9. H. B. EVANS, C. H. COTTERELL, H. SURKALO, AND W. L. KINNEY, Marathon Oil Company, Littleton, Colorado

LOGGING OBSERVATION WELLS IN AN *In Situ* COMBUSTION TEST

The Fry *In Situ* Combustion Test was conducted in a 3.3-ac. site in the Robinson Sandstone. Six observation wells were cored through the reservoir during various stages of expansion of the combustion front. These cores were sampled for porosity, permeability, grain density, formation factor, saturation exponent, residual fluids, and clay content. These data and core examinations show that the reservoir consists of three sandstone units, each having distinct reservoir properties.

Several combinations of logging devices were run in the observation wells to evaluate their effectiveness in tracking the front laterally and in estimating the degree of combustion vertically.

Gamma-ray-neutron, density, induction, and focused resistivity logs were run open-hole in two wells after combustion. Core, GRAPE,* and density-log porosity were compared with neutron-derived porosity. Both gas saturation and invaded-zone water saturations were calculated. Both methods outline the vertical variations in combustion. In two wells, no logs were run before casing was set. Conventional neutron logs were run through casing but it was necessary to construct departure curves for the conditions encountered. Gas saturations were calculated using the neutron-derived porosity values and core or GRAPE porosity values. This technique yields a qualitative picture of the vertical combustion distribution.

A small-diameter neutron device was run through tubing in one well. In this well, the device was run before the front reached the well and again after combustion occurred. This technique permits evaluation of the vertical extent of combustion using just the ratio of the two response curves.

Of the combinations listed, the neutron-density-focused-contact-resistivity program was most effective in open hole for quantitative determinations of the degree of vertical combustion. In cased holes, the neutron device was satisfactory for identifying the burned zone but the logging program was not designed for quantitative interpretation.

10. GEORGE S. GARBARINI, Sun Oil Company, Denver, Colorado, AND HARRY K. VEAL, Wolf Exploration Company, Denver, Colorado

POTENTIAL OF DENVER BASIN FOR DISPOSAL OF LIQUID WASTES

A reconnaissance subsurface geologic study has shown that three types of reservoirs are available for liquid waste disposal in the Denver basin. These are fractured Precambrian rocks, porous sandstone reservoirs, and thick shale suitable for disposal by the hydraulic-fracturing technique.

From 1962–1965, fractured Precambrian rocks at a depth of 12,000 ft. were being used as a disposal reservoir for toxic effluent produced at the Rocky Mountain Arsenal near Denver. The disposal well presently is shut in pending investigation of the possible relation between waste injection and Denver-area earthquakes which increased in frequency and magnitude during the injection period. Data points on the Precambrian of the Denver basin are sparse because only a few test wells reached it in search for oil and gas. Two borings on the Apishapa uplift indicate the presence of a good fractured Precambrian reservoir.

Porous sandstone reservoirs considered most favorable for waste disposal are the Permian Lyons Sandstone, the Triassic Dockum Sandstone, the Triassic-Jurassic Jelm-Entrada Sandstone, and sandstone bodies of the Cretaceous Dakota Group and Hygiene zone. The Lyons, Dockum, and Dakota are best suited for waste disposal in the southern part of the basin. Exploratory activity for oil and gas in this part of the basin has been very low in recent years, whereas activity is moderate to brisk in the central part of the basin where the Lyons and Dakota are prime drilling objectives. The Dockum Sandstone, potentially the best disposal reservoir volumetrically, is restricted to the southeast part of the basin. The Jelm-Entrada Sandstone and sandstone beds in the Hygiene zone offer potential disposal reservoirs along the heavily populated strip between Denver and Cheyenne.

Cretaceous marine black shale suitable for disposal by the hydraulic-fracturing technique is present everywhere in the basin. The shale crops out in large areas. Beneath the populous strip along the Front Range, the shale locally is covered by as much as 2,000 ft. of Late Cretaceous and Tertiary transitional and continental rocks.

11. HARRY PERRY, U. S. Bureau of Mines, Washington, D.C.

COAL IN LONG-RANGE ENERGY PATTERN OF UNITED STATES

Coal, in 1900, supplied nearly 90% of United States energy demand, but only 23% in 1965. Oil and gas, which together contributed 8% in 1900, accounted for 73% in 1965. Nuclear energy is expected to contribute 5% of demand in 1980 but fossil fuel production will continue to grow, with coal consumption increasing from 470 million tons in 1965 to 750 million tons in 1980; natural gas increasing from 16 Tcf. in 1965 to 25 Tcf. in 1980; and oil increasing from 4 billion bbls. in 1965 to 6.7 billion bbls. in 1980.

Despite the inroads of nuclear fuels, electricity generation will account almost entirely for the tonnage increase in coal consumption during this period. To secure this increase, research and development activities are being intensified to lower the cost of the delivered coal and to effect improvements in the combustion of coal in conventional thermal power stations. Ash deposits and corrosion are under intensive investigation, as are economical means for abating the emissions of sulfur and nitrogen compounds and fly ash that contribute to atmospheric pollution. Studies in progress on the location of power plants over the coal measures include means of economizing on water requirements and on long-distance power transmission. Coal-fired gas turbines and magneto-hydrodynamics are actively being investigated. Methods to improve the production of coke, char, and chemicals from coal carbonization are studied continuously.

The increasing consumption of oil and natural gas is expected to create pressure on domestic supply by 1980. The gap between supply and demand in the period beyond 1980 may be filled in part by substitution of electricity for gas and by synthetic oil and pipeline gas derived from coal or oil shale. Research activities

* Gamma-Ray Attenuation Porosity Evaluator.