonelock + 50 sacks cement if required	1	
19	Move small rig	Total 20	13
20	Remove casing		23 reg
21	Cement to surface with neat Chem Comp cement - 300 sacks	1	0.5
22	Demobilize and restore surface depending on local laws and attitudes	1-2	1
23	Disposal of brine	?	0.5

LOG OF DAILY PROGRESS - AEC #1, LYONS KANSAS

<u>Date</u>	<u>Time</u>	<u>Log</u>
Wed. Nov. 14		Rigged up - Cleaned well to bottom with 6 5/8 inch bit. Solids and sludge from 1208 feet to 1300 feet. Black to grey color. Sample taken during clean-up. Analysis given in Table I.
Observers: Pete Stubbs		
Thurs. Nov. 15	9 a.m.	Welex on location to caliper well
	12 p.m.	Caliper completed. Some solids on bottom
	3 p.m.	Pipe on bottom ready to acidize 2000 gal total (Dowell)
	4 p.m.	Acidized - flushing acid from hole - samples taken
	6 p.m.	260 barrels salt water used in flush. Returns neutral.
Visitors: G. Toman, Hank Nauor		
Observers: Pete Stubbs, L. H. Eilers		
Fri. Nov. 16	8 a.m.	Rigging to pump cement (Dowell)
	11 a.m.	Cement mixed - 11 barrels salt water - 7.5 pounds citric acid - 75 sacks Chem Comp cement - in paddle mixer
	11:10 a.m.	Started cementing - 18 barrels
	11:17 a.m.	Started flush - six barrels salt water
	11:30 a.m.	Rig helper smashed finger - only accident of operation
	12:30 p.m.	Reverse circulated all cement above 1068 feet
Observers: Pete Stubbs, L. H. Eilers		
Sat. Nov. 17		Rigged for coring cement and maintaining on rig
Mon Nov. 19	8 a.m.	Core barrel into well
	9 a.m.	Core barrel on bottom. Starting to core - 1068 feet
	1 p.m.	Cored to 1078 feet
	2 p.m.	Cores out and wrapped in plastic
	3 p.m.	Drilling to 1084 with 7 7/8 bit
	6 p.m.	Drilling completed and pipe out
Observers: Pete Stubbs, L. H. Eilers		

LOG OF DAILY PROGRESS (cont'd)

<u>Date</u>	<u>Time</u>	<u>Log</u>
Tues. Nov. 20	8 a.m.	Rigging to swab
	9 a.m.	Dummy run to make sure pipe clear
	9:30 a.m.	Starting to swab. Samples of solids caught
	11 a.m.	Started sleeting and snowing
	3:30 p.m.	Swabbed - 70 runs - 10 feet brine remaining (Wellbore remained clear - solids are magnetite)
	4:30 p.m.	Pipe removed from wellbore

Observers: Pete Stubbs, L. H. Eilers

Wed. Nov. 21	8 a.m.	Starting motors and rigging glass bottom bailer
	9 a.m.	Dummy run of bailer - Borehole clear - solid bottom
	10 a.m.	Start mixing epoxy resin - batch one in drum. Total 37.5 gallons - sample taken. Some delay in dissolving catalyst
	11:20 a.m.	First batch dumped - second batch started. Premixed catalyst before starting.
	12:10 p.m.	Second batch epoxy resin dumped - starting clean-up

Visitor: G. Toman

Observers: Pete Stubbs, L. H. Eilers

Thurs. Nov. 22 - Thanksgiving

Fri. Nov. 23	8 a.m.	Rigging to pump cement
	9 a.m.	Tagged bottom hard with drill pipe - 1057 feet Waiting for salt water tanks to be filled
	11:45 a.m.	Rigged to mix 18 barrels cement in paddle tank
	12:25 p.m.	Pumped 18 barrels cement - 1.5 to 2 BPM
	12:37 p.m.	Pumped two barrels salt water to clear tubing

Visitors: G. Toman, N. Biegler

Observers: Pete Stubbs, L. H. Eilers

Sat. Nov. 24	10 a.m.	Tagged bottom with bailer - cement firm
	1 p.m.	Setting up to mix epoxy in drum
	1:45 p.m.	First 37.5 gal epoxy mixed
	2:15 p.m.	First batch dumped - second being mixed
	2:45 p.m.	Second 37.5 gal epoxy mixed
	3:05 p.m.	Second batch dumped

Observers: Pete Stubbs, L. H. Eilers

LOG OF DAILY PROGRESS (cont'd)

<u>Date</u>	<u>Time</u>	<u>Log</u>
Mon., Nov. 26	8 a.m.	Tallying in pipe for cementing to base of surface casing (Dowell)
	9:30 a.m.	Tallied in - waiting for salt water
	11 a.m.	Salt water prime - rigging for continuous cement mix
	11:20 a.m.	Continuous cement - Salt water with 0.1% citric acid and Chem Comp cement blown in to 15.7 lb/gal density
	11:35 a.m.	Finished cementing 54 barrels slurry - 230 sacks
	12:15 p.m.	Lower end of tubing at 316 feet and excess cement circulated out with fresh water

Observers: Pete Stubbs, L. H. Eilers

Tues. Nov. 27	9 a.m.	Well tight. No change in water level. Will be afternoon to perforate
	10 a.m.	Checked with Union Carbide. They want to grout both zones.
	5 p.m.	Welex perforated - 305-310 feet then 295-305 feet Welex perforated - 116-126 feet then 106-116 feet Used Super Dynajet - two shots per foot

Observers: Pete Stubbs, L. H. Eilers

Wed. Nov. 28	7 a.m.	Preparing solutions for Zonelock 150. Mix at Great Bend station
	11 a.m.	Baker on location with packer. Dowell on location with pumper
	12:05 p.m.	Baker starting packer into casing. Dowell starting to mix Zonelock 150
	1 p.m.	Packer won't go below 110 ft. No ream available closer than Enid, Oklahoma. Swede Nelson, Acme Tool, has 7 7/8 milling tool
	1:30 p.m.	Dowell truck sent to dump Zonelock
	4 p.m.	Started milling
	5 p.m.	Past 126 feet to 133 feet
	6 p.m.	Cannot get past 133-134 foot level

Visitors: Mr. Klein, T. Tamura

Observers: Pete Stubbs, L. H. Eilers, Swede Nelson, B. Horsch (Baker Tools)

LOG OF DAILY PROGRESS (cont'd)

<u>Date</u>	<u>Time</u>	<u>Log</u>
Thurs. Nov. 29	8 a.m.	Starting packer into casing
	8:30 a.m.	Packer will not pass 134 feet. Set 130 feet.
	9:50 a.m.	Pumped water for breakdown - 450 psi back to 400
	10 a.m.	Start mixing 750 gallons (18 barrels) Zonelock 150
	10:10 a.m.	Start mixing 50 sacks Class A cement
	10:20 a.m.	Start Zonelock - 2 BPM - 350-400 psi
	10:30 a.m.	Two barrels flush followed by 12 barrels cement - 400 psi
	10:42 a.m.	Start flush - 400 psi
	10:53 a.m.	Finish flush - 450 psi
	12:30 p.m.	Pressure to 0 - No flow back - Packer removed
	1 p.m.	Start 55 gallons 10-20 mesh sand into casing
	2:15 p.m.	Injection test - 200 psi - back to 100 (must be upper zone - lower zone required 400 psi)
	2:20 p.m.	Start Zonelock 150 mix (750 gallons - 18 barrels)
	2:30 p.m.	Start 12 barrels Class A cement mix
	2:38 p.m.	Start Zonelock 150 - 3 BPM - 75 psi
	2:44 p.m.	Two barrels spacer - 12 barrels cement - 75 psi
	2:57 p.m.	Six barrels flush - pressure to 100 psi
	3:10 p.m.	Noted 20 to 30 gallons fluid had broken through to surface - 30 to 35 feet from casing
Visitors: T. Tamura, Ken Jehlik (Dowell)		
Observers: Pete Stubbs, L. H. Eilers		
Fri. Nov. 30	8 a.m.	Start drill out of cement plug - Observations given in report
Observer: Pete Stubbs		
Dec. 1-2		Drilling rig converted for washover use
Mon. Dec. 3	8 a.m.	Unloading and setting up power swivel unit and washover pipe
	1 p.m.	Starting power swivel with first section of washover pipe and shoe. Freezing rain and sleet starting.
	1:30 p.m.	Hydraulic hose coupling frozen and broken on swivel
	2 p.m.	Returned to Great Bend for hose replacement

Observers: Pete Stubbs, L. H. Eilers

LOG OF DAILY PROGRESS (cont'd)

<u>Date</u>	<u>Time</u>	<u>Log</u>
Tues. Dec. 4	8 a.m.	Removing ice (1/2 inch) from lines and pipe. Re- placing broken hose
	1 p.m.	Starting washover. 700 psi + torque - 65 RPM
	3:40 p.m.	28 feet drilled- Removed pipe to set spider
	4 p.m.	Back into hole - lost three feet - mudding up and adding salt water
	5 p.m.	Leaving location
Observers: Pete Stubbs, L. H. Eilers		
Wed. Dec. 5	8 a.m.	Still ice on motors and lines
	9 a.m.	Difficult to stab second pipe in first. Too icy for man in derrick
	10 a.m.	Started washover
	3 p.m.	Down to 61 feet Left location to get tongs, etc. to handle the 10 3/4 washover pipe - also load of sand

Visitors: Martha Katelle, Wayne Knowles, John Schreiber

Observers: Pete Stubbs, R. F. Walters, L. H. Eilers

Thurs. Dec. 6	8 a.m.	Starting engines, etc.
	9:30 a.m.	Rigged up - extra joint of pipe stabbed
	11 a.m.	Propane tank down in pressure in 18°F temp - obtained larger tank
	2 p.m.	Down to 90 feet - 1000 psi torque - 60 RPM
	4:30 p.m.	Down to about 111 feet - raising sections of washover pipe into derrick

Visitors: Martha Katelle, R. F. Walters

Observers: Pete Stubbs, L. H. Eilers

Fri. Dec. 7	8 a.m.	Starting washover
	8:30 a.m.	Found bridge at about 80 feet
	9 a.m.	To bottom and washing over
	11:30 a.m.	New section added - about 121 feet
	4:30 p.m.	Down to about 136 feet

Visitor: Martha Katelle

Observers: Pete Stubbs, L. H. Eilers

LOG OF DAILY PROGRESS (cont'd)

<u>Date</u>	<u>Time</u>	<u>Log</u>
Sat. & Sun.		Short hand on rig
Mon. Dec. 10	9 a.m.	Starting washover - found bridge at 80 feet - another at 110 feet
	10 a.m.	To bottom and drilling - 136 feet
	4:30 p.m.	Down to 148 feet
Observer: L. H. Eilers		
Tues. Dec. 11	9 a.m.	To bottom - Circulating and conditioning mud
	6:25 p.m.	To 177 feet - Bottom of washover pipe. Will circulate well overnight - Remove casing tomorrow.
Visitors: G. Toman (State Plugger), Larry Schultz (American Salt)		
Observers: R. F. Walters, L. H. Eilers		
Wed. Dec. 12	8:20 a.m.	Starting to remove 10 3/4 washover pipe
	10:10 a.m.	All six joints removed
	11 a.m.	Dia-Log rigging to shoot primacord opposite collar at 166 feet
	12 p.m.	Pipe not uncoupled. Surface section unscrewed. Decided to use circular jet charge.
	3 p.m.	First attempt to shoot off pipe - misfired
	3:15 p.m.	Repaired electric lead and fired at 144 feet
	3:30 p.m.	Removing casing - Collars tack welded. Last section of casing - 140-144 feet split and flared
Visitor: Larry Schultz (American Salt)		
Observers: R. F. Walters, L. H. Eilers		
Thurs. Dec. 13	9 a.m.	Returning washover pipe to hole - now shoe. Pipe caught on top of casing - 144 feet
	10 a.m.	Drilled about three feet of casing - back into original hole
	11:15 a.m.	Drilling at original depth - 177 feet
	4:30 p.m.	Down to 184 feet
Observers: R. F. Walters, L. H. Eilers		
Fri. Dec. 14	8:30 a.m.	Starting washover - to 184 feet - no fill-up
	10 a.m.	Adding oil to drilling fluid because of increased torque
	5 p.m.	Down to 198 feet - slow going
Observer: Pete Stubbs		

LOG OF DAILY PROGRESS (cont'd)

<u>Date</u>	<u>Time</u>	<u>Log</u>
Sat. Dec. 15	5 p.m.	Down to 215 feet
Observer: ?		
Mon. Dec. 17	10 a.m.	Drilling at 220 feet - torque 1200 psi - Full weight of pipe on shoe. Occasional snag stops rotation.
	5 p.m.	Increasing pump rate no apparent help Down to 237 feet
Observers: Pete Stubbs, L. H. Eilers		
Tues. Dec. 18	8:30 a.m.	Back to bottom only trace of fill-up
	11 a.m.	Drilling rate increasing to 247 feet
	5 p.m.	To 265 feet - circulated hole well - snowing heavily
Observer: L. H. Eilers		
Wed. Dec. 19	8 a.m.	Snowing seriously, 10°F, wind 30 MPH Some trouble getting motors started - Pumps to circulate and handling frozen pipe.
	10 a.m.	To bottom and drilling
	1 p.m.	Down to 270 feet - drilling slow - torque high 1400 psi
	2:30 p.m.	Rotation stopped - pipe stuck. Pull to 50,000 pounds raised pipe about two feet. No rotation. Will try spotting oil and acid - also rapid pumping.
Observer: L. H. Eilers		
Thurs. Dec. 20	8:30 a.m.	Some trouble making connections in 5°F weather
	9:30 a.m.	Circulating both rig pumps steel connections while Dowell truck hooks in to crude oil truck
	10:45 a.m.	Stopped rig pumps - no success - pumping oil
	11 a.m.	Spotted 8-9 barrels oil on bottom - pumping acid - 1 BPM
	11:05 a.m.	Pumping washover pipe out of hole
	11:10 a.m.	Pipe will pump up - will not fall or rotate
	11:30 a.m.	One joint of pipe out of hole - can rotate - cannot circulate
	11:45 a.m.	Circulation starting - slow but increasing
	12:30 p.m.	Pipe moving freely - circulation restored fast rate - Dowell truck released
	1 p.m.	Washover pipe stuck again - pulled free 35,000 pounds
	3 p.m.	Got O.K. to remove as much casing as possible
Observer: L. H. Eilers		

LOG OF DAILY PROGRESS (cont'd)

<u>Date</u>	<u>Time</u>	<u>Log</u>
Fri. Dec. 21	9 a.m.	Casing has block at 145 feet - cannot get tools through. Probably thick mud since heavy weight goes through
	9:30 a.m.	Shot pipe at 268.5 $\pm$ 0.5 feet
	10 a.m.	Removing washover pipe used as guide into casing
	11:30 a.m.	Completed removal of washover pipe
	1 p.m.	Latched onto casing with spear
	2 p.m.	Half section of 8 5/8 pipe - 20 inches long missing from top
	2:30 p.m.	Last section of casing has cross-threaded collar at 266 feet. Did we drill into casing?
	3 p.m.	Got O.K. to prepare to mill remaining casing.

Observers: Pete Stubbs, L. H. Eilers

Dec. 22-24 Preparing mills and converting rig

Wed. Dec. 26	9 a.m.	Starting mill and collars into hole
	11 a.m.	On bottom - milling at 268.5 feet
	3 p.m.	Down to 273 feet - crew change
	11 p.m.	Down to 278 feet - milling slow - change mill

Observer: L. H. Eilers

Thurs. Dec. 27	1:30 a.m.	Round tripped drill pipe - new mill on bottom
	7 a.m.	To 284 feet - crew change
	3 p.m.	To 290 feet - crew change
	10 p.m.	To 300 feet - circulating hole - no night crew

Visitor: Hank Nauor

Observers: Pete Stubbs, L. H. Eilers

Fri. Dec. 28	7:30 a.m.	Start milling operation
	3 p.m.	305 feet - crew change
	8 p.m.	309 feet - no steel after 306 feet
	9 p.m.	Circulation stopped - removing drill pipe

Observers: Pete Stubbs, L. H. Eilers

LOG OF DAILY PROGRESS (cont'd)

<u>Date</u>	<u>Time</u>	<u>Log</u>
Sat. Dec. 29	7 a.m.	Starting drill pipe into hole - open ended
	8:15 a.m.	Starting hook-up for cementing
	9 a.m.	Extra fresh water for flush on location
	9:35 a.m.	Start fresh water flush - 50 barrels water at 4-5 BPM (turbulent flow) contains 10 gallons surfactant to clean
	9:47 a.m.	Start cement - neat Chem Comp - 56% water - 15.6 density
	10 a.m.	Cement around and to surface
	10:02 a.m.	Stopped cement - 65 barrels pumped
	10:30 a.m.	Drill pipe removed - cement 21 feet down

Observers: Pete Stubbs, L. H. Eilers

L. H. Eilers

L. H. Eilers

LHE/js

no. 1

SWABBING METHOD FOR BRINE REMOVAL

no. 2

GLASS BOTTOM BAILER

no.3

DEMONSTRATION PLUG AEC NO.1 LYONS, KANSAS

AGE

FORMATION

SEALANT

QUATERNARY

CRETACEOUS

KIOWA
SHALE

HARPER

STONE CORRAL

NINNESCAH
SHALE

PERMIAN

WELLINGTON FORMATION

HUTCHINSON
SALTNOLANS
ODELL

21

NEAT CHEM COMP CEMENT

110

SILICATE AND CEMENT GROUTS

315

SALT SATURATED
CHEM COMP CEMENT808
828

EPOXY RESIN

SALT SATURATED
CHEM COMP CEMENT1059
1084

EPOXY RESIN

SALT SATURATED
CHEM COMP CEMENT

SULFATE: QUALITATIVE METHOD**Equipment**

9.26 The following materials are required to qualitatively determine the presence of sulfate:

- a. Test tube.
- b. Dropper bottle of barium chloride solution (61 g per 1000 cm³).
- c. Dropper bottle of strong nitric acid.

Procedure

9.27 Place 1 to 3 cm³ of filtrate in a test tube. Add a few drops of barium chloride solution. The formation of a white precipitate indicates the presence of sulfates and/or carbonates. Add a few drops of concentrated nitric acid. If the precipitate dissolves, it is carbonate; if not, it is sulfate. Record the amount of precipitate remaining after the acid treatment as light, medium, or heavy.

FORMALDEHYDE**Equipment**

9.28 The following materials are required to determine the formaldehyde content of drilling muds in which paraformaldehyde has been used as a preservative, either alone or as the major constituent of commercial preservatives:

- a. Phenolphthalein indicator (1 g per 100 cm³ of 50-per cent alcohol.)
- b. Sodium hydroxide solution, 0.02 normal (N/50).
- c. Sulfuric acid solution, 0.02 normal (N/50).
- d. Sodium sulfite solution (4 g per 10 cm³ of distilled water).

NOTE: This solution deteriorates readily; if older than 30 days, it should be replaced with a fresh solution.

- e. Titration vessel, a test tube or casserole.
- f. Graduated pipette, 10 cm³.

Procedure

- 9.27 a. Pipette 3 cm³ of the mud filtrate into the casserole or test tube. Add 2 drops of phenolphthalein indicator solution. If the sample remains colorless, add sodium hydroxide solution drop by drop, with agitation, until a faint pink color develops. Then add sulfuric acid drop by drop to dispel the color.
- b. If, upon the first addition of phenolphthalein, the filtrate becomes colored, add sulfuric acid dropwise until the color is just dispelled.

- 9.30 a. To the neutralized filtrate, add 1 cm³ of sodium sulfite solution; a red color will develop.
- b. After approximately 30 sec, titrate with sulfuric acid until the sample is a very faint pink. Record the amount of acid in cubic centimeters.
- c. Repeat the foregoing procedure (a and b) using distilled water instead of mud filtrate.

Calculation

- 9.31 Formaldehyde content, lb per bbl* = (0.07)
(cm³ of acid for filtrate — cm³ of acid for blank.) (9.11)

CATION EXCHANGE CAPACITY**Equipment**

9.32 The following materials are required to estimate the cation exchange capacity of drilling mud solids or clays by the methylene blue method:

- a. Methylene blue solution (1 cm³ = 0.01 milliequivalent) containing 3.74 g USP grade methylene blue (C₁₆H₁₈N₃SCl•3H₂O) per 1000 cm³.

NOTE 1: The water content of USP grade methylene blue may vary from that of the formula. Moisture content must be determined each time the solution is prepared. Dry a 1.000 gram portion of methylene blue to constant weight at 200 ± 5 F (93 ± 3 C). Make the appropriate correction in the weight of methylene blue to be taken to prepare the solution as follows:

$$\text{Weight sample to be taken} = \frac{0.855}{\text{weight of dried sample}} \times 3.74$$

- b. Hydrogen peroxide, 3% solution.
- c. Dilute sulfuric acid, approximately 5N.
- d. One 1-cm³ syringe or one 1-cm³ serological pipette.
- e. Erlenmeyer flask, 250 cm³.
- f. Burette, 10 cm³.
- g. Graduated cylinder, 50 cm³.
- h. Stirring rod.
- i. Hot plate.
- j. Filter paper.

*kg per m³ may be obtained by multiplying the lb per bbl value by 2.85.

Procedure

9.33 Add 1 cm³ of mud (or suitable volume of mud to require from 2 to 10 cm³ of reagent) to 10 cm³ of water in the Erlenmeyer flask. Add 15 cm³ of 3% hydrogen peroxide and 0.5 cm³ of sulfuric acid. Boil gently for 10 minutes. Dilute to about 50 cm³ with water.

9.34 Add methylene blue solution from the burette to the flask. After each addition of 0.5 cm³, swirl the contents of the flask for about 30 seconds. While the solids are still suspended, remove one drop of liquid with the stirring rod and place the drop on filter paper. The end point of the titration is reached when dye appears as a blue ring surrounding the dyed solids as shown in Fig. 9.1.

9.35 When the blue tint spreading from the spot is detected, shake the flask an additional 2 minutes and place another drop on the filter paper. If the blue ring is again evident, the end point has been reached. If the ring does not appear, continue as before until a drop taken after shaking 2 minutes shows the blue tint.

9.36 Report the cation exchange of the mud as the methylene blue capacity, calculated as follows:

$$\text{Methylene blue capacity} = \frac{\text{cm}^3 \text{ of methylene blue}}{\text{cm}^3 \text{ of mud}} \quad (9.12)$$

NOTE 2: Drilling muds frequently contain substances in addition to bentonite that adsorb methylene blue. Treatment with hydrogen peroxide is intended to remove the effect of organic materials such as CMC, polyacrylates, lignosulfonates, and lignites. If other adsorptive materials are not present in significant amounts, the bentonite content of the mud can be estimated as follows:

$$\text{Bentonite, lb per bbl}^* \text{ mud} = 5 \times \text{methylene blue capacity} \quad (9.13)$$

NOTE 3: The cation exchange capacity of clays (shales, etc.) can be determined by the above method. A weighed quantity of clay is dispersed into water by a high-speed stirrer. Titration is carried out as above except that hydrogen peroxide is not added. The cation exchange capacity of clays can be expressed as milliequivalents of methylene blue per 100 g of clay.

*kg per m³ may be obtained by multiplying the lb per bbl value by 2.85.

*Note: Free dye detected immediately after adding 6th cm³ is adsorbed after two minutes and indicates that end point has not quite been reached.

FIG. 9.1

SPOT TESTS FOR END POINT OF METHYLENE BLUE TITRATION

No. 1 Gardner Denver 2000
workover rig in place
showing rig (center) tanks
(right) and auxiliary pump
(left)

No. 2 Rig from Reverse Side
showing crew's quarters (Dog
House) and drill pipe stacked
in derrick.

No. 3 Small Paddle Mixer and Pumper
used in acidizing and small
cement placement operations.

No. 4 Jet bits used in cleaning
well to bottom.

Nos. 5 and 6 Cracking of glass containers by expanding Chem Comp Cement even though the weather was cold.

No. 7 Swabbing unit used to remove brine.

No. 8 Special head on drill pipe to divert brine to pit.

Nos. 9 and 10 Mixing equipment used in preparing small batches of epoxy resin used in setting the special plugs.

No. 11 Mill used in removing burrs from pipe to set packer.

No. 12 Seepage noted to be rising by auxiliary pump after grouting.

Nos. 13 and 14 Washover shoe tipped with sintered Cutrite
used in removing casing.

Nos. 15 and 16 Power swivel hose connections to hydraulic
power unit used in washover operation.

No. 17 Packer used to isolate the perforated sections while grouting water zones.

No. 18 Spider used to clamp washover pipe.

No. 19 Pipe split at 166 ft. by primacord in attempt to spring (unscrew) collar.

No. 20 Charge used by Dialog to sever casing at 144 and 268 ft.

Nos. 21 and 22 Two views of the split produced
by the shot to sever pipe at 144 ft.

No. 23 The section of casing milled
off on re-entering the washover
slot at 144 ft.

No. 24 The smoother cut produced
by severing the pipe at
268 ft.

No. 25 Cross-threaded collar on last joint of 8 5/8 casing.

No. 26 Spear used to remove lower section of casing from well.

Nos. 27 and 28 Two views of the last section of casing removed from the well. The slight bend can be noted at the cross-threaded collar.

Nos. 29 and 30 Types of mills used by Acme to remove the last 38 feet of casing and cement shoe from AEC #1.

No. 31 The hole as it appeared at the start of the washover operation.

No. 32 The hole as it appeared at the end of washover operations. Note oblong nature.

Nos. 33 and 34 Continuous mix cementing equipment used on last stage of sealing. This was used to bring neat Chem Comp Cement to surface.

Nos. 35 and 36 Variation in size of holes produced on opposite sides of casing by jet charges at 110 ft. The casing was at sufficient slant or bend to place jet gun against one side.