the course of the retorting can be installed readily. Designing, conducting, and evaluating this part of the investigation will require about two years.

(2) Design and conduct an experiment using a single nuclear explosive. Because the criteria for selecting a site for a nuclear fracturing experiment are different from those for selecting a site for other types of in situ experiments, considerable additional exploratory work over that designated in phase "A" will be required. A site for a nuclear experiment must be located in an area where the thickness of the shale is great enough to make complete use of the fracturing potential of the device and where the combined thickness of shale and overburden is great enough to insure complete containment. For experimental purposes, this site should also be in a sparsely populated area away from other developments including mine workings and tall above ground structures. The location of aquifers, if any, must be known. Following the nuclear fracturing, an extensive program to determine the characteristics of the broken shale will be completed before retorting and recovery are started. Preparations for nuclear experiment will be started in the first year of the program. Following selection of a suitable site, which is currently underway, one to two years will be required for preparing the site and detonating the nuclear device, and two or three years to evaluating the fracturing results, conducting the retorting and recovery experiment, and evaluating the results.

(3) Develop recovery techniques suitable for application to masses of rubble created by multiple nuclear explosions. Site selection for this experiment will probably have been accomplished at the same time that the site for the single explosion is selected. The placement of the nuclear devices, the conducting of the actual detonations, and the post-shot exploratory work on the extent of fracturing accomplished will be similar but on a larger scale than when a single device is used.

This investigation of multiple nuclear explosions will not be started until sufficient information has been obtained from the single shot experiment to indicate that the multiple shot concept has merit. This will be in the sixth to seventh year of the program. Then, as with the single device experiment, one to two years will be required for the nuclear fracturing phase of the experiment and two to three years for the combustion and recovery phase of the experiment. Therefore, this part of the program will be started and completed during the 10-year program. If successful, experimentation may extend beyond a total of 10 years.

(4) Develop techniques suitable for recovering oil from the fractured zone adjacent to or between nuclear chimneys.

OIL SHALE COMPOSITION, SURFACE RETORTING, AND SHALE OIL UTILIZATION

Objectives

1. Develop improved techniques for obtaining shale oil from oil shale.
2. Upgrade the quality of shale oil.
3. Investigate products obtainable from shale oil, particularly chemical by-products.
4. Determine characteristics of oil shale and shale oil and how these characteristics affect the technology of shale-oil production.
5. Investigate problems of spent-shale disposal.

Program

A 10-year program is proposed to perform both basic and applied engineering research on: (1) The physical and chemical properties of oil shale and kerogen (the solid organic material in oil shale from which shale oil is derived by heat treatment) as related to occurrence in the deposit and how the properties vary with geologic conditions; (2) composition of shale oil, shale-oil components, and shale-oil fractions with particular reference to heavy hydrocarbon fractions; (3) application of basic data on the properties of oil shale to improve processing methods; (4) fundamentals of catalytic, thermal, and chemical treatment of shale oil; (5) effects of retorting temperature variables; (6) effect of physical properties of oil shale on efficiency of crushing; (7) methods for retorting oil-shale fines; (8) techniques of utilizing spent (retorted) shale; and (9) spent-shale disposal problems.

The total cost of this research over the 10-year period is estimated at $13.0 million.