SPOUTED BED OIL SHALE RETORT

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INTRODUCTION

Spouting is a new technique for contacting fluids with granular solids. The spouted bed can be described as a combination of a dilute fluid phase and coexistent moving expanded bed. Gas enters through an opening at the apex of a conical inlet (fig. 1). This entrance is so abrupt that the gas has no chance for lateral distribution over the total cross section of the shell. This effect forms a central channel of a dilute fluid phase in which the solids are entrained upward. The solids enter the channel mainly from the conical section, but also enter laterally along the length of the channel. The solids concentration in the channel increases with height and at the same time the outline of the channel becomes less distinct. At the upper end of the channel the solids spill over into an annulus surrounding the central channel. The annulus can be described as an expanded bed in which the particles maintain their relative positions as they move downward. The coexistence of these two phases produces a solids flow pattern where the solids are entrained upward in the dilute phase and then descend by gravity in the denser annulus.

Many size ranges of materials of similar physical properties to those of oil shale have been successfully spouted to depths of 36 inches. The air requirements needed for spouting are comparable to the air requirements needed for fluidization of similar materials.[1,2] From these considerations it was proposed that a spouted bed be considered as a means of retorting the fines produced from the shale crushing and mining operations as the gas combustion retort will not effectively handle them. This process is a feasibility study of the application of a spouted bed as an oil shale retort.

PROCESS OPERATION

Reactor. As referred to in the introduction, the reactor consists of a conical transition section and a cylindrical reaction vessel. In most of the previous work on spouted beds[3,4] the conical section was small in comparison with the size of the cylindrical section. This design is not satisfactory for use as an oil shale retort, because when the retort is being operated auto-

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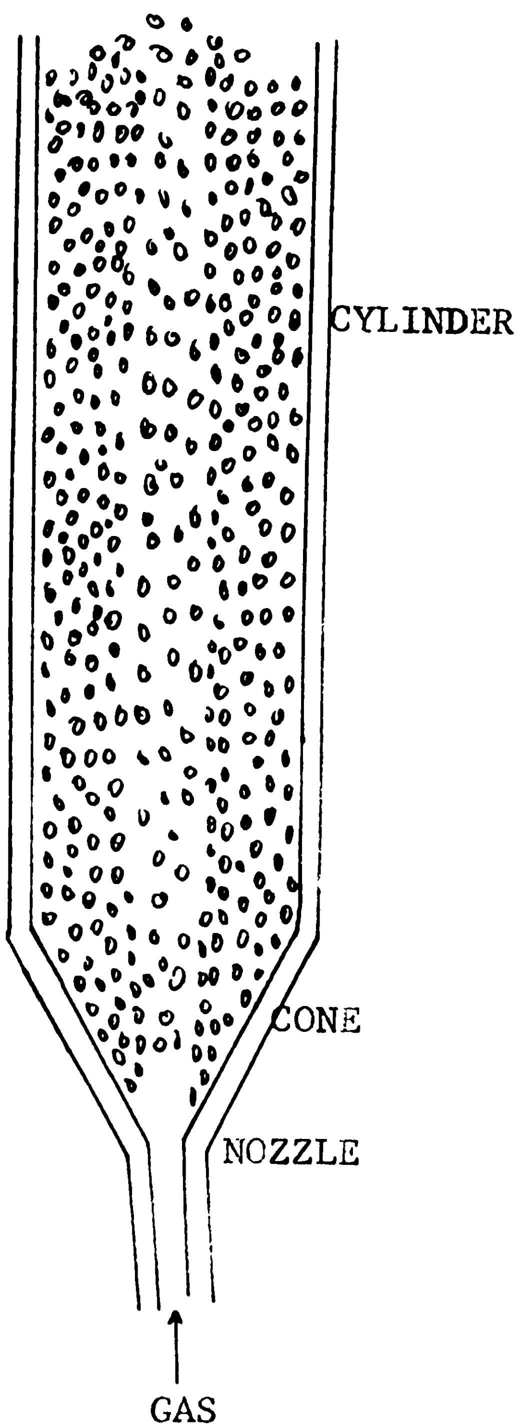

FIGURE 1. — Spouted bed.

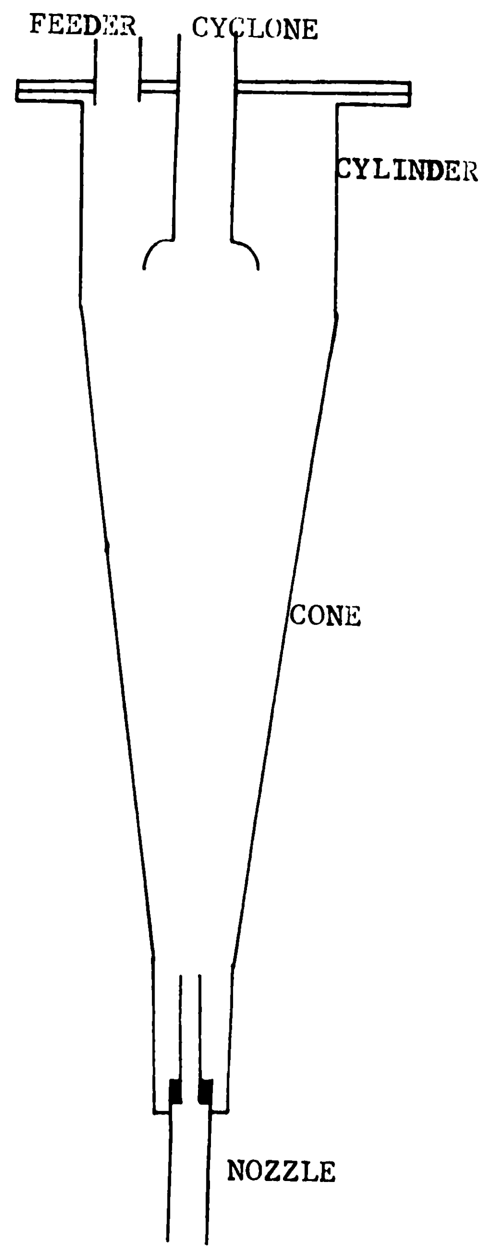

FIGURE 2. — Reactor.

thermally the process is highly exothermic: a temperature rise of 1000°F through the reactor is common. This temperature rise increases the volume of the gas and therefore increases the velocity of the gas in the reactor. By making the main part of the reactor conical (fig. 2), the cross sectional area of the bed increases approximately at the same rate as the gas volume increases. As a result the gas velocities throughout the length of the bed are approximately constant. Without this design the increase in gas velocities would fluidize the upper part of the bed and destroy the spouting effect.

Contrary to the design for previous applications of the spouted bed,[5] the shale is carried out with the gas stream and separation occurs beyond the reactor. This carry over is accomplished by using a conical exit tube in the top of the reactor (fig. 2). As the spout rises above the bed level in the reactor, most of the entrained solids fall back into the annulus of the bed, however, some of them attain sufficient kinetic energy to rise above the spout

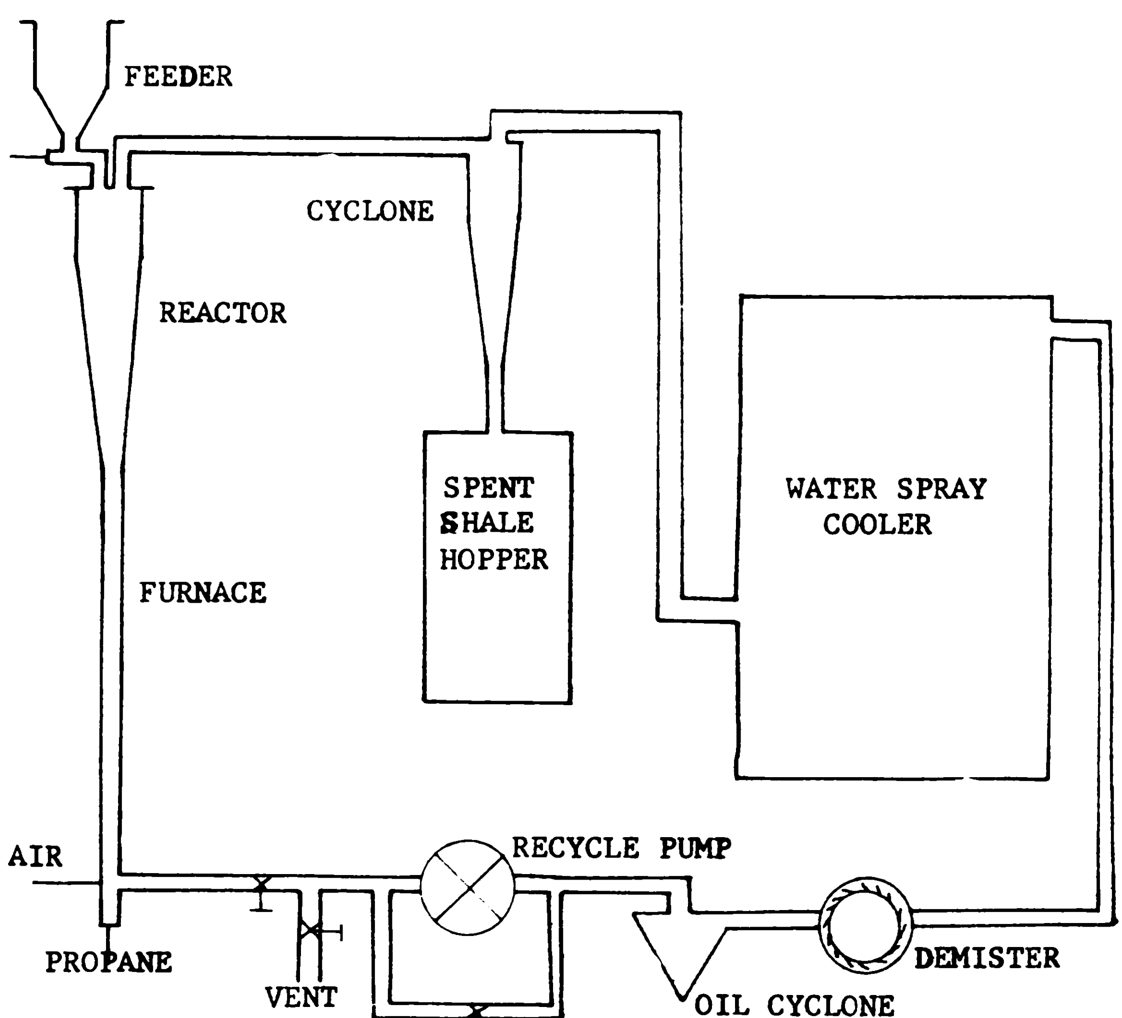

FIGURE 3. — Flow sheet.

into the upper part of the reactor. As the exit gas reaches the conical exit tube its velocity increases carrying out some of the solids. Solids that are not carried out fall back into the bed.

This method of removing solids from the reactor is selective in the particles that are carried out. As expected the less dense and the smaller particles are preferentially carried out.[6] This selectivity is beneficial since the retorted particles are smaller and less dense than the unretorted particles, and also because the small particles. retorted faster than the larger particles. need less time to be fully retorted.

During the retorting operation the shale undergoes three important physical changes that enhance the operation of the retort: (1) The shale becomes less dense due to the loss of organic matter and expansion of the rock: (2) the shale becomes soft and breaks up into small particles easily: also as the outer surface of the larger particles is retorted it breaks off exposing an unretorted surface: (3) the cold shale feed as it enters the hot reactor tends to explosively cleave into small particles.

Feeder. Since this is a pseudo-steady state continuous process, shale must be fed into the reactor at a rate equal to the rate of removal of shale in the exit gas. Fresh shale is fed in at the top of the reactor from a sealed hopper by a solids feeder. The shale flows into the rectangular barrel of the feeder until it reaches its angle of repose, the slope at which solids will no longer flow by gravitational forces alone (fig. 4). A blast of gas from the rear of the barrel forces all of the shale that extends below the hopper into the reactor (fig. 5). Shale flows into the barrel as before. As the frequency of this cycle is controllable. the shale flow rate into the reactor can be regulated.

Cyclone. The solids separation is accomplished by a cyclone attached to the reactor outlet. This 4-inch cyclone is capable of separating from the gas stream all particles greater than 10 microns in diameter.[7] which accounts for 97 percent of the total solids. A sealed hopper is attached to the bottom of the cyclone for spent shale collection.

Water spray. Most of the solids remaining in the gas stream after passing through the cyclone are knocked out by a water spray in a direct contact cooler. Although this contact essentially eliminates all of the remaining solids. it has little effect on the gas stream other than cooling it. The oil in the gas stream having been cooled below its condensation temperature forms a very stable mist and remains in suspension as it passes through the cooler. The oil which is retained is of a very heavy nature and represents a very small percentage of the oil produced.

Demister. The mist after passing through the water spray is collected by a mechanical mist eliminator. The unit coagulates the submicron particles into larger particles that can be easily taken out of the gas stream. The unit also removes a small quantity of water from the gas stream. The water and

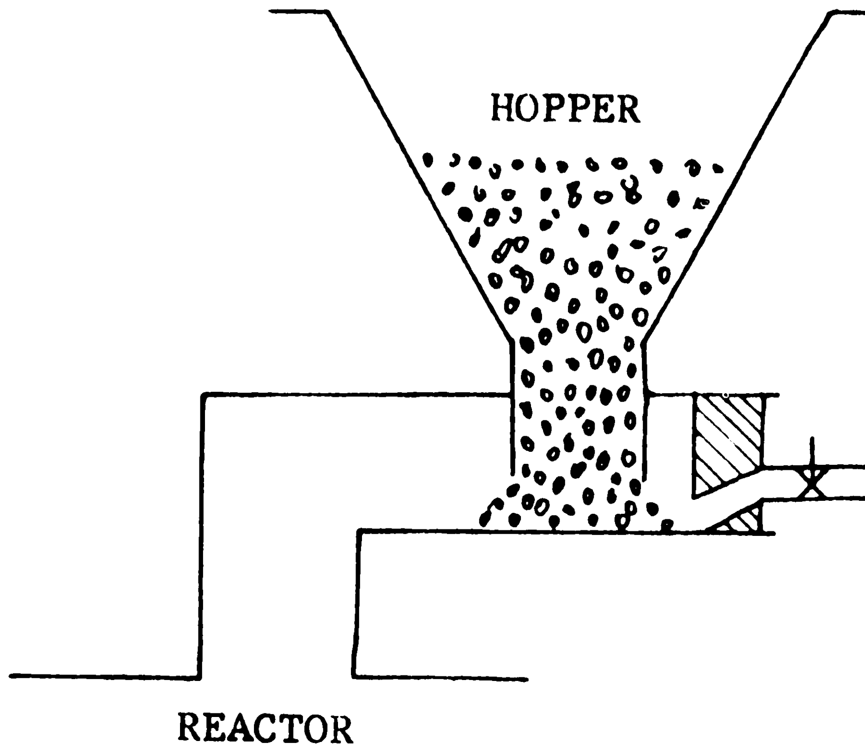

FIGURE 4. — Feeder.

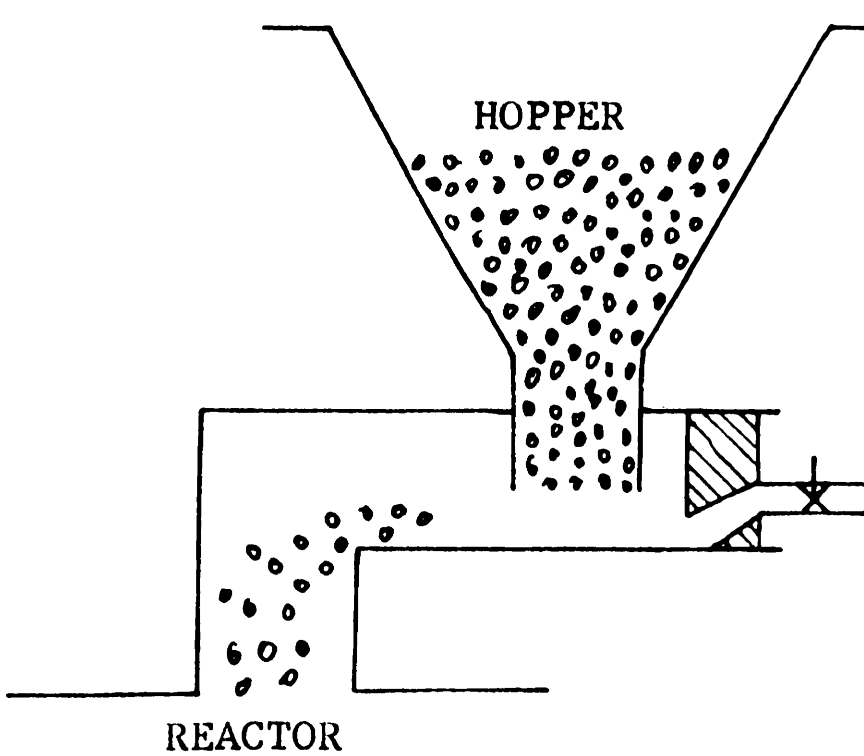

FIGURE 5. — Feeder.

the oil in the form of an emulsion are removed from the gas stream by the oil cyclone.

Recycle pump. The gas stream from the demister passes into a pump for recirculation. Gas which is not recirculated is vented to the atmosphere.

Bed control. The residence time of the solids can be controlled by adjusting the solids flow and the volume of the reactor. This procedure can be described as follows: as the flow rate of the feed into the reactor is increased, the bed depth increases until the carry over is equal to the feed rate. This increase in carry over is due to the decrease between the top of the spout and the outlet tube as the bed height increases. Carry over can also be increased by increasing the gas flow into the bed. Thus by adjustments of the gas velocity and the solids feed rate, the bed depth and therefore the residence time can be controlled.

Temperature control. Temperature is controlled by the amount of oxygen put into the reactor since the rate at which the coke burns is proportional to the partial pressure of the oxygen. The gas stream from the mist eliminator, being essentially oxygen free, is recycled into the reactor. The ratio of recycle to air adjusts the partial pressure of oxygen and therefore controls the temperature in the reactor (fig. 6).

The temperature can be controlled accurately anywhere along the curve. The maximum of the curve represents the point at which the coke starts to

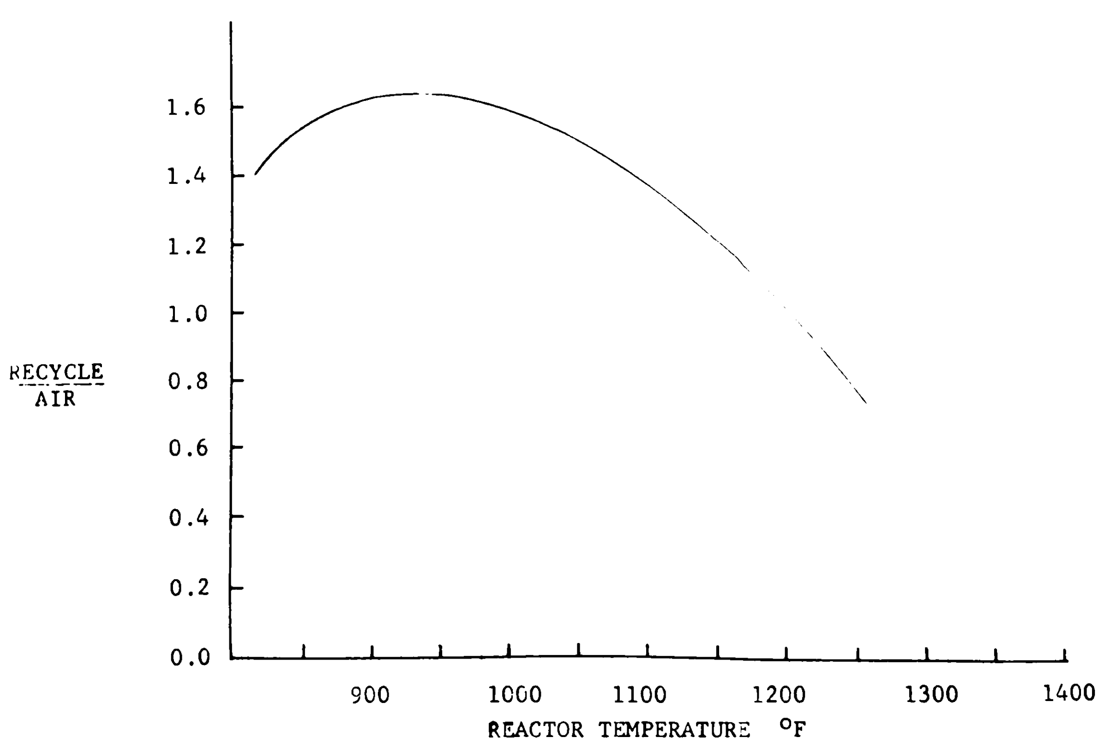

FIGURE 6.—Temperature control curve.

burn efficiently. The curve in figure 6 is representative of the shape of the temperature curve, but its exact location is dependent on the operating conditions.

CONCLUSIONS

The results obtained from the research on the application of a spouted bed as an oil shale retort give the following conclusions:

1. The unit can be operated successfully at any temperature from 950°F to 1350°F by controlling the air to recycle ratio.
2. The reactor will handle a full size range of particles smaller than 1/4 inch at a capacity of 1/4 ton per day (anticipated capacity of 1 ton per day). The size range covers the 10 to 20 percent from mining and crushing that the gas combustion retort will not handle.
3. Oil yields are comparable to values obtained by other researchers using entrained solids technique of retorting.
4. Anticipated capacities for the unit will give air rates comparable to values for fluidized oil shale retorts.
5. A lower grade of shale than that used in the experimental work could be retorted since the residual carbon content was significant. It is also anticipated that this type of retort will handle much higher grades of shale without any foreseeable difficulties.

The conclusions indicate the feasibility of using a spouted bed as a oil shale retort.

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