THE GEOKINETICS HORIZONTAL IN SITU RETORTING PROCESS

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Geokinetics is a small company in the business of producing shale oil. In cooperation with the United States Department of Energy, we are engaged in developing a true in situ extraction process that does not require the construction of a mine or surface retort. This process is designed specifically for areas where the oil shale beds are relatively close to the surface.

In the process, a pattern of blastholes is drilled from the surface, through the overburden, and into the oil shale bed. The holes are loaded with explosives and fired, using a carefully planned blast system. The blast results in a fragmented mass of oil shale, with a high permeability. The void space in the fragmented zone comes from lifting the overburden, and producing a small uplift of the surface. The fragmented zone constitutes an in situ retort. The bottom of the retort is sloped to provide drainage for the oil to a sump where it is lifted to the surface by a number of oil production wells. Air injection holes are drilled at one end of the retort, and off gas holes are drilled at the other end. The oil shale is ignited at the air injection wells, and air is injected to establish and maintain a burning front that occupies the full thickness of the fragmented zone. The front is moved in a horizontal direction through the fractured shale towards the off gas wells at the far end of the retort. The hot combustion gases from the burning front heat the shale ahead of the front, driving out the oil, which drains to the bottom of the retort, where it flows along the sloping bottom to the oil production wells. As the burn front moves from the air-in to the off gas wells, it burns the residual coke in the retorted shale as fuel. The combustion gases are recovered at the off gas wells. This gas is combustible and can be used for power generation. Progress of the burn front is monitored by thermocouples set in thermocouple wells.

The initial costs involved in starting a production operation using this technique are relatively low and start-up time is short. The process eliminates the need for a mine and related mining equipment, surface retorts, and all rock moving machinery. The equipment required includes a number of drill rigs to drill the blastholes. The same drills will drill the air injection wells, the off gas wells, and the oil production wells. Low pressure blowers are used to provide air to the retort and small oil field type pumps are used to lift the oil to the surface. The off gases from the retort are moved at low pressure through thin walled, large diameter pipe to off gas cleanup units to remove the sulfur and ammonia compounds, and can then be burned as a source of power. Supplies used are explosives, diesel fuel for the drills, and diesel fuel or electricity to power the blowers.

The application of the process is directed to areas where the overburden is relatively thin. At the present time we do not know what the upper limit of overburden thickness will be. We have effectively blasted retorts with 55 feet of overburden, and expect that we can go to thicknesses of 100 feet. How much beyond 100 feet we can go we will learn as we continue our testing program.

There are many locations throughout the world where we find satisfactory overburden conditions for the process. In the United States, there are large areas in Colorado, Utah and Wyoming and in the eastern states

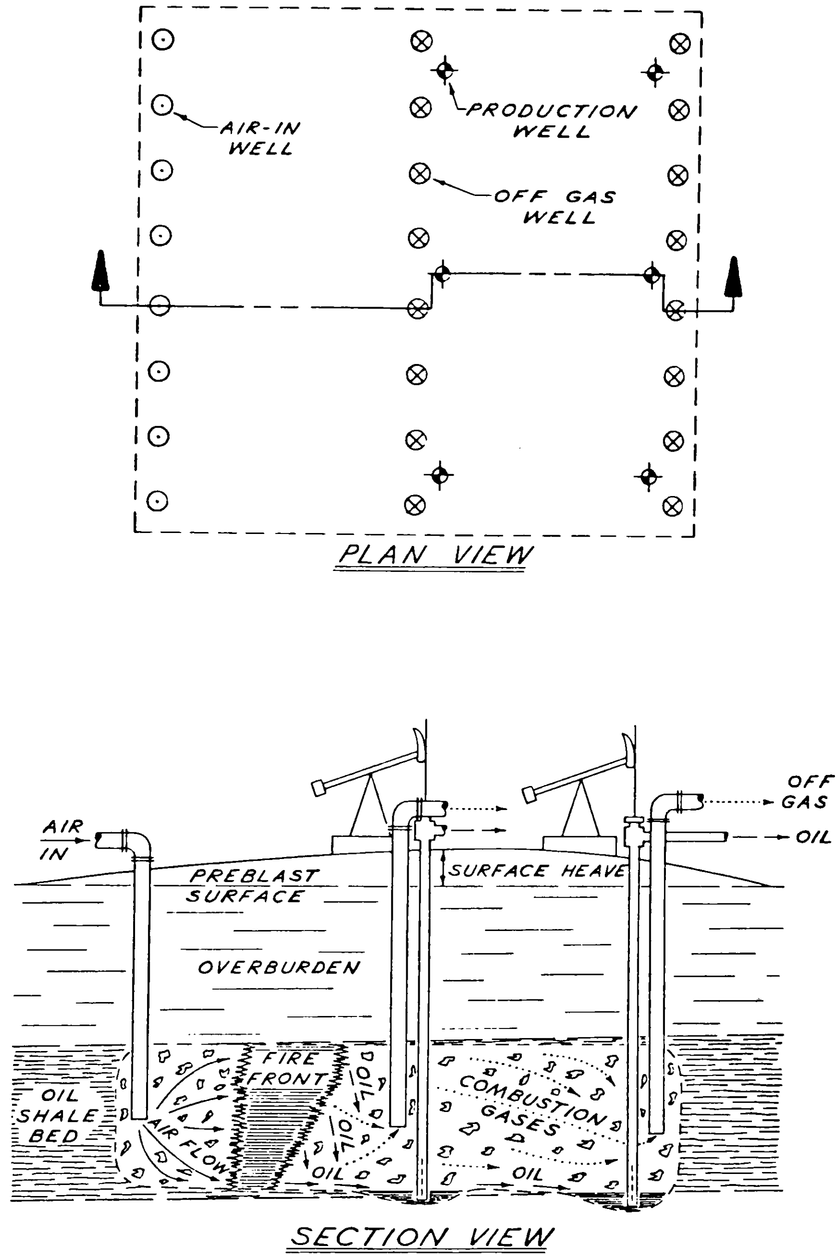

Figure 1. Plan and Cross-Section of a Typical Horizontal In Situ Retort

where the oil shale beds are within 105 feet of the surface. In Brazil, a substantial portion of their widespread oil shale deposits are at relatively shallow depths. In Australia, the Julia Creek deposit in central Queensland includes a very substantial area with less than 120 feet of overburden. In Morocco, the Tarfaya deposit is a potential site for this process. At Tarfaya, exploratory drilling has defined an area of 15 square miles where the overburden is less than 75 feet, and an area three times as large where the overburden is less than 150 feet. In addition to areas that have been identified, there are undoubtedly other areas throughout the world that will be suitable for this process.

Operations began at a test site in Utah in April of 1975, and have continued without interruption to date. Over $10 Million have been spent to date in field testing the process. The test site. Kamp Kerogen, is located 70 miles south of Vernal, Utah, in the north half of Section 2, R22E, T14S, on land owned by the State of Utah. Oil shale rights are leased by Geokinetics, and 320 acres are dedicated as a test site. The Mahogany Zone is approximately 30 feet thick and has a grade of 23 gallons per ton. The beds strike in an east-west direction, and dip to the north at about 120 feet per mile. Overburden ranges from zero at places where the shale forms the surface of the ground to a maximum of 110 feet.

Prior to 1980, 23 retorts had been blasted and 13 retorts had been burned. This work has established the technical viability of the basic process, as follows:

1. It is possible to drill a pattern of blastholes from the surface into the oil shale and fracture the shale with explosives to establish a zone of high permeability with a relatively impermeable zone between the fragmented shale and the surface.

2. It is possible to drill through the rubblized material and construct the various wells necessary for the operation, including air-in holes, off gas holes, oil recovery wells and instrument wells.

3. A point ignition can be made in the rubblized shale and expanded into a burn front that covers the cross section of the retort.

4. The burn front can be moved down the length of the retort as a cohesive temperature front, with satisfactory sweep efficiency.

5. Produced oil can be recovered from a well drilled to the bottom of the rubblized zone.

6. Recovery of in place oil of up to 50 percent can be achieved.

In addition, basic retorting parameters such as air injection pressures, air injection rates, rates of fire front advance and recovery factors were established on small retorts. A specific blasting pattern was selected to be scaled up to full size. The environmental impacts of the process upon air, water, land, vegetation and animal life were investigated.

During 1980, Retort #25 was blasted, and Retort #18 was burned. Retorting equipment was fabricated and installed on Retort #24, and the retort was ignited near the end of the year. A number of significant environmental and operating permits were granted. Crude shale oil was sold to a number of refineries and research organizations for refining tests. Two patents were granted covering blasting technology. A number of foreign companies and governments have expressed an interest in the process.

Retort #18, which was ignited during the previous year, was operated until June 18, 1980. A total of 5,500 barrels of oil was produced from this retort. This represents 45 percent of the in place oil. On Retort #24, surface and underground construction was completed, and the retort ignited on December 1, 1980. Retort #24 is a full-size retort, measuring 230 feet long by 217 feet wide by 30 feet thick with 45 feet of overburden. Start-up of the retort involved ignition of eight ignitor holes in a three-day interval. By the end of the year, a stable burn front had been established and air was being injected at the rate of 3000 scfm. Retort #25 was blasted on July 18, 1980. This retort is the same size as #24, with minor modifications in the design to optimize fragmentation. The blast was very successful, and resulted in improved breakage of the oil shale with less damage to the overburden.

A number of significant permits were secured during the year. A PSD permit was granted by the EPA to cover anticipated air emissions for 1981 and 1982. An Underground Injection Control (UIC) permit was granted by the Utah State Department of Oil, Gas and Mining permitting construction of a deep well for underground disposal of retort waters. A geological study of the subsurface formations in the vicinity of the test site indicated excellent conditions for disposal of retort water at a depth of 5,000 to 5,500 feet below the surface. Additional permits were secured for operation of the camp facilities.

The environment program was very active. In addition to securing the PSD and UIC permits, a new 1-1/2 acre evaporation pond was designed, permitted and constructed and revegetation studies continued or were initiated on eight spent retorts.

Sandia National Laboratories participated in the blasting of Retort #25 by providing high speed motion picture photography of surface motion at blast time. However, they were not able to field the normal array of blast time instruments due to limitations on their budget. As a result we were unable to gather as much data from this blast as we desired. This represented a serious loss of valuable information. Sandia ran tracer tests in a number of retorts to evaluate rock fragmentation and flow permeability. Sandia also finalized plans for instrumenting the burn of Retort #23. Retort #23, a relatively small retort (100 feet long by 50 feet wide by 24 feet thick) will be heavily instrumented by Sandia and operated to yield the maximum amount of retorting data. Design and acquisition of instrumentation was completed during the year.

An extensive post-burn coring program has been completed on Retorts #16 and #17. A total of 28 core holes were drilled, including two core holes drilled outside the retort zone as baseline samples. Extensive chemical and mineralogical tests will be made on the cores. Funding for this project is being provided by the EPA.

Over 20,000 barrels of crude shale oil have been produced in the course of the test work. This oil has been sold for:

(1) Direct boiler fuel
(2) Blending and refining tests
(3) Hydrotreating and refining tests
(4) Blending and marketing as #5 Fuel Oil

Geokinetics holds leases on 30,000 acres of oil shale land in the vicinity of the test site, containing 1.7 billion barrels of oil in place. Of this total, 273,000,000 barrels are overlain by less than 100 feet of overburden, and are considered available to the process.

A commercial operation would consist of a number of retorts burning at the same time and each producing from 100 to 200 barrels per day. Each retort would have a life of six to eight months, and would produce from 15,000 to 25,000 barrels of oil. A self-contained production unit would produce from 2,000 to 3,000 barrels of oil per day.

Our objective is to recover fifty percent of the oil in-place within the boundary of the retorts. Recent retorts have had recoveries close to this, and we feel that we will be able to achieve or exceed fifty percent recovery.

By the end of 1982, we expect to have completed our test program and be ready to begin design and construction of a commercial facility on our Utah properties which contain about 100,000,000 barrels of shale oil recoverable by the horizontal in situ retorting process.

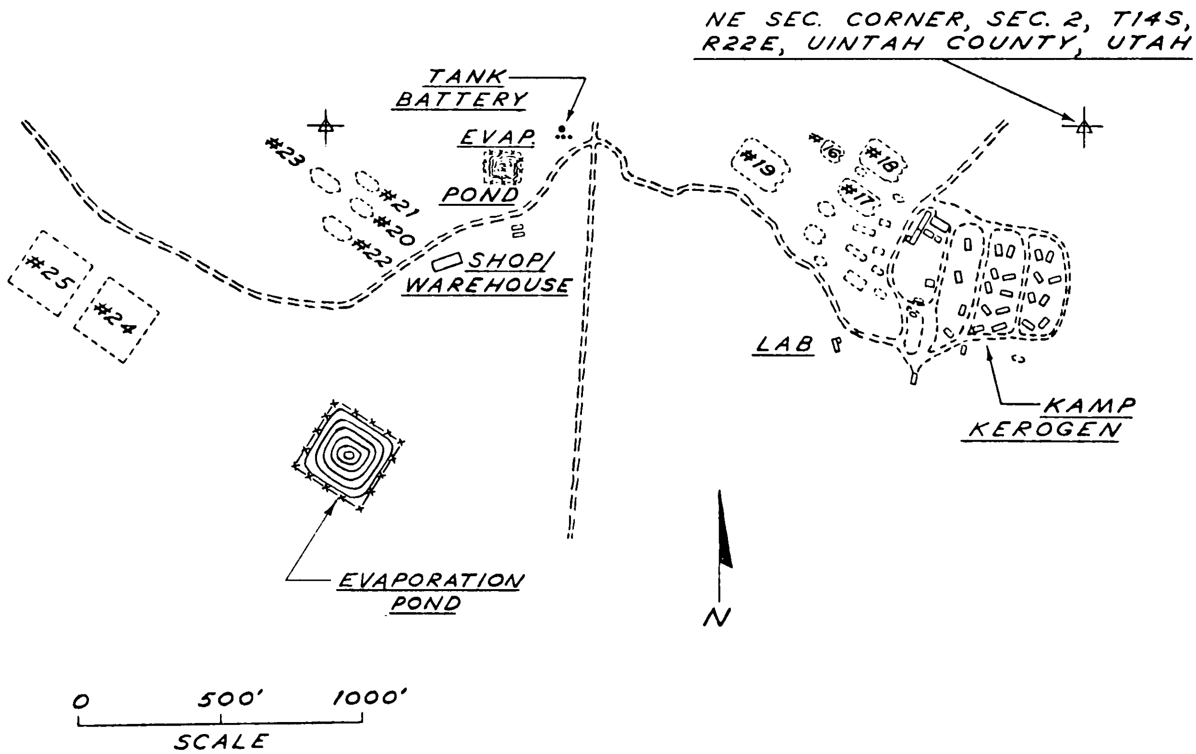

Figure 2. Geokinetics Field Site at Kamp Kerogen, Showing Locations of All Retorts

Retort Number	Date Blasted	Date Ignited	Thickness of Shale	Average Overburden Thickness	Width	Length	Barrels of Shale Oil Recovered
1	7/75	9/76	10'	0'	10'	50'	56
2	7/75	3/76	3'	10'	10'	30'	28
3	1/76	7/76	10'	17'	20'	40'	82
4	2/76	2/77	10'	16'	20'	40'	146
5	2/76	5/77	11'	19'	20'	81'	354
6	Abandoned-Not blasted						
7	11/76	----	10'	15'	20'	50'	---
8	11/76	----	23'	22'	20'	83'	---
9	12/76	9/77	22'	22'	40'	83'	1,007
10	12/76	1/79	11'	14'	20'	50'	445
11	3/77	4/77	12'	14'	20'	45'	272
12	3/77	----	11'	31'	30'	50'	---
13	6/77	----	11'	31'	30'	50'	---
14	6/77	2/78	12'	29'	40'	70'	384
15	7/77	5/78	20'	31'	50'	75'	1,003
16	8/77	8/78	20'	41'	62'	87'	2,067
17	5/78	6/79	17'	26'	72'	156'	3,700
18	7/78	11/79	17'	27'	108'	156'	5,500
19	12/78	----	30'	50'	126'	182'	---
20	4/79	----	24'	36'	40'	100'	---
21	6/79	----	23'	35'	40'	100'	---
22	6/79	----	23'	34'	50'	100'	---
23	9/79	----	24'	36'	50'	100'	---
24	11/79	12/80	28'	45'	217'	230'	---
25	7/80	----	28'	55'	217'	230'	---

Figure 3. Summary of Data on Retorts #1 through #25 (to 12/31/80)

Constituent	Mean	Standard Deviation	No. Samples	"Typical"	High
Hydrogen (H_2)	6.514	1.432	96	6.618	9.904
Carbon Monoxide (CO)	6.597	1.583	96	7.954	9.206
Oxygen (O_2)	2.282	1.100	96	1.214	2.078
Carbon Dioxide (CO_2)	22.979	3.436	95	21.415	25.778
Nitrogen (N_2)	59.541	4.419	96	59.054	49.169
Methane (CH_4)	1.564	0.500	95	3.032	2.681
Ethane (C_2H_6)	0.295	0.075	94	0.211	0.465
Ethene (C_2H_4)	0.082	0.045	92	0.060	0.092
Propane (C_3H_8)	0.141	0.041	94	0.620	0.244
Propene (C_3H_6	0.096	0.040	93	0.096	0.134
Butanes (C_4H_{10})	0.078	0.057	96	0.074	0.115
Butenes (C_4H_8)	0.058	0.031	95	0.054	0.080
C_5	0.058	0.021	80	0.049	0.069
Hydrogen Sulfide (H_2S)	0.193	0.061	51	0.255	-
Ammonia (NH_3)	0.045	0.034	45	0.032	-

Figure 4. Retort #18 Gas Analysis Data Summary - By Volume

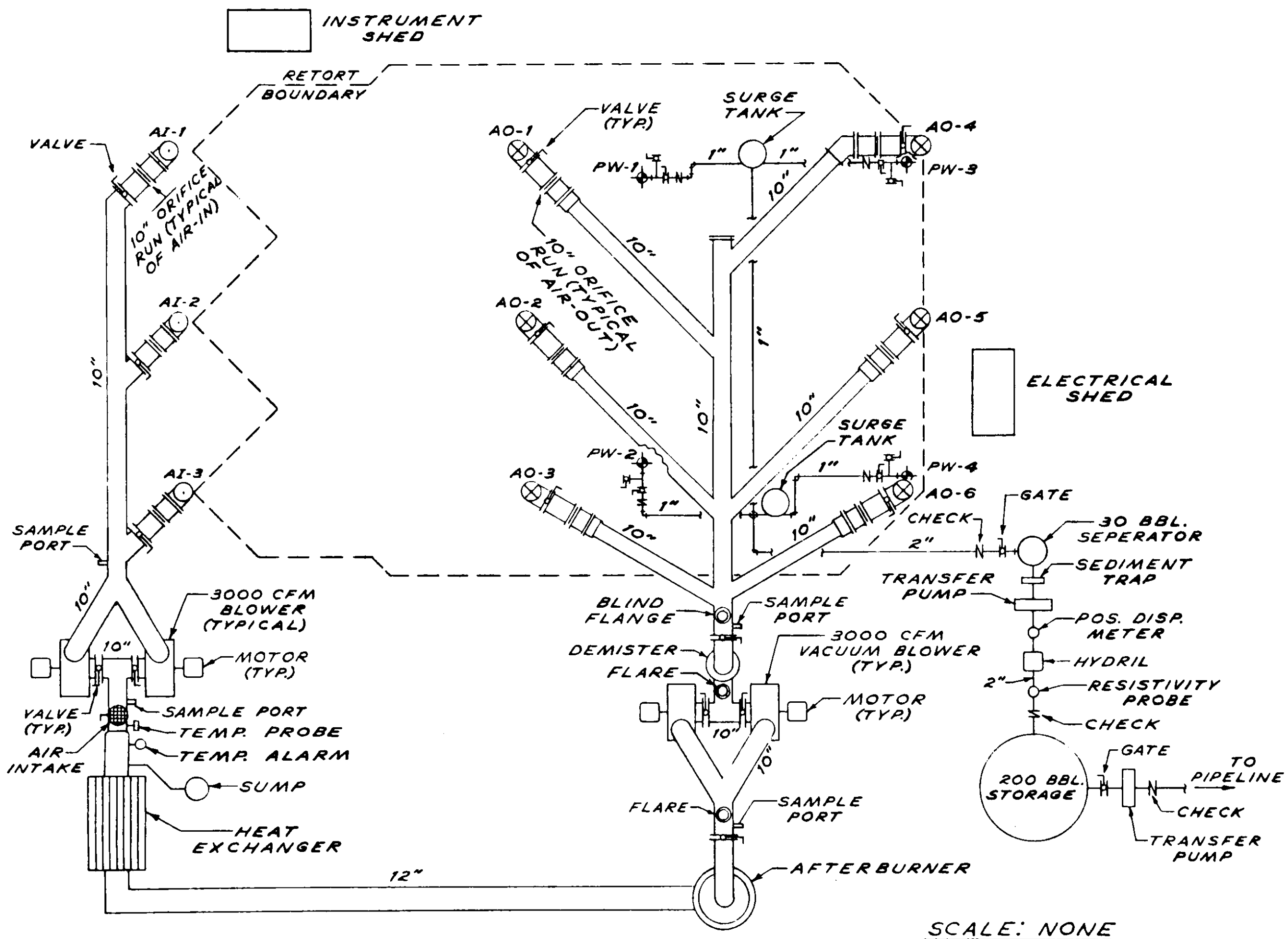

Figure 5. Surface Facilities Layout, Retort #18

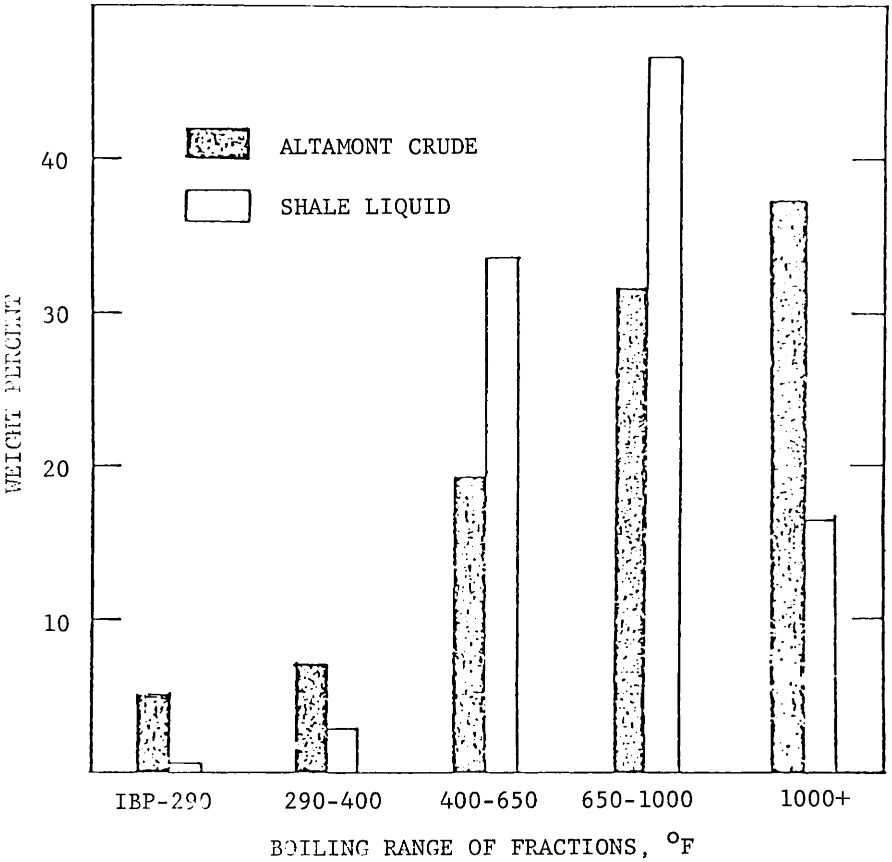

Figure 6. Distillation Fractions, Altamont Crude and Geokinetics Shale Oil