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SCIENCE

Oil Recovery with Supercritical CO_2

Supercritical fluids are being employed in a variety of applications in the food, pharmaceutical, and chemical industries, and additional uses are in sight. Supercritical carbon dioxide at temperatures around 40°C is being used to extract caffeine from coffee and undesirable substances from hops. Supercritical propane is used to extract hydrocarbons from heavy and residual oils. Supercritical toluene can extract the organic matter of coal, leaving the ash. Another interesting example is the use of supercritical CO_2 to enhance oil recovery. This application is likely to have large-scale economic and strategic consequences.

When liquids are heated in a closed space, the vapor pressure and the density of the vapor above the liquid phase increase. At the same time, the density of the liquid decreases. Ultimately, at the critical temperature, the density of the gas phase and that of the liquid phase become equal. Above that temperature, no liquid phase exists. The volume of the container is filled with a fluid whose density is dependent on pressure. Thus, above the critical temperature, one may have a fluid (not a liquid) that has a density greater than liquids below the critical temperature. The critical temperature of CO_2 is 31°C, and fluid CO_2 can be used above that temperature. Supercritical fluid CO_2 is an excellent solvent for fats and hydrocarbons.

The great target for use of CO_2 is enhanced oil recovery. In the United States, more than 300 billion barrels of oil have been left in known formations after production by earlier technology. With oil priced at $29 per barrel, the known oil in the ground is a most enticing target. This treasure is being tapped in a number of ways, including steam flooding and use of surfactants. In future, the method of choice is likely to involve CO_2. About 18 trillion cubic feet of the gas is available in geological formations in Colorado. Already the major oil companies are investing billions of dollars for pipelines and other facilities to bring the CO_2 to oil fields in the Permian basin of western Texas and New Mexico.

When CO_2 is injected into oil-bearing formations, the maximum pressure that can be attained is related to the weight of the overburden. In general, the CO_2 fluid can be made to have a density of 0.7 or more. Franklin M. Orr, Jr., has written,* "When the pressure is high enough that the CO_2 is a dense phase that extracts hydrocarbons efficiently from the oil, the CO_2 can displace nearly all the oil it contacts." The important proviso is "all the oil it contacts." Circumstances deep underground are complex. Large variations in porosity and permeability occur within short distances. On injection, the CO_2 will relatively easily reach part of the oil-bearing stratum and bypass the remainder. Ultimately, when production of oil is attempted, a limited yield will be attained. Production engineers are exploring substances that can be injected to clog the easy paths and ensure more uniform contact with the oil. Such efforts are only beginning to achieve results. Each oil field is different and requires its own special production scheme. Engineers are using very large computers in efforts to model the fields and their behavior. Samples of the oil-bearing rocks are subjected to laboratory measurements, and these are used in various studies of hypothesized field conditions. The hope is that results from major field tests in the near future will serve as ground truth.

With billions of dollars invested in CO_2 injection, it is clear that the major oil companies expect a good economic return on the ventures. Orr is sufficiently optimistic to suggest that CO_2 produced in power plants may ultimately be captured for use in oil recovery. In view of recent advances in separation techniques the concept might eventually prove practical. In the meantime, trillions of dollars worth of oil sits in the ground awaiting the arrival of displacing fluids.—Philip H. Abelson

*F. M. Orr, Jr., *Journal of Petroleum Technology*, July 1983, p. 1285.