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AEC IN SITU OIL SHALE PROGRAM

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AEC IN SITU OIL SHALE PROGRAM

James S. Kahn

ABSTRACT

In order to meet the energy requirements essential to continued U.S. economic strength and growth, new sources of energy must be developed. The vast oil shale deposits of the Western U.S. are such a resource.

The AEC recommends an accelerated program to develop the technical base essential to the commercialization of a modified in situ technology. A void volume is created by mining a portion of the oil shale deposit and rubblizing the rock above the volume. The rubble zone is then retorted underground. Technical and economic analysis of these field programs would determine the commercial feasibility of the process. If feasibility is determined, the field program would be scaled up to larger volumes.

The following technical issues have been identified as critical to commercial feasibility: 1) determination of minimum porosity; 2) determination of rubblization procedures to achieve minimum porosity; 3) determination of process variables affecting maximum retort rates, highest conversion efficiency and optimum product quality; 4) control of process parameters; 5) identification and resolution of mine safety issues; 6) identification of key environmental issues; 7) analysis of the operation of the total retorting system; and 8) the demonstration of the process on a commercial scale and technology transfer.

These technical issues will be resolved by a two phase field program, a laboratory process development program and an instrumentation development program.

Several suitable sites exist for this proposed program, however, none have been committed.

Joint industry government participation is deemed desirable. Discussions with several industrial groups are currently being held. No industry commitments have been made to date. For this reason the program at present is envisioned as a completely funded government program among AEC laboratories and the U.S. Bureau of Mines. Although industry participation can be accommodated at any stage of this proposed work, it is recommended that joint participation be accomplished at least by the commercial-scale demonstration phase.

INTRODUCTION

It has been estimated that approximately 700 billion barrels of oil lies untapped in the Western United States oil shale deposits. This proposed Atomic Energy Commission oil shale rubblization program has two goals: 1) within three years of initiation of this in situ program to have established the base foundation essential for the commercialization of this proposed technology; 2) within approximately six years from the start of this program to have demonstrated the feasibility of an economically viable commercial in situ oil shale technology. This program is designed to obtain early results in order to rapidly assess the commercial feasibility of this proposed means of resource recovery.

PROGRAM CONCEPT

The rubblization program consists of identifying an oil shale deposit of adequate vertical height and removing a portion of the oil shale to create an open void into which the shale rock can be rubblized and collapsed. Piping and instrumentation would be emplaced in the rubblized volume, a burn front initiated, and the oil shale retorted.

TECHNICAL TARGETS, TASKS AND TIME SCALE

In order to achieve the technical base for commercialization, we believe eight technical issues must be addressed. These are:

- 1) The determination of minimum porosity necessary for the sustainment of an in situ burn;
- 2) The determination of the specific rubblization procedures to achieve the appropriate rubble size and minimum porosity;
- 3) The identification of the production variables essential to an economical and satisfactory in situ retorting process;
- 4) The control of the production variables, by means of an information retrieval system from the retort to a surface control room;

- 5) The identification and resolution of mine safety problems attendant with this new technology. Success in this technology demands that underground development of rubblized zones proceed simultaneously with retorting. In order to achieve this, one must monitor the temperature and deformation of oil retort walls and the composition of the underground atmosphere surrounding each rubblized chamber. Walls should be sufficiently strong and integral to sustain the overburden and prevent noxious fumes from escaping into areas where miners are operating.
- 6) The identification and resolution of key environmental issues associated with this modified mining technology.
- 7) The evaluation of the integrated information obtained from each discrete component of this total system;
- 8) The demonstration of in situ oil shale recovery technology on a commercial scale and transfer of this technology.

Field and laboratory programs are planned to address the key technical issues. The field program consists of two phases: 1) an early, relatively shallow phase to address as many of the critical issues as quickly as possible; and 2) a deeper phase aimed at demonstrating commercial feasibility.

The shallow rubblized volumes, as shallow as possible (200-500 ft deep), are planned with dimensions on the order of 50x50x100 ft. Two such volumes are proposed, with a third optional one. It is expected that a yield of approximately 200 barrels per day would be generated from each of these small volumes and a total of 4000 barrels of oil would be generated upon completion of the retorting of each volume.

The deeper phase, approximately 2000 ft deep, aimed at demonstrating commercial feasibility, is planned to have one set of rubblized volumes with dimensions on the order of 100x100x300 ft. Two such volumes are proposed with a third optional. These volumes would generate approximately 800 barrels of oil per day during retorting operation and a total of 50,000 barrels upon the completion of retorting of each volume. A total

of 100,000 barrels for two such volumes is anticipated. Another deep volume on the order of 250x250x1000 ft is planned upon the satisfactory completion of the retorting of the 100x100x300 ft volumes. Here 5000 barrels per day of oil is envisioned with a total production of 1 million barrels upon completion of the retorting.

Phase I, the shallow volumes, would be approached from a site which can be obtained immediately. It may consist of an already existing mine, or it may have to be developed from an outcrop on the side of a mountain or from a shallow deposit. Figure 1 illustrates the concept for Phase I. Here an existing mine drift has been extended and an initial volume of oil shale has been removed from the drift. In this particular example, the blocks have been developed by standard mining techniques. Upon completion of the rubblization the necessary air inlets and outlets are installed, instrumentation is emplaced, the retort burn is initiated and the underground rubblized blocks are put into operation. Figure 2 is an illustration of the concept in a deeper portion of the oil shale reserves. Several blocks are being retorted, and one is under development.

One of the essential factors in the commercialization of this technology will be the ability to attract industry to this effort. The government may have to pioneer the early shallow phase. However, at the decision point to extend this technology to deeper and larger volumes, it would be appropriate and unquestionably desirable for industry to join with the government in the Phase II portion of this program. This approach precludes difficulties in the technology transfer.

FIELD PROGRAM - TASKS, TIME SCALE

Tables 1 and 2 represent the tasks associated with the two phases of the proposed field program. Table 1 illustrates the development of the shallow rubblized volumes. Table 2 summarizes the time scale and the tasks associated with the deep rubblized volumes.

A) Shallow Program - Phase I

In Fiscal 75 it is proposed that a site be selected, the environmental impact assessed, and the underground construction be initiated. Mine access,

road upgrading and the extension of specific drifts in the mine would be completed in FY75. In addition, mine ventilation and mine safety issues would be defined and begin to be addressed. The plan for the disposal of the material removed from the mine will be developed. The surface facility, consisting of compressors, piping, storage tanks, as well as an instrumentation control room will be designed. Equipment installation will be initiated. In FY76, rubblization would be completed, all instrumentation would be installed, the surface facility would be completed and retorting operations would begin. By the end of FY76 it is anticipated that blocks 1, 2 (and 3 if necessary), will have been retorted. Post mortem examination of the retorted material will be performed in FY77. Analysis of the operation of this shallow system will determine the feasibility of proceeding to the next and deeper phase of this program.

B) Deep Program - Phase II

While the Phase I work is being undertaken, it is essential that FY75 see the initiation of site selection work for the deep shaft and the deep rubblization program. It is further essential that the environmental impact assessment begin, as well as the hiring of a mine design team. FY76 will see the complete preparation of the site, completion of the environmental impact assessment, completion of the mine design and initiation of mine construction. The waste management problem will have been addressed and resolved. Installation of the surface facility would begin. FY77 would see the continuation of the mine construction and the initiation of rubblization in the first two larger volumes. The instrumentation installation associated with those blocks will be initiated and by the end of FY77 retorting operations could commence. Analysis of the Phase I program will indicate the feasibility of proceeding to deeper and larger rubblized volumes. If these analyses indicate insurmountable technical problems or an uneconomic technology, the program would cease.

If on the other hand the results of the shallow rubblization program indicate feasibility, the program would be in the position to immediately scale up to the larger volumes and commercial demonstration. Retorting operations on 100x100x300 ft blocks would then begin in FY78 and continue

through FY79. The 250x250x1000 ft block will have been rubblized during FY78 and FY79 and retorting initiated in FY79. By the middle of FY80, or perhaps as early as the end of FY79 the commercial feasibility of this technology will have been established. Blocks on the order of 100x100x300 ft, may in themselves be a commercial size operation.

PROCESS DEVELOPMENT

There are five areas essential to the establishment of an oil in situ process. They are: 1) Fracturing and rubblization of oil shale; 2) Retorting of rubblized oil shale; 3) Characterization of the rubblized oil shale and the oil shale retorting product; 4) Identification and resolution of critical environmental issues; and 5) The identification and resolution of mine safety issues.

1) Fracturing and Retorting

One of the key parameters in the in situ process is the minimum void volume and subsequent permeability essential to sustain and retort the shale. The rubble size is also of importance to the efficiency of retorting. Void volume and subsequent permeability may be predicted from an understanding of the fracturing mechanisms and general rubblization properties of oil shale rock. In order to develop a theoretical model which may estimate a priori an increase in permeability, the mechanical properties, the equation of state and the general failure criteria of the oil shale must be determined. In order to do this the oil shale material must be subjected to both static and dynamic experimentation in the laboratory and in the field. The laboratory experiments would be conducted on blocks of material ranging in size from a cubic meter to perhaps several cubic meters. The field experimental work may be conducted by drilling holes from the surface into an oil shale deposit, filling the hole with explosive in some specific geometry, detonating the explosive, rubblizing the shale and then characterizing the shale after explosive detonation.

For the depths being considered for this technology, it may be imperative to evaluate commercial chemical high explosives available from industry. If necessary, a high explosive program will be initiated which will develop and test explosives necessary for a satisfactory commercialization technology.

2) Retorting

Prior to the establishment of the commercial technology, a theoretical retorting model must be developed. This model will be tested and refined by correlating the theoretical predictions with data obtained from bench scale and larger adiabatic pilot retort experiments. The refined model would then permit the scaling up of this effort from the laboratory to the size of blocks recommended for this program.

In addition to the theoretical modelling and experimental program associated with the retorting, it is critical that the oil product properties be correlated to processing parameters such as retorting temperature, air flow rates and gas composition.

3) Oil Shale Properties

Laboratory programs will be established to correlate the mechanical properties of varying grades of oil shale under simulated pressure and temperature regimes. This work will assist in resolving the maximum height of oil which can be optimally retorted.

4) Environmental Studies

An environmental impact statement already exists for the oil shale regions of Colorado, Utah and Wyoming. Development of a commercial in situ technology will undoubtedly require resolution of environmental issues unique to this technology.

5) Mine Safety

Commercial feasibility implies retort operations and block development proceeding in parallel. In order for miners to develop rubble volumes adjacent to retorts, we must insure that the walls of the retort are strong enough to sustain any overburden and are also crack-free to prevent the flow of gas from the retort into the manned working areas. Stress conditions in the retort walls must be monitored during this program and the results extrapolated to larger retorts.

PROCESS MONITORING AND CONTROL

The five areas defining the technical foundation for process monitoring and control are: 1) Characterization of the rubblized material; 2) Identification and monitoring of the burn front and retort front parameters; 3)

Monitoring the process parameters; 4) Development of surface controls; and 5) Development of any necessary new mine safety instrumentation.

1) Rubble Characterization

Since a proper permeability must be established by the fracturing process, the increased permeability and the fracture-generated porosity created by the rubblization must be measured. This information is critical to the engineer's design for the retorting process. Not only will overall average properties be necessary, but it would be desirable to determine any gradients within the volume prior to burn initiation.

2) Burn Front and Retort Front Parameters

The location, thickness, temperature, and the shape of both the burn front and the retorting zone must be established in three dimensions in order to understand the interrelationship among the process parameters. In addition, channeling phenomena which may occur during the retort must be identified and mapped.

3) Process Parameters

While the front is progressing from the top to the bottom of the rubble column, temperature, gas flow rate and composition, including oxygen concentration, must be monitored continuously. On-site gas analysis will be correlated to the conditions in the retort and will help to establish optimum oil yield and quality.

4) Surface Instrumentation and Control

The process engineers will monitor and adjust the retorting process in a surface control room. This surface control system acts as a data acquisition and analysis center and is the location of the feed-back mechanism which controls the process.

5) Mine Safety Instrumentation

If necessary, instrumentation essential to the monitoring of the stress and strength and integrity of the walls of the retort volume will be developed.

BUDGET SUMMARY

It is estimated that the FY75 program as outlined in this proposal will cost \$12.55 million. The field and mining portion of the program is estimated at \$6.7M, the process technology at \$5.15M, and the process control at \$.7M. The program costs as currently estimated for the first three years are as follows: First year - \$12.55M; Second year - \$17.15M; Third year - \$20.6M. A total cumulative cost for the first three years is approximately \$50M. The final three years of this program will add approximately \$50M to the total, making this an estimated \$100M program.

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FIGURE 1

OIL SHALE RUBBLIZATION/RECOVERY PROCESS

FIGURE 2

OIL SHALE RUBBLIZATION/RECOVERY PROCESS

TABLE 1:

FIELD PROGRAM – TASKS, TIME SCALE

Phase I – Shallow

	FY75	76	77	78	79	80
1. Site criteria – selection _____	■					
2. Environmental impact assessment _____	■					
3. Mine design _____	■					
4. Construction	■	■				
A) Access/upgrading _____	■					
B) Mine _____	■					
C) Rubblization _____		■				
D) Ventilation/safety _____		■				
5. Waste management _____	■	■				
6. Instrumentation installation _____	■	■				
7. Surface facility _____	■	■				
Design _____	■					
Procurement _____		■				
Installation _____		■				
8. Retort operation _____		■				
Block 1 (50X50X100) _____		■				
Block 2 (50X50X100) _____		■				
Block 3 (optional) _____		■				
9. Process analysis and evaluation _____		■	■			

TABLE 2:

FIELD PROGRAM — TASKS, TIME SCALE

Phase II — Deep

	FY75	76	77	78	79	80
1. Site criteria — selection _____	_____					
2. Environmental impact assessment _____	_____	_____				
3. Mine design _____	_____	_____				
4. Construction		_____	_____	_____	_____	
A) Access/upgrading _____		_____				
B) Main shaft _____		_____				
C) Rubblization						
Block 4 _____			_____			
Block 5 _____			_____			
Block 6 (optional) _____				-----		
Block 7 _____				_____	_____	
D) Ventilation/safety _____		_____	_____	_____	_____	
5. Waste management _____		_____	_____	_____	_____	
6. Instrumentation installation _____			_____	_____	_____	
7. Surface facility _____		_____	_____			
8. Retort operation _____				_____	_____	-----
Block 4 (100X100X300) _____				_____		
Block 5 (100X100X300) _____				_____		
Block 6 (100X100X300) (optional) _____					-----	
Block 7 (250X250X1000) _____					_____	-----
9. Process analysis and evaluation _____				_____	_____	-----

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