IN SITU PROCESSING OF OIL SHALE

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Processing of oil shale in its existing formation—referred to as in-situ processing—has long been the dream and hope for large-scale oil production from this nation's immense oil shale reserves. The advantages were obvious. Mining of the ore and the total materials handling would be dramatically less, spent shale would be left underground, the costs would have to be less, and—as a result—lower grade ores could be processed economically. The latter point alone would increase the recoverable reserves by several times over more conventional mining and aboveground processing systems. Until recently the disadvantage was also obvious—no one had successfully demonstrated a method which had any prospect for high yields and low costs, the essential keys to commercial success. For as most of you know, oil shale is not a porous rock nor is it found in permeable formations. It is this factor, almost alone, which has caused the failure of most in situ tests. Most conventional fracturing techniques have been tried in an attempt to create adequate flow paths for gas and oil between even closely spaced wells. Some met this limited technical success, such as being able to maintain combustion in tight fractures, and produce some oil. But in no known attempt was gas flow even partially controllable and oil yields were essentially negligible.

Garrett Research and Development Company has taken a different approach. Accepting the facts of negligible porosity and permeability, we concluded that a modified in situ process would yield many of the projected advantages and overcome the proven disadvantages. The modified in-situ process consists of creating underground chimneys of tightly packed but broken oil shale by *mining* the required void volume and subsequent breakage of overlying oil shale by the use of conventional explosives.

In its simplest form, the Garrett process consists of three basic steps: (1) a limited amount of conventional mining; (2) blasting of the overlying oil shale to form the retort, and (3) retorting in place, normally

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using air and underground combustion as in NTU retorting. The mining step creates the void volume in the form of a room underlying or overlying the oil shale zone to be retorted. The rock mined is conveyed to the surface, where it may either be stacked and vegetated or added to other mined shale and retorted. The second step in the process consists of drilling vertical longholes from the mined-out room, either up or down or both, loading those holes with ANFO and detonating that explosive with appropriate timing delays so that the rock, as it breaks, spreads out to fill the entire volume, that is, both the volume of the room and the volume of the rock before blasting. Finally, connections are made to both the top and bottom and retorting is carried out. Air is circulated downward through the rock pile, and combustion is initiated at the top with the aid of an outside fuel source for a matter of hours. The heat released retorts the top shale to produce shale oil, some gas, and a residual carbon left on the shale. This carbon then becomes part of the required fuel. Part of the off gas is recirculated to control the oxygen concentration in the incoming air and this gas provides needed additional fuel. The oil flows or drains to the bottom of the retort where it is collected in a sump and pumped to underground storage. The gas not recycled is burned with a potential for power generation significantly in excess of the plant's needs. The process is simple in concept.

Field testing of the Garrett process started in mid-1972. Initially, the tests were aimed at demonstrating the overall concept by showing that chimneys with low void volumes and relatively large average particle size could be formed and subsequently retorted efficiently with a low pressure drop. In one sense, these first tests are scaleups of NTU retorts, such as the Bureau of Mines has run at Laramie. In another sense, however, they are dramatically different in that they are formed underground and the reactor geometry is completely different. The NTU retort is a tall, narrow vessel having a relatively small cross section. The retorts in the Garrett system may also be tall but must have a large cross section for high yields from the formation. The Bureau's retort loading system assures an even void volume distribution with 40 to 45 percent void volume; the Garrett *blasting* technique *must distribute* the *mined* void volume and has as its target a maximum of 15 percent. Even so, the first tests of the Garrett system represent a scaleup of 20 to 40 times the largest NTU retort. Retort number 1 contained 3,000 to 4,000 tons of broken shale at 25 percent average void volume and produced over 60 percent oil yield based on Fischer assay. Twelve-hundred barrels of oil were collected and placed in storage.

A few other interesting points can be reported on this particular experiment. The rock mass broken was 60 feet thick and subsequent drilling into it at five locations showed that rubble existed to within 1 to 2 feet of the anticipated top, that is, the rock broke as expected and bulked full. Reactor temperatures, gas yields, and the retorting advance rate agreed, to a great extent, with predictions arrived at by mathematical modeling of the complete reaction system. The gas produced was almost as expected with 2 to 4 percent CO as well as some hydrogen, light hydrocarbons and inerts. Even with this noxious gas being produced and recycled, we were able to seal the retort adequately so that normal mining operations could and did proceed safely. Carbon monoxide monitors were used in key locations.

The critical questions related to process feasibility have all been answered affirmatively and the emphasis is now on scaleup to commercial size underground retorts. We will, in 1974, prepare a 250-foot high retort with breadth and width of over 100 feet each. This room will be at a new location, near the existing test site, and will be mined essentially as the first commercial room.

Let's turn our attention now to the original list of advantages for in situ processing and compare them with this process as presently being developed.

(1) A true in situ process would eliminate all mining. The Garrett process greatly reduces the mining required but does not eliminate it. In fact, the mine planned on our present site will be a large mining operation by almost any standard even though it will be far smaller than more conventional planned oil shale mines.

(2) Spent shale is left underground in the Garrett process. The very nature of the process requires that the retort chimneys be essentially tight so that the spent shale is confined and kept isolated. Extensive leaching will not occur. In addition, the saline minerals deposition at our present location was minimal so that there is not much potential for leaching.

(3) I am not free to discuss process economics, but it should be obvious that a greatly reduced mining operation and elimination of most of the aboveground retorting facilities has the potential for reduced costs.

(4) Because the costs are lower than for mining and aboveground systems, it becomes possible to process lower grade ores economically. Our present site has a 60- to 80-foot seam of oil shale averaging 25 gallons per ton; and yet we are proceeding

with a room 250 feet in height. Much of this additional oil shale contains 10 to 15 gallons per ton and is not even considered ore in government and industry reserve calculations. Admittedly, a large amount of low-grade rock must be processed in-place to yield a reasonable oil-production rate, but we believe it is feasible, both technically and economically.

(5) Because of the added retort height over conventional room and pillar mining, overall recovery from a given location can be several times that projected for other systems. This will be true, however, only if close spacing of large retorts can be accomplished and high yields obtained. With rooms 160 by 160 feet in breadth and width and 40-foot pillars between rooms, the pillars loss would be comparable to room and pillar mining. On the basis of our present work, yields of 70 percent of the oil in a given chimney, appear totally feasible.

In summary, the Garrett process does obtain most, but not all, of the expected advantages projected for in situ processing of oil shale. It has been demonstrated on a relatively large basis under actual field conditions and it is being scaled up rapidly with the objective of reaching fullscale commercial operations at the earliest possible date. There is a lot of development work ahead and some unforseen problems will probably arise in the scale-up. Nevertheless, we do not now see any technological hurdles that have the potential for making the process unattractive.