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Increasing Eastern U.S. Natural Gas Reserves from Gas Bearing Shales

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ABSTRACT

The U. S. Energy Research and Development Administration (ERDA) has initiated a multi-year project directed toward the stimulation of natural gas production in the Eastern Petroliferous basins. The objective of the project is to stimulate increased commercial production of natural gas by providing reliable resource data, developing economical extraction alternatives, and demonstrating the commercial feasibility of promising production techniques. The project should provide a significant contribution to the domestic energy base, supply a clean fuel for eastern industrial use, and help to alleviate anticipated near-term and long-term shortages of natural gas.

The ERDA Eastern Gas Shales Project will be oriented specifically toward determining the true magnitude of potential gas reserves in the Devonian Age Shale, thoroughly characterizing the shale, and evaluating and improving state-of-the-art gas exploration and extraction technology. Results will be continually evaluated to determine areas in which new or additional studies may be needed and the desirability of planning and conducting a more extensive research, development, and demonstration (R, D & D) program. The project will concurrently monitor and protect the environment from possible damage resulting from natural gas development activities.

References and illustrations at end of paper

The project envisioned consists of the major elements listed below.

1. An inventory of the natural gas resource and recoverable reserves contained in the Eastern Shales.
2. A characterization of the nature of the shales in the three major sedimentary basins in the east (Appalachian, Illinois, and Michigan).
3. The development of exploration methods for locating fractured shale and other gas reservoirs associated with shale.
4. The performance of research and development studies on methods for improving gas recovery from the shales.
5. The implementation of a concurrent Field-Test Program to transfer the concepts in exploration, drilling, stimulation, and production to the natural gas industry.
6. The performance of environmental assessments to assure acceptable environmental impacts from exploratory and demonstration activity.
7. The performance of economic analyses to indicate commercial viability of various options.

8. Transfer of developed technology to the private sector as rapidly as possible by the timely publication of research information.

This effort will be directed to shales in all three of the sedimentary basins in the eastern United States. The Appalachian Basin will, however, receive the most emphasis, because results there will have an immediate effect on gas production.

INTRODUCTION

Natural Gas supplies about 33 percent of our current national energy needs and will continue to be a major contributor for the remainder of this century. Industrial requirements for gas represent 50 percent of the total demand with a large portion of this demand centered in the eastern United States. Demand is exceeding supply, and major cut backs in industry have already occured, increasing unemployment and slowing economic growth in some of the highly industrial areas. Projected gas discovery rates indicated that expected demand will outstrip supply by 14 trillion cubic feet per year by 1990.

It is important that potential reserves be exploited. Increased production will reduce dependence on imports, and help satisfy long-range energy needs until alternate energy sources can be developed.

The shales in the eastern and southwestern United States (Fig. 1) are a vast, essentially unexploited source of gas. These shales are estimated to contain up to 1300 cubic feet of gas per ton and the wells that are productive yield gas at relatively constant rates for extended periods of time. However, the amount of gas contained in the shales and the characteristics of the shales in areas which have not been adequately tested remains a question. Reserve estimates need to be firmly established and concerted effort directed toward developing technology to stimulate production of larger amounts of this gas.

In 1968, when natural gas reserves began to decline, U. S. Bureau of Mines (now ERDA) personnel began a program to examine marginal gas resource and to determine what methods would be required to extract the vast amounts of gas trapped in the Devonian Shales in the Appalachian states.

Results of past studies indicate that gas accumulates in natural fractures in the shale. These fractures serve as reservoirs and also as conduits for movement of the gas to the wellbore. Thus efforts have been directed toward connecting the wellbore with larger numbers of natural fractures by drilling wells deviated in a specific direction so as to intercept the largest possible number of natural fractures. In addition, techniques of induced hydraulic and explosive fracturing have been investigated as methods for connecting more natural fractures with the wellbore. Various types of airborne remote sensing imagery have been used to map the location of large faults, fracture zones, and zones of high fracture density which have a direct bearing on the rate of gas production from the shales. Much additional work needs to be done to establish new techniques for locating fracture zones by the use of such tools as the borehole gravity meter, 3-dimensional reflection seismographic surveys, side looking radar imagery, satellite imagery and high altitude aerial photography.

The project will concentrate on establishing the utility of two types of directional drilling processes to improve production rates. Massive hydraulic fracturing methods will be studied and tested to establish the technology. Conventional hydraulic fracturing methods will be extensively tested utilizing several types of fluids designed to improve production rates and ultimate recovery.

Sufficient core material will be obtained from the shale in several regions to determine the chemical, mineralogical and physical properties which may affect drilling, stimulation and completion techniques. The characterization program will consist of investigations to determine the amount of organic carbon present which may be yielding the gas as well as the pore size distribution which will affect the rate of diffusion or desorption of gas from the shales. The core data will also be used to make stratigraphic correlations from one region to another so that volumes of gas present can be more accurately estimated.

This project is a comprehensive and coordinated Federal-State-University-Industry effort aimed at the optimum environmentally acceptable extraction of gas from the shales.

PROJECT DESCRIPTION

Objectives

The ultimate objective of the Eastern Gas Shales Project is to increase production of natural gas from the three eastern shale basins through advanced exploration and extraction techniques. The project is specifically directed toward determining the magnitude of potential gas reserves, thoroughly characterizing the shale, and improving current state-of-the-art stimulation technology. Based on a review with gas industry personnel experienced in Devonian Shale drilling, stimulation, and production, it is expected that the following goals should be achieved in eight years by the project.

The major goals of this project are:

1. To develop a technique for locating fractured reservoirs in the shales.

2. To determine the mechanisms which control the rate of production of gas from the shales.

3. To develop a methology for accurately estimating gas and oil reserves in the shales of the Appalachian, Illinois, and Michigan Basins.

The goals resulting from implementation and completion of the project are:

1. To double the average open flow production rate of new shale wells.

2. To increase the average total gas reserves added per well drilled from 300 to 600 million cubic feet.

3. To add 3.5 trillion cubic feet of gas to reserves in the Appalachian Basin.

It is hoped that achievement of these goals will stimulate a much larger response from priviate industry to develop these resources. It should be noted that due to the economic uncertainties associated with shale gas production, particularly if the production is sold on the controlled interstate market, and if exploited independently by industry using risk capital, very little new production may be realized from the Eastern Shales in the next decade. Some production would, however, be developed for intrastate markets. In general, widespread industrial commercialization of shale gas will require the premise of suitable profit margins which are dependent upon prevailing wellhead prices for natural gas and the costs of applying the technology to a given reservoir. It is felt that successful implementation of this project will remove much of the technical risk, and possibly develop more cost-effective technology. In any event, the wells developed in the cooperative ERDA-industry program will produce significant quantities of gas in regions where demand is very high.

Strategy

The primary strategy of this program is to utilize in an efficient and productive manner the expertise currently resident in several state geological surveys, universities, federal agencies, and the private sector to implement the major tasks as expeditiously as possible with available funding. A PERT-type diagram showing the interactions between the various tasks is presented in Figure 3.

Project management will be provided by Morgantown Energy Research Center-ERDA who will administer and coordinate the entire program and be responsible for dissemination of results.

Resource inventories will be conducted by contract with state geological surveys and universities and will be compiled and synthesized regionally by the United States Geological Survey.

Characterization studies will be conducted both by contract to universities, research institutes, and industry and be an active in-house program.

R&D to develop and improve methods for producing gas and to develop exploration techniques will also be conducted both in-house and by contract to universities, research institutes, and industry.

Field testing of stimulation techniques will be conducted primarily through cost-shared contracts with private industry in the same manner as other enhanced oil and gas recovery field projects already initiated by ERDA. This approach is designed to stimulate concurrent large-scale projects in different areas using a wide variety of techniques and is designed to accelerate the process of developing promising techniques from field test status to commercialization status. The overall oil and gas program is gaining widespread acceptance, with many companies responding to requests for proposals, and significant industry participation in the Eastern Gas Shales Program is anticipated.

Environmental assessments will be made for all planned field activities to guide the conduct of the effort. These functions will be treated as an integral part of each project and will be included as subtasks of each key project.

During the performance of each key project whenever applicable, data will be collected for economic analysis. These analyses will demonstrate the cost effectiveness of each particular exploration or production process based on the cost of the process compared to the projected increase in yield produced.

The overall project will thus consist of a large number of separate but related activities involving state, university, industry, and federal organizations working within a planned project structure.

Resource Inventory

The project element of Resource Inventory includes the following five sub-elements:

- Drilling, Coring, Logging and Testing
- Stratigraphic Analysis
- Physical Characterization

- Strctural Analysis
- Resource Assessment

A stratigraphic framework will be prepared from existing well log data and used to select core well sites. Core will be obtained by cooperative agreement and by contract and supplied to the various geological surveys, universities, and cooperators for the characterization studies. Outcrop samples will be obtained to fill gaps in coverage from previous investigations. The resource evaluation will include the combined data from coring, outcrops, and well cuttings. Samples will be tested for organic carbon content and distribution, mineralogy, and physical properties. All of the data, including the data from the characterization studies, will be correlated with geophysical well logs to develop a rapid method for total resource evaluation. A data bank will be established by collection and collation of production data. A regional synthesis of state geologic and resource data and stratigraphic analsysi will be done by USGS. The data bank will be accessible at MERC and USGS locations.

Characterization Studies

The project element of Shale Characterization includes the following three sub-elements:

- Lithological Characterization
- Geochemical Characterization
- Physical Characterization

The analytical studies for the characterization of the eastern hydrocarbon bearing shales will include detailed studies on both outcrop and sub-crop samples. Parts of the analytical study will be made through contracts and/or cooperative agreements with industry, educational institutions and other government agencies.

The characterization program will (1) identify and classify the eastern shale deposits with respect to their chemical, physical, and mineralogical properties, (2) obtain information to aid in well-log interpretation, i.e., bulk density logs, kerogen logs, fracture porosity and radioactivity logs, to aid in a more rapid field analysis of the resource, (3) supply information to aid in recovery of reserves, through well stimulation techniques such as fracture design (4) evaluate techniques of analytical instrumentation for a rapid resource assessment.

Exploration Technology R&D

Most of the gas produced from eastern shale has come from fractures within the shale. Current studies indicate that migration through fracture is by far the most dominant mechanism of transport of gas to the wellbore. This points up the need for research to develop techniques for providing information on the location, intensity, and orientation of fracture systems. Such techniques would be extremely beneficial to the development of gas production from the shale.

Much progress has been made on delineating earth fracture systems, but much remains to be done on the detection and analysis of fracture patterns and determining their relation to hydrocarbon production. The research conducted under this program element would be directed toward developing methods for detecting and defining zones of intense fracturing with the shale. The major exploration research tasks would include testing, evaluating, and applying: (1) seismic tools and interpretation techniques; (2) LANDSAT, Skylab, and high altitude aircraft image analysis technique; and (3)gravity surveying techniques. Successful completion of this research will provide improved methods of locating potential producing areas. As a result, the rate of successful well completions will be increased.

Production Technology R&D

The productivity of shale wells depends on the density and extent of natural fractures within the shale, fracture porosity and permeability, matrix porosity and permeability, and the degree of communication between the wellbore and the fracture system. Research to define and solve problems associated with enhancement of these formation characteristics would contribute to improved gas production rate and increased reserves. The research conducted under this program element would address these problems. The major thrust of the production research effort will be directed toward: (1) evaluating the potential of the shale matrix to recharge the fracture system; (2) investigating the abrading and degrading effects of various fluids and hydraulic fracture proppants on the shale matrix; (3) determining the potential of recompleting and dually completing old wells to improve gas production; (4) assessing the efficiency of various drilling and coring techniques; (5) deriving preditive models for use in the development and production of shale gas fields; (6) provide background information required for planning and instituting directional drilling and stimulation demonstration projects; and (7) investigating the potential of various fluids and bacteria to increase matrix permeability and improve the rate of flow of gas to the fracture system feeding the wells.

Field Test and Technology Transfer

Field tests and transfer of viable technology to industry will be expedited through five sub-element categories:

- Hydraulic Fracturing

- Explosive Fracturing
- Configuration Drilling
- Completions
- Planning, Testing and Evaluation

The continual development of new techniques of stimulating gas and oil production is of major importance in being able to meet our future energy needs. However, the early and successful application of new R&D technology is of even greater importance. Under normal conditions, it usually takes about 10 years for a newly discovered technique to be accepted by the industrial community. Thus the need for a viable demonstration program is well established. Most gas and oil producers, independent and large companies, do not wish to risk money on new stimulation techniques which have not been well demonstrated.

The demonstration program will include ERDA-industry cooperation in demonstrating the application of state-of-the-art hydraulic fracturing, deviated wells, massive hydraulic fracturing, explosive fracturing, and combined fracturing methods for the Devonian Shale. This will include the demonstration of dual completion and recompletion of old wells. The demonstration of the newest stimulation techniques as a means of enhancing production could significantly increase the reserves and production rate of the Devonian Shale.

Environmental Assessment

A thorough understanding of the environmental implications of new drilling and fracturing techniques is important to the success of this program. Similarly, the field activities undertaken by this project must be conducted in such a manner as to minimize adverse environmental impact. Environmental assessments will be made of all planned field activity to guide consideration of environmental effects. Data compiled and analyzed during the activity should prove a sound basis for predicting the environmental impact of commercial operations utilizing similar technology.

The environmental assessment functions will not be treated as separate projects but will be included as tasks of each Key Project in the detailed schedule for that project.

Economic Analyses

During the performance of each Key Project, whenever applicable, data will be collected for use in the economic analyses. These analyses will demonstrate the cost effectiveness of each particular exploration or production process based on the cost of the process compared to the projected increase in yield produced.

Information Management

Large amounts of data will be generated by the various contractors during the life of the project. In order to make this data available to the public as rapidly as possible, a system for collecting, evaluating, and disseminating the data will be generated. This system will collect all well data, core analysis data, etc., and place it in a data bank where it can be evaluated and retrieved for example, to make maps of various parameters which geologists and petroleum engineers can use for exploration and development of gas from the shales.

DISCUSSION

This project was formally initiated in January 1976 although project definition and planning was initiated in May 1975. Several ongoing projects and cost sharing contracts were incorporated into the project. Contracts and in-house research expenditures totaling more than 10 million dollars have been let during the period July 1, 1975 - September 30, 1976.

Two major contracts on the use of massive hydraulic fracturing of the shales have been awarded to Columbia Gas to test these stimulation techniques in W.Va. Two contracts to examine explosive fracturing have also been awarded to Petroleum Technology Corp. Consolidated Gas Supply Corporation has been awarded a contract to test the concept of drilling directionally deviated wells to intercept natural fracture systems. Kentucky-West Virginia Gas Company is also participating in the directional well program. They completed a vertical core and test well in December 1975 and are planning the deviated well drilling phase now. Sandia Labs, Lawrence Livermore Labs, and the U.S.G.S. have been conducting technical support studies to map the hydraulic fractures induced by the massive fracturing operations.

Contracts for Resource Inventory and Shale Characterization studies have been awarded to the following: Alfred University, Battelle Columbus Lab, Illinois Geological Survey, Indiana Geological Survey, Juniata College, University of Kentucky Research Institute, New York Geological Survey, Ohio Geological Survey, Pennsylvania Geological Survey, Tennessee Geological Survey, U.S. Geological Survey, West Virginia Geological Survey, West Virginia University, University of Cincinnati, and University of North Carolina.

Contracts are being negotiated for R&D work on Production Technology by Los Alamos Labs and Mound Laboratory. Contracts are also being negotiated with East Ohio Gas Company and recompletion concepts in eastern Ohio and new

stimulation techniques in southeastern Ohio respectively.

Requests for proposals to field test other stimulation, exploration, or R&D concepts will be advertised over the next several years. Reports on progress on all stages of the project will be made annually.

The potential for developing additional natural gas reserves from gas bearing shales in Appalachian, Illinois and Michigan basins is good, but it will require a concerted effort by Industry, academia, state and federal agencies to accomplish the fact. ERDA believes a good start has been made, and invites continued support by the private and public sectors.

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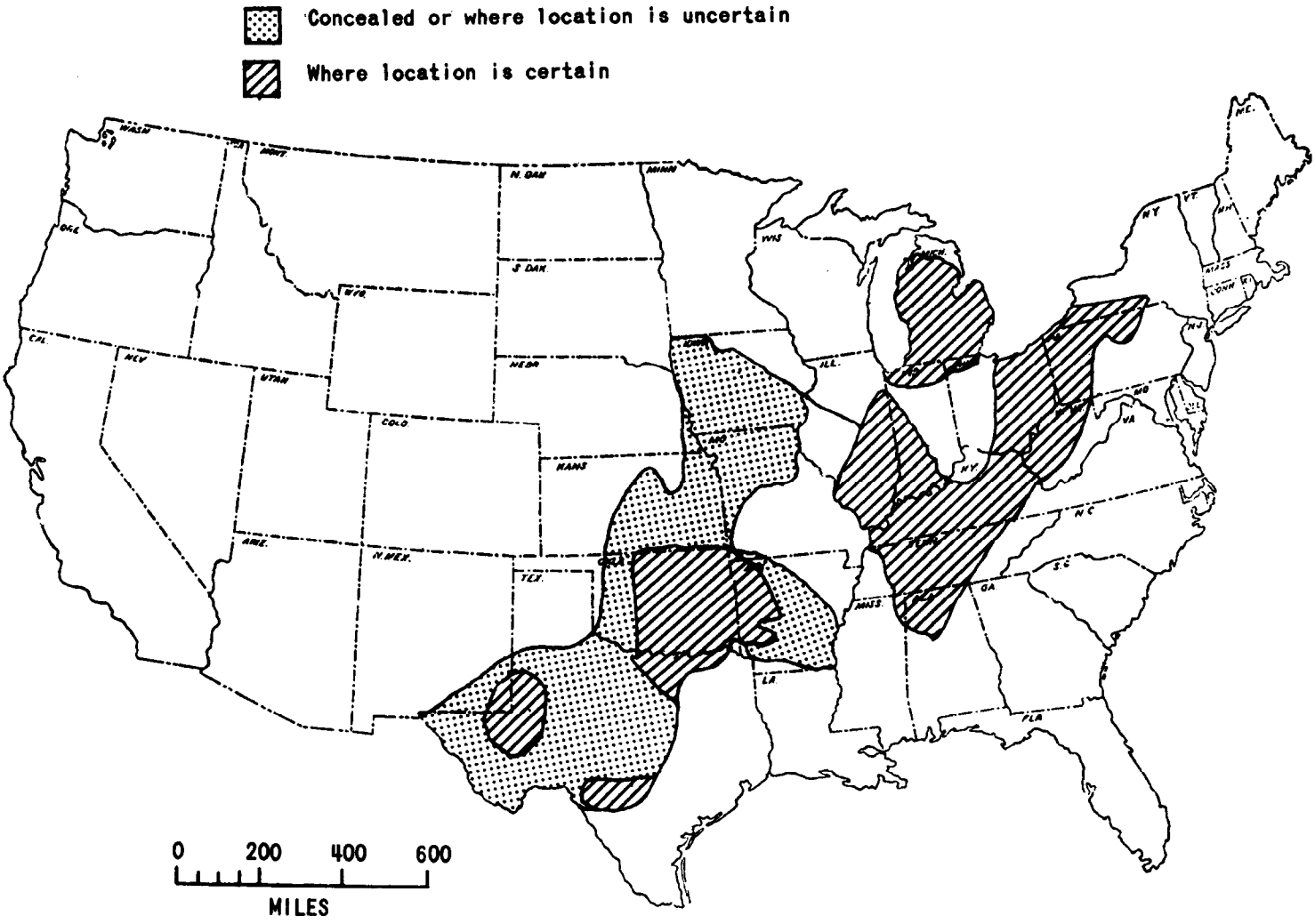

FIG. 1 - DEVONIAN AND MISSISSIPPIAN SHALE DEPOSITS OF THE UNITED STATES.

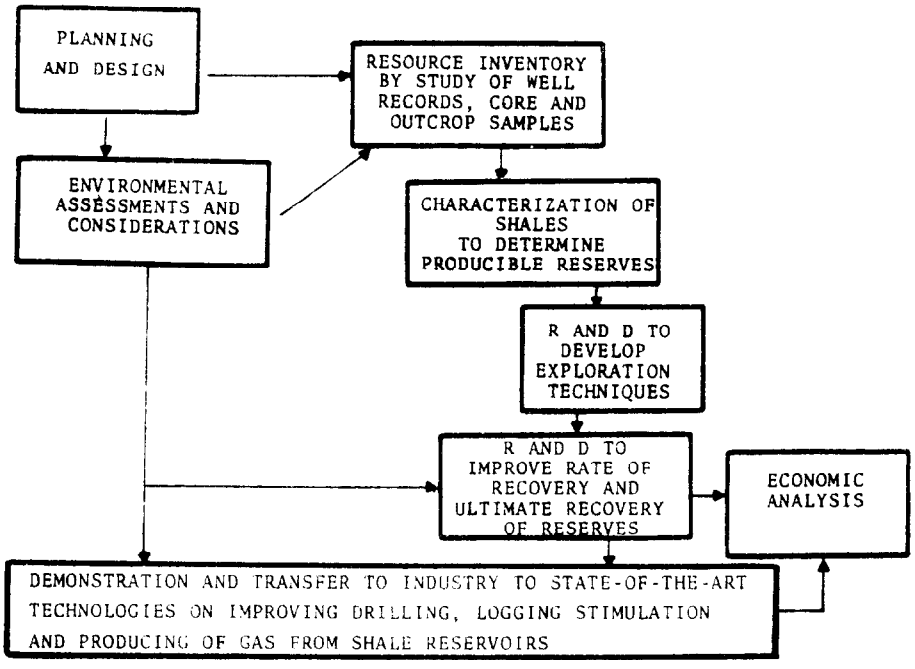

FIG. 2 - INCREASING GAS RESERVES IN EASTERN U.S. SHALES.

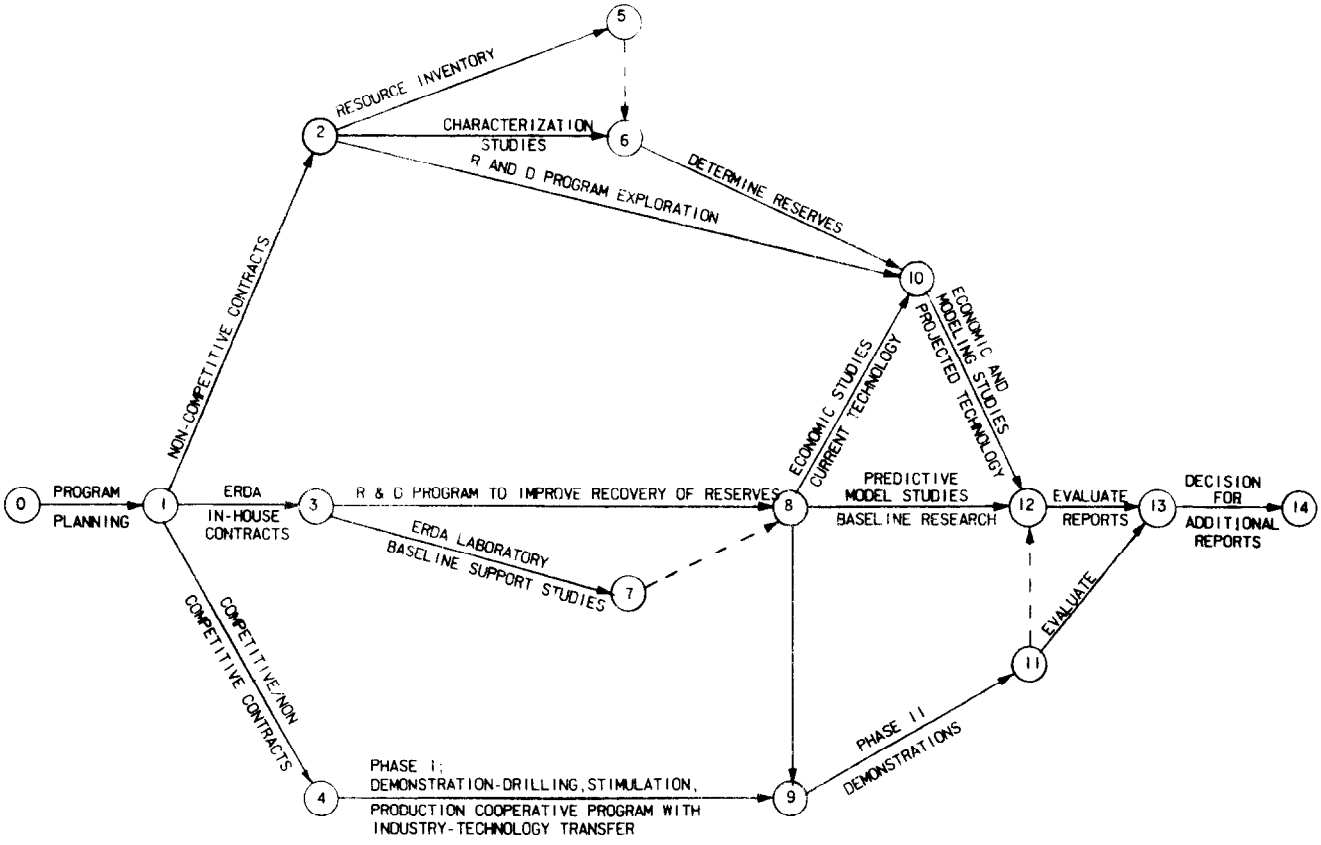

FIG. 3 - PROGRAM TO INCREASE PRODUCTION FROM EASTERN U.S. NATURAL GAS RESOURCES