DOE Office of Petroleum Reserves – Strategic Unconventional Fuels

Fact Sheet: Oil Shale Conversion Technology

Background

- Oil shale must be heated to temperatures between 400 and 500 degrees centigrade to convert the embedded sediments to kerogen oil and combustible gases.
- This can be achieved by mining the shale and heating it in surface retorts, or by contacting and heating the oil shale in-place (in-situ).

Surface Retorting

Numerous approaches to surface retorting were tested at pilot and semi-commercial scales during the 1970s. Two major types of surface retorts, vertical and horizontal, have offered significant promise.

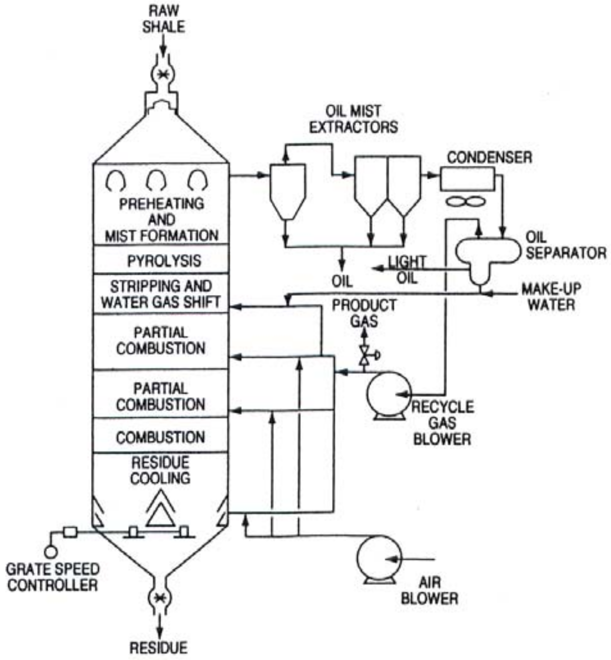
A. Vertical Retorts

Vertical shaft retorts have been used with increasing success and efficiency since the earliest days of oil shale operations in Scotland.

The Gas Combustion Retort (GCR), developed by Cameron Engineers and the U.S. Bureau of Mines is one of the most successful vertical retorts (Figure 1). GCR achieves high retorting and thermal efficiencies. GCR requires no cooling water, an important feature in semi-arid regions. A variation called Petro-Six is operating in Brazil.

- Crushed shale moves downward by gravity.
- Recycled gases enter the bottom and are heated by retorted shale. Air is injected and mixes with the rising hot re-cycle gases.

Figure 1. Gas Combustion Retort



- Combustion of gases and residual carbon from the spent shale heats the raw shale above the combustion zone to retorting temperature.
- Oil vapors and gases cooled by the incoming shale leave the top of the retort as a mist.

In another GCR variation, the **Paraho** process:

- Crushed shale (fines removed) descends by gravity.
- Zones for each step in processing the shale are maintained by managing gas flow in the retort.
- The retort can be operated in a direct or indirect combustion mode. The indirect combustion mode burns process gas in a separate furnace and hot gases carry heat to the retort.
- This technology is currently being considered for a major non-U.S. oil shale development effort.

B. Horizontal Retorts

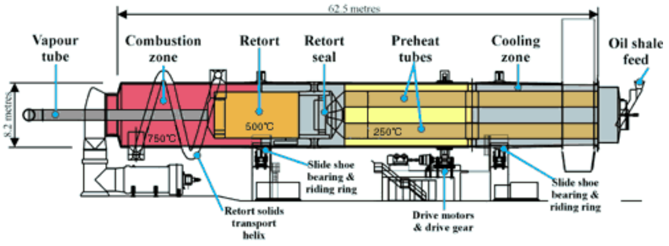
Both the TOSCO II and the Alberta Taciuk Processor (ATP) use horizontal rotating kilns for pyrolysis.

- TOSCO II, terminated in 1972, preheated shale in a bed, then circulated the shale in a hot rotating drum with heated ceramic balls.
- The ATP process combines gas recirculation and direct and indirect heat transfer from circulated hot solids in a rotating kiln.
- The ATP process is largely energy self-sufficient. Some of the hot processed shale is re-circulated in the retort with fresh shale to provide pyrolysis heat by direct, solid-to-solid heat transfer.

ATP has been reported to increase kerogen oil and gas yields, improve thermal efficiency, reduce process water needs, and minimize residual coke on spent shale, enabling environmentally-safe disposal.

ATP's ability to handle fines could be important for U.S. carbonate shales, which can disintegrate into fine particles. These particles can find their way into the shale oil and be difficult and costly to remove.

Figure 2. ATP Horizontal Rotary Kiln



ATP Caveat: Design issues and scale-up limitations have raised critical questions about ATP's viability for use in large scale commercial operations.

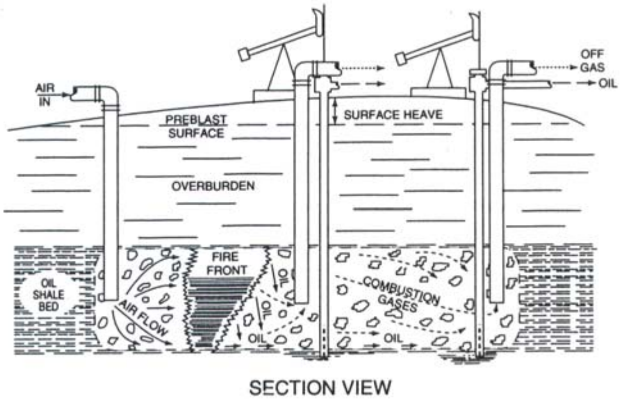
In-Situ Processes

In-situ processes can be technically feasible in deeper, richer deposits where the rock has natural permeability or where permeability can be created by fracturing.

True in-situ processes involve no mining.

- The shale is fractured, air is injected, the shale is ignited to heat the formation, and shale oil moves through fractures to production wells.
- Difficulties in controlling the flame front and the flow of oil can limit oil recovery, leaving areas unheated and some oil unrecovered. (Figure 3)

Figure 3: Conventional True In-Situ Process Schematic



Modified in-situ (MIS) may involve mining below or above the target shale deposit before heating to create void space of 20 to 25 percent.

- The shale is heated by igniting the top of the target deposit and recovering fluids from ahead of or beneath the heated zone.
- Modified in-situ processes can improve performance by heating more of the shale, improving the flow of gases and liquids through the rock formation, and increasing volumes and quality of the oil produced.

Environmental Caveat: Both true and modified in-situ processes are challenged by the potential for contamination of groundwater by pyrolized oil and other metals and toxics that may be left behind.

Shell ICP: Shell's new in-situ conversion process (ICP) could produce high quality fuels in a more, economic and environmentally sound manner. In this substantial modification of the "true in-situ" process:

- Electric or gas heaters, placed in closely spaced vertical wells, slowly heat the shale for 2-4 years.
- The slow heating creates microfractures in the rock that augment natural permeability and enhance fluid flow from heated zones to production wells.
- Resulting shale oil and gases are moved to the surface by conventional wells and vapor recovery technology.
- Slow heating improves product quality; subsequent product treating is less complex, than for surface retorts or other in-situ approaches.
- Much more oil and gas may be recovered from a given area as shale oil and combustible gas products can be produced at greater depths than are accessible by other oil shale technologies.
- The ICP process involves no subsurface combustion of the resource, reducing environmental impacts.
- Close spacing, adjustable heat sources, and modern downhole monitoring technologies vastly improves temperature control.
- Innovative "freeze wall" technology is being tested to isolate production areas from intrusion of groundwater until shale heating, production, and post production flushing has been completed.

Shell is currently operating a modest field research effort in northwestern Colorado's Piceance Basin to test ICP's viability on the basin's world-class oil shale reserves. Critical issues include:

- Development of reliable heater technology
- Improvements of heater durability relative to down hole rock mechanics
- Validation of efficacy of freeze wall technologies.

Figure 4: Shell In-Situ Conversion Process Schematic