3013 SCIENCE APPLICATIONS
INVESTIGATION OF JET CUTTING TECHNIQUES FOR THE IN SITU EXCAVATION OF

2 Copies

Harak
OSh

INVESTIGATION OF JET CUTTING TECHNIQUES FOR THE IN SITU EXCAVATION OF OIL SHALE

SCIENCE APPLICATIONS INCORPORATED

SAI 1-027-71-790-01

Hawk
osh

INVESTIGATION OF JET CUTTING TECHNIQUES FOR THE IN SITU EXCAVATION OF OIL SHALE

TECHNICAL DISCUSSION

SUBMITTED TO:

U. S. Department of Energy
Laramie Energy Research Center
Laramie, WY 82071

Attn: Dr. A. W. Decora

Prepared by:

Science Applications, Inc.
9485 W. Colfax Ave.
Lakewood, CO 80215
(303) 232-7900

February 27, 1978

TABLE OF CONTENTS

LIST OF FIGURES

1.0 EXECUTIVE SUMMARY

Science Applications, Inc. is submitting this technical discussion to DOE/LERC to explore the potential applications and benefits of using high pressure water jets to cut oil shale during the preparation of in-situ retorts. If successful, this approach would provide a "low cost" method of framing the required void volume for expansion of the shale for retorting. This approach would have application to both Wyoming and Utah shales which may not otherwise be exploitable by modified in-situ processing.

The proposed study would be conducted in three phases. Phase I would consist of predictive model correlations, using exploratory laboratory studies of small samples, and a planning effort for field testing. Phase II would involve proof-of-principle field testing for a cutting tool having a simple design. Phase III would include proof-of-principle testing using a more complex design of tool, together with a field testing program more nearly representative of true in-situ retort preparation techniques.

A specific and unique (but optional) part of the Phase I program is to evaluate the potential of using chemically modified cutting fluids toaugment the cutting efficiency.

The overall program is intended to coalesce with one of LERC's planned in-situ oil shale retorting demonstrations at a future time. If things work out as planned, the jet cutting method could be comparatively evaluated against other approaches.

Phase I of the proposed program is discussed in the greatest detail in this study. To illustrate how such a study could be done, we have proposed a plan that would be carried out with our staff. Phase I is estimated to cost $119,841 and would be completed within 8 months, depending upon the availability of samples of Tipton shale.

The program would be conducted by the staff of SAI/Lakewood and SAI/Fort Collins, under the direction of Dr. Harry E. McCarthy. Specific contributions will be made by Mr. Tom Sladek of the Colorado School of Mines Research Institute, and Mr. Thomas Labus of SCIRE Corporation, a pioneer and leader in jet cutting technology.

2. TECHNICAL DISCUSSION

True in-situ retorting of oil shale has the potential to be a cost-effective way to develop much of our domestic oil shale reserves. To date, much work has been done on the problems of developing an economical and technically feasible method on in-situ oil shale retorting. A major stumbling block in the creation of in-situ retorts has been the economic factors of creating sufficient void volume prior to blasting to achieve good rubblization of the shale bed to be retorted. Water jet cutting tools could prove to be an economical method of creating such a void volume for in-situ retorting.

There have been several studies done on developing water jet tools for rock cutting and the results have been encouraging. The U.S. Bureau of Mines (Twin cities Research Center) has developed a downhole slurry mining tool (using water jets) that has been tested with success incoal and uranium sands (Ref. 1). A sketch of this system is shown in Figure 2.1. The heart of this device is two high pressure rotating nozzles which do the cutting. These nozzles are rotated through a predetermined number of cuts, until the maximum cutting distance is achieved and the tool is then lowered and the process repeated. The material is brought to the surface with a slurry jet pump.

Although very little experimentation has been done on oil shale, quite a bit of work has been done cutting harder rocks such as sandstone, limestone and granite in the laboratory with positive results. Labus (Ref. 2) has performed some preliminary tests on shale oil samples from the Tipton Formation. From his very limited data (Fig. 2.2), he has extrapolated that a 3/8" nozzle operating at 4,000 psi can produce a cut 11 1/2 feet deep in oil shale.

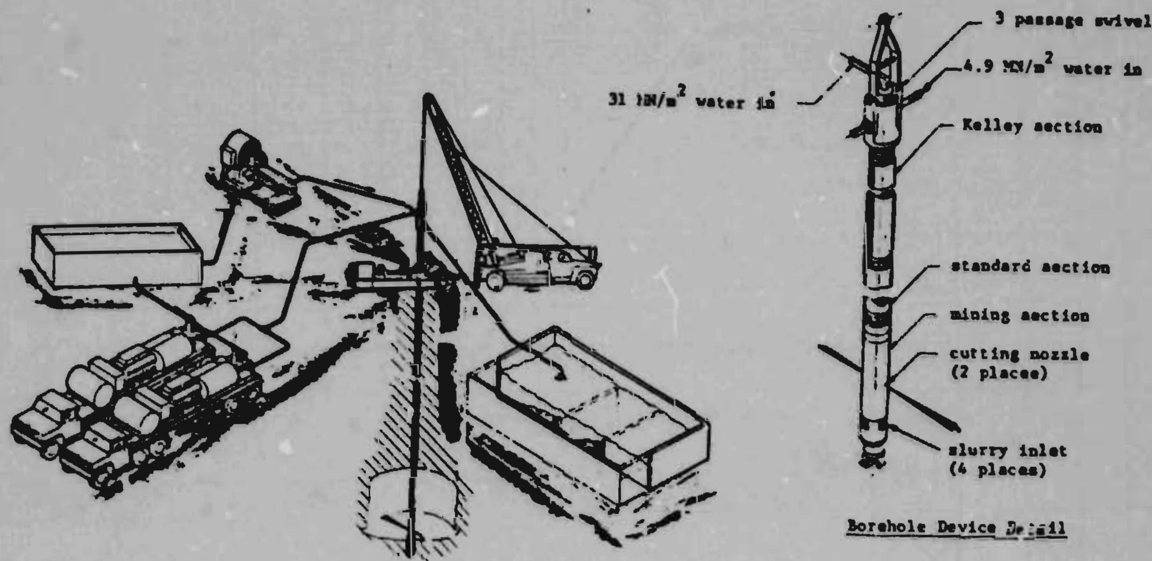


Figure 2.1 Bureau of Mines Slurry Mining Tool

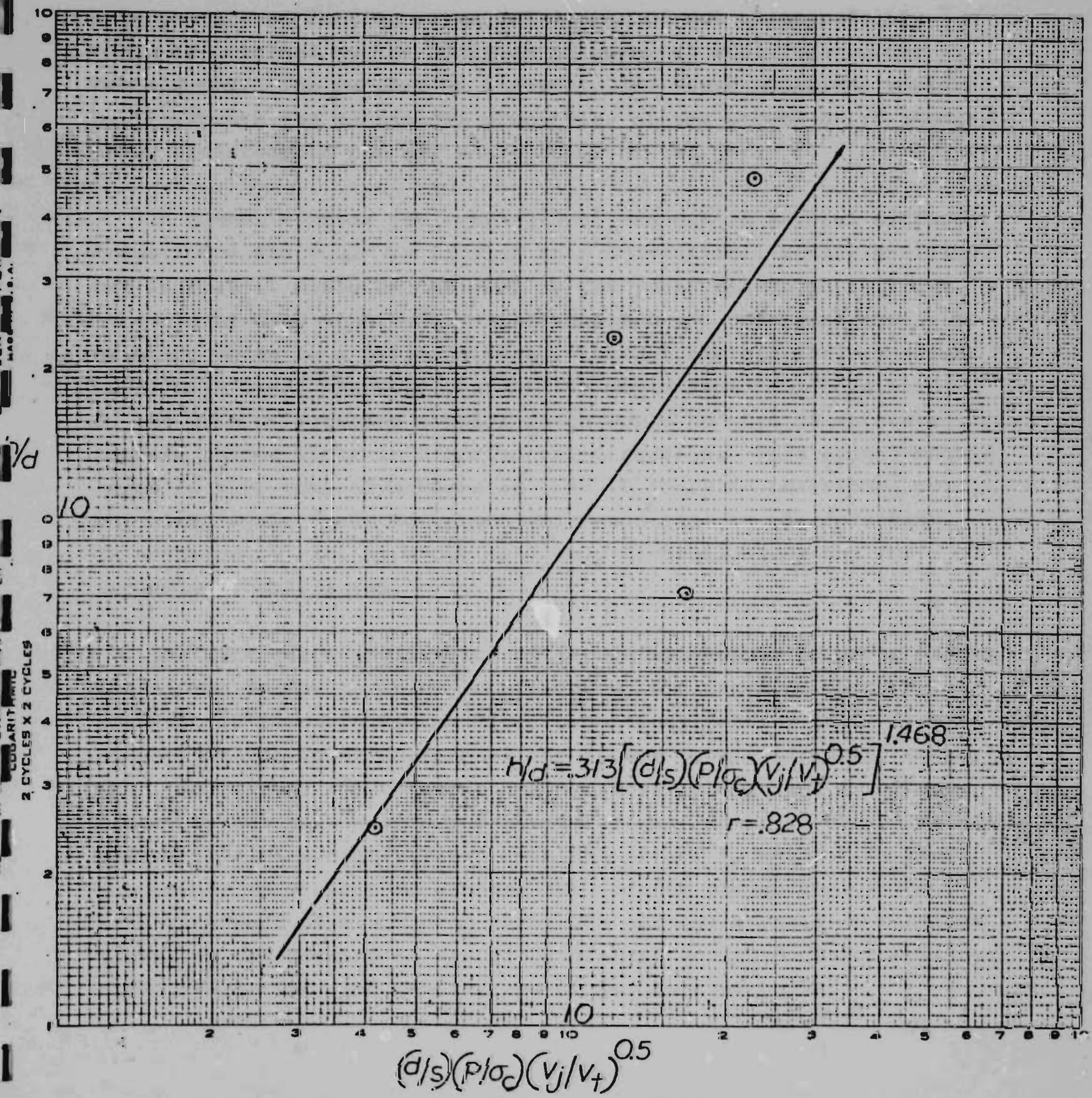


Figure 2.2. Jet Cutting Data for Oil Shale

These tests were run on some of the harder parts of the formation; the use of larger nozzles at higher pressures, or working in weaker sections, should be able to produce even larger cuts. Improved cutting rates and depths of cut quite possibly could be obtained by the addition of chemical additives to the water spray. The purpose of incorporating these additives would be to improve the mechanical properties of the stream or to chemically disintegrate the oil shale ahead of the jet.

A downhole water jet cutting tool can cut in several different modes. One way would be similar to a conventional rotary drilling bit in that it would be designed to cut vertically. In this way it could be used to actually drill holes or to underream out existing holes to a larger diameter through the oil shale section to be rubblized. Another possibility would be a tool consisting of one or more rotating nozzles which would be used to excavate pancake shaped slots in a horizontal direction. This second method seems to have some advantages in that it could be positioned to cut along weaker beds or structural weaknesses in the formation. In addition, a slot type cut is a very favorable geometry for explosive rubblization.

An intriguing application of jet cutting would be undercutting the Tipton Formation prior to explosive rubblization. Such a scenario is shown in Figure 2.3. Laboratory testing (Ref. 3) has shown that the lower section of the Tipton is significantly weaker than the rest of the formation as is shown in Figure 2.4. These weaker layers have a high percentage of clay minerals which are very susceptible to mechanical and chemical attack by water. In the laboratory we propose to examine the cutting properties of the various layers of the Tipton Formation and the effects of chemical agents on jet cutting to better understand and predict the applications, potential, and limitations of jet cutting tools.

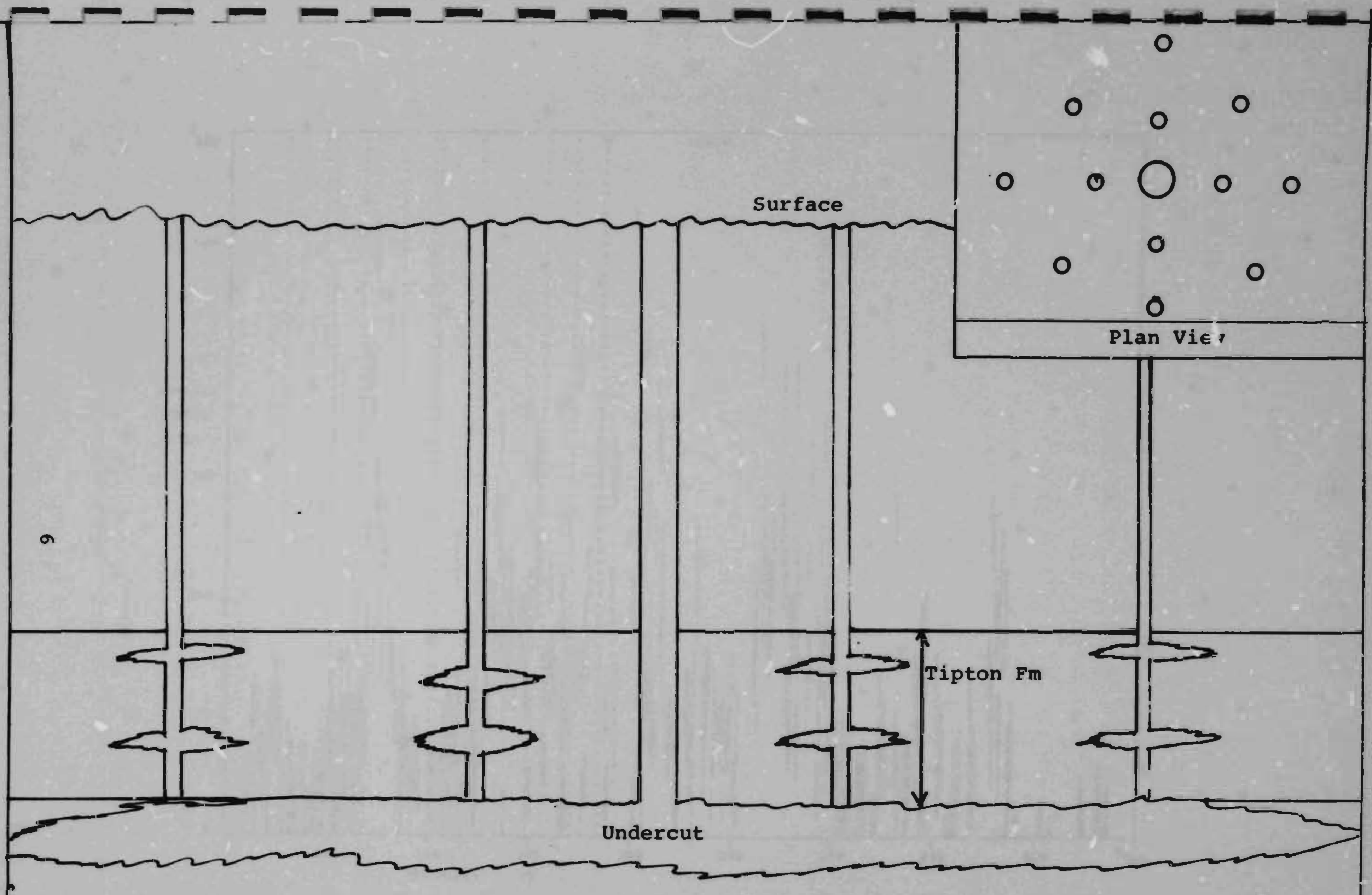


Figure 2.3 Undercutting Tipton Formation

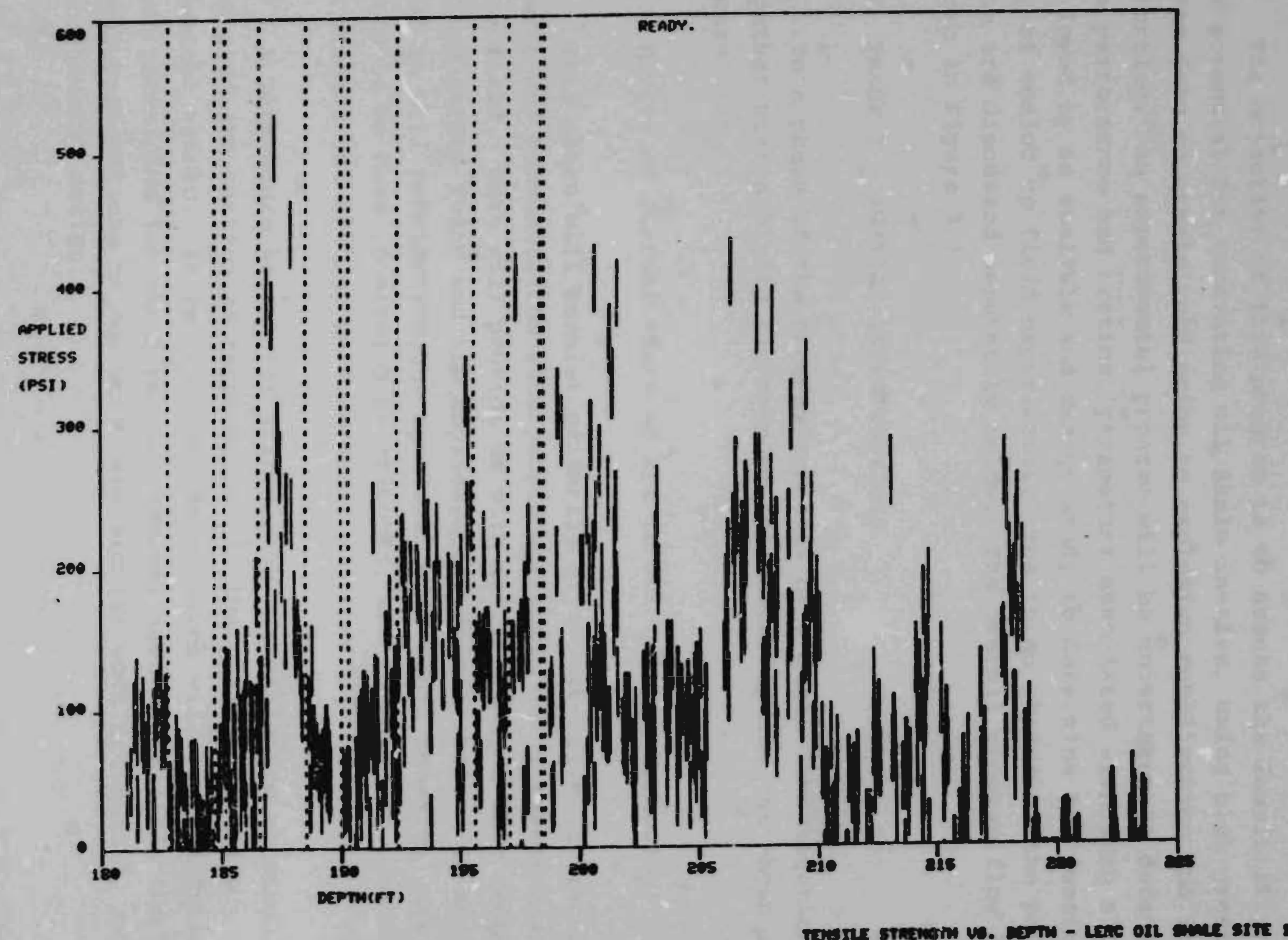


Figure 2.4 Tensile Strength vs. Depth (Tipton Formation)

3.0 WORK SCOPE AND PROGRAM PLAN

The objective of this program is to assess the feasibility and potential for excavating oil shale in-situ, using high pressure water jets to create void prior to explosive rubblization and in-situ retorting. An experimental program will be undertaken to determine the performance and critical parameters associated with such a tool followed by an analysis and design study to determine the feasibility of scaled up field experiments. The three phases of the program are discussed separately below. The overall program flow is shown in Figure 3.1.

3.1 PHASE I - INITIAL INVESTIGATIONS

This phase of the program consists of a basic investigation, together with a highly recommended additional option, as shown in Figure 3.1.

1. Review of Current State of Art in Jet Cutting Technology

This phase will consist primarily of an extensive literature search and communication with people currently doing research in this field. This will provide us with information on what technology exists today and its applicability to oil shale. In addition it will provide insight into what additional research work needs to be done, designing experiments, and formulating equations to predict jet cutting performance.

A literature search for information pertaining to chemically assisted jet cutting is recommended for the option involving chemical agents. It is felt that this search will yield information pertaining to the types of chemical agents available and their applications to our work, any similar work being done, and experimental design.

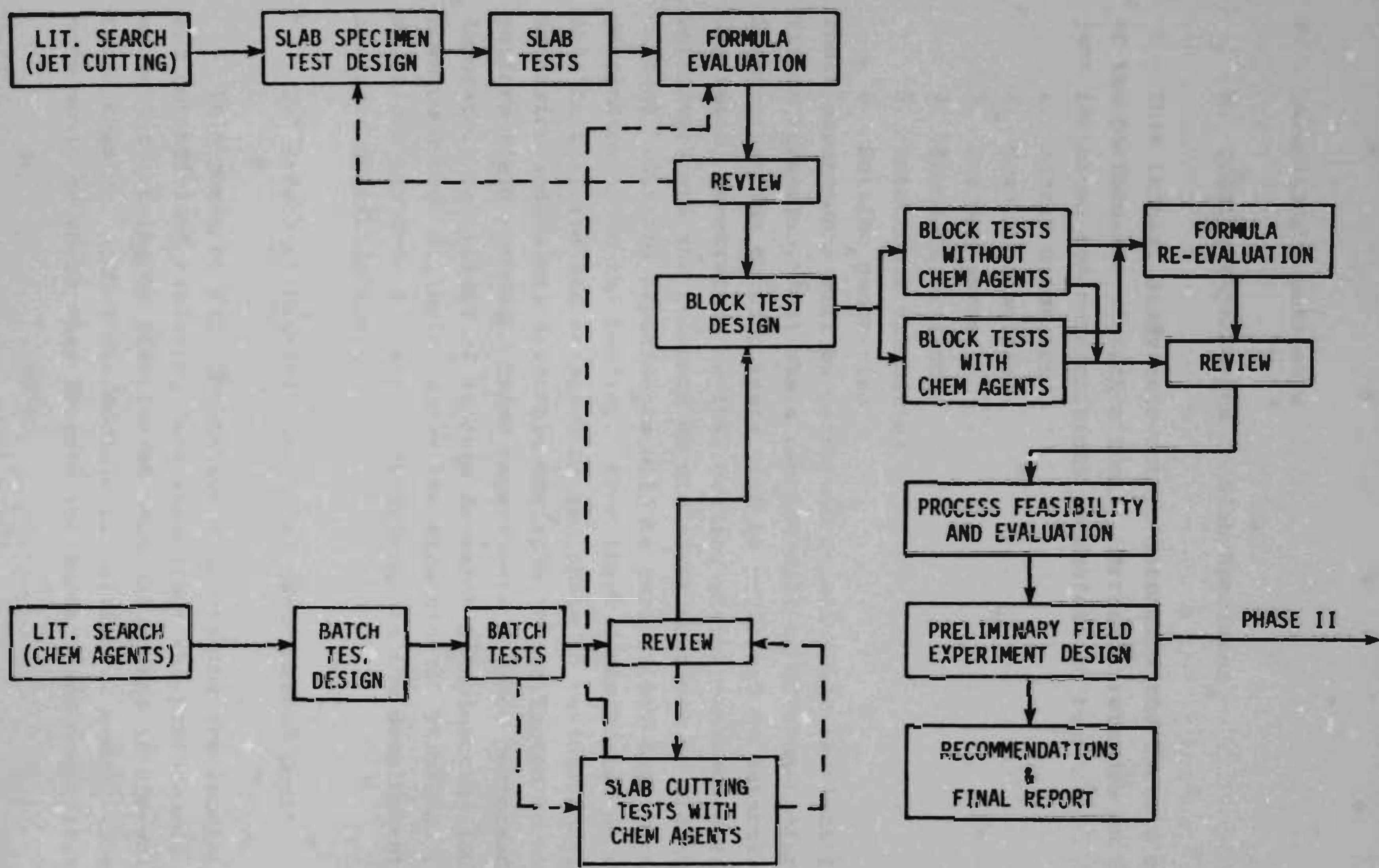


Figure 3.1 Program Plan

2. Laboratory Experiments

A. Cutting Experiments on Slab Specimens

This initial study sets out to determine the factors critical to the performance of such a tool. Current literature on the subject indicated the more critical parameters to be:

1. Nozzle diameters
2. Nozzle geometries
3. Jet pressures
4. Standoff distances
5. Rotational velocities
6. Cutting geometries

These experiments will be performed on oil shale sections from the Tipton Formation. Oil shale samples will be government-furnished items. Various cutting tests will be performed to determine cutting rates, penetration depths, cutting widths, optimum operating parameters and the response of different sections of the shale to cutting. Cutting experiments will be carried out both parallel and perpendicular to the bedding. From these experiments, we will be able to evaluate the response of the shale to various cutting scenarios and select favorable horizons in the Tipton Formation to perform field testing. These experiments will be performed at the laboratory facilities of Science Research & Engineering (SCIRE) in Downers Grove, Illinois, under the direction of Thomas J. Labus. Mr. Labus has over 8 years of experience in the development of high pressure hydraulic tools.

B. Effect of Chemical Additives (Recommended Option)

This phase of experimentation will examine the feasibility and potential of assisting (and improving) the performance of the water jet cutting by addition of chemical agents to the water. These chemical agents can work in two different modes. The first mode would be where they improve the surface and mechanical properties of the water jet stream, (such as low concentrations of long chain polymers) thereby improving the cutting efficiency of the tool. A second mode is where the chemical agents would directly weaken and/or disintegrate the oil shale ahead of the cutting jet. These agents can be grouped into three categories:

1. Chemical agents that would react with clay minerals. This could have significant potential in horizons with high clay content.
2. Acids that directly attack the carbonate minerals such as calcite and dolomite which typically comprise 50% of oil shale.
3. Solvents which dissolve the kerogen.

These experiments would be performed at the facilities of the Colorado School of Mines Research Institute (CSMRI) in Golden, Colorado.

3. Development (and/or refinement) of Empirical Formulae to Predict Performance of Jet Cutting Tools for Oil Shale

Several authors have presented empirical formulae to predict the performance of jet cutting tools in rock. Labus (Ref. 1) proposes the formula $h/d = K, (d/\varepsilon) (P/\sigma_c) (V_j/wr)^{\alpha}$ where:

h = penetration
d = nozzle diameter
p = jet pressure
σ_c = unconfined compressive strength of specimen
v_j = jet velocity
w = rotational bit speed
r = radial position of jet nozzle
K, α = constants

For oil shale K, = .313 and α = 1.468. Crow (Ref. 4) proposed a formula predicting the depth of cut (slot depth) in Berea Sandstone $h = \frac{d_o (P_o - P_c)}{\tau_o} F \frac{V}{c_e}$ where:

h = depth of cut
d_o = nozzle diameter
P_o = jet pressure
P_c = minimum pressure required for cutting
τ_o = shear strength of specimen
F = universal function of v/c_e
c_e = effective intrinsic speed of hydraulic rock cutting

Several other formulas (Ref. 4, 5) have also been proposed.

It is our goal here to examine the applicability of these formulas to oil shale. We will examine the correlation with our data and if necessary develop our own empirical formulae, if no existing formulae apply to our data.

4. Cutting Experiments on Large Block Specimens

This phase is essentially a scale up of the cutting tests on smaller slab specimens. At this time we will be able to check out how the data in the lab on smaller speciment correlates to larger samples. It will provide a means of deciding how well empirical formulae derived from the slab specimens can be used to predict field performance. In addition to this we will be able to examine in greater detail the effects of structural irregularities in oil shale such as jointing, mineral inclusions, etc., on the performance of the jet cutting tool. After these tests are completed, a re-appraisal as discussed in 3. above will be made.

5. Investigation of Jet Cutting Applications to Field Experiments

This phase will include the design and economic analysis of field experiments using water jet cutting tools based on the work covered in the previous phases. We plan to examine the feasibility of three different excavation plans.

1. Horizontal Cutting
2. Borehole Underreaming
3. Borehole Underreaming followed by horizontal cutting

A. Horizontal Cutting

This system consists of drilling a borehole of sufficient size to accommodate the jet cutting tool and excabating one or more horizontal cuts in the shale bed to be retorted. These cuts will then be loaded with explosives and the shale section can be rubblized and retorted. A sketch of such a system is shown in Figure 3.2.

The purpose of developing a horizontal void across the shale section is to create a sufficient void volume for effective rubblization to occur. This system would consist of a rotating nozzle which enlarge the borehole over a specific interval. With this method it should be relatively simple to create multiple layered voids. A configuration of multiple layered explosive charges is very favorable to provide good rubblization of the shale bed to retorted. As stated previously, this method looks promising as a way to easily undercut the Tipton Formation to create significant void volume.

As part of the design and economic analysis the following variables will be considered:

1. Equipment requirements and constraints
2. Drilling requirements - production rates
3. Technical Feasibility
4. Capital costs
5. Operating costs
6. Maintenance
7. Crew training
8. Safety considerations
9. System constraints

B. Borehole Underreaming

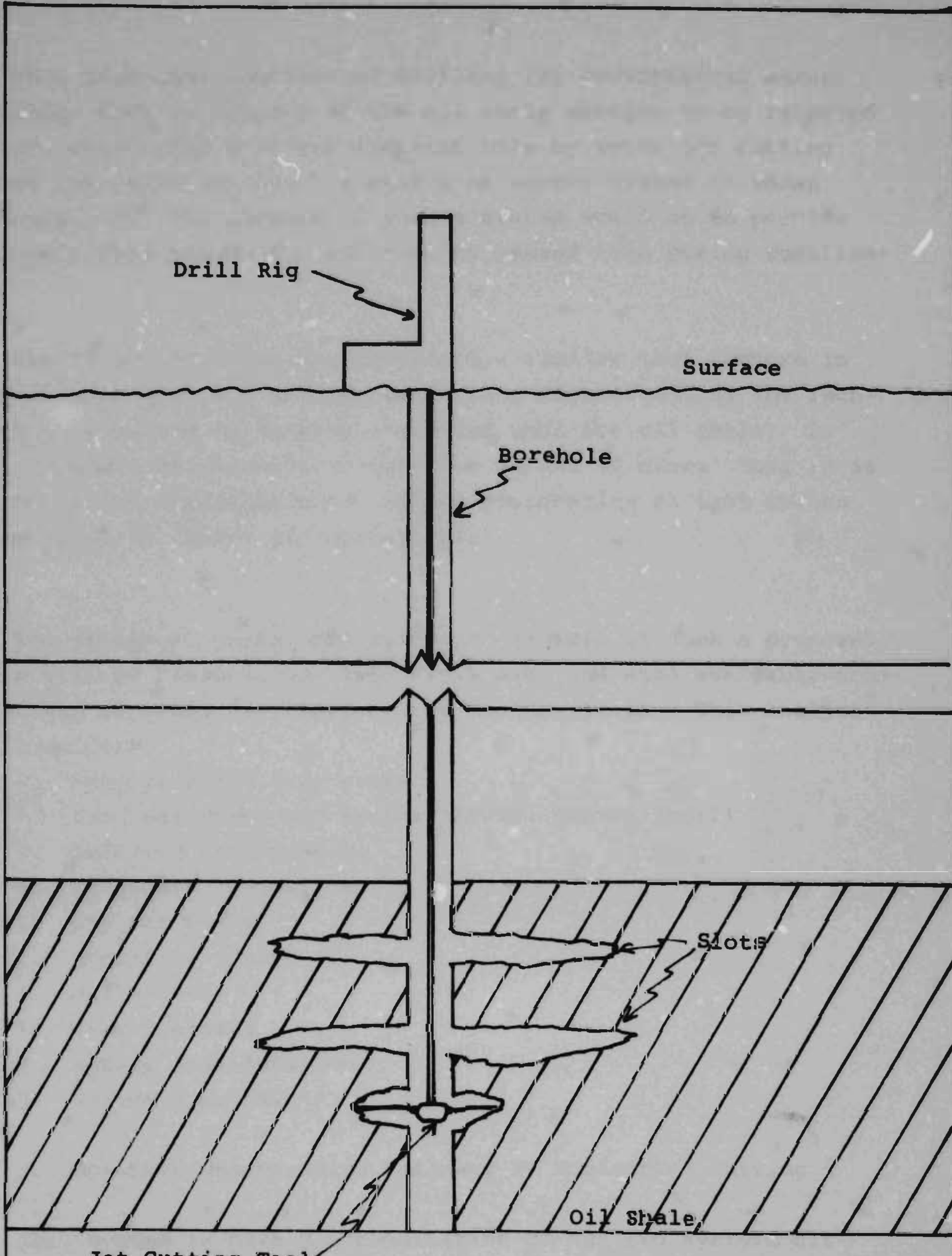


Figure 3.2 Horizontal Cutting

This technique consists of drilling (by conventional means) a borehole down to the top of the oil shale section to be retorted and then excavating a larger diameter hole by water jet cutting through the shale section. A sketch of such a system is shown in Figure 3.3. The purpose of such a system would be to provide sufficient void volume for the rock to expand into during rubblization.

The Bureau of Mines has developed a similar tool for use in slurry mining coal and uranium sands (see Figure 2.1), so the technology base exists to develop a similar tool for oil shale. In fact, it might be possible to tuse the Bureau of Mines' tool as is or with slight modifications. (Close cooperation of twin cities mining research center is anticipated.)

The technical design and economic analysis of such a proposed system will be based on our laboratory data and data available from the Bureau of Mines for their slurry mining system. This analysis will consider:

1. Projected drilling rates
2. Cost effectiveness (water jet vs. conventional)
3. Drilling requirements
4. Technical feasibility
5. Capital costs
6. Operating costs
7. Maintenance
8. Crew training
9. Safety considerations
10. System constraints

C. Borehole Underreaming Followed by Horizontal Cutting

This system is merely a combination of the two systems discussed previously. In designing such a system, a number of differ-

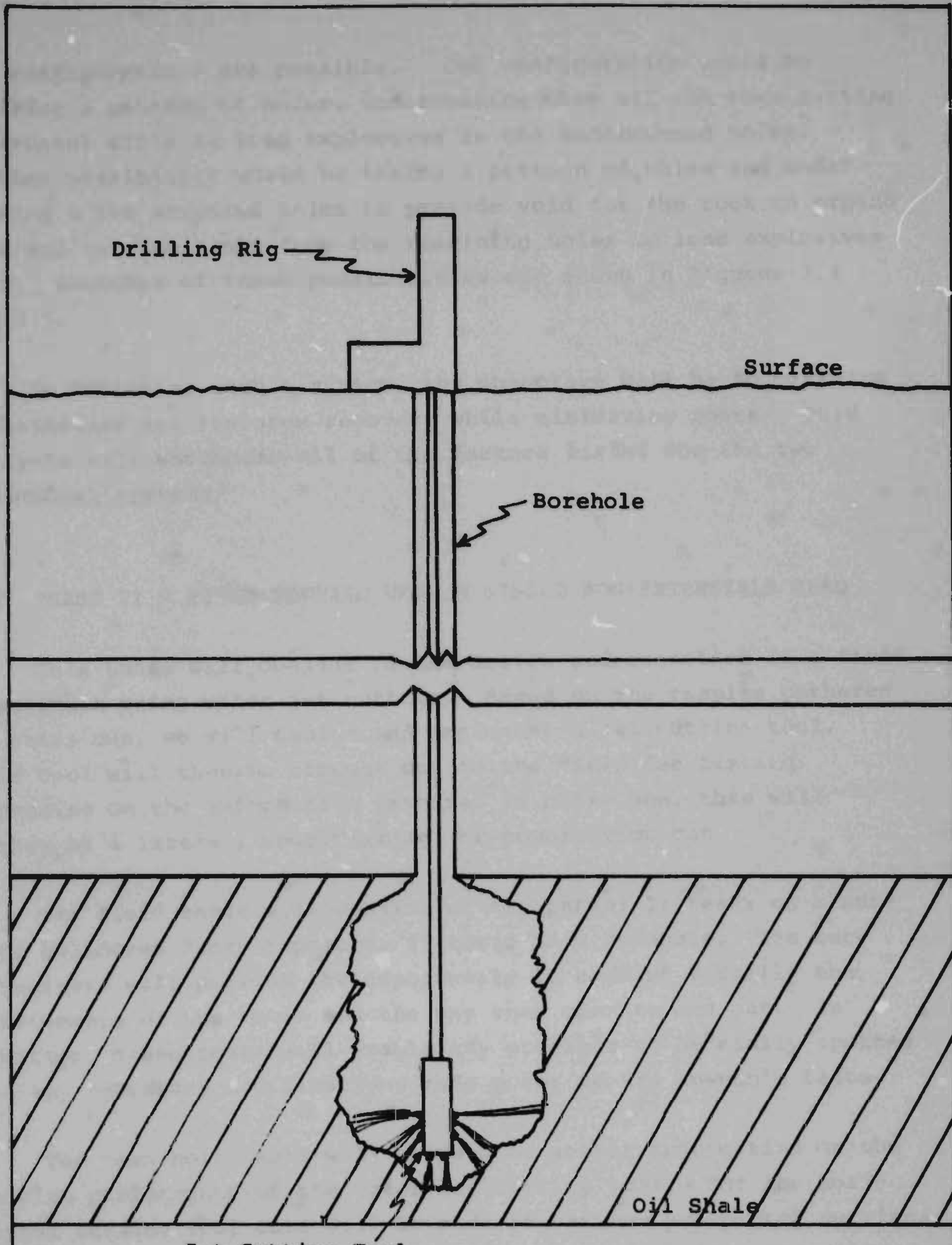


Figure 3.3 Borehole Underreaming

ent configurations are possible. One configuration would be drilling a pattern of holes, underreaming them all and then cutting horizontal slots to load explosives in the underreamed holes. Another possibility would be taking a pattern of holes and underreaming a few selected holes to provide void for the rock to expand into and cutting slots from the remaining holes to load explosives into. Sketches of these possibilities are shown in Figures 3.4 and 3.5.

In designing such a system, the objective will be to maximize rubblization and resource recovery while minimizing costs. This analysis will encompass all of the factors listed for the two individual systems.

3.2 PHASE II - FIELD TESTING WITH A SINGLE NON-EXTENSIBLE HEAD

This phase will consist of the design and execution of a field experiment using water jet cutting. Based on the results gathered in phase one, we will design and implement a jet cutting tool. This tool will then be brought out to the field for testing. Depending on the information gathered in phase one, this will either be a lateral, underreaming, or combination cut.

The field tests will consist of two parts: 1) tests on a surface bulldozed fresh exposure, 2) tests in a borehole. The surface tests will provide the opportunity to examine visually the performance of the tools and the way they operate and cut. In addition, these tests will enable any problems to be easily spotted and any necessary modifications made prior to the downhole tests.

The down hole tests will be used to gather information on the in-situ performance of the water jet cutting tool. For the horizontal cutting tool cuts will be made at various pre-picked sections of the Tipton Formation. It is envisioned that various operating pressures, nozzle diameters, standoff distances, geometrics, and

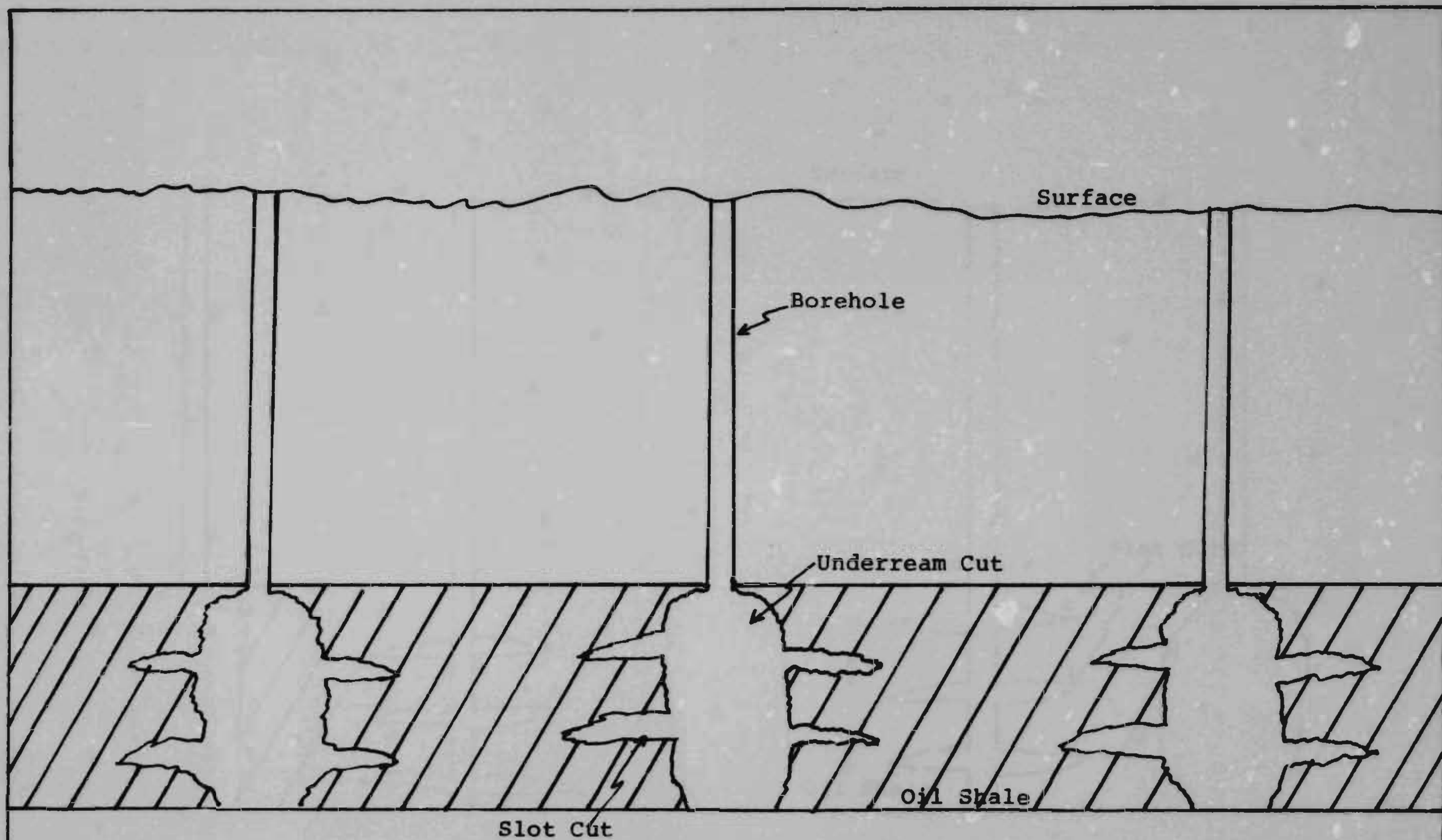


Figure 3.4 Borehole Underreaming followed by Horizontal Cutting

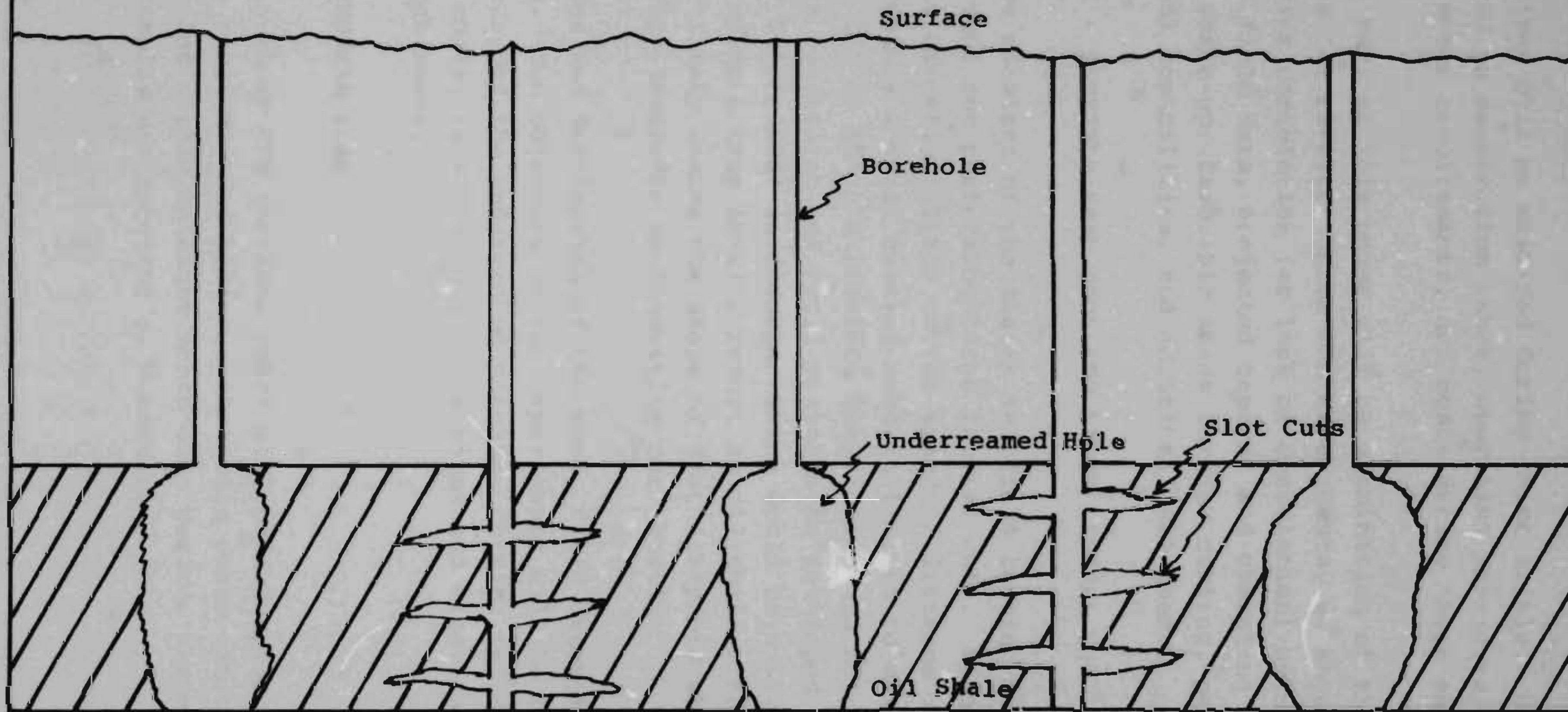


Figure 3.5 Borehole Underreaming and Slot Cutting

chemical additives will be examined during these trials. Data will be gathered on penetration rates, operating pressures, power requirements, water requirements, and costs during these experiments.

The final part of this phase will be examination of the data and summarizing the results. From the experiments, we should be able to determine correlation (or lack of correlation) between laboratory and field data, projected capital and operating costs for a further scale-up, favorable zones for jet cutting, penetrating rates, tool capabilities, and additional R&D needs.

3.3 PHASE III - FLEXIBLE HEAD TOOL FOR LARGE LATERAL CUT

This phase consists of the design and field testing for a flexible head tool for performing large lateral cuts. Since the depth of cut is directly related to the standoff distance of the jet a non-extensible lateral cutting head is limited to making cuts less than 10' or 15'. A flexible head tool would not be subject to this constraint and could possible be developed to extract a void 50' to 100' in diameter which would be a significant asset in developing a true in-situ retort in oil shale. Such a cut would most likely assume the shape of flat ellipsoid which is considered a very favorable configuration for blasting.

Upon design and fabrication of the tool, field experiments will be set up. The objective of the experiments will be to determent the geometry of the underground pancake, cutting rates, power requirements, costs, feasible cutting patterns and sizes, and additional research needs.

3.4 PHASE I PROGRAM PLAN

Figure 3.6 shows the subtasks which will be accomplished in Phase I of the program. SAI believes that this phase can be successfully accomplished within an eight month time period, assuming that all material samples are received on schedule.

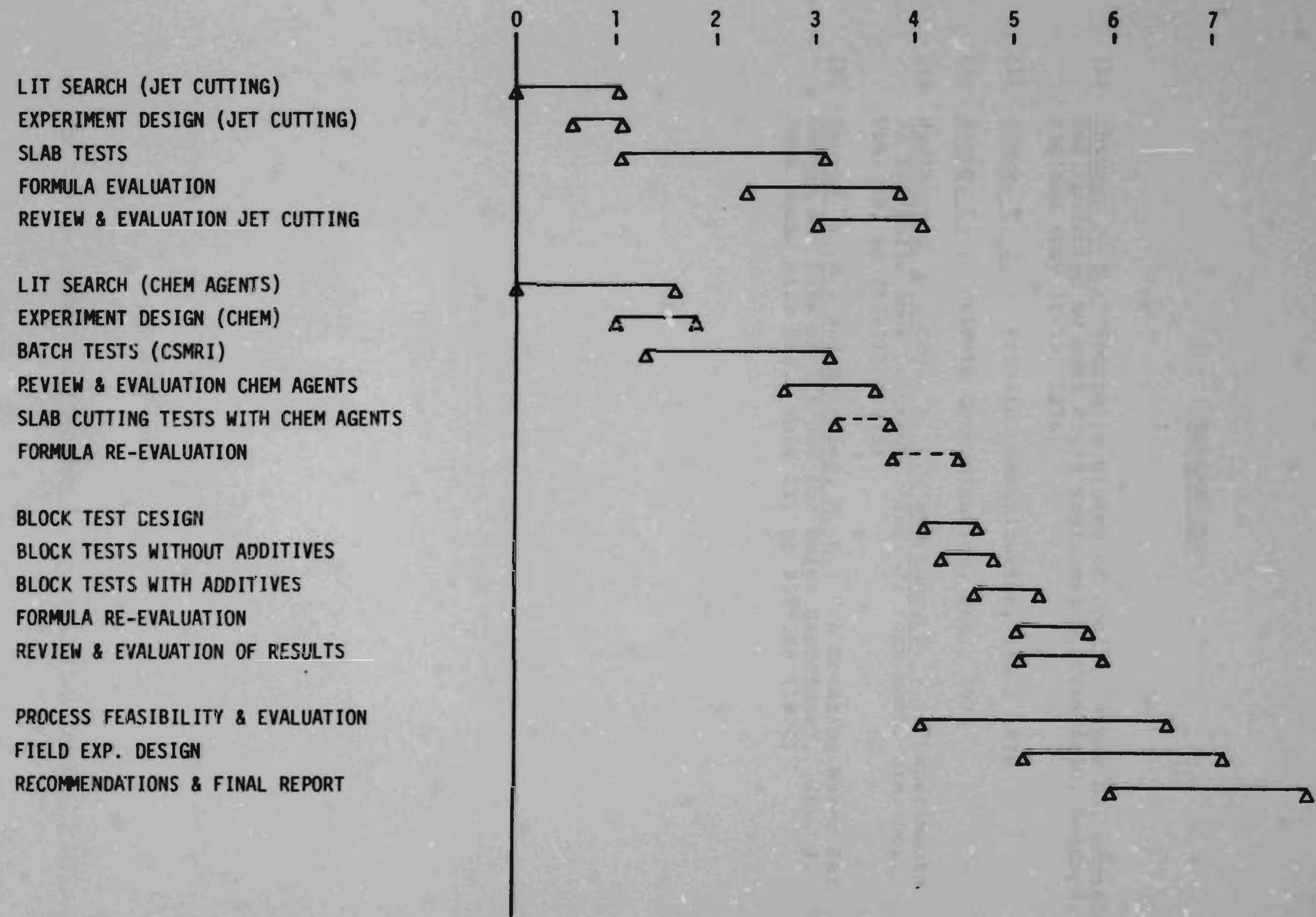


Figure 3.6 Program Subtasks

REFERENCES

(1) Cheung, J. B.: "Hydraulic Mining of Coal". Paper D3, organized and sponsored by BHRA Fluid Engineering, Cranfield, Bedford, England (May 11-13, 1976)

(2) Labus, T. J. : Private Communication, Jan., 1978

(3) Young, C. : Private Communication, Feb., 1978

(4) Hurlburt G. H., Crow, S. C., and Lude, P. V.: "Experiments in Hydraulic Rock Cutting". Int. J. Rock Mech. Min. Sci., Vol. 12, pp 203-212 (1975)

(5) Harris, H. D., and Brierley, W. H.: " A Rotating Water Jet Device and Data on its Use for Berea Sandstone". Int. J. Rock Mech. Min. Sci., Vol. 11, pp 359-366 (1974)

4.0 STATEMENT OF WORK

The contractor shall perform the Phase I jet cutting research study as described in proposal 1-027-71-790-01. The work shall consist of literature search, supervision and correlation of laboratory experimentation using government-furnished slab and block samples of Tipton oil shale, empirical formulae correlations, and the investigation of jet cutting applications to field experiments. Work shall be accomplished according to the Phase I program plan as proposed.

The deliverables shall consist of monthly letter progress reports, a mid-term briefing, and a final report and briefing to be presented at the end of the period of performance.

1-027-71-790-01R1

WORK ORDER

Contract No. 31-109-38-3764

Work Order ____________ Date 7 August 1978

This Work Order is issued pursuant to the agreement effective 1 January 1977 between Argonne National Laboratory and Science Applications, Inc.

1. Scope of Description of Services

The Contractor shall perform the following services:

Phase I Jet Cutting Research Study

(See attached Statement of Work)

2. Schedule Completion requested by 21 February 1979

3. Dollar Ceiling - The total amount to be paid by the Laboratory under this work order shall not exceed $91,991.

4. Applicable Rate Category is Company 1, Category 1.

5. Technical Representatives

LETC ____________

Contractor ____________

6. Cost Code: ____________

7. Other Conditions

a. Computer and Lab Rental are considered to be miscellaneous material cost within the meaning of BOA Article IV, Section E.

b. Work will be complete 6 months after receipt of authorization to proceed.

8. Terms and Conditions

This Work Order, the performance of the services described herein and the rights and obligations of the parties with respect thereto are governed by Contract No. 31-109-38-3764 between the parties dated 1 January 1977, including all supplements thereto, and such terms and conditions as are set forth in this Work Order pursuant to such contract. The terms and conditions set forth in such Contract are hereby incorporated herein by reference.

Accepted and Agreed to:

LARAMIE ENERGY TECHNOLOGY CENTER	CONTRACTOR:
By ______________	By [signature] A. I. Dow
Title ______________	Title Manager of Contracts
Date ______________	Date 7 August 1978

1-027-71-790-01R1

PHASE I JET CUTTING RESEARCH STUDY

Cost Breakdown

	FY 1978 21 Aug - 30 Sept 1978			FY 1979 1 Oct 78 - 21 Feb 1979			
Labor	Hours	Rate	Amount	Hours	Rate	Amount	Total
Scientist 432	30	61.44	$ 1,843	120	63.42	$ 7,610	
Scientist 431	95	52.88	5,024	377	54.59	20,580	
Scientist 422	74	49.02	3,627	296	50.60	14,978	
Scientist 312	154	31.64	4,873	618	32.66	20,184	
Tech. Typist	15	15.42	231	60	15.92	955	
Subtotal			15,598			64,307	$79,905
Travel & Per Diem (Ref. A)			405			810	
Admin. Handling (13%)			53			105	
Subtotal			458			915	1,373
Other Direct Cost							
Computer	1	$180	180	2	$180	360	
Lab Rental			400			1,600	
Reproduction						710	
Equipment & Installation			5,745				
Subtotal			6,325			2,670	
Admin. Handling (19.1%)			1,208			510	
Subtotal			7,533			3,180	10,713
TOTAL			$23,589			$68,402	$91,991

1. clay degradation

+ CSM - $20,000 2.

Reference A 1-027-71-790-01R1

TRAVEL

6 R/T - Lakewood, CO/Laramie, WY (2 men/2 days - driving 250 miles R/T)

		COST
Air Fare: No. of Trips x Cost per Trip		
Auto Rental: Trips x Days x Cost per Day		
Airport Parking: Trips x Cost per Trip		
Local Mileage: No. of Miles x Cost per Mile	1,500 17¢	$ 255
Communications:	24 calls @ $5/call	120
	TOTAL TRAVEL	375
PER DIEM		
No. of Trips x No. of Days x Rate per day	12 2 $35	840
	TOTAL TRAVEL AND PER DIEM	$1,215

Air fares proposed are based on prices from the current Official Airline Guide - North American Edition.

PERSONNEL

This project will be conducted at SAI/Lakewood and SAI/Fort Collins with the following staff of professionals:

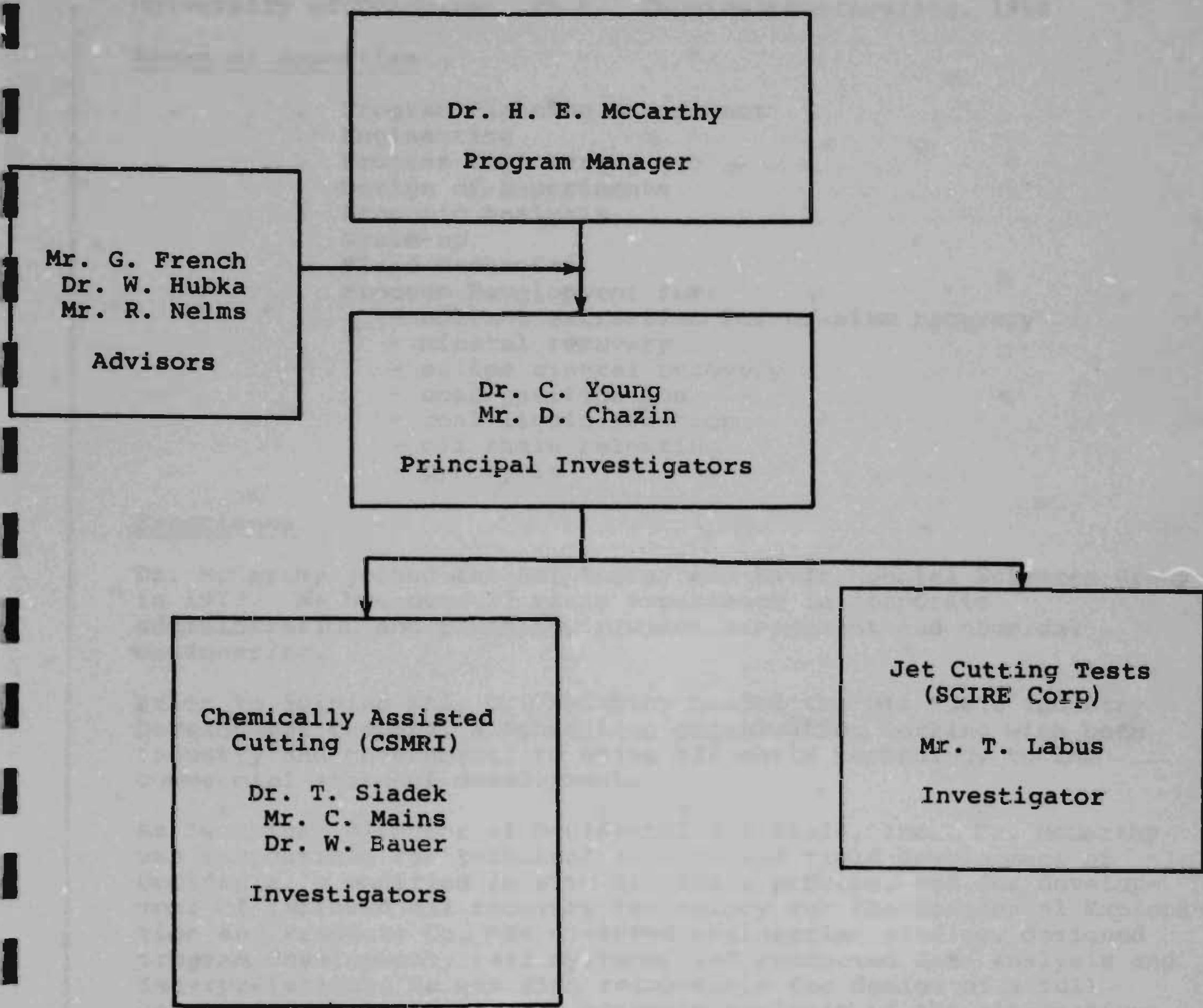
Dr. H. E. McCarthy	-	Program Manager
Dr. C. Young	-	Principal Investigator
Mr. D. Chazin	-	Principal Investigator
Mr. G. B. French	-	Principal Advisor
Dr. W. F. Hubka	-	Advisor (Systems Analysis)
Mr. R. Nelms	-	Advisor (Drilling & Borehole Engineering)

In addition to the SAI staff, important contributions will be made to the project from the staffs of Science Research and Engineering (SCIRE Corp.) and the Colorado School of Mines Research Institute (CSMRI) using the following people:

Mr. T. J. Labus (SCIRE)	-	Investigator (Jet Cutting)
Dr. T. A. Sladek (CSMRI)	-	Investigator (Chemically Assisted Cutting)
Mr. C. J. Mains (CSMRI)		Investigator "
Dr. W. C. Bauer (CSMRI)		Investigator " "

The staffing and management setup is shown in Figure 6.1. Resumes of these individuals are included in the pages following.

Staffing and Management



HARRY MCCARTHY

Education

Colorado School of Mines: B.S., Petroleum Refining Engineering, 1960
University of Delaware: M.S., Chemical Engineering, 1966
University of Delaware: Ph.D., Chemical Engineering, 1969

Areas of Expertise

- Program Planning Management
- Engineering
- Process Engineering
- Design of Experiments
- Economic Analysis
- Scale-up
- Fluid Mechanics
- Process Development for:
  - solvent extraction for uranium recovery
  - mineral recovery
  - saline mineral recovery
  - coal gasification
  - coal liquidification
  - oil shale retorting
  - pyrolysis

Experience

Dr. McCarthy joined the SAI Energy and Environmental Sciences Group in 1977. He has over 17 years experience in corporate administration and planning, project management and chemical engineering.

Prior to joining SAI, Dr. McCarthy headed the Oil Shale Industry Development Company, a consulting organization working with both industry and government, to bring oil shale technology to the commercial state of development.

As Technical Director of Occidental Oil Shale, Inc., Dr. McCarthy was responsible for technical aspects and field development of Occidental's modified in situ oil shale process, and for development of improved oil recovery technology for the Occidental Exploration and Products Co. He directed engineering studies, designed program development, test systems, and conducted data analysis and interpretation. He was also responsible for design of a full commercial-scale plant, and economic analysis of the alternatives.

Dr. McCarthy was previously at the Garrett Research and Development Company, as Vice President and Laboratory Director, for 4 years. He was responsible for all research, development, and administration of the laboratory projects. Projects included process development in the areas of: coal liquefaction, coal gasification, solid waste pyrolysis, in situ oil shale retorting, saline mineral recovery, hydrometallury, and agricultural chemicals. His responsibilities included supervising 130 people and research budget of $4 million. For 2 of his 4 years at Garrett Research he was responsible for process development and commercialization studies for a $15 million project utilizing solar evaporation to process a natural ore-bearing brine, and for development of a unique liquefaction process, for which patent applications have been filed.

While acting as Laboratory Director he directed the research activities for development of solvent extraction process. These included production of a pure phosperic acid from which super phospheric acid could be produced. In addition, a process for recovery of Uranium from phosphoric acid by application of solvent extraction technology was developed.

Other experience included research, development, and manufacturing consultation in the areas of handling, classifaction, grinding and dispersion of solids, and emulsification of liquids. He developed a process for production of a nylon carpet yarn, involving the oxidation of mechanically crimped nylon. He was responsible for production of test lots from the laboratory scale production unit, and for scale-up to a commercial unit.

He holds patents and/or application in coal conversion, oil shale processes, grinding, classification, geothermal, etc. He received the Professional Engineering Industrial Achievement Award, California Society of Professional Engineers in 1972, and is a Registered Professional Engineer; a member of the American Institute of Chemical Engineers, American Chemical Society, Sigma XI, and Science Advisory Panel - California Polytechnic Institute.

LABUS, THOMAS J.
Engineering Consultant
High Pressure Technology

EXPERIENCE

Mr. Labus has over eight years experience in the areas of fluid mechanics, acutation/control systems, fluid power engineering and high pressure technology. Prior to joining SCIRE Corporation in 1976, he was employed at IIT Research Institute. He has been involved in the design and development of high pressure water jet equipment for coal mining and rock quarrying including the design of a hydraulic control system for a water jet coal mining machine. He has directed research in the development of miniature hydraulic power sources, performance testing of hydraulic components and systems for paving machines, water jets applied to marine environments, runway grooving using high pressure water jets, hydraulic valve evaluations, isostatic compaction and hydrostatic test and evaluation. Other areas of activities include modification of a biaxial test stand for composite materials testing, fatigue evaluation of medical sterilizers, and fracture mechanics due to water jet impact.

Prior to joining IITRI, Mr. Labus was employed by the Sundstrand Corporation, Aviation Division, where he worked on the design and development of aircraft appendage actuation systems. This work included experience in hydraulics devices(pumps, motors, valves, circuits, etc.), ball-screw actuators, controls, etc.. His experience also includes work in test and development of hot-gas hydraulic power units.

He has taught courses in fluid mechanics and strength of materials, and presented numerous lectures on various fluid power application.

He is a registered professional engineer in the State of Illinois, Certificate No. 62-31998.

EDUCATION

B.S., Aeronautical Engineering, Purdue University
M.S., Theoretical and Applied Mechanics,-University of Illinois
Additional Graduate Work-Northern Illinois University and
Illinois Institute of Technology

PROFESSIONAL AFFILIATIONS

Fluid Power Society
ASTM-Member of G02 Committee on Erosion and Wear
ASME

PUBLICATIONS

1. "Coal Mining Using High Pressure Water Jets," with M.M. Singh and L.A. Finlayson, U.S. Bureau of Mines (Under Contract H0111789), IITRI Report D6062, October, 1973, p. 77.

2. "Photoelastic Study of Water Jet Impact," with I.M. Daniel and R.E. Rowlands, Proc. Second International Symposium on Jet Cutting Technology, Cambridge, England, April 2-4, 1974

3. "Field Testing of Water Jets for Coal Breakage," with M.M. Singh and L.A. Finlayson, Proc. Second International Symposium on Jet Cutting Technology, Cambridge, England, April 2-4, 1974

4. "Water Table Use in Studies of Pressure Waves in Fluid Power Systems," with C.F. Holt and J.M. Robertson, T&AM Report No. 339, University of Illinois at Urbana-Champaign, April 1971, p. 32.

5. "High Pressure Water Jetting, An Emerging Technology," with M.M. Singh, Proc. 30th National Conference on Fluid Power, Philadelphia, Pennsylvania, September 1974.

6. "Design of a Hydraulic Jet Coal Miner," with M.M. Singh, L.A. Finlayson and W.M. Silks, U.S. Bureau of Mines (Under Contract H0133119), IITRI Report D6088, Dec. 1973.

7. "Water Jet Tests to Establish a Specific Energy Curve for Rocks," with M.M. Singh, U.S. Department of Transportation, Federal Railroad Administration, Report FRA-ORD-D74-53, IITRI Report D6091, Aug. 1975.

8. "Programmable Servo System for Hydraulic Testing of Composite Laminate Cyclinders," with W.C. Cole, Proc. Second National Fluid Power Systems and Controls Conference, Madison, Wisconsin, May21-23, 1975.

9 "Steam Generator Cleaning Using High Pressure Water Jets," Knalls Atomic Power Laboratory, (Under P.O. No. NPD74-0255-ATO), IITRI Report No. D6104, March, 1975

10. "Energy Requirements for Rock Penetration by Water Jets," Proc. Third International Symposium on Jet Cutting Technology, Chicago, Illinois, May 11-13, 1976.

11. "A Hydraulic Coal Mining Machine for Room and Pillar Application," Proc. Third International Symposium on Jet Cutting Technology, Chicago, Illinois, May 11-18, 1976.

12. "Runway Grooving Using High Pressure Water Jets," with M.S. Khan, Department of Transportation, Federal Aviation Administration, (Under Contract No. N68335-75-M-1669), IITRI Report No. D6112, January 1976.

13. "An Experimental Investigation of an Underwater High Pressure Water Jet Metal Cutting Tool," with J.A. Hilaris, Naval Training Equipment Center, (Under contract No. N61339-75-6-0028), IITRI Report D6103, January, 1976.

14. "Development of a High Density Hydraulic Power Unite for Active Control Wind Tunnel Models", with J.A. Hilaris, National Aeronuatics and Space Adminstration, (under contract No. NAS1-13809), IITRI Report No. D6107, March, 1977.

15. "Hypergolic/Fluid Jet Mine Neutralization", with A.J. Tulis J.N. Keith and W.K. Sumida, U.S. Army Mobility Equipment Research and Development Center, under contract No. DAAK02-75-C-0020, IITRI Report No. C6327, November, 1975.

16. "High Pressure Water Jet Applications in Drilling Operations", Proc. of 6th AIRAPT International High Pressure Conference, Paper No. B-14, University of Colorado, Boulder, Colorado, July 25-29, 1977.

17. "Development of a Compact Hydraulic Power Unit for Wind Tunnel Models", with J.A. Hilaris, Proc. 33rd National Conference on Fluid Power, Chicago, Illinois, Oct. 25-27, 1977.

18. "Marine Applications of High Pressure Water Jets", ASTM STP No. Erosion: Prevention and Useful Applications, American Society of Testing and Materials, Philadelphia, Pennsylvania,

19. "Applications of Water Jet Technology to Shipbuilding", Proc. of REAPS Technical Symposium, IIT Research Institute, New Orleans, La., June 21-22, 1977.

20. "Hypergolic Fluid Jet Destruction of Land Mines", with A.J. Tulis, W.K. Sumida, J.N. Keith and D.C. Heberlein, Proc. of 9th Symposium on Explosives and Pyrotechnics, Philadelphia, Pennsylvania, September, 1976

CHAPMAN YOUNG

Education

Cornell Uiversity: B.A., Geology, 1961
Stanford University: M.S., Geology, 1963
Stanford University: Ph.D., Geophysics and Materials Science, 1966

Areas of Expertise

- Rapid, Excavation and Tunneling
- Rock Fragmentation and Drilling
- High-explosive Characteristics & Applications
- Numerical Calculation of Rock Response to Static & Dynamic Loadings Mechanisms & Engineering
- Geology & Geophysics
- Materials Science & Civil Engineering
- High-pressure, High-temperature Rock Testing
- Shock Wave Generation & Measurement
- 1-D and 2-D Finite Difference Codes
  Continuum Theory of Dislocaitons

Experience

- Associate Professor, Civil Engineering, Colorado State University, 1975 to present. Conducting research on upper-mantle convection, earthquake mechanisms, origins of the geodynamic rock mechanics.
- Head, Materials Science Section, Institut CERAC SA, Lausanne, Switzerland. 1971 to 1975. Directed and coordinated basic and applied research efforts on dynamic rock properties, rock fracture, dynamic powder compaction, impact rock breakage, water jet impact and novel rapid excavation and tunneling techniques.
- Senior Geophysicist and Head, Geodynamics Group, Physics International Co., San Leandro, California. 1969 to 1971. Managed both in-house and contract research programs related to explosive applications and dynamic rock deformation.
- Assistant Professor of Geophysics, Stanford University, Stanford, California. 1966 to 1969. Conducted basic research and taught courses on magnetic measurements, mechanisms of rock deformation, experimental rock deformation and earthquake engineering.

- Research Assistant and Associate, Center for Materials Research, Stanford University. 1965 to 1966. Conducted basic research on dislocation mechanisms of deformation in various minerals, especially olivine.

Technical Reports and Publications

"Geology North of White Cloud Canyon, Stillwater Range, Nevada," Master's Thesis, Stanford University, 1963.

"Applications of Dislocation Theory to Upper Mantle Deformation," Ph.D. Thesis, Stanford University, 1966.

"Triaxial Compression of Syntactic Foam," Department of Geophysics Report, Stanford University, September 1968.

"Dislocations in the Deformation of Olivine," American Journal Science, v. 267, pp. 841-852, 1969.

"Application of Anomalous Stick-Slip in Marble to Earthquake Mechanisms," Department of Geophysics Report, Stanford University, February 1970.

"Parameter Sensitivity Calculations for the Explosive Stemming of Wells," C. Young, R. Hoffman and N. Birnbaum, Physics International Co., Technical Report PITR-263-01, August 1970.

"Contamination Tests of Liquid High Explosive Candidates for the Explosive Stemming of Wells," C. Young and J. Patton, Physics International Co., Technical Report PITR-263-05.

"Characterization of DBA-210X for the Explosive Stemming of Wells," C. Young, J. Patton, and S. Hancock, Physics International Co., Technical Report PITR-263-07.

"An Electromagnetic Stress Gauge," C. Young, R. Fowles, and R.P. Swift, Proceedings of the 17th Sagamore Conference, Shock Waves and the Mechanical Properties of Solids, Raquette Lake, New York, September 1970.

"An Experimental and Calculational Study of Decoupling Behavior," C. Young and J.D. Watson, Physics International Co., Technical Report, PITR-240/241, September 1972.

"High Energy, Low-Velocity Impact Rock Breakage," Institut CERAC Report No. 20, December 1973.

"50 mm Precision Impact Facility," Institut CERAC Report No. 29, August 1974.

"Electromagnetic-Gage Measurement of Shear-Wave Stresses and Particle Velocities," C. Young and O. Dubugnon, presented at the 1975 Spring Meeting of the Society of Experimental Stress Analysis, Chicago, May 12-16, 1975.

"Rock Breakage with Pulsed Water Jets," Institut CERAC Report No. 401:1, February 1976.

"A Reflected Shear-Wave Technique for Determining Dynamic Shear Strengths," C. Young and O. Dubuqnon, Institut CERAC Report No. 406:1, February 1976.

"An Electromagnetic Shear-Stress Gage for Large Amplitude Shear Waves," C. Young and O. Dubuqnon, Institut CERAC Report No. 406:2, March 1976.

DAVID CHAZIN

Education

City College of New York: 1974
Colorado School of Mines: B.S. 1977

Areas of Expertise

- Mathematical Analysis
- Computor Modeling
- Writing and Editing Computor Programs
- Project Costing of Mining Ventures
- Economic Analysis of Mining Ventures
- Mining Engineering

Experience

Mr. Chazin is presently governing project costing for underground mining surface retorting, and modified In-situ processes for oil shale, at Science Applications, Inc. (SAI). He has developed computor codes to evaluate the sensitivity of the DCF-ROI of proposed oil shale investment to the various factors influencing the profitability of a project. Currently, he is in the process of developing a computor simulator for an underground mine, producing shale oil from a modified In-situ retort.

During the period of 9/76 to 10/77, Mr. Chazin was a research assistant on U.S.B.M. research contract, "Arrestment Devices for Manned Conveyances." He was responsible for foumulating a mathematical analysis and devising a computer model to simulate an emergency stopping devise for a mine cage. Mr. F.A. Benning, project head, Card Corporation, P.O. Box 117, Denver, CO 80201

At the Colorado School of Mines, Mr. Chazin was the student assistant to the Chief Consultant at the Computer Center. Writing, editing, and debugging new and existing programs, were all responsibilities in the computor library.

In the summer, fron 5/75 to 9/75 he was a general laborer on underground mine and concrete crews at Climax Molydenum Corporation - Climax Mine.

Societies and Committees

American Institute of Mining Engineers
Rocky Mountain Association of Geologists

GORDON B. FRENCH

Education

Missouri School of Mines: M.S., Geological Engineering, 1956
Missouri School of Mines: B.S., Mining Geology, 1954

Areas of Expertise

- Project Management
- Systems Engineering
- Resource Characterization
- Uranium Mining
- Rock/Fracture Mechanics
- Process Analysis
- By-products Utilization
- Geological Engineering
- Mining Engineering

Experience

Mr. French is an engineer with 20 years experience in mining operation.

Prior to joining SAI, he was employed by Occidental Exploration and Production Corporation as a Manager for oil shale mining and development. He has worked with Occidental Research Corporation in the capacity of an operations manager on the Logan Wash oil shale operations in Colorado.

While at Allied Chemical Corporation from 1960 to 1972, he occupied three management positions. Initially as a staff member in the mines and geology department he was responsible for the project management for mine design, such as the Green River and RONA project. Later, Mr. French acted as superintendent of nine mining operations and three solution mining operations.

Following is a partial listing of Mr. French's patents for improved recovery:

- Solution mining roof padding for improved recovery.
- Method of recovering oil and water from in situ oil shale retort flue gas.
- Method of forming a hollow column in an ore deposit preparatory to fragmenting the adjacent ore.
- Method of loading a blast hole with explosives.
- Method of fragmenting a recovery zone in an ore deposit
- Recovery of liquid and gaseous products from an in situ retort.
- In situ recovery of constituents from fragmented ore.
- In situ recovery of shale oil

- Multiple land preparation of oil shale Retort
- Multiple Zone preparation of oil shale Retort
- Con-method of recovering oil & water from In situ oil shale retort flue gas.
- Determining the locus of a processing zone in a Retort through tuff beds
- Method of attenuating air blast from detorating explosives in an In-situ oil shale Retort
- Removal of pillars from avoid for explosive expansion toward the void
- Ventilation air and process air distribution for In situ oil shale Retorts
- In situ oil shale Retort and method for making and operating save covering the use of valves in blast holes through a sill pillar for controlling gas flow to the Retort

Memberships

Director - Colorado Mining Association
Member - American Institute Mining Engineer (AIME)
Member - Canadian Institute Mining (CIM)
Member - Geological Association of Canada (GAC)
Member - Association of Professional Geological Scientists (#2414)
Member - Rocky Mt. Association of Geologists

He has served as a consultant on solution mining to AMAX for Canadian Potash, to Russia on solution mining in the Turkmenistan District. He was loaned to the Government of Chile to investigate the potential for solution mining mineral deposits in the Northern Alta-Plano District, and has conducted extensive saline-carbonate solution mining evaluations in Mexico and the U.S.

Mr. French was responsible for numerous hydraulic fracture saline solution mining programs for Allied including the installation of Canadian Morton salts, Windsor Field, Allied's Moundsville Brine Field, Batton Rouge Bayou Choctaw's solution mining and Ethane, Propane storage and Tully New York's retreat solution mining systems.

During a two year period in the late 1950's Mr. French conducted extensive explorative and mining evaluation on western Uranium deposits.

During the period 1966-1968, Mr. French supervised all exploration and development for the Industrial Chemical Division of Allied Chemical. Some of the mining projects worked on during this period included:

1) Evaluation of existing phosphate production in Israel
2) Geologic evaluation, mine design for an Allied-Israel phosphate operation

3) Northern Spain fluorspar production potential
4) North central Italy fluorspar sustained production capacity
5) Argentinian soda ash production evaluation
6) Open pit mine design for chemical quality limestone, Great Lakes area, and
7) Mexico's Rio Verdis fluorspar mine installation design.

WILLIAM F. HUBKA

University of Denver: B.S., 1962 Mechanical Engineering
M.S., 1965 Engineering Science
Ph.D., 1972 Engineering Mechanics

Summary

Dr. Hubka has significant experience in System Analysis and Systems Engineering, Technical Program Evaluation, Technology Assessment, and Engineering Analysis. He has performed research into high energy mechanical and thermal effects on solids and structures and has developed models to predict these effects. He has supported the POLARIS, POSEIDON, and TRIDENT programs as a SETA consultant to SSPO since 1967. He has analyzed the status and applications of foreign technology for the USAF since 1968.

Professional Experience

Science Applications, Inc.

Manager, Technology Programs Division (3 years) and Director, Systems Engineering (1 year). At SAI, Dr. Hubka has accomplished studies of several types for the DoD and DOE. These have included analyzing the technology and applications of charged particle and laser devices for the USAF and USN/SSPO, supporting the TRIDENT program for SSPO, accomplishing specialized technical symposia, and assisting in the development of program evaluation methodology for the Office of the Secretary of Defense. He has also conducted a study of accelerated commercial development problems for oil shale for the DOE/LERC.

Effects Technology, Inc. (subsidiary of the General Research Corp.)

Division Manager (1 year, 8 months). At ETI, Dr. Hubka accomplished studies of countermeasure effects on reentry vehicle materials and structures. He served on the AFWL/SAMSO/DNA Executive Committee that planned the Nuclear Hardness Evaluation Procedures (NHEP) program. He analyzed NDT techniques for composite materials in support of a company product/service line.

Kaman Sciences Corporation

Scientist and Project Manager (7 years). At KSC, Dr. Hubka supported several programs under Navy, Army, Air Force, and DNA sponsorship. He supported the POLARIS and POSEIDON programs, contributing as a system engineer and vulnerability analyst. He developed numerous computer codes to analyze structural response to nuclear effects, and applied these codes to UGT prediction and to vulnerability/lethality analysis. During this time he was a member of the MK3 Vulnerability Working Group, the SPARTAN Missile Structure Vulnerability Working Group, the SAFEGUARD Lethality Working Group, and the TRIDENT Design Review Group.

University of Denver Research Institute

Research Engineer (1 year, 4 months). At DRI, Dr. Hubka contributed to two projects: the development of stiffness matrix elements for thin shell analysis, and an evaluation of the industrial sabotage potential of liquid metal embrittlement.

Martin-Marietta Corporation

Engineer (2 years, 2 months). At Martin-Marietta, Dr. Hubka worked as a dynamics and loads engineer on the Titan III project. He analyzed dynamic transfer functions and conducted tests to verify computed dynamic load factors.

The University of Denver

Graduate Student. Dr. Hubka was a part-time graduate student for the period 1962-1971. He received his M.S. in March, 1965, and presented a thesis entitled: The Analysis of Plates of Arbitrary Shape and Boundary Condition. He received his Ph.D. in March, 1972, and presented a dissertation entitled: Dynamic Buckling of the Elastic, Cylindrical Shell Subjected to Impulsive Loading.

SCIENCE APPLICATIONS, INC.

RALPH L. NELMS

Education

Colorado School of Mines: B.S. Petroleum Engineering, 1974
University of Southwestern Louisiana: Graduate School,
Petroleum Engineering Department, Night School 1975-1976
Colorado School of Mines: B.S. Mining Engineering, 1977

Areas of Expertise

. Petroleum Engineering
. Drilling and Production
. Mining Engineering
. Computer Programming

Experience

Currently Mr. Nelms is employed at SAI as a Petroleum/Mining Engineer.

Prior to joining SAI, he was employed by Sun Oil Company as an Associate Drilling Engineer. He had responsibilities in the planning, cost analysis and field operations for deep drilling and workover operations, on land and water.

Areas in which Mr. Nelms has planning experience and field operations supervision capabilities are:

. Interpretation of correlative well information
. Selection of casing points
. Determination of drilling mud weights and types
. Design and placement of casings strings and tubing
. Conventional and squeeze cement operations
. Bit programs
. Hydraulics programs
. Computerized drilling optimization techniques
. Snubbing operations
. Stuck pipe operations
. Logging operations and log analysis
. Well completions

Mr. Nelms also has experience in mine planning and feasibility studies.

Memberships

Member, Society of Petroleum Engineers of AIME
Member, Society of Mining Engineers of AIME

THOMAS A. SLADEK
Senior Project Engineer
Energy Division

Education

B.S., Chemical Engineering, University of Michigan, 1967
M.S., Chemical and Petroleum-Refining Engineering, Colorado School of Mines, 1969
Ph.D., Chemical and Petroleum-Refining Engineering, Colorado School of Mines, 1971

Special Fields

Extraction and utilization of synthetic fuels, simulation of transport phenomena

Experience

Colorado School of Mines Research Institute, Golden, Colorado
Senior Project Engineer. Responsible for utilization of chemical sources of energy. Primary involvement with coal preparation and conversion and with fuels from non-conventional sources such as oil shale, tar sands, waste matter, and other carbonaceous materials.

Colorado School of Mines, Golden, Colorado
4 months. Adjunct Associate Professor of Chemical and Petroleum Refining Engineering. Teaching graduate-level course in chemical kinetics and chemical reactor design.

Inland Steel Company, East Chicago, Indiana
4 years. Research Engineer, Research and Development Laboratory. Projects included determination of thermal properties of iron and iron alloys, mathematical heat transfer models, physical modeling of fluid-flow phenomena, patent and process evaluation.

Amoco Chemicals Corporation, Chicago, Illinois
(Summer employment.) Chemical Engineer. Assisted in design and supervision of construction for a petrochemical plant in Decatur, Alabama.

Professional Affiliations

American Institute of Chemical Engineers

Publications and Presentations

Sladek, T.A., 1968, Determination of Low Temperature Thermal Conductivities for Several Grades of Oil Shale: Master's Thesis, Colorado School of Mines.

Sladek, T.A., 1971, A Determination of the Composition and Temperature Dependencies of Thermal Conductivity Factors for Green River Oil Shale, Doctoral Dissertation, Colorado School of Mines.

Sladek, T.A., 1974, Recent Trends in Oil Shale: Part 1, History, Nature and Reserves: Colorado School of Mines, Mineral Industries Bulletin, Vol. 17, No. 6.

Sladek, T.A., 1975, Recent Trends in Oil Shale: Part 2, Mining and Shale Oil Extraction Processes: Colorado School of Mines, Mineral Industries Bulletin, Vol. 18, No. 1.

Sladek, T.A., 1975, Recent Trends in Oil Shale, Part 3, Shale Oil Refining and Some Problems with Oil Shale Development: Colorado School of Mines, Mineral Industries Bulletin, Vol. 18, No. 2.

Sladek, T.A., 1974, Lecture on oil shale for a short course entitled "Liquid Hydrocarbons from Oil Shale" which was presented jointly by the Colorado School of Mines Research Institute and the Center for Professional Advancement.

Sladek, T.A., 1975, Lecture on oil shale for a short course entitled "Development of Colorado Energy Resources" presented by the Colorado School of Mines in Golden, Colorado.

Sladek, T.A., 1975, A practical approach to development of a shale oil industry in the United States: Report prepared for the Gary Operating Company, Englewood, Colorado, October 1, 150 p.

Sladek, T.A., 1976, Lecture on oil shale for a short course entitled "Energy Resources Today and Tomorrow" presented by the Colorado School of Mines and the Colorado Petroleum Association, Golden, Colorado, July 1.

Sladek, T.A., 1977, Lecture on oil shale for a short course entitled "Energy Resources Today and Tomorrow" presented by the Colorado School of Mines and the Colorado Petroleum Association, Golden, Colorado, July 8.

Publications and Presentations

Sladek, T. A., 1977, Application of solar energy to production agriculture in Colorado: Report prepared for the Office of Energy Conservation, State of Colorado, December 15, 31 p.

Sladek, T. A., 1978, Production and marketing of alcohol motor fuels from Colorado agricultural commodities: A tentative description: Report prepared for the Colorado Gasohol Task Force, Denver, Colorado, January 31, 177 p.

Sladek, T. A., 1978, Fuel alcohol from Colorado agricultural commodities: Paper presented to the Colorado Farm Bureau, Denver, Colorado, March 6.

Fausett, D. W., and Sladek, T. A., Mathematical modeling of oil shale pillars during in situ retorting: Paper presented at the 11th Annual Oil Shale Symposium, Golden, Colorado, April 12-14.

Sladek, T. A., and Cox, C. H., 1978, Coal beneficiation with magnetic fluids: Paper presented at the National Meeting of the American Institute of Chemical Engineers, Philadelphia, Pennsylvania, June 4-8.

Sladek, T. A., 1978, Lecture on oil shale for the Field Summer School presented by the Colorado School of Mines and the Colorado Petroleum Association, Golden, Colorado, July 11.

CHARLES J. MAINS
Project Engineer
Energy Division

Education

BSChE, University of Colorado, 1948

Special Fields

Oil shale, coal gasification, formcoke, natural soda ash, and chromite ore processing and process design. Solution mining of trona.

Experience

Colorado School of Mines Research Institute, Golden, Colorado
Project Engineer - Specialist responsible for process, mechanical, and operating aspects of alternate fuels pilot plants and studies. Primary involvement is with oil shale and non-conventional sources of energy such as coal liquids, coal gases, coal beneficiation, waste matter, tar sands, and other carbonaceous materials.

Stearns-Roger, Denver, Colorado
5-1/2 years. Project Engineer III. Designed and costed coal and dolomite handling, preparation, and feed systems for pilot pressurized (1500 psia) fluid bed combustor. Designed and costed feed, discharge, gasification, and regeneration systems for feasibility study on commercial CO_2 Acceptor coal gasification plant. Made designs and costs of oil shale retorting, oil recovery, and spent shale disposal systems for feasibility studies of several commercial retorting methods. Designed in detail the coal-flux feed, gasification, and slag systems for the (1500 psia) BiGas Coal Gasification pilot plant at Homer City, Pennsylvania.

Union Supply Co., Denver, Colorado
10 months. Sales Engineer. Sold mining, milling, and industrial equipment over a large portion of western Colorado.

Oil Shale Corporation (TOSCO)
7-1/2 years. Chief Plant Engineer. Responsible for pilot plant development, construction, maintenance, and operation on oil shale, coal, and tar sands. Made economic evaluation of coal in the TOSCO II process. Did plant engineering, maintenance liaison, advising, and consulting at 1000 TPD oil shale retorting demonstration plant. In the early development of the TOSCO II process, provided advice and consulting to contract operating group.

FMC Coke Plant, Kemmerer, Wyoming

16 months. Senior Process Engineer. Responsible for process control and improvement in the fluidizing and briquetting sections of the plant, along with statistical studies of briquetting variables and liaison with contractor making equipment changes and repairs.

FMC Soda Ash Plant, Green River, Wyoming

9 years. Engineer-at-Large. Managed small pilot chromite-to-sodium dichromate plant in Montana which included operations, maintenance and changes, purchasing, and payroll. Assisted with technical process help in startup of FMC Coke Plant. As Cost Control Supervisor, responsible for industrial engineering and cost control in 1,000 T/D soda ash plant and underground mine. As Process Project Supervisor, responsible for process control of every part of the surface plant at one time or the other. This also included new process design and development, technical sales service, product quality control and improvement, trona solution mining experiments, and crystallizing pilot plant construction, operation, and data reporting. Responsibility also included cooperation with the engineering department to furnish process designs and flowsheets, cost estimations and evaluations, and contractor-constructor liaison on plant expansion.

U.S. Bureau of Mines, Anvil Points, Colorado

5 years. Chemical Engineer GS-9. In charge of operation, maintenance, and construction of all pilot plants to include test run planning and data reporting. Made pilot plant process designs, and the process design of the 25o T/D Gas Combustion Demonstration Plant. Early work here was monitoring the shift operation of pilot plants.

Professional Affiliations

American Institute of Chemical Engineers
Registered Engineer in Colorado, No. 7629

Publications

Mains, C. J. and Matzick, A., 1953, U.S.B.M., R. I. 4995, "Theoretical Consideration of Heat Transfer in the Gas-Flow Oil-Shale Retort."

William C. Bauer
Consultant

Education

B.S. Chemical Engineering, University of Colorado, 1939.
S.M. Chemical Engineering, MIT, 1941.
Sc.D. Chemical Engineering, MIT, 1949.

Special Fields

Chemical engineering, glass technology, food sciences, industrial engineering.

Experience

Engineering Consultant, Golden, Colorado.
Research and engineering in solar energy applications, heat storage technology, glass production, energy conservation, batch briquetting and melting efficiency, air pollution control, electrochemistry, coal-fired glass furnaces, spent oil shale by-product use, and consulting to food processing industries in microbiological and food science.

FMC Glass Technology Laboratory, Golden, Colorado.
12 years. Manager. Glass technology research is a major factor in customer service by soda ash producers, and FMC group has made major contributions to benefit glass industry. Many publications covering mixing and demixing, air pollution control, glass batch preparation, electrochemistry, and improved chemical additions to increase melting efficiency. Have contributed to improvements in glass batch melting which have more than doubled furnace capacities. Numerous patents covering glass batch preparation and general glass technology. Co-author of chapter on "Batch Preparation and Handling" in new edition of "Handbook of Glass Manufacturing". Have twice been invited to present papers at foreign glass technology meetings.

FMC Corporation, Green River, Wyoming.
4 years. Assistant to Resident Manager. Involved with some management functions. Responsible for customer service, liaison with Marketing Department, and new product development. Two publications during this period.

6 years. Technical Superintendent. In charge of all technical activities during start-up and major expansions of soda ash-from-trona plant (now the world's largest soda ash operation). Responsible

for process engineering, trouble shooting, new process development, pilot plants, control laboratory, etc. Numerous patents on chemical processing, industrial chemistry, solution mining, etc.

MIT, Cambridge, Massachusetts.

1 year. Assistant Professor, Department of Food Technology. Assigned to Food Technology to develop an undergraduate course in unit operations slanted towards food processing. Also helped establish a curriculum for degrees in Biochemical Engineering.

11 years. General classroom teaching, Department of Chemical Engineering. Taught both undergraduate and graduate, covering unit operations, heat transfer, industrial stoichiometry, thermodynamics, economic balance. Also served at various times as Director of all three chemical engineering field stations in the MIT School of Chemical Engineering Practice. After first year, Assistant Professor rating. Two papers published during this period.

Professional Affiliations

American Institute of Chemical Engineers
American Chemical Society
American Ceramic Society
Registered Professional Engineer, State of Colorado

END OF

PAPER