Section 16

UNION OIL'S SHALE OIL DEMONSTRATION PLANT

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INTRODUCTION

Union Oil Company of California pioneered the development of upflow surface retorting technology. Technical feasibility of the shale upflow concept was demonstrated in a small 2 T/D pilot retort nearly 35 years ago. This work was followed by the construction and operation of a 50 T/D unit and later scaled to semi-works size in the late 1950's at Union's site near Parachute, Colorado. This effort, in which retorting rates up to 1200 T/D were attained, further demonstrated the technical feasibility and operating reliability of this retorting scheme. However, shale oil production was not economically attractive at that time.

In 1972, Union again initiated a major shale development program. The incentives for this work were based on new retorting concepts from our continuing research and the increasing costs of finding incremental petroleum supplies.

TECHNOLOGY

All of Union Oil Company's retorting technology utilizes the upflow of solids. Demonstration of the feasibility of this novel approach to retorting was first carried out in a 2 T/D capacity pilot plant in the early 1940's. To accomplish this, the solids are literally pumped upward through an expanding cone as shown in Figure 1. A feed piston reciprocating within a translatable feed cylinder is used to pump the crushed and screened solids. In all arrangements of the solids pump, the mechanism is totally immersed in relatively cold product oil.

During the past 35 years, the development of the solids pump has been carried through several stages of scaleup. This program culminated in the very successful extended semi-works operation in Retort A in 1956-58. The solids pump on this unit had a feed piston diameter of 5.5 feet and a pumping rate of 1200 T/D was sustained at peak retorting rates. Each larger version of the solids pump has retained the basic mechanical simplicity of the original design. Extended operation of the pump in both pilot plant and semi-works retorting has confirmed the mechanical and operating reliability of the solids pump concept.

As the solids are pumped upwards through the expanding conical retort shell, a cone of retorted shale is formed above the top edge of the retort. The shape of this pile of solids is determined by the natural angle of repose of the retorted material. A countercurrent stream of hot gas heats the rising bed of oil shale to the necessary retorting temperature. Several very important process advantages are obtained by using solids upflow and retorting gas downflow as listed on Table 1.

Kerogen in the oil shale is decomposed on retorting and is liberated from the rock as oil and gas vapors and quickly forced downward by the educting gas towards the cooler shale in the lower portions of the retort. Residence time of the oil at high temperature is minimized resulting in less polymerization, condensation and coking.

As the oil vapor is condensed on the bed of cooler incoming shale, gravity assists its drainage away from the retorting zone. This eliminates potential agglomeration within the retort bed caused by refluxing and coking of the product oil.

Use of the cold incoming shale feed to condense the bulk of the oil product substantially reduces the capital and operating costs for external condensing equipment common to most other surface retorting schemes.

Condensation of the product oil within the retort bed is accompanied by a filtering action which gives a rundown oil stream having a relatively low particulate content.

Because there is always a positive force available to move solids up through the retort, any tendency for more than localized solids agglomerates to form can be mitigated by continued solids pumping until retorting conditions can be adjusted to return the unit to stable operation. Also, operation at high mass velocities is feasible because of positive solids flow and high gas/solids heat transfer rates.

Finally, retorting conditions can be established which will cause the retorting to take place near the top of the retort bed. At this level, the contact pressure between shale particles is at a minimum. This is especially important when retorting rich Colorado shale since a plastic condition exists under certain retorting conditions. If the particle contact pressures are too high under these conditions, agglomeration occurs leading to a severe loss of bed permeability.

Retorting efficiencies for recovering energy from oil shale in the form of liquid and gaseous products can vary widely. Table 2 shows an approximate energy distribution for Colorado shales. In general, if no effort is made to recover the energy remaining in the carbonaceous deposit on the retorted shale, the retort make gas will have to be burned to energy-balance the retorting complex. Oil will be the only product and the thermal efficiency will be about 70-75 percent.

If the retorted shale is processed for energy recovery, the make gas will also become a salable product and the thermal efficiency will increase to 80-85 percent. Thermal efficiency is defined as Btu's output in the form of products divided by Btu's input in the form of raw oil shale plus other required energy such as steam and power.

Union's first retorting concept, Retort A, as shown on Figure 2, recovered the energy in the carbonaceous deposit on the retorted shale to supply the heat of retorting. This direct heating process, which was demonstrated in the semi-works plant in Colorado from 1956-58, proved to be reliable and easy to operate. Because it used once-through air flow, peak temperatures in the burning zone near the top of the retort reached 2000-2200°F and resulted in low liquid yields of about 75 volume percent of Fischer assay. The heating value of the product gas was low at about 120 Btu/scf because of dilution with nitrogen from the air and carbon dioxide from combustion and the decomposition of mineral carbonates.

Low-Btu gas is not a valuable product in the Piceance Basin of Colorado. It cannot be transported economically over long distances and therefore must be used for generation of electric power near its place of origin. The final selling price for generated power is determined by the value of competitive strip-mined coal in the area which is relatively low in cost per million Btu's as compared to oil.

In an attempt to improve product yields and quality, a retorting concept called Retort B was developed. Again referring to Figure 1, retorting is accomplished by indirect heating utilizing a recycle gas heated in a fired heater to 950-1000°F. Both fixed-bed and continuous pilot plant operations give high yields of liquid product, essentially equal to Fischer assay values. The retort make gas has a high heating value, above 800 Btu/scf. Product quality is excellent and the discarded retorted shale contains a nominal 4 wt percent carbonaceous deposit.

The oil shale is retorted as it rises through the retort cone and is contacted by countercurrent flow of hot recycle gas. As the retorted shale rises above the lip of the upper cone, it forms a freestanding pile. A rake slowly rotates just above the surface of the pile to break up any localized agglomerates that may form.

The space above the freestanding pile is enclosed by a dome. The retorted shale sloughs off the pile by gravity and slides down chutes through the dome wall at the retorted shale outlets. Hot recycle gas is introduced into the space above the retorted shale pile and flows downward through the rising shale to provide the heat required for the retorting process. The oil shale kerogen decomposes into liquid and gaseous organic products which diffuse from the shale particles while leaving behind a solid carbonaceous deposit on the retorted material. The bulk of the liquid product trickles down through the cool incoming shale and the balance, in the form of mist, is carried from the retort by the cooled gases.

The gas and liquid are separated from the shale in the slotted wall section comprising part of the lower shell cone. A disengaging section surrounds the lower cone and the liquid level in this section is controlled by withdrawing oil product.

Shale particles which fall through the slots into the disengaging section are recycled by screw conveyors into the feed chute. Very fine shale particles which may collect at the bottom of the feeder case are pumped in an oil slurry back to the retort by way of the disengaging section. Product oil rises in the feed chute to the level necessary to balance system pressure. All of the above fines and solids handling systems have been successfully demonstrated during extended operation of the moving-bed pilot plant and/or the 1000 T/D semi-works unit.

As shown on Figure 3, the retorted shale is conveyed by pipe to the retorted shale cooling vessel. Retorted shale is discharged from the cooling vessel through a mechanical pressure letdown device. A rotary wetting drum may be used to add sufficient water to the retorted shale to make it environmentally acceptable for disposal in a stable pile which can be revegetated. Steam which is generated in the quenching and cooling operation is condensed and returned to the cooling vessel.

Gases discharged from the disengaging section are scrubbed and cooled in a venturi scrubber. Agglomerated mist plus condensed light ends and water are sent to an oil-water separator. The separated oil is recycled to the disengaging section through the shale feed chute and the water, after stripping to remove ammonia and hydrogen sulfide, will be used in cooling and wetting the retorted shale. The scrubbed gas is separated into a make gas stream and a recycle stream. Table 3 shows a typical make gas analysis from retorting 34 gpt shale. The recycle stream is compressed and heated in a conventional fired heater prior to injection into the top of the retort.

The retort make gas is processed by compression and scrubbing to remove heavy ends and hydrogen sulfide. Oil is used to scrub out the heavy hydrocarbons and Union's proprietary Unisulf Process will be used to remove hydrogen sulfide. The sweetened make gas is then used as plant fuel.

Retort B produces high yields of superior quality oil. Rundown oil yields are close to 100 percent of Fischer assay and the C_4-plus yield is significantly above 100 percent of assay. Properties of the full-range liquid product from the retort are given in Table 4. As shown, solids upflow retorting combined with an oxygen-free recycle gas gives a product oil having a moderately low pour point and a low Conradson carbon residue. This oil can be hydrogenated directly, eliminating the need for coking. The oil is treated sequentially to remove solids, arsenic and light ends. Solids removal is accomplisehd by two stages of water washing and the shale fines collected are disposed of along with the spent shale. The 50 ppm of chemically combined arsenic can be reduced to less than 1 ppm using a proprietary Union Oil process. It is reacted with an absorbent which picks up arsenic to about 80 percent of its weight. The dearsenited shale oil is then sent to a stripping column for stabilization.

In addition to producing high-quality products, a major advantage of Union's Retort B process is the ability of the retort to successfully process oil shale feeds covering a wide range of shale quality. Extended pilot plant operations have been conducted on shale feed averaging 29.5-42.5 gpt. As mentioned earlier, kerogen decomposition in Union's B-mode retorting takes place largely near the top of the retort bed. Here, the particle-to-particle pressure between the shale surfaces is at a minimum. With rich Colorado shales, a plastic condition exists under certain retorting conditions. If the particle contact pressures are too high, agglomeration occurs.

Fixed-bed retorting tests were conducted to quantify the process factors causing agglomeration. Runs were programmed to simulate the pressure and temperature profiles of particles in a moving bed retort. Permeability loss and percent compaction were measured and retorting was considered complete at 925°F.

The variables found to be most important were shale quality and particle pressure as shown in Figure 4. At 12 percent compaction, gas pressure drop has increased to the limit of practical commercial operation. This compaction normally occurred at a temperature around 800°F when the particle pressure was high enough.

At 40 gal/ton, the critical contact pressure is 1 lb/in^2 and at 30 gal/ton, 4.5 lb/in^2. Retorted shale exerts a static pressure of about 0.4 lb/in^2 per foot of height, so there is an upper limit to the height of a column of solids above the critical temperature zone. The temperature/pressure profile in the Union retort can be controlled to avoid agglomeration by selection of the proper recycle gas-to-solids ratio.

PLAN FOR COMMERCIAL DEVELOPMENT

More than 50 years ago, Union Oil Company of California began to acquire oil shale properties in the Parachute Creek area of Garfield County, Colorado. Today, Union owns nearly 20,000 acres of oil shale lands as shown in Figure 5. These lands contain about two billion barrels of recoverable oil in the Mahogany and associated high yield zones. These zones are sufficient to produce 150,000 barrels of shale oil per day for more than 25 years. Also, there are about two billion additional barrels of reserves in adjoining zones.

In March 1978, Union announced plans, subject to government action on necessary incentives, to construct and operate an initial 10,000 barrel/day Experimental Retort B module, followed by the design, permit acquisition and construction to expand operations to produce 50,000 barrels of shale oil syncrude per day.

All shale retorting approaches, with the exception of true in situ, will require underground or strip mining. Technology required in such mining is available and ready for use. A sketch of a typical room and pillar mine such as Union Oil Company is planning to use is shown in Figure 6. In this type of mining, about 25% of the oil shale will be left in 60-foot by 60-foot pillars to support the mine ceiling. Accessibility to the seams to be mined will be from adits on the cliff faces.

The 10,000 barrel/day commercial retort module would look something like the schematic diagram shown in Figure 7. The solids pump will be comprised of a single feed piston, 10-ft in diameter, reciprocating in a feed cylinder supported by a carriage assembly which is reciprocated slowly from the feed chute position to under the retort cone by a hydraulic cylinder. This unit is designed to charge 12,800 T/D of 34 gpt shale. Retorting of the shale in the 10,000 B/D unit will use the same arrangement of auxiliary facilities as has been described previously.

The retort will be in a setting such as shown on the artist's conception in Figure 8. The retorted shale is moved to a chute through which it will drop to the valley floor deposit area. There it will be spread, compacted, contoured and vegetated with native plants so as to blend into the adjacent landscape. The first laydown of retorted shale will be highly compacted into an essentially water-impervious barrier which will protect the underground water supply from contamination. Any excess runoff will be collected in a drainage pond and used in the retorting process.

Water for the commercial project's initial operations will be taken from wells on Union Oil property and will be recycled. As additional retorts and process facilities are added, water will be drawn from the Colorado River, where Union has long-established water rights. Table 5 shows the water requirements for shale oil, synthetic oil from coal and steam generation from oil. Shale oil is not very demanding of water.

All necessary permits for construction and operation of the Experimental Retort B have been obtained.

In summary, upflow retorting as employed in Union's B retorting technology using indirect heating with a circulating gas stream has several major important advantages which include:

(1) Oil liberated from the shale is forced downward rapidly toward cooler shale by the countercurrent gas flow. This quenches polymerization reactions which form heavy oil that is difficult to refine.

(2) Gravity assists drainage of oil away from the retorting zone and avoids refluxing and coking of the product oil.

(3) Retorting takes place near the top of the retort where contact pressure between particles is a minimum. As a result, agglomeration and gas flow pressure drop buildup can be avoided regardless of the richness of the shale feed.

(4) The high heat capacity of the recycle gas and high gas/solids heat transfer rates combined with positive solids flow permit retorting at exceptionally high solids mass velocities.

REFERENCES

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2. Duir, J. H., Deering, R. F. and Jackson, H. R., New Developments in Oil Shale Retorting by Union Oil Company, API Refining Department, 42nd Midyear Meeting, Update of Alternate Fossil Fuel Technology, Chicago, Illinois, May 10, 1977.

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FIGURE 1

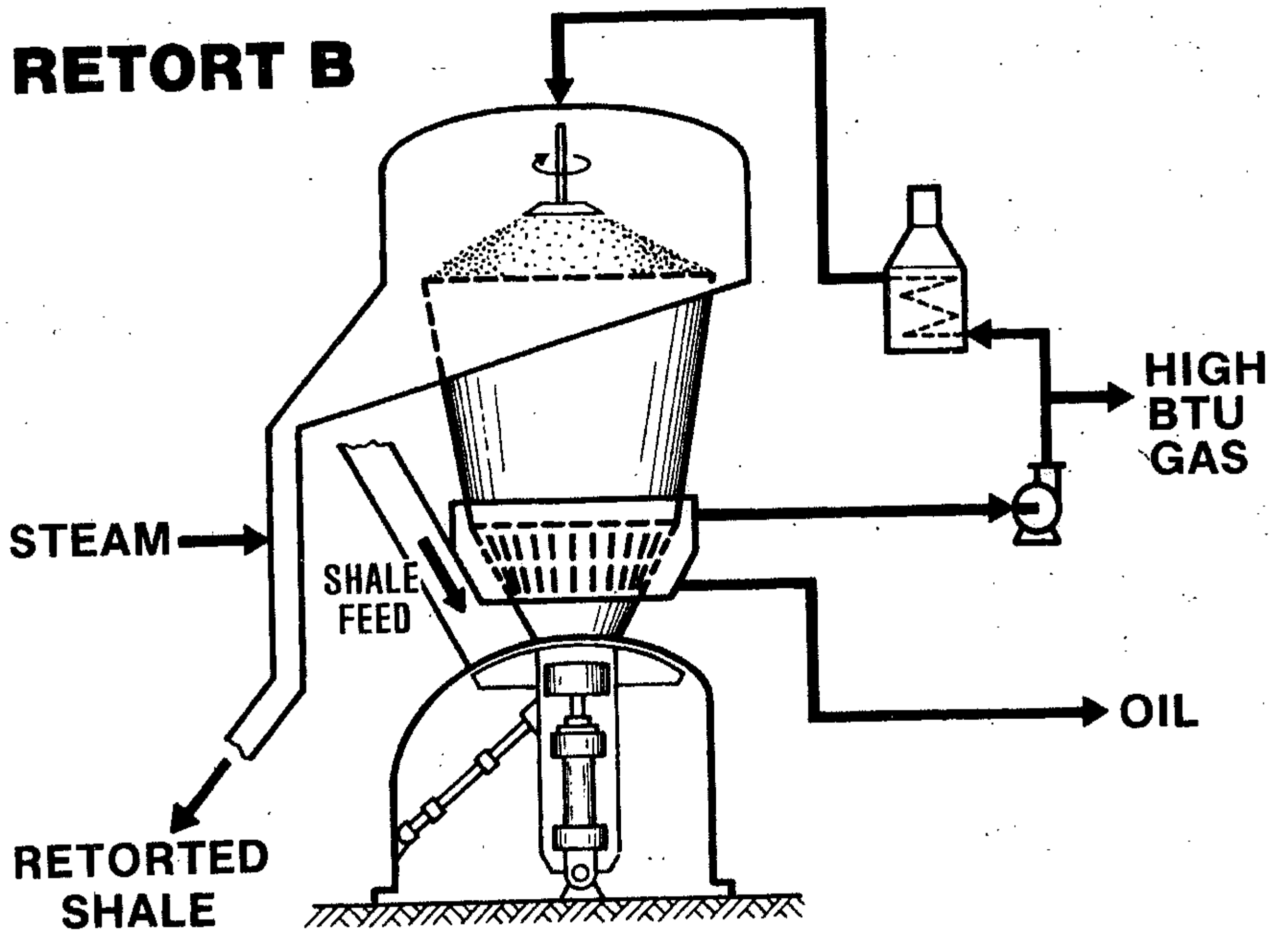

FIGURE 2

RETORT A

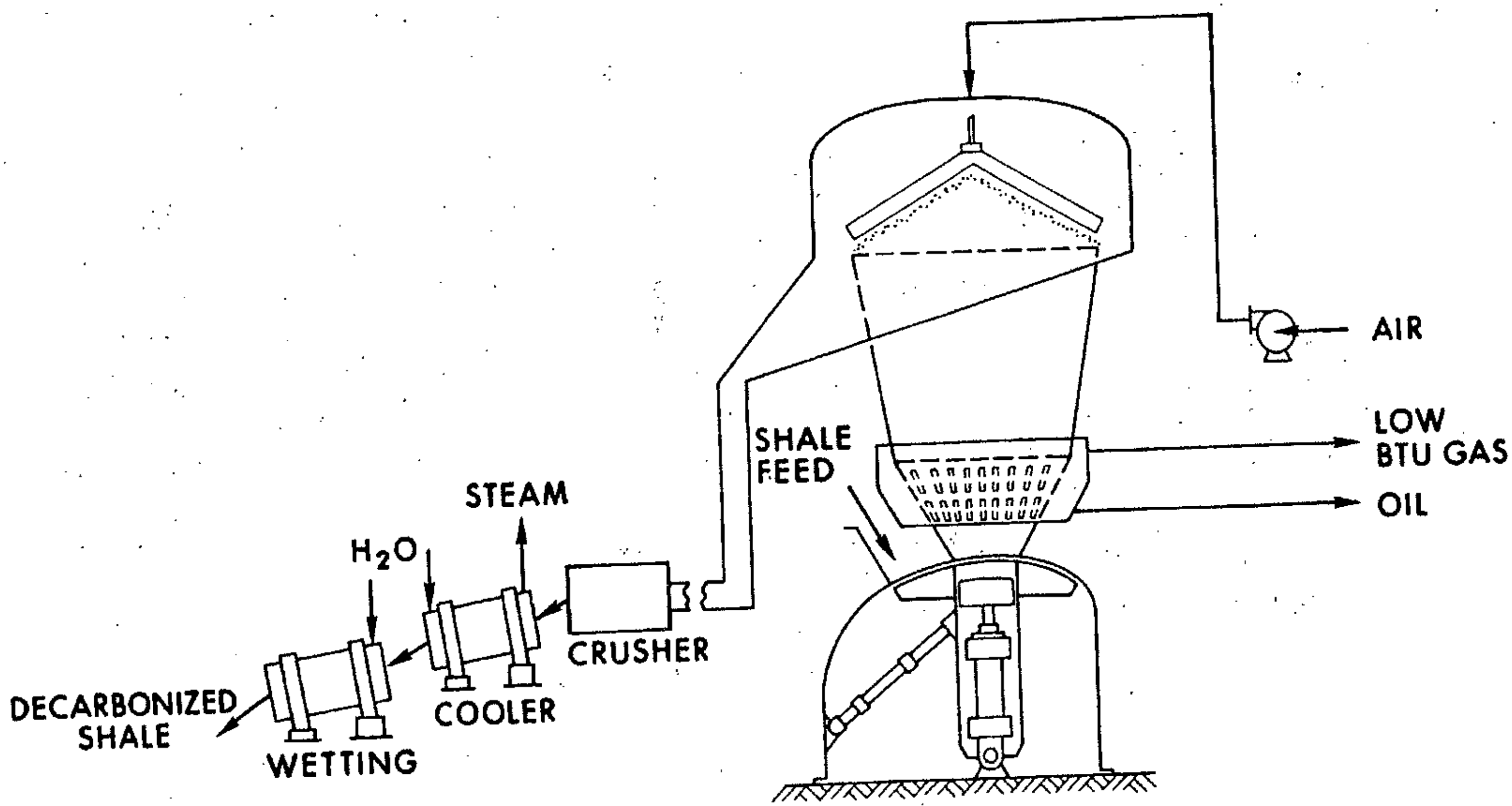

FIGURE 3

UNION RETORT B FLOW DIAGRAM

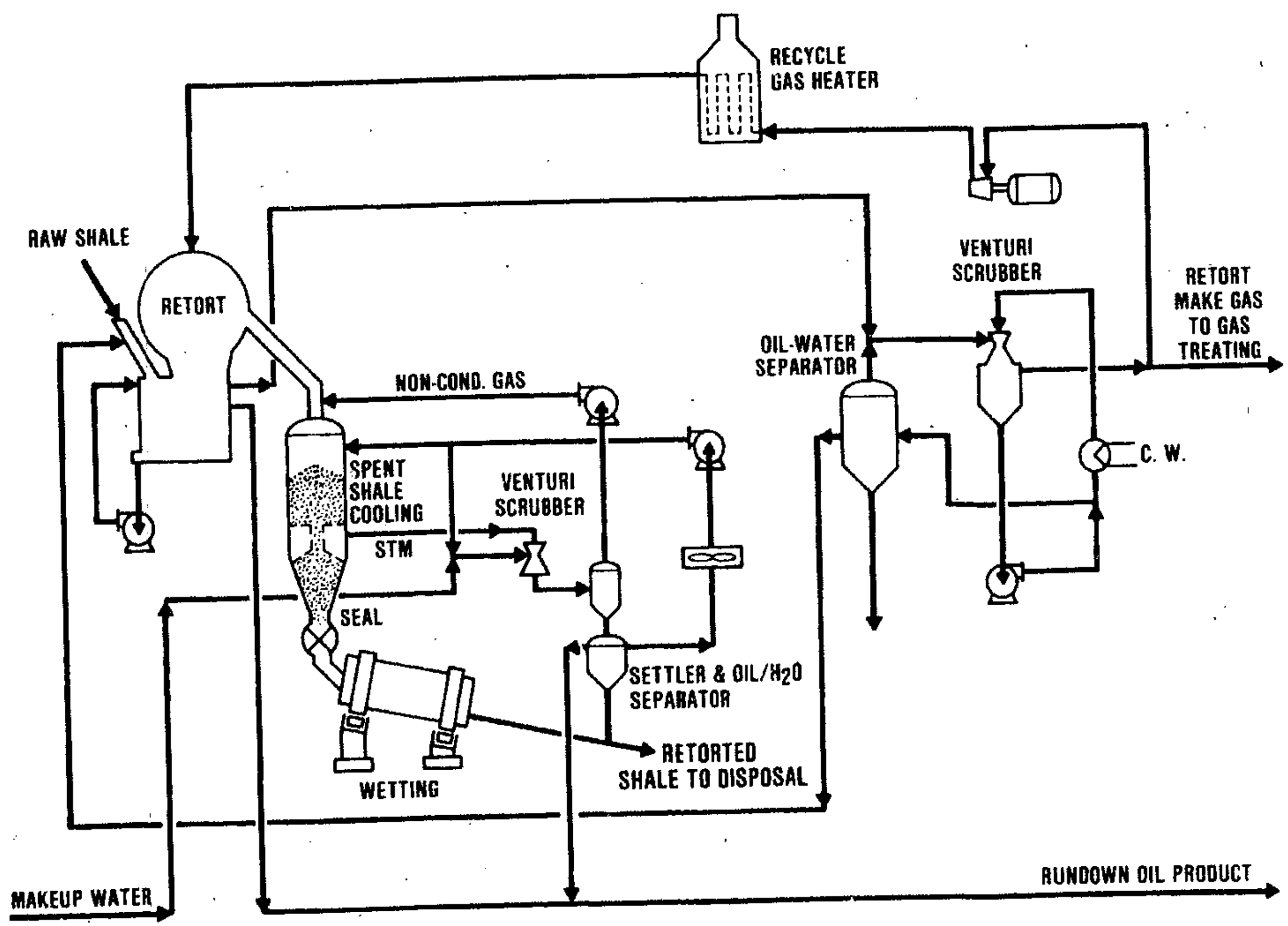

FIGURE 4

EFFECT OF ASSAY ON ROCK PRESSURE FOR 12% COMPACTION

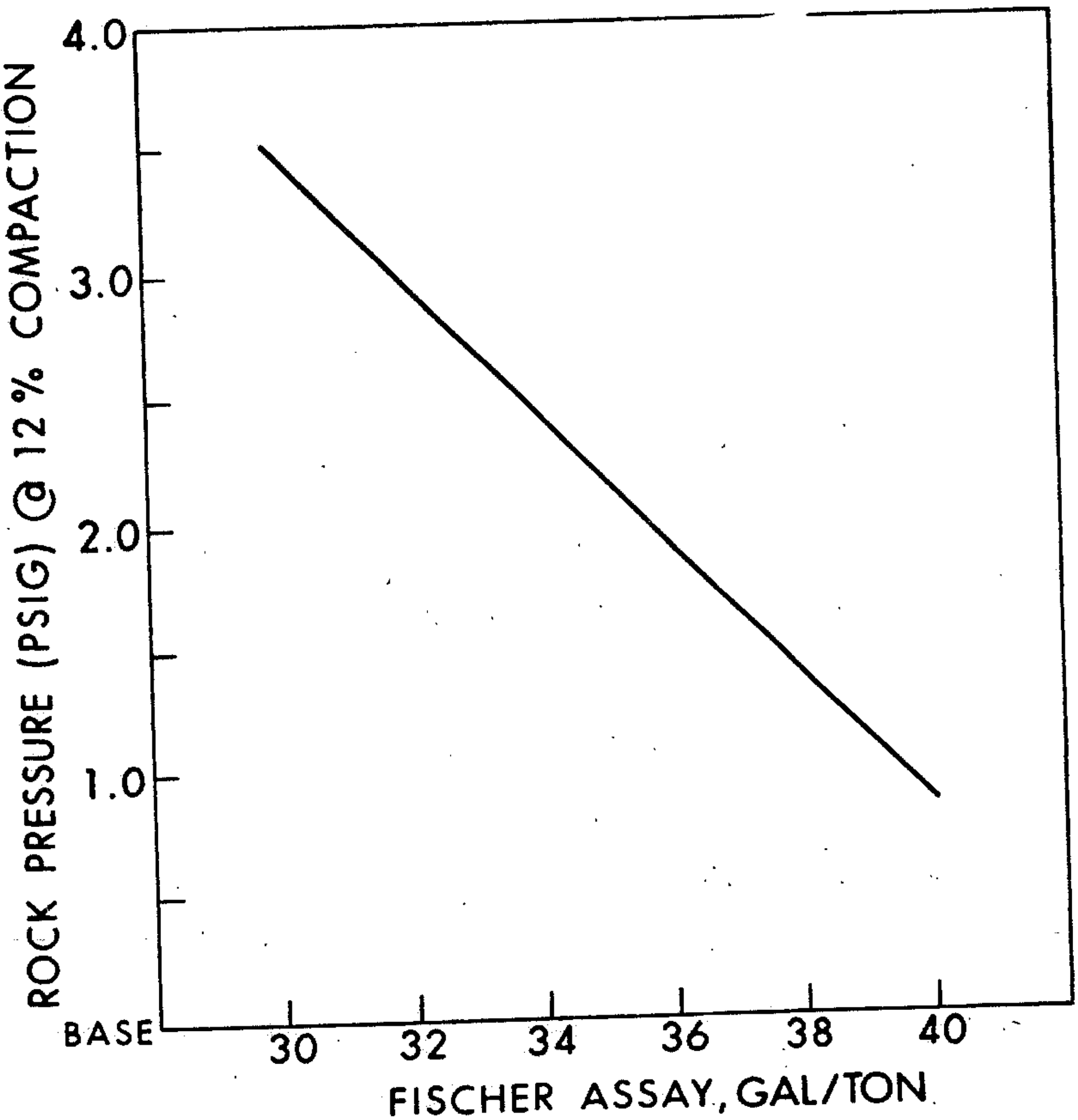

FIGURE 5

UNION'S OIL SHALE HOLDINGS

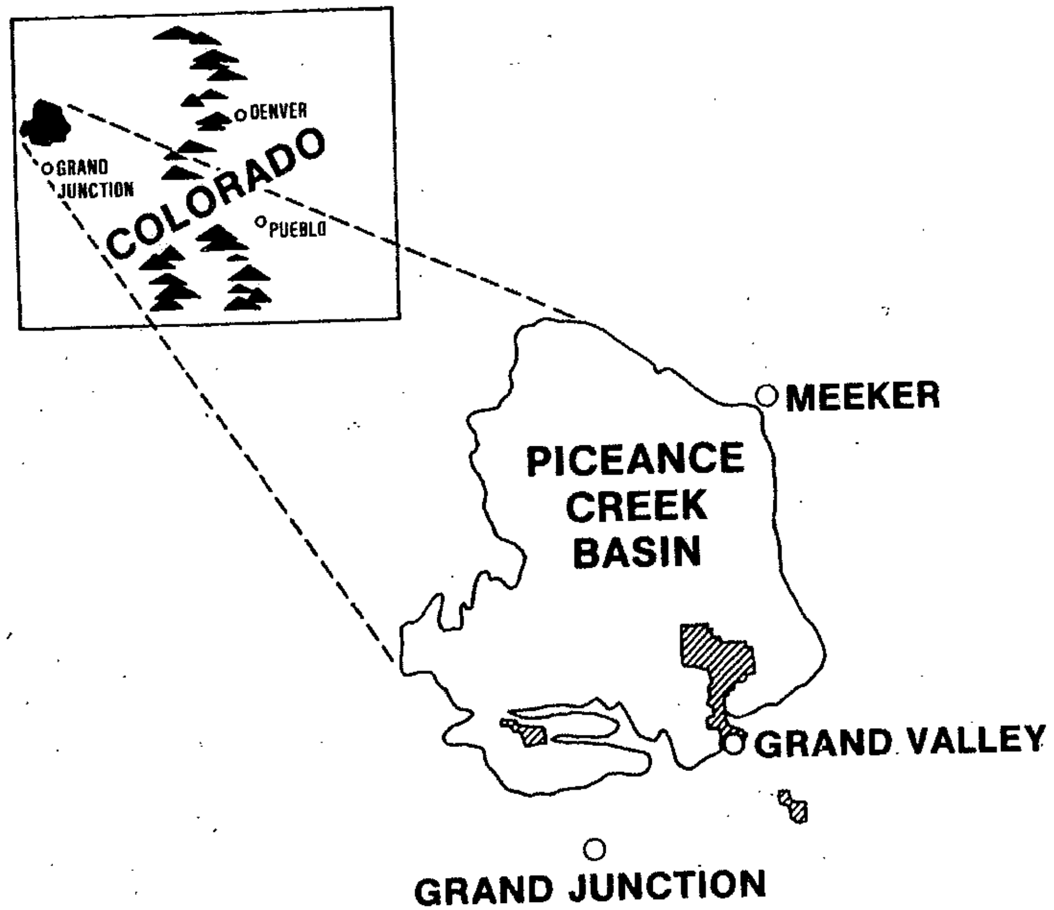

FIGURE 6

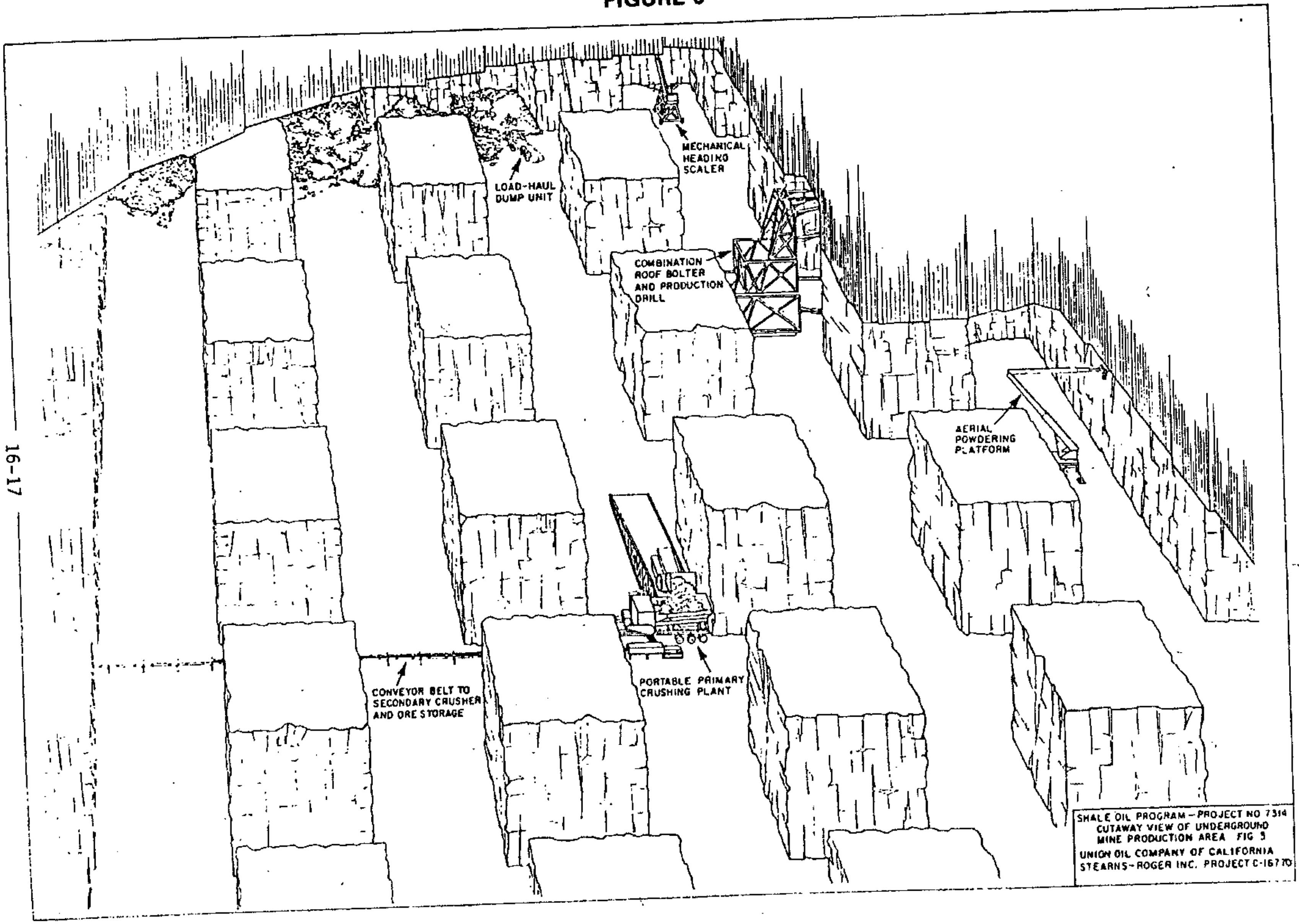
MECHANICAL HEADING SCALER
LOAD-HAUL DUMP UNIT
COMBINATION ROOF BOLTER AND PRODUCTION DRILL
AERIAL POWDERING PLATFORM
PORTABLE PRIMARY CRUSHING PLANT
CONVEYOR BELT TO SECONDARY CRUSHER AND ORE STORAGE
SHALE OIL PROGRAM – PROJECT NO 7314
CUTAWAY VIEW OF UNDERGROUND MINE PRODUCTION AREA FIG 5
UNION OIL COMPANY OF CALIFORNIA
STEARNS-ROGER INC. PROJECT C-16770

FIGURE 7

UNION UPFLOW RETORT

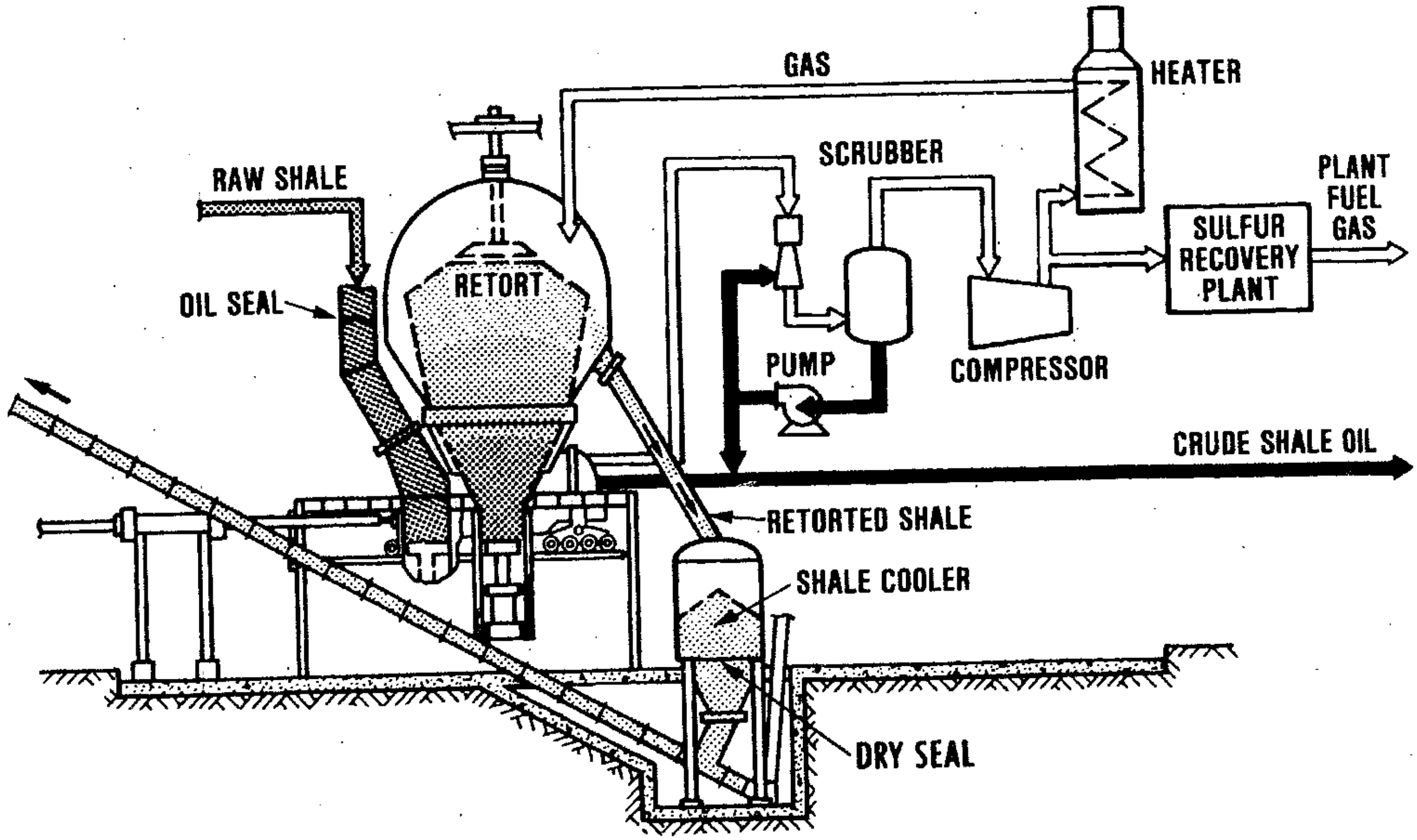

FIGURE 8

TABLE 1

ADVANTAGES -- UPFLOW SOLIDS AND DOWNFLOW GAS

- RESIDENCE TIME OF OIL AT HIGH TEMPERATURE MINIMIZED RESULTING IN LESS POLYMERIZATION, CONDENSATION AND COKING OF THE OIL.
- RETORTING OCCURS NEAR THE TOP OF THE SHALE BED WHERE CONTACT PRESSURE BETWEEN PARTICLES IS AT A MINIMUM AND THUS SOLIDS AGGLOMERATION AND PRESSURE DROP ARE AVOIDED EVEN WHEN PROCESSING VERY RICH SHALES.
- OPERATION AT EXCEPTIONALLY HIGH MASS VELOCITIES IS FEASIBLE BECAUSE OF THE POSITIVE SOLIDS FLOW AND THE HIGH GAS/SOLIDS HEAT TRANSFER RATES.
- CAPITAL AND OPERATING COSTS FOR EXTERNAL OIL CONDENSING EQUIPMENT ARE GREATLY REDUCED BECAUSE OF THE VERY EFFECTIVE ACTION OF THE RETORT AS A HEAT EXCHANGER.
- RUNDOWN OIL HAS A LOW PARTICULATE CONTENT BECAUSE OF THE FILTERING ACTION OF THE RETORT SHALE BED.

TABLE 2

DISTRIBUTION OF ENERGY IN OIL SHALE * AMONG RETORT PRODUCTS

PRODUCT	PERCENT OF ENERGY IN OIL SHALE
OIL	75
GAS	12
COKE (ON RETORTED SHALE)	13

*SHALE ASSAYED 34 GALLONS OF OIL PER TON. ITS CALORIMETER HEATING VALUE WAS 3175 BTU/LB.

TABLE 3

UNION RETORT B
MAKE GAS PROPERTIES

(DRY BASIS)

	MOL %
H_2	25
C_1	24
C_2	10
C_3	8
C_4	5
C_5	2
C_6 - PLUS	1
CO	5
CO_2	16
H_2S	4
TOTAL	100
HEATING VALUE, GROSS BTU/SCF	980

p

TABLE 4

PROPERTIES OF CRUDE SHALE OIL
UNION RETORT B

GRAVITY, ^{o}API	22.2
ASTM, D-1160 DISTILLATION, ^{o}F	
IBP	150
10	390
50	770
90	1010
MAX	1095
SULFUR, WT%	0.8
NITROGEN, WT%	1.8
OXYGEN, WT%	0.9
POUR POINT, ^{o}F	60
ARSENIC, PPM	50
CONRADSON CARBON RESIDUE, WT%	2.1

TABLE 5

WATER REQUIREMENTS
(PER BARREL OF OIL)

SHALE OIL	1-2 BBL
SYNTHETIC OIL FROM COAL	6-8 BBL
STEAM GENERATING PLANT	10 BBL