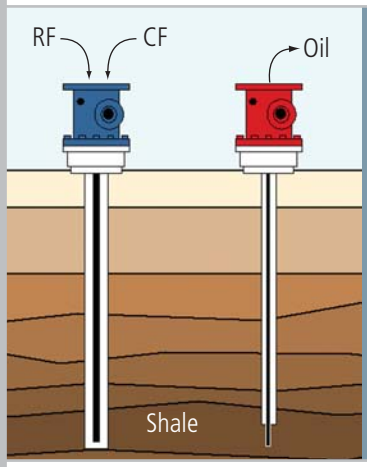
Raytheon

Radio Frequency/Critical Fluid Oil Extraction Technology



Radio frequency (RF) energy combined with critical fluid (CF) technology may help efficiently and safely extract oil from shale. It is projected that the same process may also be used to extract oil from tar sands and to revive spent wells.

Benefits

- Uses half to one-third the energy of competing methods
- Faster overall process than competing methods (months vs. years)
- Less environmental impact than competing oil-shale extraction methods
- Potential to reduce greenhouse gases
- No mining involved in process
- Potential for heat and carbon-dioxide recovery and reuse
- Generates less thermal pollution than competing methods
- Extremely efficient; very high recovery yield

Enormous Oil Shale Reserves

According to the latest studies, the United States has an oil reserve of at least three times that of Saudi Arabia locked in a 16,000–square mile formation of oil shale deposits beneath federal land in Colorado, Utah and Wyoming. Interest in the land goes back to 1910 when the government saw it as a potential source of fuel for the U.S. Navy.

If successfully harvested, shale could provide a long-term source of reliable, affordable and secure oil. In fact, federal officials estimate that this resource could yield anywhere from 500 billion to more than two trillion barrels of oil — enough to meet U.S. demand at current levels for more than 250 years.

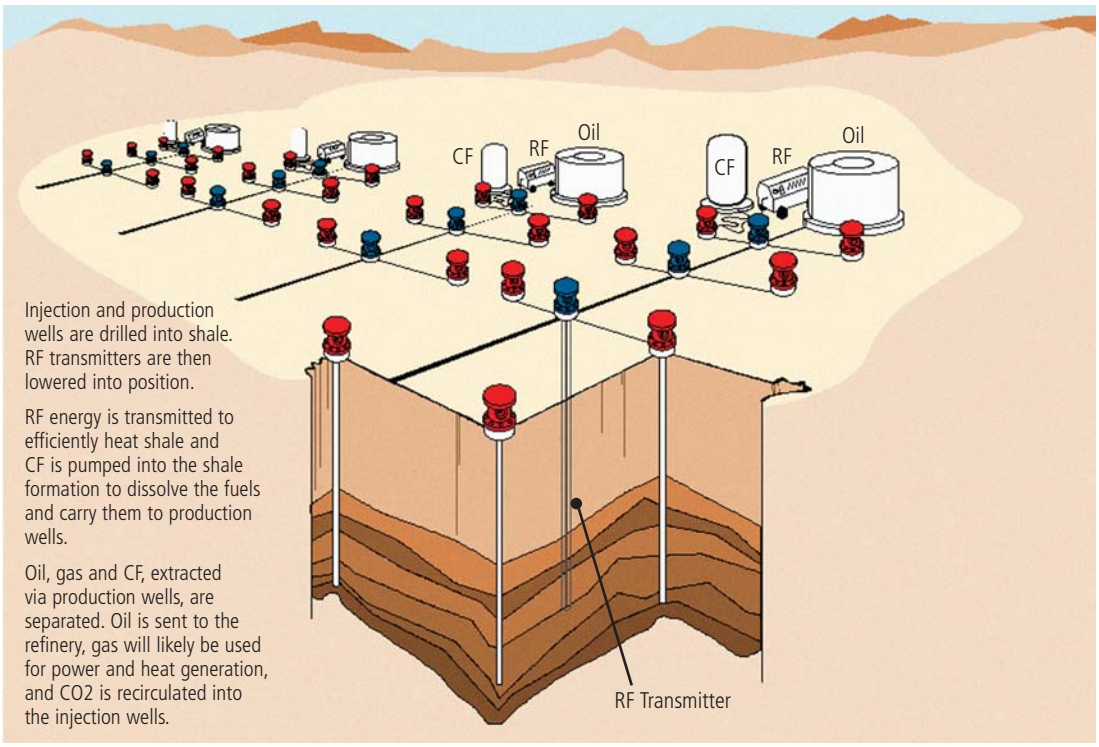
Oil shale, also known as organic marlstone, contains kerogen — a waxy hydrocarbon that can be converted into oil or natural gas when heat and/or pressure is applied. However, this material has not yet received sufficient geological heat and pressure for conversion to fossil fuels.

Potential Solution to Century-Old Roadblock

Nearly 100 years after the U.S. government set the land aside, the shale reserves remain 1,000 feet underground. During this time, various companies have tried to recover oil from the shale with little success due to the environmental and economical ramifications of standard extraction methods. The question remains: How can fossil fuel be extracted from the shale in a cost-efficient manner without wreaking havoc on the environment?

Raytheon, in collaboration with CF Technologies of Hyde Park, Mass., has a solution capable of solving the riddle — and unlocking this enormous oil reserve.

Radio Frequency/Critical Fluid Oil Extraction Technology



RF/CF Hydrocarbon Extraction

Standard oil well head

A Revolutionary "Combinatorial" Technology

The patent-pending solution developed by CF Tech and Raytheon involves the use of radio frequency (RF) technology, more commonly used for radars and guidance systems, in conjunction with "critical fluids" — compounds that rapidly penetrate substrates and safely dissolve a wide range of chemicals. CF Tech, a leading developer of critical fluid processes, and the designer and manufacturer of the processing equipment, is providing Raytheon with critical fluids expertise.

Under this extraction scenario, oil wells are drilled into the shale strata using standard oil industry equipment. RF antennae, or transmitters, are lowered into the shale. The antennae then transmit RF energy to heat the buried shale. Super-critical carbon-dioxide is pumped into the shale formations to extract the oil from the rock and carry the oil to an extraction well. At the surface, the carbon-dioxide fluid is separated and pumped back into injection wells, while the oil and gas are refined into gasoline, heating oil and other products.

It is projected that the same process may also be used to extract oil from tar sands and to revive spent wells.

More Cost-Efficient Than Alternate In-Ground Heating Methods

The combination of RF energy heating the shale and critical fluids flushing the resulting products from the shale enables quick and efficient extraction of fuel, using far less power than other proposed technologies. It is estimated that this combinatorial technology would retrieve four to five barrels of oil for every barrel consumed. By comparison, some other in-ground heating processes used to recover oil from shale formations have been reported to extract only one-and-a-half to three barrels for every one consumed.

In addition, the technology would enable the fuel extraction to start in only one to two months. In-ground heating methods that do not employ radio waves, by contrast, are projected to take years to heat the target area sufficiently for production to start.

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