PROCESSING OIL SHALE

Unlike conventional petroleum, shale oil cannot be pumped directly from the ground. It must be processed by a technique known as retorting, wherein the rock is heated to release crude shale oil, shale gas and water. Processing can be accomplished by mining the oil shale and retorting it on the surface, called ex-situ processing; by using underground methods known as in-situ recovery; or by a combination of the two methods. Crude shale oil is upgraded to remove certain impurities, such as sulfur and nitrogen, and then further processed in an oil refinery to produce gasoline, clean diesel fuel, jet fuel and other petroleum based products.

Ex-Situ Processing

Ex-situ processing of oil shale has been practiced for over a century in various parts of the world. Projects based upon this approach have been operating for decades in China, Estonia and Brazil. These processing facilities look much like any modern industrial complex. First the oil shale is mined by underground or surface mining methods. In Colorado and Utah underground room and pillar mines were opened decades ago and are still in stable condition. Because of the strength of the oil shale beds, large stable rooms can be created supported only by pillars of oil shale and rock bolts placed in the ceiling. This contributed to the excellent safety record for these mines. This is very different than many underground coal mines that have small openings in relatively weak rock. Underground oil shale mines are more like subterranean quarries, and consequently large trucks, loaders and drilling equipment can be used in them to keep costs low. After oil shale is mined, it is reduced in size in machines called crushers, conveyed to the retorting plant, and converted into crude shale oil, water and shale gas. A number of well-tested ex-situ retorting technologies are candidates for commercial projects, but none are operating at commercial scale in the United States. The waste rock that results from retorting is known as spent shale. It constitutes about 70-80% by weight of the mined oil shale, and expands somewhat as a result of size reduction in mining and crushing of the mined rock. After cooling and conditioning, the spent shale is conveyed to a surface disposal area or back into the mine. At the disposal area spent shale is compacted to assure its stability, covered with top soil and vegetated. Large spent shale embankments created in the U.S. over two decades ago are stable, support vegetation and have not contaminated water supplies. Some amounts of spent shale may find applications in construction materials such as bricks and cement.

In-Situ Processing

In-situ processing employs techniques similar to the drilling and production of conventional petroleum. In this approach, wells are drilled into the oil shale strata, and retorting is conducted in the ground without mining. Other wells are drilled into the same area for production of crude shale oil liberated by underground heating. The method of supplying heat to the underground oil shale varies by technology. A number of research and development projects have been conducted using various in-situ techniques, but none have yet reached a commercial level of production in the U.S. Insitu processing was successfully conducted in Sweden between 1941 and 1960, and experiments were conducted in the United States beginning in the 1970's (e.g. Equity Oil Shale project in Colorado). There are a number of active in-situ R,D&D projects including the American Shale Oil project in Colorado. In-situ technologies are most applicable to thick oil shale deposits where mining is more difficult, such as the center of the Piceance Basin of Colorado where oil shale deposits are about 1000-feet thick and buried under 1000-feet of overburden. Crude shale oil, shale gas and water are produced from in-situ retorts. The crude shale oil produced is a quality that requires less upgrading than oil from most ex-situ processes, but recoveries are somewhat less. Studies indicate that the shale gas produced is sufficient to supply a large portion of the heat needed for oil shale retorting. Alternatively, the

shale gas may be processed and sold as natural gas. Produced water may be used internally by the project or cleaned and returned to the subsurface. The spent shale resulting from in-situ processing is left underground and need not be reclaimed in the conventional sense. However, ground water in the processing area may be impacted by the spent shale and hydrocarbons left behind if mitigation measures are not taken. Concepts for excluding ground water and mitigating potential impacts to ground water are being developed.

Other Processing Methods

Modified in-situ is an approach that uses a combination of ex-situ and in-situ techniques. In one case some of the oil shale is mined underground to create a cavity for subsequent in-situ retorting. In this approach an underground void is created into which an adjoining mass of oil shale is made into rubble through explosive fracturing conducted in preparation for subsurface retorting. In another approach, the EcoShale technology, oil shale is mined, crushed, and placed into a lined and covered pit equipped with piping for in-situ retorting. Both approaches have been demonstrated at pilot scale in the field. During World War II Germany used a modified in-situ process. Oil shale was mined and placed in excavated tunnels where it was retorted using in-situ techniques to avoid bomb damage to retorts on the surface.

Thousands of patents have been issued for oil shale extraction technologies. They include the retorting methods described above and other concepts that do not use heat as the principal method of extraction (e.g. extraction of kerogen by methods like flotation, gravity separation, or chemical methods such as dissolution of the oil shale rock matrix). The use of electromagnetic stimulation, electrical conduction, fuel cells, carbon dioxide injection, and biological digestion have also been explored, but none have been tested at large scale.