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1980 Annual Report

Underground Coal Gasification Projects

After completing four underground coal gasification (UCG) field tests in 1979, the Underground Coal Conversion (UCC) program in 1980 concentrated on evaluating the field test results. These field tests, Hanna II, Hoe Creek 3, and Rawlins Test 1, were cored to determine extent of gasification; contracts were proposed for the coring of the fourth field test. The Department of Energy (DOE) contract with the Gulf Research and Development Co. was modified based on the results of the first U.S. field test of UCG in a steeply dipping bed (SDB) of coal. The contract management responsibilities were transferred to LETC. The assessment of UCG in the state of Washington was completed and a draft final report was prepared. A follow on field test plan was prepared for new activities in Washington. LETC sponsored the Sixth Annual Underground Coal Conversion Symposium. The UCC Program Opportunity Notice, published in 1979, resulted in no award being made.

Hanna

Although no UCG field tests are planned at Hanna, considerable site activity was in evidence. The Wyoming Department of Environmental Quality (DEQ) required LETC to obtain a Permit to Mine for all previous Hanna tests. This permit necessitates a major environmental monitoring effort at Hanna, particularly in the area of groundwater quality monitoring. LETC's In Situ Hydrology Task Force, ISHTAF, was charged with the responsibility of obtaining the necessary data. This resulted in extensive drilling, coring, and logging at Hanna followed by groundwater sampling and analyses. The sampling and analyses will continue for several years. The Division of Resource Characterization and Environmental Sciences are responsible for the sampling and analyses. The Office of Environment and Conservation is responsible for interpretation of the data and submission of the permit application to the DEQ.

Late in 1980, LETC received funds to perform a post-burn coring task at Hanna. Hanna II, phases 2 and 3, conducted in 1975 and 1976 but still the most successful UCG field test in the U.S., was selected as the test to be cored. Ten rotary holes were drilled to determine the approximate burn zone boundaries, and then a total of twelve core holes were drilled and logged. The cores were analyzed to determine extent of gasification versus pyrolysis, the thermal effects on the overburden material, and the effect of coal mineral and maceral content on the gasification process. Results of the analyses will be available in 1981 and will be the subject of a series of publications.

Hoe Creek 3

LETC transferred funds to Lawrence Livermore National Laboratory (LLNL) to perform the post-burn coring of Hoe Creek 3. Hoe Creek 3, completed in 1979, was the first UCG field test in the U.S. to employ long-term steam/oxygen injection for the production of medium-Btu gas. As described in the LETC 1979 annual report, Hoe Creek 3 employed a drilled channel

between process wells spaced 100-130 feet apart. The drilled channel was enlarged by reverse combustion prior to forward gasification. The first week of forward gasification was conducted using air injection. Following this phase, steam and oxygen, in a 1:1 ratio, was injected for 47 days, during which 3,950 tons of coal were consumed. The average product gas heating value was 215 Btu/scf.

About two weeks after the test was terminated, a subsidence crater appeared on the surface between the injection and production wells. This crater enlarged and stabilized with dimensions of 33 by 66 by six feet deep. The crater is being monitored regularly for slow changes in the subsidence pattern.

The subsidence created unusual problems in the post-burn coring of Hoe Creek 3. It was decided to drill 12 vertical core holes and three slant core holes in the vicinity of subsidence. The coring has been completed. Core samples will be sent in early 1981 to LETC, which is responsible for analysis of the Hoe Creek 3 cores along with the Hanna II cores. Initial interpretation of the cores is that little of the coal below the drilled channel was gasified. Regardless of the positive link between process wells, the gasification rapidly rose to the top of the coal seam and resulted in an override. This less efficient gasification may be due to the wet (30% water) coal seam and the weak, wet overburden. There are laboratory test results to indicate the drilled channel will perform better in drier coals such as exists at Hanna.

Steeply Dipping Beds Test 1 and Test 2

Gulf Research and Development Co., under contract to the DOE, completed the first U.S. UCG field test in a steeply dipping bed (SDB) of coal. SDB Test 1, completed in 1979, consumed over 1,200 tons of coal over a 35-day period. The first 30 days of forward gasification, using air injection, consumed 1,020 tons of coal and produced 145 Btu/scf product gas. The final five days of forward gasification, using steam/oxygen injection, consumed 195 tons of coal and produced 250 Btu/scf product gas. In 1980 LETC transferred funds into the Gulf contract to perform the post-burn coring of SDB Test 1 and to prepare for Test 2. Four core holes were drilled in 1980; a fifth core hole will be drilled in 1981. LETC ran TV logs of the four core holes. Results of core analyses will be available in 1981. Preliminary indications are that a 50-foot chimney was created in the overburden due to roof collapse.

The draft final report for SDB Test 1 was prepared in late 1980 and was submitted to LETC for review. The DOE contract with Gulf for the SDB project was modified to reflect the inclusion of SDB Test 1 results in the design and operation of SDB Test 2. SDB Test 2 will include the following:

1. A longer and deeper simple module

2. Multiple injection wells

3. A ninety-day test period

5. More extensive instrumentation for gasification cavity shape and growth definition.

Major tasks to be performed under the terms of the modified contract include:

1. Post-burn coring and evaluation of SDB Test 1. To date, the best technique to determine cavity dimensions, extent of gasification versus pyrolysis, and thermal stresses on the overburden, is coring. The subsurface instrumentation in Test 1 was insufficient for these purposes. The data from the coring and evaluation will have direct impact on the design of Test 2, particularly with respect to the number, location, and constitution of the instrument wells. As mentioned earlier, LETC arranged to have this task completed before the contract renegotiation was completed.

2. Preliminary test design. Based on Test 1 results, post-burn coring of Test 1, the Soviet SDB experience, and Test 2 objectives, the preliminary test design through the 40% design review will occur early in 1981.

3. Final site characterization. The location for Test 2 will be characterized sufficiently to confirm the subsurface conditions relative to the Phase I site Qualification study, and these data will be input to the final test design.

4. Drilling program. It is necessary to perform the drilling tasks in late 1980 or early 1981. The process wells will be drilled first based on the test objectives; the number and location of instrument wells will be determined at this time and drilled after the process wells.

5. Final test design. Based on the preliminary test design and the final site characterization, the detailed final test design will be completed by the end of 1980.

6. Surface facility fabrication. Upon acceptance of the final test design, the fabrication of the surface facilities will commence. Due to weather conditions and the lack of quality assurance in field fabrication, it is necessary to shop fabricate the surface processing facilities. Other subtasks will include preparing the Test 1 ancillary surface facilities for Test 2, relocating facilities as necessary.

7. Surface facility assembly. As weather permits in the spring of 1981, the shop-fabricated surface processing facilities will be installed at the Test 2 location. It is expected that the earliest possible date will be April 1981.

8. Environmental compliance. A continuous task in this project is compliance with Federal, State, and local environmental regulations. This task will continue for the lifetime of the project.

9. Economic analysis. The present modification of the Gulf contract requires performance of a detailed economic analysis of UCG of SDB. It is expected that some preliminary work may be performed in 1981 but most of it will be performed in 1982 after the test results of both Test 1 and Test 2 are analyzed and understood.

10. Post-burn coring of Test 2. Upon completion of Test 2 and as soon as the burn is quenched and it is judged safe to proceed, the Test 2 site will be cored and the cores evaluated.

11. Site restoration. The present modification of the contract requires termination of field tests at this site after Test 2. At this time, site restoration will proceed.

Test 2 will have four process wells: a slant injection well, SIW; a vertical injection well, VIW: a slant production well, SPW; and a vertical linking well, VLW. One exploratory well will be drilled to confirm the lithology definition. Four hydrology wells will be completed for water quality monitoring. Approximately ten instrument wells will be completed to monitor reactor growth and shape.

Although the operating plan for Test 2 has not been finalized, the purpose for four process wells is two-fold. First, in Test 1, there were indications that the high pressure reverse combustion linking of the process wells may have damaged the cement bond in the injection well. Therefore, Test 2 will use the vertical linking well to complete the reverse combustion link from SIW to SPW to VLW.

Second, an attempt will be made to "step" the gasification process from one injection point to another. Slant process wells, particularly injection wells, are more expensive than vertical wells. If vertical injection wells can be used for UCG of SDB, a major economic advantage may be realized. The Soviet experience has been that vertical wells do not survive due to overburden collapse, but the overburden at the present facility is stronger than that in the Soviet experience. The present plan is to begin gasification using SIW as the injection point. When the gasification cavity reaches the vicinity of VIW, injection will be switched to that well and Test 2 will be completed in that mode. If VIW fails due to overburden collapse, injection wells will be switched back to SIW and Test 2 will be completed in that mode.

Test 2 will be conducted starting at about 600 feet true vertical depth and gasified, updip for about 200 feet. Steam/oxygen will be the injection fluid for the production of medium quality gas (250 Btu/scf). The test is scheduled for the fall of 1981, and is scheduled to be conducted for ninety days.

In 1980, responsibility for management of the Gulf contract was transferred to LETC. The contract will be renegotiated by LETC and Gulf in early 1981.

Tono Project

In 1979, Congress appropriated funds to investigate the feasibility of UCG in the coal resources of Washington state. The DOE prepared and

executed a site selection and characterization study which was performed by SNL, LLNL, LETC, the Washington Irrigation and Development Co. (WIDCo), and the State of Washington. The objective of the study was to select and characterize a site or sites suitable for conducting a UCG field test. The study consisted of:

1. Screening potential sites within the state.

2. Determining detailed geotechnical characteristics and environmental factors of the selected site.

3. Assessing potential markets for the product gas.

4. Developing a follow-on field test plan.

Coal is widely distributed in Washington with the principal deposits found along the western margin of the Cascade range. Almost all coal-bearing strata in the state have been folded and faulted. Promising locations for an underground coal gasification process were identified by applying a set of general criteria, based on previous UCG experience, to the cataloged coal-bearing districts in the state. The criteria employed in selecting potential sites were:

1. Coal seam thickness should be in excess of six feet. Heat loss to base and cap rock during the UCG process decreases the thermal energy available to drive the endothermic gasification reactions and can result in reduced gas heating value. This heat loss becomes an unacceptable fraction of the available thermal energy in seams less than four feet thick according to Soviet experience.

2. Depth to coal should be at least 300 feet and preferably no more than 1,000 feet. By considering coal at depths in excess of 300 feet, containment is provided for the UCG process and competition is avoided for coal resources that may best be recoverable by surface mining techniques. The 1,000-foot depth limit is imposed primarily for economic reasons in this characterization study and any subsequent tests.

3. A demonstrated resource should be available for a commercial operation. Defined in terms of electric power generating station for a period of 30-35 years; this will require a demonstrated resource of 50 to 60 million tonnes of subbituminous coal or 40 to 50 million tons of bituminous coal. A subbituminous coal resource is preferred because it shrinks upon heating which is a desirable characteristic.

4. The structural geology should be relatively simple. It is desired to have areas free of major faulting and major structural folds in which the coal can be gasified. The faulting and folding need to be identified so that an appropriate gasification test can be designed.

5. The coal seam(s) of interest should be overlain by thick (2 or 3 times seam thickness), relatively competent and impermeable strata. Seams directly overlain by an aquifer should be avoided. The coal seams should be only moderately permeable so that groundwater intrusion into a gasification zone can be controlled with acceptable gas losses. The seam(s) of interest should be underlain by relatively impermeable strata.

6. Good ground access is important. The district should be separated from major urban areas to avoid environmental problems, yet close enough to provide for gas markets.

Only three areas in Washington were identified that satisfied the general criteria. These were the Bellingham Field, the Roslyn Field and the Centralia-Chehalis Field. Upon further investigation of these candidates, the Centrali-Chehalis location was chosen for characterization because: (1) a large quantity of subbituminous coal is contained in the Centralia-Chehalis district, (2) although the geology of the district is complex, there is enough gentle to moderate geologic structure to provide for gasification sites, (3) a potential market, the Centralia Steam Electric Generating Plant, is sited within the district.

Much of the coal in the Centralia-Chehalis district is owned by WIDCo, the operator of the surface mine which supplies coal to the Centralia Steam Plant. With the assistance of WIDCo, a location to conduct detailed site characterization activities was selected in the Tono Basin. There, a suitable 47-foot thick coal seam (the Big Dirty) exists at a depth of about 600 feet and is of sufficient areal extent to support commercial exploitation. Existing geological data suggested acceptable overburden and hydrology characteristics. A joint agreement was negotiated with WIDCo to allow access to the coal property for purposes of detailed site characterization.

Actual field activities consisted of using surface geophysical techniques, borehole and cross-borehole geophysical techniques, taking and analyzing overburden and coal cores, and hydrological testing. The surface geophysical techniques were used to delineate geologic structure and to determine coal seam continuity. The borehole geophysical logs were used to identify coal seams and their thicknesses, to help determine overburden and coal quality, to determine lithology, and to develop stratigraphic correlation between exploratory boreholes. The cross-borehole, in-seam seismic wave studies were used to determine coal seam continuity. The coal quality was determined from chemical analyses of coal cores. The hydrology tests were used to determine the permeability of the overburden and coal seam and to estimate water influx rates.

A total of eight exploratory boreholes and two hydrology wells were drilled at the site. Surface geophysical surveys were conducted concurrent with the drilling activities. Of the surface work conducted, the high resolution reflection seismic survey proved most valuable in providing detailed geologic structure. Other surface techniques were employed, and they provided supporting information on the geology. Of the borehole

logging performed, the most useful data were supplied by the gamma-gamma density, sonic, and single point electrical resistivity logs. Cores were taken to examine the overburden stratigraphy. The reflection seismic data, borehole logs and core interpretation were used to generate structural cross sections of the proposed UCG test site.

Cores were also used to determine coal quality. Proximate, ultimate, free swelling index, and equilibrium moisture analyses were performed on representative coal samples from four boreholes. The results verified that the Big Dirty is a non-swelling, non-coking, subbituminous coal of high volatile C rank. It contains high ash (38%) and high moisture (18%) and has a relatively low average, as received, heat content of 5060 Btu/lb. This low heating value is caused by shale, clay and siltstone partings present in the seam. These partings predominate near the bottom of the seam and become less numerous near the top of the seam where the coal heating value is 8070 Btu/lb. The effect of the high ash content on gasification must be determined. Two hydrology wells were drilled, and the resulting data confirmed that groundwater intrusion into an underground gasification zone should be minimal. Hydraulic conductivity and permeability is low, and the siltstone above the Big Dirty seam should provide a good gas seal.

Information of the current environmental quality of the Tono Basin was collected. Because of poor drainage characteristics, the site cannot support agriculture. A road through the Basin is used by WIDCo personnel and local traffic. Migrating wildlife (primarily elk, deer, and small mammals) frequent the basin. Based on this information, the environmental impact should be minimal.

In summary, the results of the UCG site selection and characterization study in the State of Washington have not disclosed any characteristics which would preclude conducting a gasification process in the Tono Basin. However, lack of extensive site characterization data at existing UCG process conditions do not allow a definite conclusion to be reached. Therefore, several characteristics need to be evaluated further prior to committing to a UCG test. These are:

1. The effect of the high ash content of the coal on the UCG process.

2. The effect of a possible high permeability zone near the top of the Big Dirty coal seam.

3. The directional permeability of the Big Dirty coal seam.

4. The hydrogeologic characteristics of a sandstone strata some 60 feet above the Big Dirty seam.

5. The hydrology throughout the Basin.

A preliminary plan for a UCG field test in the Tono Basin was developed based on the known characteristics of the site. The UCG field test should result in data to provide: (1) an assessment and correlation of pre-burn site characteristics and the UCG process, (2) an assessment

of product gas quality and its potential use, and (3) an assessment of the environmental effects of the UCG process on local water, air, and land quality.

There are five phases in the test plan:

1. Final site characterization including baseline environmental monitoring.

2. Laboratory tests on small coal blocks.

3. Large block tests at the WIDCo mine site including post-burn excavation.

4. At least one field test including post-burn coring.

5. Post-test analysis and evaluation.

The site selection and characterization study yielded data that were adequate to establish the suitability of the Tono Basin for a UCG field test. However, more extensive baseline and specific site information is required to assess the UCG process and the environmental aspects of a field test. Specific objectives of Phase I are to:

1. Determine the directional permeability of the overburden and of the coal seam.

2. Determine the permeability distribution within the coal seam.

3. Determine the chemical and petrographic characteristics and variabilities of the coal seam.

4. Determine the local hydrologic conditions in the Tono Basin.

5. Determine the baseline environmental quality levels of the ground and surface water, air, and land.

6. Obtain the required environmental permits and approvals.

Laboratory tests on small blocks of coal have been performed to obtain data regarding the behavior of the coal to be gasified. Specific objectives of Phase 2 are to:

1. Obtain process information related to coal composition and structure, e.g., how a directionally drilled hole will perform in the UCG process.

2. Obtain data correlating petrography to the UCG process.

3. Provide data for process models.

One of the problems with UCG is that early time cavity development is not understood. There is a different visualization for every proces model. Small laboratory tests are beginning to provide data relevant to early time cavity growth, but the scale is insufficient. A logical extension to larger blocks, perhaps three to six meters on a side, is needed. These large block tests can practically be conducted only at a mine site. WIDCo has offered to make such blocks available at their coal mine. The specific objectives of Phase 3 are to:

1. Quantify early time cavity growth.

2. Obtain optimum operating and parameters for the full scale field test.

Three large block tests are planned. The field test, designated Tono I, will involve: (1) the use of a directionally drilled hole as the link between vertical process wells, and (2) the use of steam/oxygen as injection fluid for production of medium quality product gas. Therefore, the large block tests will use drilled links and two of the tests will use steam/oxygen injection. One test will use air injection. Each test will operate for about five days, and will consume about 18 tons of coal per day. Limited instrumentation will be used; the primary diagnostic will be excavation. Each burn will be extinguished by water flooding and the cavity will be filled with plaster or cement so the block can be excavated, broken open, and inspected visually.

Three field tests have been completed at Hoe Creek and six at Hanna, Wyoming, all in subbituminous coals. Although the tests produced encouraging results, many certainties remain to be clarified before UCG can be commercialized. The major technical issues concern cavity growth, linking channel growth, effects of overburden collapse, consistency of results, and environmental effects. How these are affected by injection fluid, flow rate, coal type, or linking method is not well understood. The objectives of Phase 4 are to:

1. Conduct a test that will provide data for an assessment of the potential of UCG at this site.

2. Design the test of minimize effects of well completion or linking technique.

3. Use steam/oxygen injection for a long enough time to establish a stable burn zone configuration so assessment of long term resource recovery, gas composition, and oxygen utilization can be made.

4. Monitor the system performance throughout the life of the test.

5. Determine environmental effects of the test.

6. Perform product gas cleanup and utilization tests on at least a portion of the product gas stream.

The Phase 4 plan consists of two field tests performed in sequence. First, a directionally drilled link test, Tono I; second, a reverse combustion link test, Tono II. This will allow a direct comparison of the results achieved by the two methods.

In Tono I, the directionally drilled link will be placed as close as possible to the bottom of the coal seam and as far horizontally as practical to test the effectiveness and the problems associated with long underground production lines. Tono I will use the directionally drilled hole as an injection well and the vertical wells as production wells. The vertical wells, if not intersecting the horizontal hole, will be linked to the channel by reverse combustion. Forward gasification will use steam/oxygen injection. Flow rates will be controlled to maintain the burn zone at the injection point and to control channel growth and particulate emission. The test will be continued until the objectives are achieved, thirty to ninety days.

Subsurface instrumentation will consist of eight to ten thermocouple wells, four HFEM wells, four to six extensometer wells, and five to eight water quality monitoring wells. It may be desirable to include some remote (surface) monitoring of the cavity growth.

After completion of Tono I, Tono II will be performed using a reverse combustion link. The test size, configuration, and instrumentation will be similar to Tono I. The reverse combustion phase will be performed with high pressure air; the forward gasification will be performed with steam/oxygen injection. Both tests will be cored to define the cavity geometry and to analyze the char zones.

This test sequence will allow a direct comparison of the results of two different linking techniques and two different well completion techniques (horizontal versus vertical injection well). The tests will provide a basis for decisions concerning the nature of future UCG efforts at this site and will add valuable information to the UCG technology base.

The final phase of the test plan is the analysis and evaluation of the data. The specific objectives of Phase 5 are to:

1. Perform post-test characterizations that will correlate site characteristics with the UCG process.

2. Evaluate the test results in terms of site characteristics, and quantify significant correlations.

The first three phases of the test plan are scheduled to begin in 1981. Preliminary site preparation, including the drilling of the link for Tono I, will also begin in 1981. Operation of Tono I is tentatively scheduled for 1982 or 1983.

As lead center for implementation of the UCG program, LETC will provide the project manager for the Tono Project. LETC is negotiating a Cooperative Project Agreement among the DOE, Washington Irrigation and Development Co. (WIDCo), Washington Water Power (WWP), and the State of Washington. The agreement will be finalized in early 1981.

LETC has assigned activity coordinators for the Tono Project. The block tests and field tests will be coordinated by LLNL. The product gas cleanup and utilization activities will be coordinated by METC. LETC will be coordinator for the final site characterization and for the environmental, safety and health tasks. In 1980, LETC submitted the master application forms for the state permits relevant to the block tests and the directionally drilled hole for Tono I.

The Sixth Annual Underground Coal Conversion Symposium, sponsored by LETC, was held in Afton, Oklahoma. Sixty-seven papers, covering all aspects of the UCG technology, were presented. Four LETC papers, nine Gulf papers, and over twelve LETC-sponsored papers were presented. Due to DOE travel restrictions, only two LETC personnel were permitted to attend the symposium. Three of the four LETC papers were presented by non-LETC personnel.

The UCC Program Opportunity Notice (PON), "Development of In Situ Coal Gasification Technology for Production of Low and/or Medium Btu Gas," 03-80ET14130, was published in 1979 and responses were accepted until February 1980. No acceptable responses were received. LETC sent a questionnaire to UCG participants to determine the cause of the poor response to the PON. Fifteen replies were received from a broad variety of interested individuals and organizations. Using the replies as a basis for clarifying the intent and requirements of the PON, LETC will generate another solicitation in 1981.

Underground Coal Gasification Projects

1980 Publications

Bartke, Theodore C., "The DOE Underground Coal Conversion Program Field Test Activities in 1979 and 1980." To be presented at the AIChE 90th National Meeting, Houston, TX, April 5-9, 1981.

Bell, Gregory J., and Gunn, Robert D., "Adiabatic Coal Gasification Tube Experiments." Presented at 6th Ann. UCC Symp., Afton, OK, July 13-17, 1980.

Covell, James R., Wojdac, Lawrence F., Barbour, Floyd A., Gardner, Gerald W., Glass, Robert, and Hommert, Paul J., "Results of the Fourth Hanna Field Test." Presented at 6th Ann. UCC Symp., July 13-17, 1980.

Gunn, Robert D., Bell, Gregory J., Bartke, Theodore C., Camp, David W., and Krantz, William B., "A Technical Analysis of the Hanna III Field Test Data." Presented at 6th Ann. UCC Symp., Afton, OK, July 13-17, 1980.

Jiacoletti, Richard J., "DOE Underground and Coal Conversion Program Implementation: Structure and Plans." Presented at 6th Ann. UCC Symp., Afton, OK, July 13-17, 1980.

Krantz, William B., Camp, David W., and Gunn, Robert D., "A Water-Influx Model for UCG." Presented at 6th Ann. UCC Symp., Afton, OK, July 13-17, 1980.

Manahan, Stanley E., Bornhop, Darryl, Farrier, David S., Sheesley, David S., and Poulson, Richard E., "Interaction of Contaminated Water and Solid Material By-Products from In Situ Coal Gasification: Implications for Pollution Control Technology." Presented at 6th Ann. UCC Symp., Afton, OK, July 13-17, 1980.

Wojdac, Lawrence F., and Andrews, Michael, "The Design and Implementation of Cost Effective UCC Projects." Presented at 88th Ann. Mtg. of AIChE, Philadelphia, PA, June 1980.

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