EXTRACTION OF OIL SHALE: SURFACE AND IN SITU RETORTING

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Summary

The pyrolytic technique of destructive volatilization is commonly referred to as low temperature oil shale retorting. This technique has been universally adopted for

processing oil shale to produce shale oil. Oil shale retorting is a very simple process since it basically involves only the application of heat to break down the kerogen followed by removal and quenching of the volatile products.

Oil shale retorts can be grouped into two broad categories: surface processing and *in situ* processing. In surface processing, the oil shale retorting plants are called "oil shale retorts," and have been operated in various countries for more than a hundred years. The oil shale retorts have many different types including directly and indirectly gas heated retorts and directly solid heated retorts. The typical retorts include the Paraho retort, Fushun type retort, Petrosix retort, Superior circular grate retort, Kiviter retort, Tosco retort, Lurgi–Ruhrgas retort, Galoter retort, Taciuk retort. Of these, only the Fushun type retort and Kiviter retort have been operating on a commercial scale for many years; and the Petrosix retort in recent years.

In the *in situ* retorting process, heat is supplied either by underground combustion or by introducing heated gases or liquids to the oil shale formation. Two methods of *in situ* oil shale retorting have been tested. The "true" *in situ* method consists of fracturing, retorting, and recovering the products through the use of boreholes from the surface. The "modified" *in situ* method involves subsurface mining to create a void, blasting the adjacent oil shale into this void area and then retorting it.

1. Introduction

Retorting conditions for oil shale have a significant effect on the properties of the shale oil and on the oil yield. Among them, heating of the individual shale pieces is the prime consideration in developing retorting concepts and in operating oil shale retorts. Therefore, the method of heat transfer to the raw shale provides a convenient way to classify the retorts. In a very broad sense, two different retorts can be distinguished: (1) directly and indirectly gas heated retort, and (2) directly solid heated retort.

In the directly gas heated retort, heat is transferred by passing hot gases directly through the shale, mostly in a vertical shaft kiln. This kind of retort can be subdivided into the following two modes: (1) internal combustion mode and (2) external combustion mode. In the internal combustion mode retort, hot gases are generated either by combustion of residual carbon in spent shale within the retort or by combustion of some retort gases. Examples of this type are the Fushun type retort, the Paraho retort, and the Kiviter retort. In the external combustion mode, retorts are heated by hot recycled product gas that is reheated in an external heat exchanger. Examples are the Union Oil retort and Petrosix retort.

In the indirectly gas heated retort, oil shale is heated through a barrier wall. This type of retort was used mainly before 1960 and is not being developed further because of the small capacity, expensive heat transfer, and low thermal efficiency.

In the directly solid heated retort, heat is transferred by mixing hot solid heat carriers with fresh shale. This method involves a more complex heat carrier circulation system but has the advantages of high oil yield, easy scale-up, undiluted product gas, direct use

of spent shale, etc. The Lurgi–Ruhrgas retort, the Tosco retort, the Taciuk retort and the Galoter retort are typical examples of directly solid heated retorts.

An attractive alternative to surface retorting processes is the *in situ* retorting process. There are many reasons to develop *in situ* techniques for recovering the oil from oil shale. In surface processing, approximately 80% of the material mined must also be disposed of as inert inorganic matter, which presents serious environmental problems and adds considerably to the cost of the oil produced. In addition, half or more of the shale oil reserves are contained in the lower grade shale, ranging down to 10 gallons per ton. Only by *in situ* retorting can oil be economically recovered with high grade sections. The *in situ* retorting process involves hydraulic pressure, chemical explosives, and the more unconventional nuclear explosives. Heat is supplied either by underground combustion or by introducing heated gases or liquids to the oil shale formation.

2. Surface Retorting Processes

2.1 Indirectly Gas Heated Retort

2.1.1 Pumpherston Retort

The Pumpherston retort emerged as the most successful retort of the Scottish oil shale industry in the second half of the nineteenth century. The plant was established in Scotland in 1947, and consisted of two benches with 52 retorts each. The capacity of each retort was 10 tons a day. Daily oil production was about 530 barrels. All products had a ready market in Scotland. Acid was recovered from the acid tars and used to produce ammonium sulfate. The tar was used as refinery fuel.

The Pumpherston retort had the advantages of producing undiluted shale gas and few restrictions on the grain size of the feed shale. But low capacity, high investment cost, and low thermal efficiency hindered further development of retorting technologies based on this indirectly gas heated type. The Pumpherston retort was closed down in 1963 because of competition from cheap and imported petroleum.

2.1.2 Salermo Retort

This type of retort was operated near Ermelo, Transvaal, in 1935. In the Salermo retort, small oil shale particles (<25 mm) were progressively shoveled through a series of semicircular troughs heated from the underside by combustion of noncondensable gases. Each retort processed about 70 tons of oil shale per day to produce 90 barrels of shale oil. The oil recovery was about 90% of Fischer assay. The spent shale containing large quantities of residual carbon (up to 40%) was discarded. The plant was closed in about 1962; by that time it had exhausted its oil shale resources. At present, one Salermo retort is still in operation in Clerbagnoix, France, to produce high sulfur shale oil. This oil is used for the production of ichthol pharmaceuticals.

2.2 Directly Gas Heated Retort

2.2.1 Paraho Retort

The Paraho Development Corporation developed new vertical shaft kiln hardware and process techniques and confirmed new technology in the 1960s by building three large commercial lime kilns. In the 1970s they adapted their lime kiln technology to oil shale retorting. Paraho obtained a lease from the US Department of the Interior in May 1972 for the use of the US Bureau of Mines oil shale facility at Anvil Points near Rifle, Colorado, to demonstrate their retorting technology.

In the Paraho retort, as shown in Figure 1, raw shale with a size of 0.6–8 cm enters a feed hopper on top of the retort. In a continuous moving bed, the oil shale flows downward consecutively through the mist formation, retorting, combustion, and cooling zones. As the shale descends, heat is efficiently exchanged with a countercurrent flow of recycle gas, which is introduced into the retort at different levels by three specific-purpose gas–air and gas distributors. Near the top of the retort the ambient temperature shale is warmed by rising hot oil vapors and gas, which, in turn, are cooled to form an oil mist that is entrained in the gas.

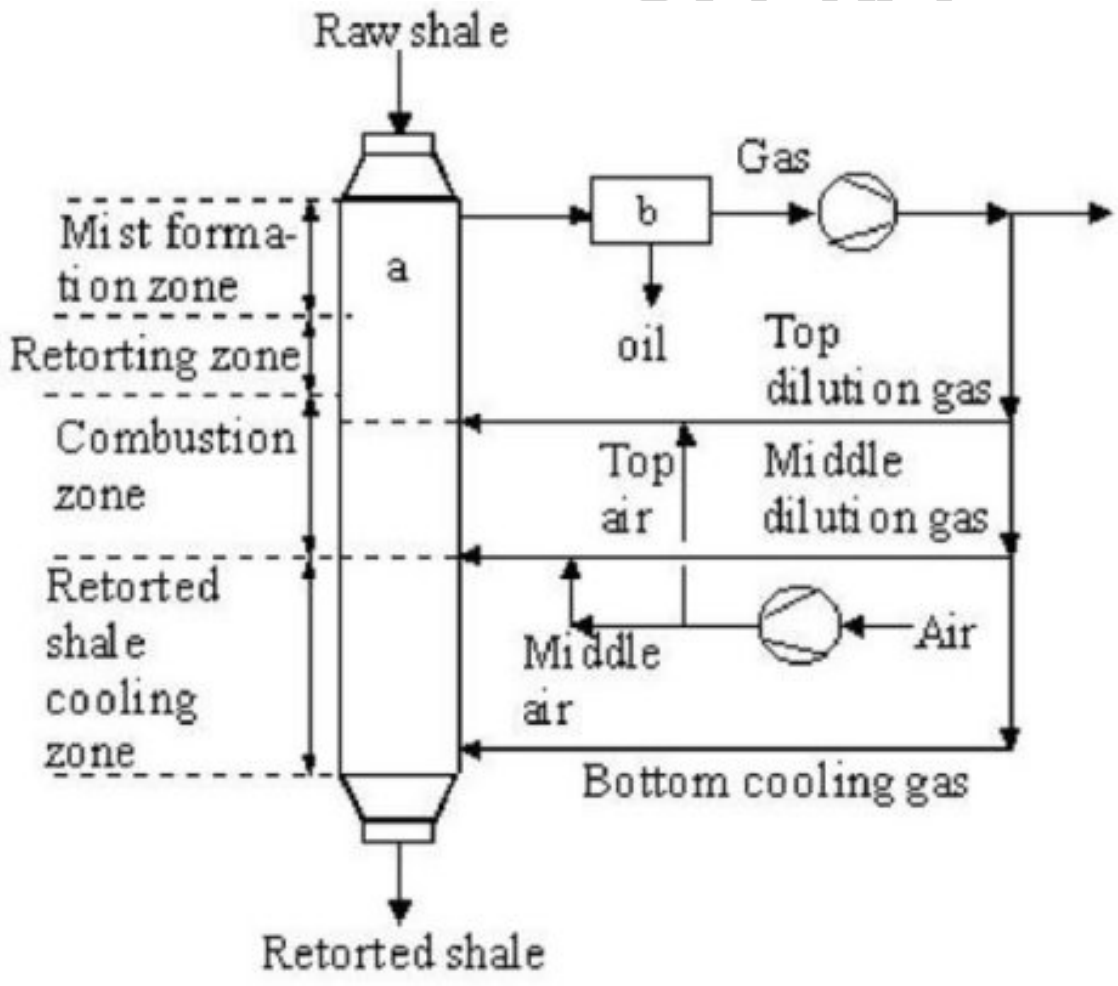

Figure 1. The Paraho retort.

As the shale continues downward into the retorting zone, it is heated by rising hot gases to retorting temperatures of 950 °F (510 °C), where kerogen is pyrolyzed into oil vapor, gas, and residue. This residue is utilized as a fuel when spent shale descends into the combustion zone, where combustion is achieved by the injection of air diluted with recycle gas through the middle and top distributors. This combustion provides the heat for the retort process.

The retorted shale is moved through the grate and is discharged through the seal to a disposal system. The oil vapors leave the retort in the gas stream as an entrained oil mist. The gas stream carries the mist out of the retort through the off-gas collectors. After removal of the liquid oil mist, retort gases are recycled to the retort through the gas distributors and are used to carry heat to the upper portion of the bed to retort and preheat the shale.

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Bibliography

Allred A. D. (1982). *Oil Shale Processing Technology*, 230 pp. New Jersey: Science Press. [This presents a detailed discussion of oil shale retorting technology.]

Hou L. (1986). *Shale Oil Industry In China*, 257 pp. Beijing: The Hydrocarbon Processing Press. [This is a systematic presentation of the production and development of the oil shale industry in China.]

Weiss H.-J. (1991). *Ullmann's Encyclopedia of Industrial Chemistry* A18, 101–126. Weinheim, Basel, Switzerland: VCH. [This presents a comprehensive discussion of the chemistry and technology of oil shale processing.]

Yefimov V., Doilov S., Pulemyotov I., and Nazinin N. (1998). Specific features of high-capacity retorts with a circular semicoking chamber. *Oilshale* 15, 55–64. [This is a summary of the Kiviter retort.]

Biographical Sketches

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