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INVESTIGATION OF THE GEOKINETICS HORIZONTAL IN SITU OIL SHALE RETORTING PROCESS

Quarterly Report for October, November, December 1980

By
David L. Hutchinson

February 1981
Date Published

Work Performed Under Contract No. FC20-78LC10787

Geokinetics Inc.
Concord, California

U. S. DEPARTMENT OF ENERGY

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INVESTIGATION OF THE GEOKINETICS
HORIZONTAL IN SITU OIL SHALE
RETORTING PROCESS

QUARTERLY REPORT
OCTOBER, NOVEMBER, DECEMBER 1980

by
DAVID L. HUTCHINSON

GEOKINETICS INC.
280 Buchanan Field Road
Concord, CA 94520

Date Published - February 1981

PREPARED FOR THE UNITED STATES DEPARTMENT OF ENERGY
Under Cooperative Agreement #DE-FC20-78LC10787

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INTRODUCTION

The Geokinetics In Situ Oil Shale Project is a cooperative venture between Geokinetics Inc. and the U. S. Department of Energy. The project is governed by DOE Cooperative Agreement #DE-FC20-78LC10787. The objective is to develop an in situ process for recovering shale oil using a fire front moving in a horizontal direction. The project is being conducted at a field site, Kamp Kerogen, located 70 miles south of Verna, Utah, on Section 2, Range 22 East, Township 14 South, Uintah County, Utah.

The process is true in situ extraction of oil from oil shale. The oil shale is fractured by means of explosives placed in blastholes drilled from the surface. After a specific area has been fractured, creating an in situ retort, air injection holes are drilled at one end and off gas recovery holes are drilled at the other. The oil shale is ignited at the air injection wells, and air is continually injected to establish and maintain a burning front. The front is moved in a horizontal direction through the fractured rock. The burning front heats the oil shale, driving out the shale oil which drains to the bottom of the retort where it is recovered through oil production wells. As retorting progresses from the air-in to the air-out wells, the residual coke serves as the primary fuel source to sustain the moving burn front. The combustion gases are recovered at the off gas wells.

SUMMARY

The ignition of Geokinetics first full-sized prototype retort was completed on December 1, 1980. Retort #24 measures 217 feet wide by 230 feet long and utilizes the full 30-foot thick section of oil shale. The retort is overlain with an average overburden thickness of 45 feet. The shale grade of Retort #24 averages 22 gallons per ton. Retort #24 was ignited using the charcoal point ignition technique at each of the eight air injection wells. Initial air-in flow rates of 43 scfm at each air-in well were gradually increased to 425 scfm per well. Downhole thermocouple instrumentation and intra-retort gas analysis indicated a successful ignition.

Recovery of oil from Retort #24 began about midway through December. Approximately 531 barrels of oil had been recovered by the end of the quarter. A "cold oil" effect, not noted in previous retorts, resulted in the accumulation of oil within the retort. Steps to increase recovery and reduce retort fluid levels were initiated.

Geokinetics successfully negotiated the sale of 5,000 barrels of crude shale oil to WESRECO of Salt Lake City, Utah. Approximately 5,191 barrels of oil were shipped during the quarter. WESRECO blended the shale oil into #5 fuel oil, which was sold to industrial users.

The U. S. Environmental Protection Agency (EPA) issued a PSD permit (in accordance with Prevention of Significant Deterioration of Air Quality Regulations) and the Utah Air Conservation Committee issued an air quality approval order. These permits authorize Geokinetics to carry out the remainder of the research planned at the field site. The liner for the new evaporation pond was installed during the quarter.

Geokinetics President Mitchell A. Lekas traveled to Morocco to participate in the Oil Shale Colloquium co-sponsored by the Kingdom of Morocco, the Agency for International Development (U. S. Department of State), and the U. S. Department of Energy (DOE). Mr. Lekas presented a description of Geokinetics oil shale retorting technology to Moroccan officials, who expressed substantial interest in the application of the process to oil shale resources in Morocco. The kingdom of Morocco plans to develop a 100,000 barrel per day oil shale industry and bring it on line as soon as possible.

The Retort #25 post-blast core drilling program was completed

in October. A total of seven core holes were drilled. Evaluation of the core samples was underway. Preliminary analysis indicated good breakage in the lower portion of Retort #25. A new technique for sealing retort surface fractures was designed and implemented on Retort #25. A layer of bentonite with gas and steam retention properties was applied to the retort surface and covered with a layer of topsoil.

Geokinetics employees received hands-on experience in using fire extinguishers during the second session of a special eight-hour fire safety training session. A safety survey of Kamp Kerogen housing facilities was initiated.

STATUS OF MAJOR TASKS AND SIGNIFICANT ACCOMPLISHMENTS

SITE PREPARATION:

Re-entry locations for 23 instrumentation wells, two air-out wells and two observation wells on Retort #23 were surveyed. Sandia National Laboratories will install instrumentation to monitor the burn of Retort #23, scheduled to begin in March 1981. Retort locations are shown in Figure 1. Retort #23 re-entry well locations are shown in Figure 2.

Preparations for re-entry drilling on Retort #25 were made during the quarter. Topographical profiles across each row of planned re-entry wells were made to enable the construction of level pads on the retort using a bull dozer and scraper. The pads were intended to eliminate access problems in the drilling of re-entry wells and expedite manifold erection. The collar locations for all re-entry air, production and observation wells on Retort #25 were staked for drilling. Levels were run, and well depths and completion plans were developed. Retort #25 re-entry air well locations are shown in Figure 11. Levels were also surveyed on the seven post-blast core holes on Retort #25. Those core hole locations are shown in Figure 10.

A new technique for sealing retort surface fractures was designed and implemented on Retort #25. The procedure calls for the removal of at least one foot of topsoil from the area to be sealed. A special grade of bentonite (GSR-60) with gas and steam retention properties is applied to the retort surface at a concentration of one pound per square foot. The bentonite is then mixed with the top two inches of soil remaining on the surface, which should contain approximately ten percent moisture. The bentonite/soil mixture is compacted to 90 percent, and the original topsoil is replaced over the compacted bentonite. This procedure is aimed at containing both wet and dry fugitive emissions.

Final site preparation work was performed at the new evaporation pond prior to installation of the pond liner. Rocks were removed by hand from the pond bed. The fence lines surrounding the new evaporation pond were staked and fencing was installed following the installation of the pond liner. The location of the evaporation pond is shown in Figure 1. Additional details about the pond and liner installation are included in the Environmental Research category.

Contractor work on the new leach field for our sewage disposal system was completed in October. The main trench and trunk

line connecting Kamp sewer facilities to the new drain field will be constructed by Geokinetics.

A building to house the 650 kilowatt (KW) natural gas powered generator was completed during the quarter.

A revised development map for the shop and retort area was drafted during the quarter.

RETORT FRAGMENTATION:

Geokinetics, DOE/LETC, Sandia National Laboratories and IRECO Chemicals were represented at a blasting meeting in November. They reviewed data and discussed results of the Retort #25 blast. Tentative plans for the blasting of Retort #26 were outlined.

No blasthole drilling or retort blasting was done during the quarter.

RE-ENTRY DRILLING:

Retort #23 air-out wells AO-1 and AO-2 were drilled to depths of 80.5 feet and 78.5 feet, respectively. Two observation wells were also drilled on the retort. Observation well OB-3 was drilled to a depth of 79 feet and OB-4 was drilled to a depth of 86.9 feet. These four wells were drilled by GKI personnel with the Chicago-Pneumatic CP-650 drill rig. The locations of Retort #23 re-entry wells are shown in Figure 2.

The drilling of re-entry instrument wells on Retort #23 was completed in December. The wells were drilled by Steve's Drilling in accordance with the instrumentation program agreed upon by GKI and Sandia National Laboratories. The text of the Retort #23 burn plan is attached as Appendix B. Retort #23 instrument well locations are shown in Figure 2.

Re-entry drilling on Retort #25 began in December. The wells listed in the table on the following page were completed by Dave's Drilling. Each well was drilled with a diameter of eight inches and cased with 6-5/8 inch diameter steel casing. Retort #25 re-entry air well locations are shown in Figure 11.

RETORT PROCESS FACILITIES

Installation of instrumentation on Retort #24 was completed prior to retort ignition. Thermocouples were installed, wellhead thermocouple wiring was set in place and wires were run for each thermowell to the instrument shed on the retort. Thermocouple

RETORT #25 RE-ENTRY DRILLING

<u>Well Designation</u>	<u>Depth (feet)</u>
Air-In AI-1	79.0
AI-2	79.1
AI-3	76.2
AI-4	76.7
AI-5	76.4
AI-6	74.0
AI-7	74.4
AI-8	73.0
Air-Out AO-1	96.0
AO-2	96.0
AO-3	94.0
AO-4	93.8*
AO-5	95.0
AO-6	90.8*
AO-7	91.7*
AO-8	90.9*
AO-9	104.9*
AO-10	105.0*
AO-11	103.6*
AO-12	103.7*
AO-13	104.0
AO-14	100.9*
AO-15	100.7*
AO-16	98.1*

* Planned depth; depths had not been verified against drill logs at time of publication.

wires were attached to the multiplexer boards inside the instrument shed. The retort data acquisition and recording system was installed and activated. A schematic representation of the system is shown in Figure 9. Pressure transducers were installed, and the retort electrical system was installed and tested. Retort #24 process equipment was in place and ready for retort ignition by the end of October. Surface equipment was painted and made ready for ignition of the retort during November. The Retort #24 surface facilities layout is shown in Figure 7; re-entry air, production and observation well locations are shown in Figure 5; and thermocouple well locations are shown in Figure 6.

Air flow tests in October indicated that significant improvements were achieved at Retort #24 air-in wells AI-1 and AI-5 after springing the wells with small explosive charges. Air flow in AI-1 was increased from 200 scfm to 1300 scfm. Air flow at AI-5 improved from 390 scfm to approximately 4000 scfm. Air-in well AI-4 was also sprung and a significant improvement resulted. Air flow increased from 100 scfm to 650 scfm at AI-4; this well may require further stimulation.

Air flow tests using the vacuum blower were conducted on Retort #24 in November. These tests indicated the need for air-out well bore enhancement. Air-out wells AO-2, AO-3, AO-4, AO-5, AO-10, AO-12, AO-14, AO-15, and AO-16 were sprung with small explosive charges.

During the first month of the Retort #24 burn, process equipment was adjusted to improve efficiency. A 32-barrel capacity mist sump was installed to replace the 18-barrel sump which was too small. Extensive work was done on production well pumps to enhance recovery of oil from the retort. Check valves were cleaned and replaced. The Hydril Net Oil Computer fluid metering system malfunctioned; recalibration efforts were underway at the end of the quarter.

The Retort #24 data acquisition system performed reliably during December. Pressure transducers, however, are undergoing further calibration and testing. Manometers were used at the transducer locations. The data acquisition system was programmed to record a full suite of thermocouple and pressure transducer readings every hour. This will enable Lawrence Livermore National Laboratories to monitor the advance of the steam front expected to pass through the retort ahead of the burn front and to map out void distribution.

Connections for a new air-out blower for Retort #24 were fabricated in December. This will enable immediate installation of the new 200-horsepower blower when it arrives at the field site. The new air-out blower should result in improved vacuum capability.

The Retort #24 afterburner operated quite well. Preliminary evaluation of early stack gas analyses by the analytical laboratory indicated that efficient combustion of retort off gas was occurring.

RETORT BURN

The ignition of Retort #24 was accomplished over a two-day period beginning November 30, 1980. Retort #24 is the first full-sized prototype horizontal in situ retort, measuring 230 feet by 217 feet by 30 feet with an average of 45 feet of overburden. The oil shale grade averages 22 gallons per ton.

Retort #24 was ignited using the charcoal point ignition technique at each of the eight air injection wells. Air-in flows were increased gradually from a level of 43 scfm per well at ignition to 425 scfm per well by the end of the quarter. The burn continued as expected during the first month. The combustion front had reached the second row of thermocouples by the end of the quarter. Thermocouple data indicated that the full cross-section of the retort was being burned.

Sampling of Retort #24 process gas began in December. Samples were collected from the air-out line by laboratory personnel using stainless steel gas-sampling cylinders. The data obtained from the sampling program in December is summarized in Appendix A.

OIL PRODUCTION AND HANDLING

Production of oil from Retort #24 began midway through December and increased gradually throughout the rest of the quarter. Approximately 531 barrels of shale oil were recovered. Difficulties in pumping fluids from the retort were encountered, and fluid levels in the retort began rising late in December. This was due to cold oil, close to the pour point temperature, building up around the well bores and plugging the pump valves. This effect was not observed in previous retorts and is due to the much larger volume of Retort #24. Pump check valves were repaired or replaced during the quarter, and heavy duty oil field pumps were ordered and will be installed upon delivery. In order to prevent the problem of oil cooling on future retorts, production wells will be drilled closer to the air-in wells.

Geokinetics began shipping shale oil to WESRECO in Salt Lake City, Utah, in November. Shipments continued in December. The oil is being blended into #5 fuel oil and sold to industrial customers. Jim Lekas met with WESRECO to discuss future ship-

ments. WESRECO indicated that they are incurring no problems with the oil and anticipate future oil shipments.

Geokinetics met with Sandy Sandholtz of the Lawrence Livermore National Laboratory (LLNL) to discuss monitoring of a steam front expected to pass through Retort #24 ahead of the combustion front during the retort burn. Retort #24 data acquisition and handling will be coordinated with LLNL.

POST-BLAST AND POST-BURN EXAMINATIONS

Drilling for the Retort #25 post-blast core sampling program was completed in October. Core holes 25C, 25F and 25G were drilled to depths of 124.3 feet, 122 feet and 129.5 feet, respectively. These three core holes were drilled vertically; four angled core holes were completed in the last quarter. Retort #25 post-blast core hole locations are shown in Figure 10. Natural gamma radiation logs of Retort #25 core holes were run by Sandia National Laboratories.

Stratigraphic and breakage sections of each of the Retort #25 post-blast core holes were drafted during the quarter. The profiles were compared to core hole EXP-24, which was drilled prior to the blast of Retort #24 approximately 500 feet to the east of the Retort #25 post-blast core holes. The location of EXP-24 is shown in Figure 3. Core hole EXP-24 was cut in solid, undisturbed shale and proved useful in determining where and how the oil shale section was affected by the blast of Retort #25. Good breakage in the lower portions of Retort #25 was indicated.

The preparation of a report to be entitled "Blast-Induced Fracturing in Geokinetics Horizontal Retorts #24 and #25 as Indicated by Post-Blast Drilling" began in November. A preliminary partial draft of the report was completed in December and is undergoing in-house review. Additional information to be obtained from re-entry drilling on Retort #25 will be incorporated in the final report. Retort #24 post-blast core hole locations are shown in Figure 4.

Krypton tracer tests were conducted on Retorts #23 and #24 by Sandia National Laboratories.

SEPARATE EXPERIMENTS

Development of an experimental burn plan for the above ground horizontal in situ retort simulator began during the quarter. The objective will be low-cost testing of various retorting parameters as applied to a horizontal burn. The first run will serve primarily as a shakedown test of the steel retort simulation facilities.

ENVIRONMENTAL RESEARCH

The Utah Air Conservation Committee issued an air quality approval order and the U. S. Environmental Protection Agency (EPA) issued a Prevention of Significant Deterioration (PSD) permit. These conditional permits cover experimental retort burns planned through 1982. All permits needed for the burn of Retort #24 have now been obtained.

The evaporation pond liner was installed. Jack Brantl of Watersaver Company supervised the placement and sealing of the liner. Monitoring wells surrounding the evaporation pond were drilled and cased. The pond was inspected by representatives of the Utah Division of Oil, Gas and Mining and the Utah Water Pollution Committee. The location of the evaporation pond monitoring wells are shown in Figure 12.

The Phase I suite of water samples for the Retort #24 Water Monitoring Program were collected in October. Six-liter samples were collected from Retort #24 observation well OB-5 and each of the 12 wells shown in Figure 8. The wells surrounding Retort #24 will be monitored during and after the retort burn.

The sixth suite of native groundwater samples were collected from Series I wells #10 and #13 and Series II well #222. The sampling study was initiated in January to provide 18 native groundwater samples during 1980 and produce additional data for characterization of native groundwater existing directly above the mahogany oil shale zone at the project site. Three samples were collected every other month from wells located at least 200 yards from any retort that has been blasted. Wells sampled were chosen randomly from the twelve wells shown in Figure 13. The water samples are undergoing analysis at the GKI analytical laboratory. Sample collection will continue in 1981.

Geokinetics received approval from the Utah Division of Water Rights to appropriate an increased amount of water from the Kamp Kerogen well. Approval of the new leach field for the Kamp Kerogen sewage disposal system was received after an inspection by the Uintah Basin District Health Department. Completion and use of the new system can now proceed.

Revegetation test areas including previously-burned Retorts #10, #17, and #18 were established during the quarter. Test areas were contoured and soils cultivated with a disk harrow, and slopes were terraced to improve water retention on the sides of retorts. The new revegetation test areas, totalling 2.5 acres, were seeded with the following native grass species: western wheatgrass, intermediate wheatgrass, bluebunch wheatgrass, pubes-

cent wheatgrass, green needlegrass and Indian ricegrass. A two-year success evaluation period is planned for the test areas. The locations of the new test areas are shown in Figure 15.

The Environmental Research Record portion of the revised Environmental Research Plan was submitted to DOE/LETC in November.

Geokinetics was represented by Hilding K. L. Spradlin and David R. Lundberg at an EPA-sponsored Conference on Environmental Regulations Relating to Energy. The meeting provided a forum for discussion of environmental regulations affecting the energy industry and synthetic fuels development.

Geokinetics met with members of the DOE Oil Shale Task Force to continue discussions of Task Force involvement in environmental research associated with the horizontal in situ shale oil extraction process. Plans include Task Force participation in areas such as hydrology, fugitive emissions, effluent water handling, reclamation, and industrial/occupational health and safety.

In a related matter, scientists from the Los Alamos Scientific Laboratory (LASL) and the University of Utah (UOU) visited the field site in October to discuss a proposed industrial hygiene sampling program. The program is part of the DOE Oil Shale Task Force studies being conducted to examine and characterize the occupational environment and evaluate potential worker exposure associated with various oil shale recovery processes. Marv Tillery and Ken Hargis of LASL and Dr. Jeff Lee of the UOU Industrial Safety Department initiated an industrial hygiene study at the field site in December. The first phase of the study consisted of taking air samples on and near the surface of Retort #24.

Geokinetics researchers David R. Lundberg and Larry Morriss met with Monsanto Research Corporation representative in Dayton, Ohio, to evaluate the fugitive emissions monitoring procedures to be conducted on Retort #24. Geokinetics plans to utilize the same fugitive emissions monitoring procedures on Retorts #25, #26 and #27.

Quarterly maintenance of mechanical meteorological monitoring equipment was conducted in November. Data tapes in the electronic weather systems were changed also. The location of meteorological towers on Section 2 are shown in Figure 14. Routine meteorological monitoring activities continued throughout the quarter.

Retort #24 emissions to the atmosphere during the quarter were limited to December. Estimated emissions for December are

compared to the maximum allowable emissions stipulated by the PSD permit in the table below.

Retort #24 December 1980 Emissions vs.
Maximum Allowable Emissions

	Maximum Est. Emission (lbs/hr)	Maximum Allowable Emissions as per PSD Permit (lbs/hr)
Sulfur Dioxide (SO ₂)	13.50	135.30
Nitrogen Oxides (NO _x)	19.42	41.10
Hydrocarbons	Not Available	1.40
Particulates	Not Available	1.00
Carbon Monoxide (CO)	Nil	Nil

December estimates of emissions were based on the results of six process gas sample suites. Direct stack gas sampling was limited to carbon monoxide for the purpose of measuring the efficiency of the stack; therefore, emissions estimates for hydrocarbons and particulates are not available. The results of the December sampling are listed below.

Retort #24 December Off Gas Sampling Data

Average flow rate	3750 scfm
Average H ₂ S	350 ppm
Average SO ₂	255 lbs/day
Average SO ₂ (per MSCF)	0.046 lbs/MSCF
Average NH ₃	628 ppm
Average NO ₂	328 lbs/day
Average NO ₂ (per MSCF)	0.060 lbs/MSCF
Total SO ₂	7905 lbs.
	4.0 tons
Total NO ₂	10,168 lbs.
	5.1 tons

Stack gas measurements of carbon monoxide have demonstrated that the Retort #24 afterburner operated efficiently. The average concentration of carbon monoxide in stack emissions was estimated to be less than 10 ppm in December. Direct stack sampling for SO₂, NO_x, hydrocarbons and particulates will begin in 1981.

ANALYTICAL LABORATORY

Analysis of the pre-burn water samples for Phase I of the Retort #24 Water Monitoring Program began in October and continued throughout the quarter. In December, gas samples were taken at all 22 retort gas sampling points on Retort #24. Analysis of those samples was also underway at the end of the quarter. The retort gas analysis data summary for December is attached as Appendix A.

During the quarter, significant improvements were made to the Hewlett-Packard 5840A gas chromatograph which will result in increased accuracy and efficiency. A capillary column conversion was installed which will result in better resolution for peak identification which will enable comparison of aromatic olefinic and parafinic constituents in relation to retorting conditions and different locations in the retort. This will aid in the development of a reliable index of coking and/or cracking during retorting. A 30-meter column was installed first, but may be upgraded to a 60-meter column due to the complexity of shale oil. (Less analysis time will be required if the 30-meter column proves satisfactory.) Analyses using the capillary column will require some pretreatment of samples, such as distillation to remove any heavy or particulate matter.

In addition, a flame photometric detector (FPD) for the HP-5840A gas chromatograph was installed. The unit will be used in the analysis of retort gas streams for sulfur gases such as hydrogen sulfide (H₂S), carbonyl sulfide (COS), carbon disulfide (CS₂), sulfur dioxide (SO₂) and light thiols. The addition of the FPD will reduce analysis time for those gas constituents from 2-4 hours per constituent to approximately 30 minutes for all constituents.

The laboratory continued to experience problems with gas chromatographs due to electrical power fluctuations or power being cut-off.

KAMP KEROGEN FACILITIES

Routine maintenance of Kamp Kerogen continued. Facilities were winterized in October; evaporative coolers were drained and

covered with plastic, and trailer furnaces were inspected. The new leach field for the Kamp sewage disposal system was prepared for inspection by local health authorities.

SUPPORT ACTIVITIES

A natural gas line to the new 650 kilowatt (KW) generator was installed. The generator was set up and put into service. Repairs of the 75KW natural gas powered generator were performed, the boom on the crane was replaced, and a transformer at the tank battery was replaced. Routine equipment maintenance and repair work continued.

A large quantity of pipe (ranging in size from 1/2-inch diameter to 10-inches diameter) and valves (ranging from 1/2-inch to 6-inches) were brought from the DOE Rock Springs site to Kamp Kerogen.

GENERAL AND ADMINISTRATIVE

The second session of a two-part, eight-hour fire safety training series was held in October. The class was part of a continuing safety training program provided by an Occupational Safety and Health Administration (OSHA) grant administered by the Utah Technical College. Fire fighting theory was outlined by a professional fire fighter, who supervised a practical demonstration of fire extinguisher use. Geokinetics staff and adult Kamp residents received hands-on experience using fire extinguishers.

Implementation of the revised Kamp Kerogen Industrial Health and Safety Plan began during the quarter. A safety survey of Kamp housing facilities was initiated.

Surplus safety equipment at a DOE facility in South Dakota was examined by GKI health and safety supervisor Larry Morriss. The use of some of the available equipment was requested.

Geokinetics President Mitchell A. Lekas traveled to Morocco in October to participate in the Oil Shale Colloquium co-sponsored by the Kingdom of Morocco, the Agency for International Development (U. S. Department of State) and DOE. The objectives of the meeting was to present U. S. oil shale technology to Moroccan officials and acquaint them with U. S. companies interested in doing business in Morocco. The Kingdom of Morocco plans to develop a 100,000 barrel per day oil shale industry and bring it on line as soon as possible. Moroccan officials expressed substantial interest in the application of Geokinetics' LOFRECO (Low Front End Cost) retorting process to their shallow oil shale deposits.

Jose Luis Bergal-Fernandez and Luis C. Fernandez-Espinar of ENADIMSA (Empresa Nacional Adaro de Investigaciones Mineras, S.A.) toured the project and were briefed on the horizontal in situ oil shale retorting process. ENADIMSA is an agency of the Spanish government.

Mr. David Gustafson of the House Energy and Power subcommittee visited Kamp Kerogen on a tour of oil shale facilities. Representatives of the Utah Division of Oil, Gas and Mining also toured the project during the quarter.

Geokinetics, Paraho, Tosco, and the White River Shale Project participated in Energy Expo '80, sponsored by the Utah Energy Office. David Hutchinson presented an exhibit describing Utah's oil shale resources and current research activities. Samples of shale oil were displayed and oil shale rock samples were distributed.

Jim Lekas represented GKI at an industrial advisory meeting in Vernal. The purpose of the meetings between existing industries and potential industries, such as oil shale, is to discuss what government could do to encourage these industries.

Geokinetics began a comprehensive study of drilling machines, equipment and techniques. Drilling rigs offered for lease and/or purchase by a number of suppliers were examined on the job; and discussions were held with the drill operators, drill users, and the manufacturers.

Figure 1. Geokinetics Inc. Field Site

PLAN VIEW

- ⊕ PRODUCTION WELL
- ⊕ OBSERVATION WELL
- ⊙ AIR-IN WELL
- ⊗ AIR-OUT WELL
- △ THERMOCOUPLE WELL

SCALE: 1" = 20'

6

Figure 2. Retort #23 - Re-Entry Well Locations

NE SEC. CORNER, SEC. 2, T14S,
R22E, UINTAH COUNTY, UTAH.

GEOKINETICS INC.

Figure 3. Pre-Blast Core Hole Locations

Figure 4. Retort #24 - Post-Blast Core Hole Locations

- ✦ PRODUCTION WELL
- ⊙ OBSERVATION WELL
- AIR-IN WELL

GEOKINETICS INC.

✦

Figure 5. Retort #24 - Re-Entry Air, Production and Observation Well Locations

LEGEND

△ THERMOCOUPLE WELL

⬡ PRESSURE WELL

PLAN VIEW

SCALE: 1" = 50'

Figure 6. Retort #24 - Instrument Well Locations

Figure 7. Retort #24 - Surface Facilities Layout

Figure 8. Retort #24 - Water Monitoring Well Locations

Figure 9. Retort #24 - Data Acquisition System Schematic

Figure 10. Retort #25 - Post-Blast Core Hole Locations

SCALE: 1" = 50'

1/6

⊙ AIR-IN/AIR-OUT WELL

Figure 11. Retort #25 - Re-Entry Air Well Locations

POND LAYOUT

CROSS SECTION

GEOKINETICS INC.

SCALE: NONE

KG

Figure 12. Evaporation Pond Monitoring Well Locations

GEOKINETICS INC.

46

0 500' 1000'
SCALE

Figure 13. Location of Native Groundwater Wells on Section 2

SEC. 2, T14S, R22E, UTAH COUNTY, UTAH

GEOKINETICS INC.

0 500' 1000'
SCALE

Figure 14. Location of Meteorological Towers

GEOKINETICS INC.

KAMP KEROGEN, UTAH

Figure 15 Revegetation Test Areas

APPENDIX A

RETORT #24 GAS DATA SUMMARY

Retort #24 was ignited on November 30 and December 1, 1980. Gas sampling began on December 12, 1980. Retort gas samples were collected from the air-out line.

The samples were collected by aspirating gas from the sample point into a steel gas sampling cylinder. The contents of each cylinder was then analyzed at the GKI Analytical Laboratory using a Hewlett-Packard 5830A gas chromatograph.

A summary of the raw data obtained in December is attached. No further analysis of the data has been completed and no evaluations or conclusions are offered at this time.

DATA SUMMARY

[illegible]

RETORT 24

DATA SUMMARY

All samples collected from air-out line.

DATE	E.D.	TIME	GAS ANALYSIS (%) (refer to Key)									
			1	2	3	4	5	6	7	8	9	
12/1	0		—	—	—	—	—	—	—	—	—	
12/2	1		—	—	—	—	—	—	—	—	—	
12/3	2		—	—	—	—	—	—	—	—	—	
12/4	3		—	—	—	—	—	—	—	—	—	
12/5	4		—	—	—	—	—	—	—	—	—	
12/6	5		—	—	—	—	—	—	—	—	—	
12/7	6		—	—	—	—	—	—	—	—	—	
12/8	7		—	—	—	—	—	—	—	—	—	
12/9	8		—	—	—	—	—	—	—	—	—	
12/10	9		—	—	—	—	—	—	—	—	—	
12/11	10		—	—	—	—	—	—	—	—	—	
12/12	11	8:30AM	62.349	5.352	0.186	0.132	0.002	0.011	0.047	0.060	0.010	
12/13	12	8:45AM	61.715	5.493	0.148	0.109	0.003	0.012	0.049	0.060	0.002	
12/14	13	8:30AM	61.197	6.067	0.148	0.109	0	0.004	0.047	0.056	0.011	
12/15	14	8:30AM	60.496	6.291	0.147	0.105	0.002	0.014	0.050	0.059	0	
12/16	15	8:30AM	?									
12/17	16	7:30AM	58.997	6.074	.163	.097	.003	.014	.050	.058	.003	
12/18	17	3:40AM	59.688	6.364	.158	.093	0	.009	.043	.049	.003	
12/19	18		?									
12/20	19	11:00AM	52.745	6.261	0.128	0.086	0.004	0.036	0.071	0.060	0.002	
12/21	20	10:30AM	58.544	7.030	.152	.101	.004	.033	.050	.052	.002	
12/22	21	10:00AM	60.500	6.839	0.128	.085	.004	.015	.043	.046	0	
12/23	22		60.531	6.584	0.115	0.071	0.009	0.023	0.042	0.043	0.008	
12/24	23											
12/25	24											
12/26	25											
12/27	26		61.868	5.773	.132	.074	.004	.011	.033	.028	.001	
12/28	27		59.221	7.933	.130	.067	.003	.011	.034	.027	.009	
12/29	28											
12/30	29				A-3							

RETORT 24 DATA SUMMARY

DATE	E.D.	TIME	GAS ANALYSIS (%)									
			10	11	12	13	14	15	16	17	18	
12/1	0		—	—	—	—	—	—	—	—	—	
12/2	1		—	—	—	—	—	—	—	—	—	
12/3	2		—	—	—	—	—	—	—	—	—	
12/4	3		—	—	—	—	—	—	—	—	—	
12/5	4		—	—	—	—	—	—	—	—	—	
12/6	5		—	—	—	—	—	—	—	—	—	
12/7	6		—	—	—	—	—	—	—	—	—	
12/8	7		—	—	—	—	—	—	—	—	—	
12/9	8		—	—	—	—	—	—	—	—	—	
12/10	9		—	—	—	—	—	—	—	—	—	
12/11	10		—	—	—	—	—	—	—	—	—	
12/12	11	8:30AM	0	0	0	0.022	0	1.084	1.353	4.214	24.314	
12/13	12	8:45AM	0.003	0	0.002	0.011	0	1.183	1.369	4.580	24.307	
12/14	13	8:30AM	0	0	0	0.006	0	1.014	1.394	4.850	24.579	
12/15	14	8:30AM	0	0	0	0.030	0	0.996	1.380	4.570	25.431	
12/16	15	8:30AM	?									
12/17	16	7:50AM	.003	0	0	.004	.003	1.279	1.438	5.739	25.664	
12/18	17	3:40PM	0	0	0	.027	0	1.755	1.348	5.173	25.214	
12/19			?									
12/20	19	11 AM	0	0	0.003	0.022	0	1.595	3.990	8.728	22.400	
12/21	20	10:30AM	0	.007	0	.022	0	1.825	1.691	5.933	24.192	
12/22	21	10:00AM	0	0	0	.026	0	2.423	1.264	5.605	22.586	
12/23	22		.004	0	0	.020	0.003	2.428	3.005	5.863	20.992	
12/24	23											
12/25	24											
12/26	25											
12/27	26		0	0	0	0	0	2.551	1.270	6.074	21.859	
12/28	27		0	0	0	0	0	1.667	1.389	6.414	22.201	
12/29	28											
12/31	29					A-4

RETORT 24 DATA SUMMARY

DATE	E.D.	TIME	GAS ANALYSIS (%)					ETHENE/ETHANE		HEAT OF COMB. (B.T.U./FT ³)	
			19	20	21	22	23				
12/1	0		—	—	—	—	—	—	—	—	—
12/2	1		—	—	—	—	—	—	—	—	—
12/3	2		—	—	—	—	—	—	—	—	—
12/4	3		—	—	—	—	—	—	—	—	—
12/5	4		—	—	—	—	—	—	—	—	—
12/6	5		—	—	—	—	—	—	—	—	—
12/7	6		—	—	—	—	—	—	—	—	—
12/8	7		—	—	—	—	—	—	—	—	—
12/9	8		—	—	—	—	—	—	—	—	—
12/10	9		—	—	—	—	—	—	—	—	—
12/11	10		—	—	—	—	—	—	—	—	—
12/12	11	8:30AM	0.398	0.466	0	0	0	0.854			
12/13	12	8:45AM	0.364	0.590	0	0	0	0.617			
12/14	13	8:30AM	0.220	0.299	0	0	0	0.736			
12/15	14	8:30AM	0.141	0.289	0	0	0	0.488			
12/16	15	8:30AM	?								
12/17	16	7:50AM	.143	.256	.005	.003	0	0.559			
12/18	17	3:40PM	.276	.400	0	0	0	0.690			
12/19	?		?								
12/20	19	11AM	1.131	1.755	0	0.003	0	0.644			
12/21	20	10:30AM	.128	.229	0	0	0	0.559			
12/22	21	10:00AM	.072	.352	0	0	0	0.205			
12/23	22		.052	.137	0	.002	0	.380			
12/24	23										
12/25	24										
12/26	25										
12/27	26		.116	.205	0	0	0	.566			
12/28	27		.274	.196	0	0	0	.593			
12/29	28										
12/30	29										

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APPENDIX B

The attached "Instrumentation and Operational Plan for Geokinetics Retort No. 22" (SAND 80-0564) prepared by Sandia National Laboratories will be used for the Retort #23 burn plan.

APPENDIX B

SAND 80-0564

**Instrumentation and Operational Plan
for
GeoKinetics Retort No. 22**

**R. L. Parrish
Oil Shale Programs Division 4734**

**P. J. Hommert
Thermal Processes Division 4737**

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ABSTRACT

Sandia Laboratories supports the Department of Energy's in situ oil shale program through instrumentation and technical evaluation of designated field experiments. This report outlines the general plan for the instrumentation and technical direction of a horizontal in situ retorting experiment to be conducted at the Geokinetics, Inc. field site in Uintah County, Utah. Bed preparation has been accomplished by Geokinetics by blasting the retort zone with explosives emplaced in wells drilled from the surface. Retorting will be a joint Geokinetics-Sandia effort--Geokinetics will operate the surface processing equipment; Sandia will provide the instrumentation and technical direction with emphasis on the acquisition of data to provide an in depth understanding of the intra-retort dynamics.

Downhole instrumentation will consist of 300 thermocouples and 28 combustion gas sampling ports to monitor the movement of the reaction front during the retorting process. Surface instrumentation will provide measurements of flow rates, gas composition, liquid products and other process parameters to monitor the overall operation of the process. The operational plan includes provision for data interpretation and real time material balance calculations in the field, including an evaluation of the effect on processing rates and oil yield due to the use of recycled combusted off gases and changes in rate of injection of inlet gases.

I. INTRODUCTION

Sandia Laboratories supports the Department of Energy's Fossil Fuels Extraction Programs through participation in field experiments related to the development of underground coal gasification and in situ extraction of oil from shale. The scope of activities includes predictive modeling, instrumentation of field experiments, diagnostic and formation assessment measurements, interpretation of experiment data, and technical evaluation of the experiments. Significant contributions to these programs are the development of instruments to more adequately interrogate the experiments and the development of advanced modeling techniques.

This report outlines the general test plan for the instrumentation and technical direction of an in situ oil shale retorting experiment to be conducted at the Geokinetics, Inc. (GKI) field site approximately 70 miles south of Vernal, Utah. This experiment is being conducted as a joint GKI-Sandia venture. Bed preparation (rubblization) and operation of the surface processing equipment during the experiment will be done by GKI; Sandia will be responsible for the technical direction, instrumentation, data acquisition, and overall evaluation. Emphasis will be placed on instrumentation and data acquisition in sufficient detail to acquire an in-depth understanding of the retorting process such that oil production and overall efficiency of future in situ projects may be maximized.

II. BACKGROUND

The Geokinetics, Inc. in situ oil shale recovery program is an industry-government cooperative venture, governed by D.O.E. Agreement No. DE-FC20-78LC10787, to develop a true in situ process for recovering shale oil by progressing a retorting front horizontally through the bed.⁽¹⁾ The oil shale at the GKI project site is in the mahogany zone, is about 30 feet (9 m) thick, and has an average grade of ~ 23 gal/ton. Overburden ranges from essentially zero to a maximum of ~ 60 feet (18 m) at this site.⁽²⁾

The GKI LOFRECO (low front end cost) true in situ process for extracting oil from oil shale is designed to retort relatively thin shale beds under shallow overburden.^(1,2) In this process the shale is fractured by means of explosives placed in boreholes drilled from the surface. After a specific volume has been fractured, injection wells are drilled at one end of the fractured zone, and off-gas and liquid recovery wells at the other. The oil shale is ignited at the injection wells and an oxidant (air or air plus recycle gas) is continually injected to establish and maintain the combustion front. The burn front moves in a horizontal direction through the fractured rock, heating the oil shale ahead of the combustion front, decomposing kerogen which produces oil that drains to the bottom of the retort where it is recovered through oil production wells (Figure 1). The residual coke left from the retorted oil shale is utilized as fuel.

Through 1979, bed preparation via blasting has been executed on 23 retort sites, of which 12 have been retorted. These retorts have been of various sizes, ranging from 40 to 156 feet (12 to 48 m) in length and 10 to 108 feet (3 to 33 m) in width, with the retort zone thickness ranging from 10 to 23 feet (3 to 7 m). The overburden has ranged from essentially zero to ~ 45 feet (14 m). The retort geometries for recent burns were similar to that shown in Figure 1.

The horizontal in situ process, as employed by GKI, wherein the porosity and permeability necessary for retorting is introduced by overburden uplift during blasting, has been successful in the production of shale oil, as shown in Table 1.(2) Recovery, based on the quantity of oil in the shale, has been on the order of 40-55% of Fisher Assay. This has demonstrated the oil production capability of this method, although gas losses through the overburden have been a problem.

Future efforts in the LOFRECO program will concentrate on regions with increased overburden thickness, together with gaining a greater understanding of the blasting and retort processes so as to maximize oil production per ton of shale. To this end, GKI will be retorting full scale modules of commercial retorts during 1980 via a pragmatic approach; Sandia will conduct a small retort (GKI Retort #22) as a scientific test module.

III. EXPERIMENT OBJECTIVES

The overall objective of burning GKI Retort 22 is to increase the understanding of the horizontal in situ retorting process, which, in turn, should lead to increased efficiency and greater oil yield. Specific technical objectives are to:

1. Determine spatial distribution of the retort and correlate this with the results of the post-blast formation assessment.
2. Quantify gas losses and their effect on over-all yield, e.g., percent injected air versus percent produced gas lost.
3. Determine intra-retort dynamics and local retorting efficiency, e.g., block versus packed bed, oil versus char combustion.
4. Determine effect of variations in injected gas compositions and rates on retorting efficiency and rates. Specifically, the effects of the addition of combusted recycle gas will be examined.
5. Determine the usefulness of point variation in the injected gas rate and/or composition for obtaining or maintaining spatial control of the combustion front.

A secondary set of objectives, relating to the determination of the viability of various analytical and instrumentation techniques are to:

1. By comparison with independent measurements, determine the usefulness of retort off-gas analyses (e.g., material balance, alkene/alkane ratios) as retort diagnostics.

2. Determine relative merits of various thermocouple materials in the retort environment.
3. Investigate the viability of the inverted thermocouple concept in an oil shale retort.
4. Determine the reliability of intra-retort gas sampling as a test diagnostic.
5. Utilize a data acquisition system for real time analyses of measured data.
6. Provide measurements for comparison of analytical models with test results, thereby determining the usefulness of the models as predictive tools.

Specific objectives may be modified as the experiment progresses, but the over-all purpose, to obtain in depth scientific information, will be adhered to.

IV. BED PREPARATION

The rubble bed for Retort 22 was created by GKI in July 1979, by the detonation of slurry explosive in blast holes drilled from the surface. The uplift of the overburden induced by the explosives allows vertical and horizontal motion of the shale during the fracturing sequence and provides a rubblized zone. Measurements of the surface uplift versus time and the residual surface heave were made by Sandia. GKI performed pre- and post-shot surface level surveys which also provided the residual surface uplift. Surface heave contours are shown in Figure 2. Estimated void volume based on surface heave is ~ 10%. Both the transient motion and residual heave measurements showed that the surface uplift was nearly uniform over the entire blast zones. Further, the maximum and residual surface uplift was less than recorded during the blasting of nearby retorts. (This was in accordance with the blast design.) As a result, gas losses through the overburden during retorting may be less, permitting more accurate retort material balance calculations.

V. FORMATION ASSESSMENT

Five post-blast cores were extracted by GKI at the locations and orientations shown in Figure 3. These cores have been analyzed by the GKI geologist. The core analyses will be coupled with other formation assessment measurements for use in the selection of downhole instrument locations and process parameters. Additional cores will be taken during the drilling of instrument wells to provide data regarding the degree of rubblization at particular instrument locations. Cores will also be used to determine the vertical distribution of shale grade and mineral content in the vicinity of the retort.

Airflow pressure tests and krypton 85 tracer tests will be conducted. Tests with the Sandia downhole injection-detection system (Figure 4) will be made in the process and observation wells (Figure 3). These measurements should provide information regarding the vertical distribution of the active void volume. Tracer tests utilizing the LETC ^{85}Kr tracer system will be conducted to ascertain estimates of the lateral uniformity of the airflow versus the distance along the retort and active void volume prior to (cold flow) and during (hot flow) retorting. These estimates of active void volume will be used for selection of instrument locations and specification of process parameters (e.g., flow rates).

Geophysical (e.g., gamma-gamma density, neutron porosity) logs will be made in and around the rubblized zone. This will provide comparative measurements of the degree of fracturing as well as baseline data regarding the relative merits of evaluating rubble in oil shale with these techniques.

thermocouple levels along the retort coupled with a nominal three foot spacing insures complete coverage of the retort zone while providing constant levels with respect to the base of the zone, simplifying analyses.

As shown in Figures 5 and 6, inverted thermocouple strings will be emplaced in three wells. Each string will have eight thermocouples; which, together with a string of six thermocouples emplaced from the surface, will provide more complete vertical coverage of the retort zone in these wells. The inverted thermocouple strings will be terminated at transmitters emplaced below the retort zone. The thermal signals will be transmitted to dual receivers located in wells outside the retort (Figure 5). The receivers will be hard-wired to the data acquisition system. The inverted thermocouple system used will be an improved version of equipment successfully tested in the Hoe Creek III Underground Coal Gasification test (3) and will be the first application of this technology in oil shale retorting. The improvements to the system will allow resistance diagnostics to be made on the thermocouples.

Intra-retort pressure and gas sampling ports will be emplaced in 14 wells, (Figure 5). Two 1/2 inch diameter pipes will be installed in each of these wells, with one sample port in each pipe at the levels listed in Table 3. The pipes will be terminated at the surface with pressure transducers and valves to permit "grab samples" of in-formation gasses. In eleven wells, the two sample ports will be at two discrete levels within the retort zone; in three wells one of the sample ports will be in the overburden for use in investigating the nature of gas losses.

VI. INSTRUMENTATION PLAN

The instrumentation plan is designed to meet specific, as well as over-all, experiment objectives as discussed in Section III. The general plan, as presented herein, will be used for procurement of hardware and definition of the data acquisition requirements. The final design layout, (e.g., specific levels of thermocouple and gas sampling ports) may be adjusted as appropriate in response to the results of the formation assessment. The plan is presented in two categories; in-formation (downhole) and surface instrumentation.

A. Downhole Instrumentation

Downhole instrumentation consisting of thermocouples and ports for pressure and gas sampling measurements will be emplaced in 26 vertical wells and one slant well ($\approx 30^\circ$), as depicted in Figure 5 and listed in Tables 2 and 3. The thermocouples will be spaced through the retorting zone and for a distance up into the overburden (Figure 6). Each well will have either six or ten 1/8 inch diameter 310 stainless steel sheathed, high temperature ($\approx 2000^\circ\text{F}$ maximum) thermocouples, spaced at either 3-feet (1 m) or 6-feet (2 m) intervals, depending on the particular well location. In addition, either two or three low temperature sheathed ($\approx 500^\circ\text{F}$ maximum) thermocouples will be placed in the overburden to determine the thermal effects near the surface. The base of the retort zone dips approximately 15 feet (4.5 m) through the total retort length; hence, the thermocouple strings will be shifted downward approximately 3 feet (1 m) per 25 feet (4.5 m) of retort length. The shifting of the

B. Surface Instrumentation

The surface instrumentation will permit measurement and analyses of the process and reaction parameters, e.g., injection and production gas flow rates, gas compositions, and oil and water production. A sketch of the surface layout, modeled after GKI Retort 17, is shown in Figure 7. The final process and instrumentation drawing (P&ID) will be coordinated with GKI.

The insertion gas flow system will provide the capability of delivering either air or a mixture of air and combusted recycle gas to the injection wells. Flow measurements will be made in the recycle lines upstream of the blowers, and in the combined gas injection lines between the blowers and each injection well. The flow section provides for measurement of the differential pressure, absolute pressure and gas temperature. The production gas flow will be measured in the same manner with flow sections in the lines between each gas production well and the demist equipment and in the total gas production line downstream of the demist system.

Combined on-line and grab sample ports will be installed in the flow lines to each injection well and in the production flow line downstream of the demist system. These lines will permit analysis of the air-recycle mix in the inlet stream and the production gases. This will allow on-line real time analysis of the retort gasses, with the grab sample as backup. The on-line sample ports will be connected to a gas chromatograph which, in turn, is linked directly to the data acquisition system.

The oil-water collection system, as used by GKI, will be installed for this retort. The interface of this system with the data acquisition system will be by manual entry, with the possible exception of the oil-water flow measurement.

VII. DATA ACQUISITION SYSTEM

The data acquisition system, housed in a Sandia instrumentation trailer, will include a field cable termination board, zone boxes, signal conditioners, and a central data collection and storage system. The central data collection system will consist of a primary system utilizing a Modcomp computer and associated peripheral equipment, with data loggers for backup data collection. The primary data to be acquired will consist of thermal measurements from ~300 thermocouples, pressure from ~36 pressure transducers, computed flow measurements, and gas analyses from the on-line gas chromatograph. Additional retort information, such as oil-water production and gas analyses from the 26 "grab-sample" gas ports on the instrument wells, will be added to the central data acquisition and storage system manually.

The primary data acquisition-storage system will permit sampling all or a portion of the temperature and pressure points at variable rates. Gas analyses from the on-line gas chromatograph, will be sampled at a variable rate with a typical frequency of one hour. These include the species O_2 , N_2 , Ar, CO, CO_2 , CH_4 , C_2H_4 , C_2H_6 , C_3H_6 , C_3H_8 , C_4 , and C_5 .

The computer system will provide a range of data listing and plotting capabilities. These will include time histories of data, well thermal profiles, and pressure and temperature contours at discrete times.

In addition to raw data, certain computed quantities, such as those that would result from material and energy balances, will be stored in the system. The status of all thermocouples will be

The oil-water collection system, as used by GKI, will be installed for this retort. The interface of this system with the data acquisition system will be by manual entry, with the possible exception of the oil-water flow measurement.

monitored through loop resistance diagnostics. A display of the current functional thermocouples will be available at all times. All user programs pertaining to data acquisition, manual data entry, plotting, listing, analysis, etc. will be organized into a tutorial system that will be user oriented (e.g., simple and convenient).

VIII. OPERATIONAL PLAN

The guidelines for the conduct of the retort attempts to address the experiment objectives as closely as is possible consistent with the site facilities. The preliminary plans are also sufficiently flexible to be adjusted as deemed advisable through the retorting period. The operational plan outlined herein assumes individual control of the two injection flow rates and the capability to inject various percentages of a combined off-gas/air mixture. The rubble zone of Retort 22 has a cross-sectional area of approximately 1150 ft². A blower system with the capability to inject at superficial gas velocities up to 1.5 ft/minute (e.g., 1800 scfm, = 900 scfm in each well) is assumed to be available.

The proposed operating conditions, based on the above assumed airflow capabilities and estimates of associated retorting rates, are presented in outline form in Table 4. In general, the plan is for ignition and establishment of combustion, burning with air injection until the flame front has proceeded about one-third of the way along the retort, addition of recycle gas through the middle third of the retort, and air only injection through the remainder of the retort. Modifications to the general plan may be addressed, based on gas losses, retorting rates, material and energy calculations, etc.

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2. Lekas, M. A., "The Geokinetics In Situ Shale Oil Recovery Project, Second Annual Report", LETC-10787-25, March 1979.
3. Glass, R. E., Editor, "Instrumentation and Process Control Development for In Situ Coal Gasification, Seventeenth, Eighteenth and Nineteenth Quarterly Reports", SAND 79-2386, February 1980.

Table 1
Summary of Data on GKI Retorts 1 through 24 (to 12/31/79)

Retort Number	Date Blasted	Thickness of Shale Blasted	Overburden Thickness	Width	Length	Cross- Sectional Area ft ²	Tons of Broken Shale	Date Ignited	Barrels of Oil Recovered
1	7/75	10 ft	0 ft	10 ft	50 ft	100	330	9/76	56
2	7/75	3	10	10	30	30	60	3/76	28
3	1/76	10	17	20	40	200	530	7/76	82
4	2/76	10	16	20	40	200	530	2/77	146
5	2/76	11	19	20	81	220	1200	5/77	354
6	Drilled--Not Blasted								
7	11/76	10	15	20	50	200	670	-	-
8	11/76	23	22	20	83	460	2600	-	-
9	12/76	22	22	40	83	880	4900	9/77	1007
10	12/76	11	14	20	50	220	730	-	-
11	3/77	12	14	20	45	240	720	4/77	272
12	3/77	11	31	30	50	330	1100	-	-
13	6/77	11	31	30	50	330	1100	-	-
14	6/77	12	29	40	70	480	2200	2/78	384
15	7/77	20	31	50	75	1000	5000	5/78	1003
16	8/77	20	41	62	87	1200	7200	8/78	2067
17	5/78	17	26	72	156	1200	13000	6/79	3775
18	7/78	17	27	108	156	1800	19000	11/79	-
19	12/78	30	50	126	182	3800	46000	-	-
20	4/79	24	36	40	100	960	6100	-	-
21	6/79	23	35	40	100	920	6100	-	-
22	6/79	23	34	50	125	1150	7700	-	-
23	9/79	24	36	50	125	1200	8000	-	-
24	11/79	28	45	217	230	6076	94000	-	-

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Table 2: Downhole Thermocouple Locations. The Z Coordinate in each well is the distance in feet above 6640 Feet M.S.L. Underlined depths denote low temperature thermocouples.

WELL	X	Y	Z															
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	5.0	-6.25		23.0	26.0	29.0	32.0	35.0	38.0	41.0	44.0	47.0	50.0				<u>60.0</u>	<u>70.0</u>
2	5.0	6.25		23.0	26.0	29.0	32.0	35.0	38.0	41.0	44.0	47.0	50.0				<u>60.0</u>	<u>70.0</u>
3	17.5	-17.5		23.0		29.0		35.0		41.0		47.0		53.0			<u>60.0</u>	<u>70.0</u>
4	17.5	0			26.0		32.0		38.0		44.0		50.0		56.0		<u>60.0</u>	<u>70.0</u>
4I	17.5	0	20.0	23.0	26.0	29.0	32.0	35.0	36.5	39.5								
5	17.5	17.5		23.0		29.0		35.0		41.0		47.0		53.0			<u>60.0</u>	<u>70.0</u>
6	30.0	-25.0		20.0		26.0		32.0		38.0		44.0		50.0			<u>60.0</u>	<u>70.0</u>
7	28.5	-12.5		20.0	23.0	26.0	29.0	32.0	35.0	38.0	41.0		47.0		53.0		<u>60.0</u>	<u>70.0</u>
8	32.5	-12.5				26.0		32.0		38.0		44.0		50.0		56.0	<u>60.0</u>	<u>70.0</u>
B-23 8I	32.5	-12.5	17.0	20.0	23.0	26.0	29.0		35.0	36.5	39.5							
9	30.0	10.0		20.0	23.0	26.0	29.0	32.0	35.0	38.0	41.0		47.0		53.0		<u>60.0</u>	<u>70.0</u>
10	30.0	25.0		20.0		26.0		32.0		38.0		44.0		50.0			<u>60.0</u>	<u>70.0</u>
11	42.5	-32.0		20.0		26.0		32.0		38.0		44.0		<u>50.0</u>			<u>60.0</u>	<u>70.0</u>
12	42.5	-16.0		20.0		26.0		32.0		38.0		44.0		50.0			<u>60.0</u>	<u>70.0</u>

Table 2 (continued)

	X	Y	Z															
WELL			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
13	42.5	0.0		20.0	23.0	26.0	29.0	32.0	35.0	38.0	41.0		47.0		53.0		<u>60.0</u>	<u>70.0</u>
14	42.5	20.0		20.0		26.0		32.0		38.0		44.0		50.0			<u>60.0</u>	<u>70.0</u>
15	55.0	-19.5			20.0		26.0		32.0		38.0		44.0		50.0		<u>60.0</u>	<u>70.0</u>
16	55.0	-10.0			20.0	23.0	26.0	29.0	32.0	35.0	38.0	41.0		47.0		53.0	<u>60.0</u>	<u>70.0</u>
17	54.0	5.0			20.0	23.0	26.0	29.0	32.0	35.0	38.0	41.0		47.0		53.0	<u>60.0</u>	<u>70.0</u>
18	58.0	5.0						29.0		35.0	38.0	41.0		47.0		53.0	<u>60.0</u>	<u>70.0</u>
18I	58.0	5.0	14.0	17.0	20.0	23.0	26.0		32.0	35.0	36.5							
19	55.0	17.5			20.0		26.0		32.0		38.0		44.0		50.0		<u>60.0</u>	<u>70.0</u>
20	55.0	30.0			20.0		26.0		32.0		38.0		44.0		50.0		<u>60.0</u>	<u>70.0</u>
21	80.0	-24.0		17.0		23.0		29.0		35.0		41.0	44.0		<u>50.0</u>		<u>60.0</u>	<u>70.0</u>
22	80.0	-12.5		17.0	20.0	23.0	26.0	29.0	32.0	35.0	38.0	41.0	44.0		<u>50.0</u>		<u>60.0</u>	<u>70.0</u>

Table 2 (continued)

	X	Y	Z															
WELL			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
23	80.0	20.0		17.0	20.0	23.0	26.0	29.0	32.0	35.0	38.0	41.0	44.0		<u>50.0</u>		<u>60.0</u>	<u>70.0</u>
24	92.5	-8.5		14.0		20.0		26.0		32.0		38.0		44.0		<u>50.0</u>	<u>60.0</u>	<u>70.0</u>
25	92.5	8.5		14.0		20.0		26.0		32.0		38.0		44.0		<u>50.0</u>	<u>60.0</u>	<u>70.0</u>
26	-15.5	0.0		26		32		38		44		50						

TS-1 Slant (30°) Well

100.3 -4.0 @ z = 82.5 [Y = -4.0 for all points, X = 100.3 - $\frac{1}{\sqrt{3}}$ (82.5 - z)]

x		62.5	64.2	66.0	67.7	69.4	71.2	72.9	74.6	76.4	78.1		81.6		87.3	93.1
z		17.0	20.0	23.0	26.0	29.0	32.0	35.0	38.0	41.0	44.0		<u>50.0</u>		<u>60.0</u>	<u>70.0</u>

Thermocouple totals

High Temp 220

Low Temp 63

Table 3
Gas Sample Port Locations

The position in each well is the
distance in feet above 6640 M.S.L.

Well	Coordinates				
	X	Y	Z1	Z2	Z3
3	17.5	-17.5	29.0	41.0	
5	17.5	23.0	23.0	29.0	
7	28.5	-12.5	29.0	38.0	
9	30.0	10.0		38.0	60.0
11	42.5	-32.0	26.0	38.0	
12	42.5	-16.0	26.0	38.0	
14	42.5	20.0	26.0	38.0	
16	55.0	-10.0	26.0	38.0	
17	54.0	5.0	26.0	38.0	
20	55.0	30.0	26.0	38.0	
22	80.0	-12.5		35.0	50.0
23	80.0	20.0		35.0	50.0
24	92.5	- 8.5	20.0	32.0	
25	92.5	8.5	20.0	32.0	

Total = 28 ports in 14 wells

Table 4. Operation Plan

Day of Test

Test Conditions

0

Ignition by propane burner.

0 - 5

Ignition phase air injection (200-400 scfm/per well)

-5 - 25

Steady air burn. Injection rates dependent upon vertical cross section taking flow. Once true flow cross section is estimated, the flow rate will provide for SGV of 1.5 ft/min. Will probably be in the range 1200-1800 scfm total injection.

-25 - 60

Recycle test. After the combustion-front has progressed past the first thermocouple well doublet, recycle gas will be introduced. The target should be to maintain same SGV as with airburn but reduced with O_2 mole fraction to the range 11-14%.

-60 - 90

Terminal phase once combustion front with recycle has passed second thermocouple well doublet. Air-only injection will be resumed. The injection rates will be determined as a function of gas loss rate, active vertical flow cross section and modeling calculations to maximize yield.

Figure 1. Plan and elevation views of a typical horizontal in situ retort.

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Figure 2. Plan view of GKI retort 22 showing post-blast surface heave contours.

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Figure 3. Plan view of GKI retort 22 showing location of core wells and retort process and observation wells.

Figure 4. Sketch depicting operation of downhole tracer system.

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Figure 5. Plan view of instrument well locations, GKI Retort 22.

Figure 6. Elevation view of instrument wells. Elevations are M.S.L.

Figure 7. Sketch of surface instrumentation, GKI Retort 22.