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for
March 1993**

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Under Cooperative Agreement
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SUMMARY

ENERGY PRODUCTION RESEARCH

Reservoir and production studies indicate that the Monell Unit of Patrick Draw field has potential for recovering additional oil from CO₂ injection after waterflooding. To investigate the amount of oil recovery and the potential economical impact of CO₂ flooding in the pilot area, and Patrick Draw field, Computer Modeling Group's compositional simulator GEM was obtained from DOE and installed in NIPER's MicroVAX computer. The simulator was successfully compiled after minor modifications and was validated by running sample problems. (BE1)

Research on the characterization of dispersion typical of surfactant-enhanced alkaline recovery systems has proven to be more complicated than anticipated. Expert opinion on the data acquired from light-scattering measurements has resulted in a consensus determination that there is not sufficient time remaining in FY93 to obtain laboratory data suitable for a project report. A new direction for this task is being proposed; it would focus on the use of CT imaging techniques to accurately determine oil saturations in field cores following the injection of surfactant-enhanced alkaline chemical formulations. (BE4B)

A paper (SPE 25453), entitled "The Effects of Layer Permeability Contrast and Crossflow on the Effectiveness of Polymer Gel Treatments in Polymer Floods and Waterfloods," was presented at the 1993 Production Operations Symposium in Oklahoma City, March 21-23. (BE4C)

Before completing interfacial tension (IFT) measurements of CO₂ systems, the solubilities of CO₂ in the aqueous and oil phases must be determined. To this end, the literature is being examined in an attempt to find equations of state that can be used in developing techniques to predict CO₂ solubility in water and brine. (BE5A)

In tests to determine permeability reduction in core samples via salt precipitation, it was observed that three parameters affect the degree of permeability reduction: the original core permeability, the quantity of alcohol injected, and the shut in time after brine and alcohol injection. For example, permeability reduction in a 500 mD core was 25% lower than that achieved in a 800 mD core; permeability reduction was 10 to 15% higher following the injection of 0.3 PV of ethanol vs. injection of 0.2 PV; and greater permeability reduction was achieved after the core was shut in for 1 week due to an increase in the particle size of the salt crystals. (BE5B)

Thin-section, XRD, and SEM analyses; mercury injection porosimetry; and routine permeability and porosity tests were conducted on Fontanbleau sandstone samples. Routine permeabilities ranged from 80 to 130 mD while porosities were in the range from 9 to 11.3%. The XRD results indicate that the rock is 99% quartz, with 1% clay (illite). SEM and thin-section analyses indicate that the rock is comprised of medium-grained, very well sorted, well rounded, quartz-cemented, quartzarenitic sandstone. The mean grain diameter is about 0.60 mm. Quartz overgrowth cement is the dominant authigenic constituent within this sandstone, accounting for approximately 19% of the bulk volume. (BE9)

A report on the results of research on Task 58—light oil steamflooding research at NIPER—was presented at the Annex IV meeting held in Caracas, Venezuela, March 2-5. The next meeting, scheduled for October 1993, is to be held at Stanford University. (BE11A)

A paper, entitled "Pore Scale Fluid Imaging in Reservoir Rock by NMR Microscopy," was presented at the ACS National Spring Meeting Symposium on Applications of Magnetic Resonance Imaging in Enhanced Oil Recovery in Denver, CO, March 28-April 2. Contacts were established with two major oil companies regarding research cooperation and possible formation of an imaging consortium. (BE12)

The heavy oil data base was sent through the TORIS screening process to analyze each reservoir for its suitability to oil recovery through the use of steam, in situ combustion, or alkaline/surfactant/polymer flooding. The results show that California still has the highest potential for future heavy oil production with 9.3 billion barrels recoverable, at \$17/barrel, using existing steam injection technology. Under the same price scenario, the U. S. Gulf Coast has only 230 million barrels recoverable, and the Midcontinent 1 million barrels. (SGP37)

Plans for final implementation of the surfactant-enhanced alkaline flooding field project in Hepler (KS) field were discussed with project participants in Wichita on March 10. Items to be resolved before final field

FOREWORD

The Monthly Progress Report for March 1993, NIPER-679, is submitted in accordance with the provisions of Cooperative Agreement DE-FC22-83FE60149 between the Department of Energy and the IIT Research Institute.

A new project, funded under the Supplemental Government Program, has been added to this report. The project, SGP73, has the objective of determining the effects of natural fractures on horizontal well production using numerical simulation to provide guidelines, screening criteria, or analytical predictions of horizontal well production. The scheduled completion of the project is September 1993.

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SUMMARY

ENERGY PRODUCTION RESEARCH

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Plans for final implementation of the surfactant-enhanced alkaline flooding field project in Hepler (KS) field were discussed with project participants in Wichita on March 10. Items to be resolved before final field

implementation include the determination of a better estimate of oil saturation and assurance that the sodium bicarbonate is compatible with the other EOR chemicals. It is anticipated that CT-monitored flow patterns can provide a better estimate of oil saturation. Laboratory experiments will establish compatibility of the sodium bicarbonate which will be acquired from a source other than that used for previous laboratory testing. (SGP41)

Thirty-five applications from students of 16 different universities were received for the summer intern program. After reviewing the resumes and transcripts of these applicants, 11 offers were made after interview. The reviewing process will continue through April. (SGP50)

Judy Kokesh assisted with the regional "Train the Trainers" session in the Oil and Gas Exploration module of the Denver Earth Science Project. Ms. Kokesh met with Milt Jarrett, Dean of Continuing Education, University of Tulsa, to discuss the University's participation in the regional "Train the Trainers," July 11-21. TU will provide classroom space, resource people, housing, and meals for participants. In addition, planning has begun for the "Oil and Gas Exploration" module workshop to be held in Oklahoma City, during the summer. Ms. Kokesh met with Dr. Edna Manning, president, Oklahoma School of Science and Mathematics to discuss their participation in the workshop, and completed preliminary discussions with the curriculum director of Oklahoma City Public Schools relating to the distribution of workshop information to science teachers. Discussions were also conducted with the Education/Career Development Committee (ECDC) and Phillips Petroleum Company regarding a joint, teacher-internship program for Phillips and NIPER during the summer of 1993. (SGP61)

The papers, extended abstracts of poster session presentations, and summary of a panel discussion have all been assembled into the Proceedings of the symposium on the field application of foams (NIPER-699). The Proceedings will be available for distribution following publication as a DOE/FE report. (SGP63)

The current series of lectures developed by Texas Independent Producers and Royalty Owners (TIPRO) and the Bureau of Economic Geology at the University of Texas at Austin was concluded. Lectures were given in the following Texas cities: Dallas (January 28, attendance 85), Amarillo (February 12, attendance 38), Abilene (February 17, attendance 60), Midland (February 18, attendance 77), Houston (February 24, attendance 77), and Wichita Falls (March 3, attendance 85). A scheduled meeting in Corpus Christi was canceled due to low registration; however, potential attendees from the Corpus area were urged to attend the Houston meeting. NIPER personnel attended and monitored each of these meetings. (SGP64)

A new project was initiated the latter part of February. The objective of the project is to determine the effects of natural fractures on horizontal well production using numerical simulation to provide guidelines, screening criteria, or analytical prediction of horizontal well production. (SGP73)

FUELS RESEARCH

Heat capacity and enthalpy studies on 8-methylquinoline were halted for cryostat repairs. After operating for approximately 50 years, the insulation on one of the calorimeter shields finally deteriorated beyond repair. Rewiring of that shield is in progress, and it is probable that measurements on 8-methylquinoline will recommence by the end of April. High-temperature heat capacity and critical property determinations by differential scanning calorimetry (DSC) for 2-methyl- and 8-methylquinoline were completed this month. Critical temperature and critical density values were determined for both compounds. (The critical properties are key engineering-design parameters). (BFR3)

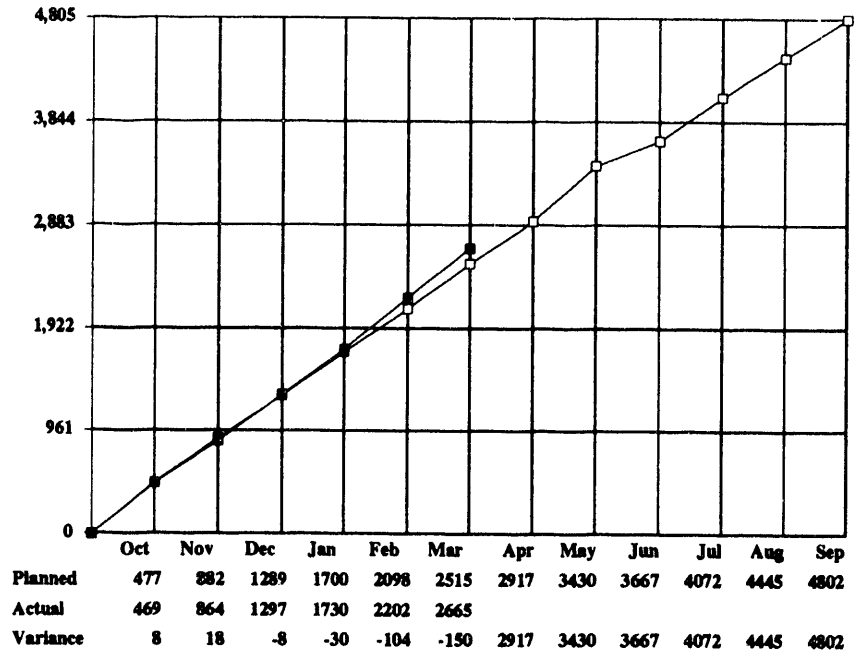
High-temperature DSC measurements on 1,10-trimethylenepheneanthrene have been completed. The DFC results extend the range of heat capacity and enthalpy studies on this compound to 700K. Thermodynamic property calculations for this four-ring hydroaromatic await completion of vapor pressure and enthalpy of combustion measurements. (SGP49)

BASE PROGRAM

FINANCIAL STATUS OF THE PROJECT FOR MARCH

Total Appropriation:		5,000,000
Less Capital Equipment:	197,600	
Appropriation Balance:	4,802,400	
Expenditures for the Month:	462,561	
Total Expenditures to Date:	2,665,007	
Net Available:	2,334,993	
Capital Equipment Expenses and Commits:	23,543	

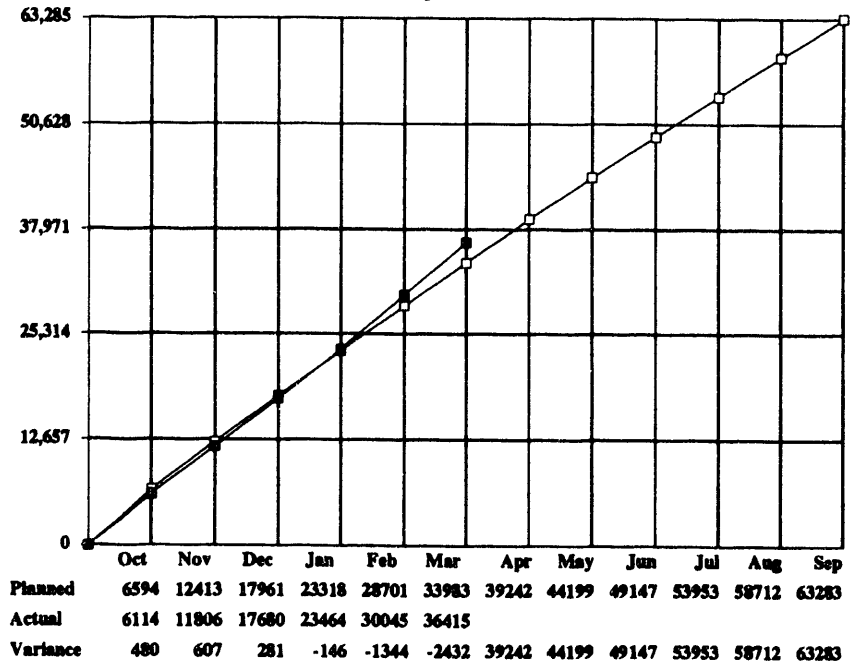
Financial Status



MANPOWER STATUS OF THE PROJECT FOR MARCH

Total Man-hours:		63,283
Man-hours used this Month:	6,372	
Total Man-hours used to Date:	36,415	
Net Available:	26,868	

Manpower Status



Legend for Key Milestones

- X = Work Completed
- C = Planned Completion Date
- C' = Revised Completion Date
- C'' = Completed Ahead of Schedule

BE1

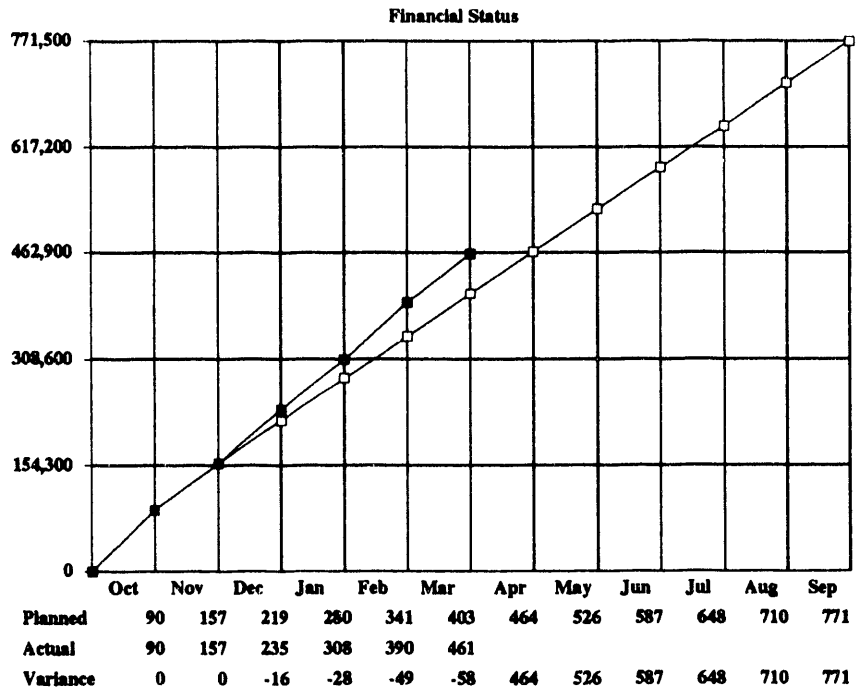
FINANCIAL STATUS OF THE PROJECT FOR MARCH

Total Appropriation:		795,000
Less Capital Equipment:	23,500	
Appropriation Balance:	771,500	
Expenditures for the Month:		70,465
Total Expenditures to Date:		460,804
Net Available:		334,196

Capital Equipment Expenses and Commits: 4,488

Annual Plan Project BE1

Reservoir Assessment and Characterization



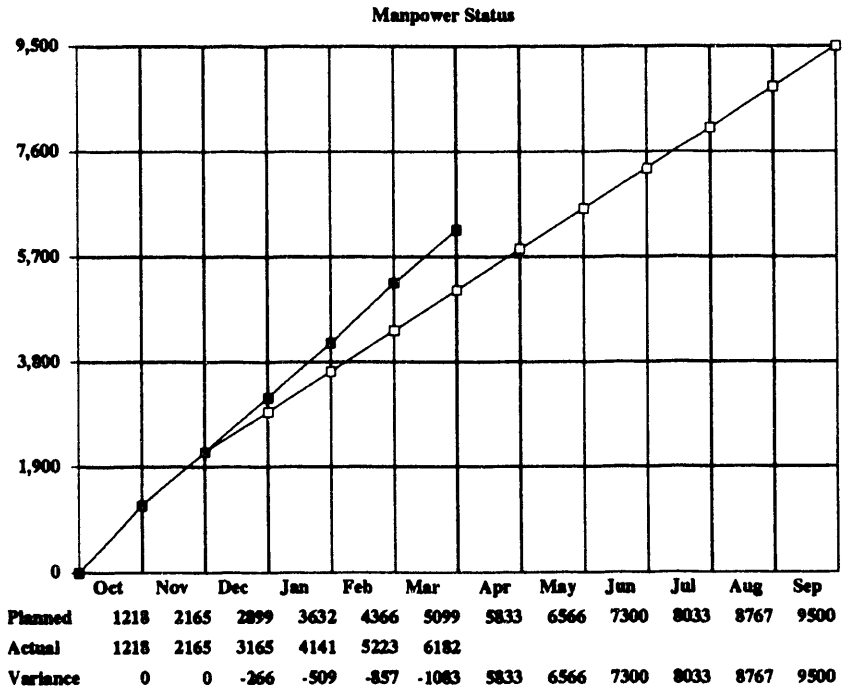
MANPOWER STATUS OF THE PROJECT FOR MARCH

Total Man-hours:		9,500
Man-hours used this Month:	959	
Total Man-hours used to Date:		6,182
Net Available:		3,318

Legend for Key Milestones

- X = Work Completed
- C = Planned Completion Date
- C' = Revised Completion Date
- C'' = Completed Ahead of Schedule

Key Milestone Status



- 1 Submit Status Report on Project Environmental, Safety, and Health Assessment
- 2 Complete Summary of Shoreline Barrier Deposits and Evaluation of Effective Oil Recovery Processes
- 3 Complete Updated Data Base on Patrick Draw Field and Annotated Bibliography on Shoreline Barrier Deposits
- 4 Prepare Chapter for NIPER Final Report Summarizing Accomplishments of Project BE1 (Draft Complete by April 15)
- 5 Status Report Describing Plan for Characterizing Class 1, Fluvial-Dominated Deltaic Reservoirs
- 6 Promote Information Exchange & Complete Technology Transfer Activities

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ENERGY PRODUCTION RESEARCH

BE1. RESERVOIR ASSESSMENT AND CHARACTERIZATION

Accomplishments

The objectives of this project are (1) to develop geological and engineering methods to predict mobile oil saturation distribution and quantify reservoir architecture and flow unit geometry for application to targeted infill drilling and EOR and (2) to synthesize reservoir and production characteristics of shoreline barrier reservoirs and to determine similarities and differences and degree to which information from one reservoir can be applied to another.

Milestone 2—Reservoir and production studies indicate that the Monell Unit of Patrick Draw field has potential for recovering additional oil from CO₂ injection after waterflooding. To investigate the amount of oil recovery and the potential economical impact of CO₂ flooding in the pilot area and Patrick Draw field, Computer Modeling Group's compositional simulator GEM was obtained from DOE and installed in NIPER's MicroVAX computer. The simulator was successfully compiled, after minor modifications, and was validated by running sample problems.

Analysis of petrographical data from 20 thin-section samples constructed from cores taken from four wells in Arch Unit of Patrick Draw field indicates that the sandstones are dominantly feldspathic litharenites, with lesser amounts of litharenite and sublitharenite. The mean total rock volume of diagenetic features that have an effect on porosity and geometry of pores include quartz overgrowths (0.9%), calcite cement (1.1%), dolomite-ankerite cement (11.1%), siderite (.03%), total clay cement (6.9%), total cements of all kinds (18.4%), and opaques and iron oxides (1.5%). The dolomite-ankerite-calcite ratio mean value is 14.2 for 10 samples that contain carbonate minerals. The high ratio is somewhat unexpected and indicates that dolomite is much more abundant in the subsurface samples than is calcite. Based on preliminary observations, this relationship may be quite different than those observed on samples taken from outcrop exposures of the Almond Formation.

A mean value of 61.2% of total feldspars are altered or show effects of corrosion. The high percentage of altered feldspars is the result of their instability in leaching subsurface fluids. Important diagenetic events recognized by Keighin, et al. (1989), include the leaching of calcite followed by late-stage leaching of ankerite. It is possible that the same fluids responsible for the leaching of carbonate minerals also had a corrosive effect on the feldspars. This would result in interparticle porosity and a moderate to great increase in microporosity.

Discussions with Dr. M. J. Fetkovich, a senior principal reservoir engineer from Phillips Petroleum Company and a pioneer in the application of decline curve analysis for production data analysis, resulted in the identification of the types of information that can be obtained from decline-curve analysis. The main conclusions reached from the discussions were that the drainage volume, the skin effect of the reservoir, the degree of carbonate cementation or massive fracturing, and the degree of layering in the reservoir can be identified from decline curve analysis when combined with other information from the reservoir.

Milestone 3—The revised draft of the report, "Annotated Bibliography on Shoreline Barrier Deposits," has been completed and is in review.

Milestone 6—Two papers were presented at the conference, Fluvial-Dominated Deltaic Reservoirs in the Southern Midcontinent, that was held in Norman, OK, March 23-24, 1993. The papers were entitled "General Reservoir and Production Characteristics for Fluvial-Dominated Deltaic Reservoirs" and "Heterogeneities Related to Deltaic Depositional Processes and Their Effect on Waterflooding and Enhanced Oil Recovery (EOR) Processes." Extended abstracts and illustrations to be included in Preprints for the conference, New Technology for Independent Producers, were completed, reviewed, and submitted. The conference will be held in Denver, CO, May 6-7, 1993.

Manpower and Financial Status

Financial expenditures and manpower are higher than predicted due to the effort required in meeting the early deliverable dates for milestones 2 and 3.

Status of Project Milestones

Project milestones are on schedule.

BE2

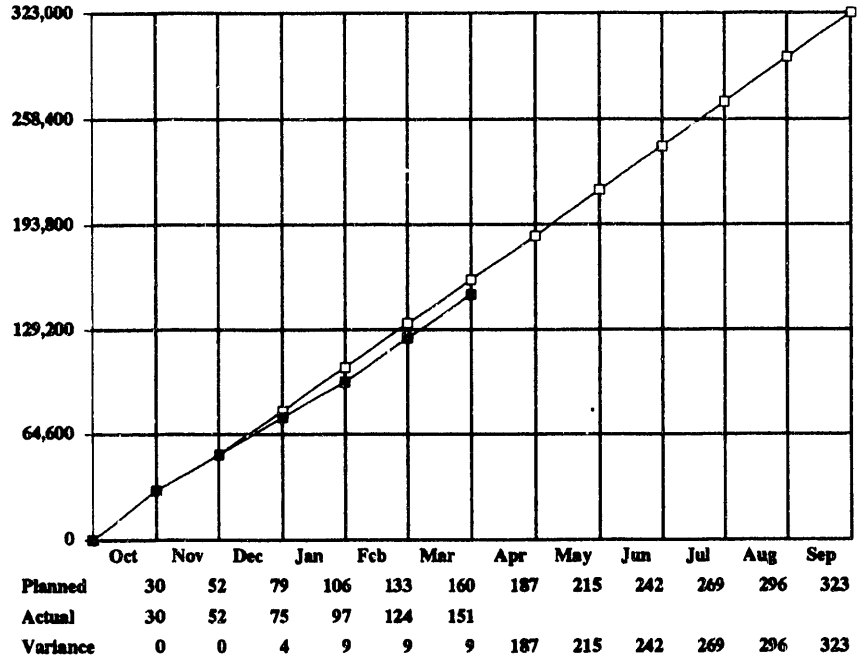
FINANCIAL STATUS OF THE PROJECT FOR MARCH

Total Appropriation:		340,000
Less Capital Equipment:	17,000	
Appropriation Balance:	323,000	
Expenditures for the Month:		26,683
Total Expenditures to Date:		150,952
Net Available:		189,048
Capital Equipment Expenses and Commita:		0

Annual Plan Project BE2

TORIS Research Support

Financial Status



MANPOWER STATUS OF THE PROJECT FOR MARCH

Total Man-hours:		3,600
Man-hours used this Month:	330	
Total Man-hours used to Date:		1,812
Net Available:		1,788

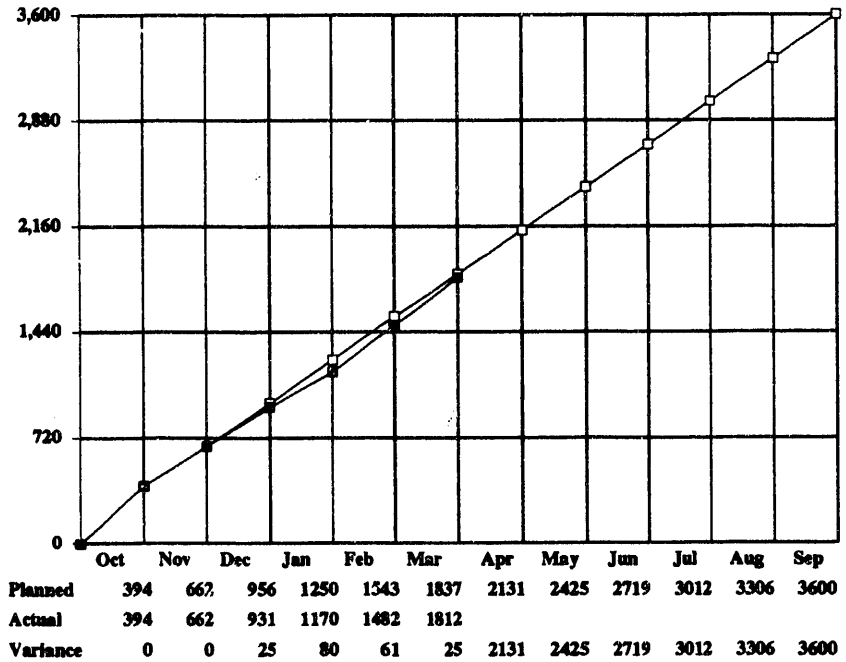
Legend for Key Milestones

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- C'' = Completed Ahead of Schedule

Key Milestone Status

- 1 Submit Status Report on Project Environmental, Safety, and Health Assessment
- 2 Status Report on Review of the INGRES Version of the EOR Project Data Base and Assessment of Future Needs
- 3 Prepare Chapter for NIPER Final Report Summarizing Accomplishments of Project BE2 (Draft complete by April 15)
- 4 Complete FY93 Research Support of EOR Project Data Base
- 5 Complete FY93 Support of RSVR Reservoir Data Base
- 6 Complete FY93 Computer Modeling Research Support
- 7 Status Report Summarizing 1991 Data Collected for Incentive Projects
- 8 Topical Report Defining Estimated Confidence Level of the TORIS EOR Predictive Models

Manpower Status



XXX	XXC											
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			XXX	XXX	XXX	XXX						C
												C
					XXX	XXX	XXX					C
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BE2. TORIS RESEARCH SUPPORT

Accomplishments

The objective of this project is to provide research support to the DOE Program Manager for the Tertiary Oil Recovery Information System (TORIS) in the areas of enhanced oil recovery (EOR) project and reservoir data base management, EOR project technology and trends analysis, and computer simulation.

Milestone 2—No work was done on review of the INGRES version of the EOR project data base because of other high priority tasks. A request to extend the completion date of this milestone to September 1993, has been approved by the BPO.

Milestone 3—A detailed outline was prepared for the chapter of the NIPER final report.

Milestone 4—Research support of the EOR Project Data Base consisted of accessing and querying the data base and preparing approved changes for data entry. The approved changes were put on tape with a transfer program and the tape was sent to EIA. These S2k input files will update this version of the data base. Work was started on a standard query language (SQL) program to update the INGRES version of the data base.

Milestone 7—Letters requesting 1992 and 1991 (when appropriate) data on the Tertiary Incentive Projects were mailed in February. Forty-nine responses have been received for 1992, three for 1991, and two for 1990. Of the total 54 forms, 43 are active, leaving 11 either terminated, abandoned, shut-in, or sold.

Milestone 8—Work under this task has concentrated on comparing oil production from 15 steam projects in the Tertiary Incentive Program to estimated oil production of the TORIS model. Since there are more steam projects than any other EOR process, this will provide the best opportunity to statistically estimate the accuracy of the model. Aggregated results show excellent agreement between the TORIS model and the selected projects. Unfortunately, the variation of actual and simulated oil production between the model and the actual project is significant. Work also concentrated on ensuring the oil in place is being properly modeled. During the course of this review process, differences were noted in the way the formation volume factors (FVF) were being determined. This would ultimately impact the OOIP* volumes generated by the pre-processor DEFLT and the IOIP** volumes from the steamflood predictive model (SFPM). After a careful review of both programs, assumptions used in the volumetric algorithms were indeed found to be different. However, the fact that there are differences does not imply that one is correct and the other is not, only that they are inconsistent in their usage. The effect of these differences will be discussed in the next quarterly report.

*OOIP Original oil in place in reservoir before primary production.

**IOIP Initial oil in place—oil remaining in produced reservoir at the beginning of project simulation.

Manpower and Financial Status

Manpower and financial expenditures are on schedule.

Status of Project Milestones

The BPO has approved a request to extend the completion date of milestone 2 to September 1993. All other milestones are on schedule.

BE3

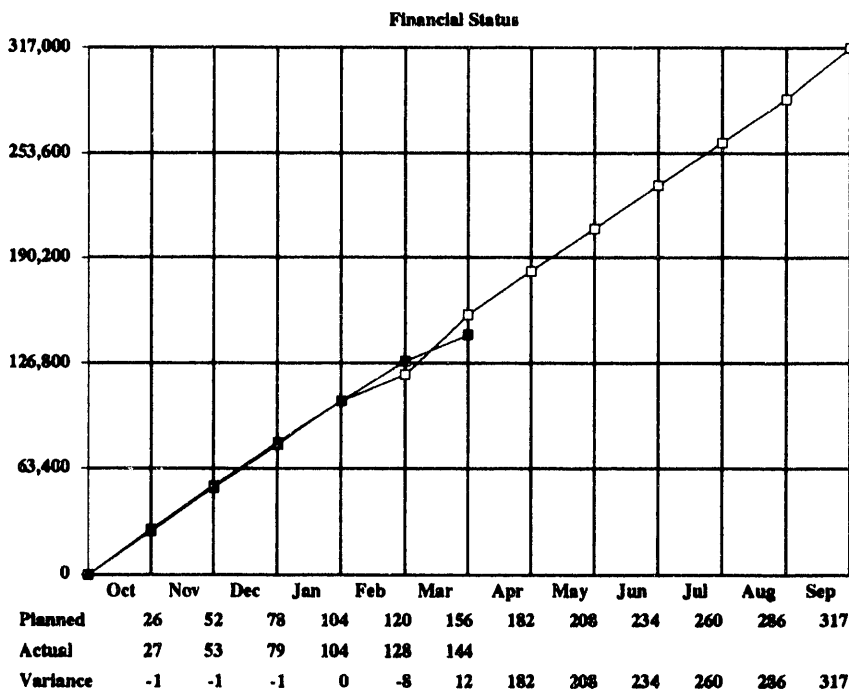
FINANCIAL STATUS OF THE PROJECT FOR MARCH

Total Appropriation:	320,000
Less Capital Equipment:	3,000
Appropriation Balance:	317,000
Expenditures for the Month:	15,857
Total Expenditures to Date:	143,838
Net Available:	176,162

Capital Equipment Expenses and Commits: 3,729

Annual Plan Project BE3

Development of Improved Microbial Flooding Methods



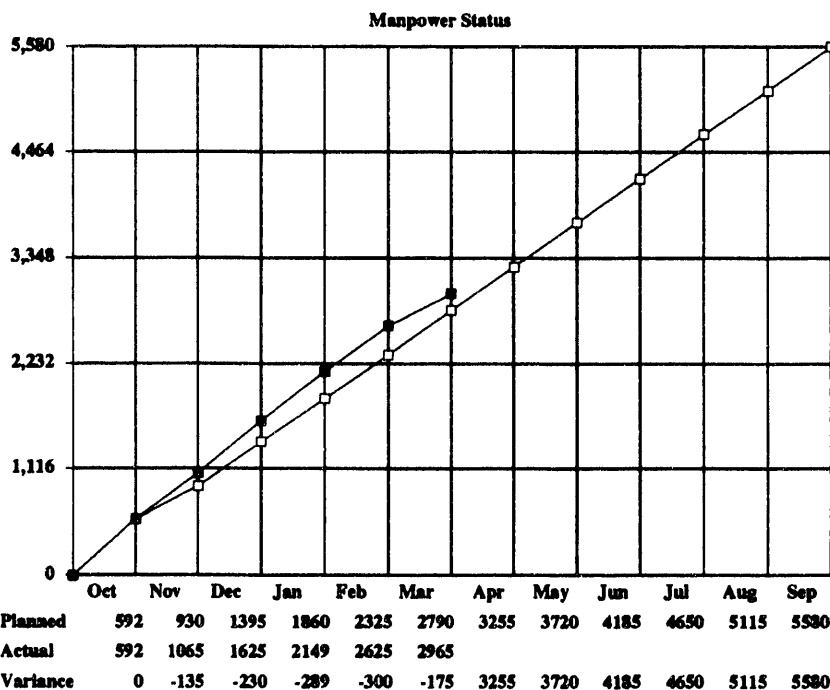
MANPOWER STATUS OF THE PROJECT FOR MARCH

Total Man-hours:	5,580
Man-hours used this Month:	340
Total Man-hours used to Date:	2,965
Net Available:	2,615

Legend for Key Milestones

- X = Work Completed
- C = Planned Completion Date
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Key Milestone Status



- 1 Submit Status Report on Project Environmental, Safety, and Health Assessment
- 2 Complete Evaluation of Microbial Systems in Porous Media Using CT/NMR-Imaging Techniques
- 3 Complete Experiments Investigating the Role of Microbial Polymer Production in Oil Recovery
- 4 Prepare Chapter for NIPER Final Report Summarizing Accomplishments of Project BE3 (Draft complete by April 15)
- 5 Finalize Development of Mathematical Descriptions for Use in MEOR Predictive Simulator
- 6 Provide Support to DOE's Cooperative Effort with Venezuela by Presenting Project Research Results at Annex XIII Meetings
- 7 Topical Report Describing Development of Mathematical Descriptions for Predicting Mechanisms of Microbial Oil Recovery

XXC

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___	XXX	XXX	XXX	XXX	XXX	___	___	C

BE3. DEVELOPMENT OF IMPROVED MICROBIAL FLOODING METHODS

Accomplishments

The objectives for FY93 are (1) to continue development of an engineering methodology for use in the design and application of microbial methods and (2) to improve oil recovery methods and refine modeling procedures for predicting the effectiveness of such methods in field applications.

Different types of microorganisms can improve oil recovery in various ways. NIPER has focused primarily on surfactant and gas-producing microbes for improvements in microscopic oil displacement efficiency. Microorganisms can also be used to plug high-permeability zones and cause fluid diversion. During the past 2 years, microbial retention experiments have been conducted with surfactant and gas-producing microbes to determine the effects of microbial adsorption and clogging in porous media. These experiments have been used to define parameters and values for the numerical MEOR simulator.

Research for FY93 will continue with laboratory experiments designed to meet both near- and mid-term objectives. Based upon the laboratory data, mathematical models are being developed to predict microbial transport, metabolism, oil recovery, and permeability modification. The resulting models can then be used to predict the behavior of microbial EOR processes under actual reservoir conditions. Injection strategies for maximizing incremental oil recovery are also being developed.

Milestone 2—A coreflood experiment is in progress using a microbial species of *Leuconostoc*. This species produces polymer when fermenting sugar and should not produce gas in the coreplug. By comparing NMR images obtained during this coreflood with previously acquired images in corefloods using gas-producing microbes, it may be possible to determine and quantify gas distribution in the pores.

Milestone 3—A coreflood was initiated with a polymer-producing microorganism to compare the results of oil recovery efficiency and pressure drop across the core during waterflooding with results obtained previously using NIPER 6 *Clostridium* which produces gas, acids, and surfactant.

Milestone 4—The chapter on microbial EOR processes for the NIPER final report has been written and submitted for review.

Milestone 5—Evaluation of the retention test data continued this month. A glass beadpack was constructed to conduct a retention test using NIPER 6 microbial species.

Manpower and Financial Status

Manpower and financial expenditures are on schedule.

Status of Project Milestones

Project milestones are on schedule.

BE4A

FINANCIAL STATUS OF THE PROJECT FOR MARCH

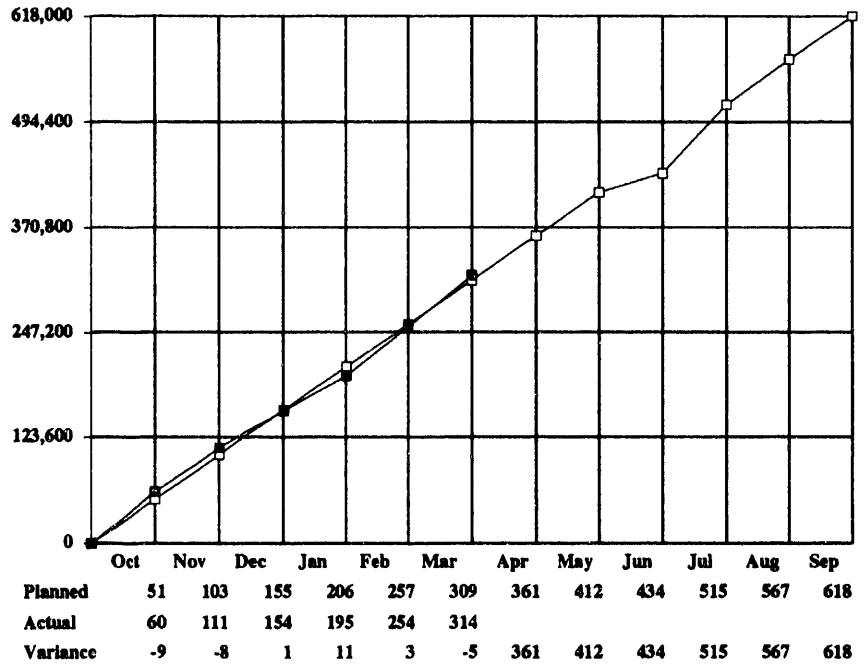
Total Appropriation:		640,000
Less Capital Equipment:	22,000	
Appropriation Balance:	618,000	
Expenditures for the Month:		59,740
Total Expenditures to Date:		313,629
Net Available:		326,371

Capital Equipment Expenses and Commits:

Annual Plan Project BE4A

Development of Improved Chemical Flooding Methods

Financial Status



MANPOWER STATUS OF THE PROJECT FOR MARCH

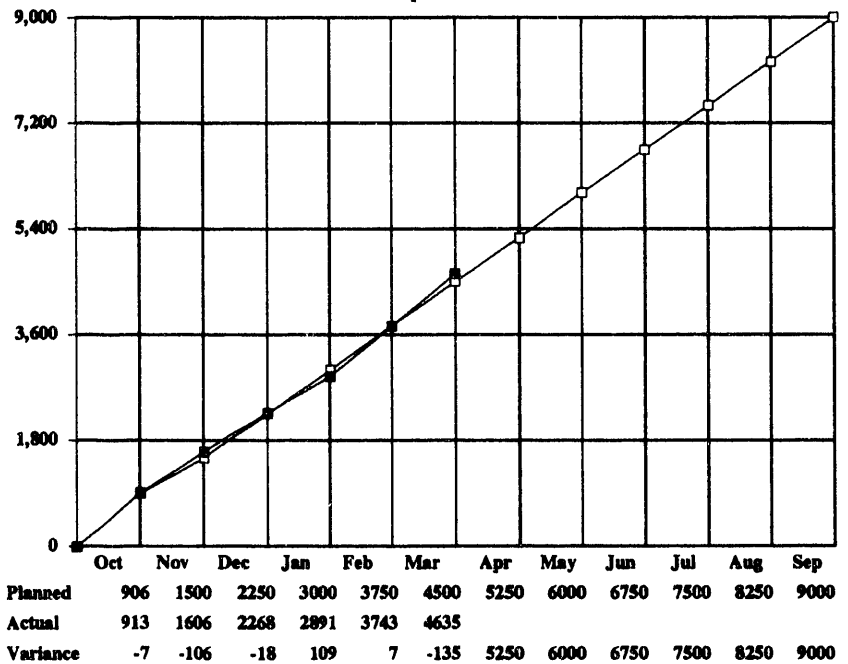
Total Man-hours:		9,000
Man-hours used this Month:	892	
Total Man-hours used to Date:		4,635
Net Available:		4,365

Legend for Key Milestones

- X = Work Completed
- C = Planned Completion Date
- C' = Revised Completion Date
- C'' = Completed Ahead of Schedule

Key Milestone Status

Manpower Status



- 1 Status Report on Environmental, Safety, and Health Review
- 2 Evaluation of Mixed Surfactants for use in Class 1 Reservoirs
- 3 Through CT-Imaged Coreflood Experiments, Determine Effectiveness of Mixed Surfactant Systems for Oil Recovery
- 4 Determine Adsorption Characteristics of Mixed Surfactant Systems
- 5 Conduct CT-Imaging Experiments to Determine Optimum Injectant Slug Size for Oil-bank Formation and Mobilization
- 6 Develop Surfactant Data Base to Facilitate Design of Chemical Flooding Systems & Submit Status Report on Its Effectiveness
- 7 Prepare Chapter for NIPER Final Report (Draft by April 15)
- 8 Top. Rpt. Describing Adsorption Studies of Mixed Surfactant Systems
- 9 Top. Rpt. Describing Effectiveness of Mixed Surfactant Systems for Use in EOR

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BE4A. DEVELOPMENT OF IMPROVED CHEMICAL FLOODING METHODS

Accomplishments

The objectives of this project are (1) to determine the applicability of advanced EOR technologies, based on mixed surfactant systems, to improve oil recovery from Class 1 and other DOE-targeted reservoirs; (2) to adapt surfactant EOR technology to different salinity and temperature ranges by developing surfactant systems that are tolerant to changes in chemical composition in selected reservoirs; and (3) to develop cost-effective systems for selected applications using low-concentration surfactants with alkaline additives or other sacrificial agents. The studies will focus on problem areas which adversely affect performance and economics of chemical EOR and thus achieve a balance between cost and oil recovery effectiveness.

Milestone 2—The phase-inversion-temperature (PIT) screening experiments using selected combinations of TRS 10-410/IBA (anionic) and the Genapol (nonionic) and Igepal (nonionic) series of surfactants, in combination with different alkanes, have been completed. The results of these experiments are currently being analyzed and correlated. Work continues on other mixed surfactant systems containing AOS surfactants as the primary sulfonate component. In earlier PIT experiments, combinations of these AOS surfactants with selected nonionic surfactants, at a fixed component proportion 50:50% by weight, indicated some trends in solution conductivity changes that can be attributed to the relative proximity of optimal conditions for these anionic-nonionic mixtures. However, additional tests with these combinations indicated that the trends with these mixtures were not as distinct as compared to earlier results with the mixtures of the TRS 10-410/IBA system and the different nonionic components. These results indicate that the AOS surfactant solution behavior appears to dominate the solution behavior of the overall mixture at the 50:50% by weight chemical proportion tested. Additional salinity scans and PIT tests are being conducted with mixtures containing nonionic component proportions greater than 50%. Preliminary results using systems with the higher nonionic component indicate very distinct phase inversion trends. These results showed that under the conditions tested (nonionic component greater than 50%) the nonionic surfactant behavior appeared to dominate the overall solution behavior. Additional tests are planned for this mixed surfactant system.

Milestone 3—An oil-wet core from North Burbank Unit (NBU), Osage County, Oklahoma, has been cleaned, and its porosity has been determined. This core will be used to examine the interaction of iododecane with the oil-wet surface in order to evaluate the effect of possible preferential adsorption of iododecane on oil saturation distribution calculations using CT-imaging techniques. For the CT-imaging experiments, either water- or oil-soluble tagging agents must be used to distinguish differences in oil and aqueous fluid saturation distributions. Surfactant solutions are very sensitive to ionic content. Therefore, tagging aqueous solutions containing chemical flooding agents may not be possible. All CT experimental of chemicals floods studies conducted to date have used iododecane to tag the oil. Preferential adsorption was not observed when corefloods were conducted using water-wet cores; however, some problems in determining oil saturation were encountered during a previous oil recovery experiment using oil-wet NBU core. If iododecane adsorbs on the oil-wet surface, the CT value of the rock will change, causing inaccurate values to be used in saturation calculations. Results of this experiment have implications concerning interpretation of CT-determined oil saturations for reservoir core of unknown or mixed wettability.

Milestone 4—Adsorption studies of mixed nonionic and anionic surfactant systems have been initiated to evaluate the problem of chromatographic separation of mixed surfactant systems during chemical flooding processes. Both static and dynamic adsorption tests will be conducted. The mixed surfactant system, Stepan's B-100, an alkyl aryl sulfonate, and Igepal DM 530, an ethoxylated alcohol, has been selected for study. Analysis of the nonionic surfactant requires separation from the anionic using an ion exchange column. Calibration curves for the analysis of the nonionic surfactant concentration have been determined for solutions that initially contained both surfactants with and without 3% added NaCl. The static adsorption tests of unadulterated and mixed surfactants have been initiated. Davidson Grade 62 silica gel, with a specific surface of 330 m²/g, was used as the adsorbent. Since reservoir rock generally has about 1 m²/g specific area, a nonconsolidated core of 1-ft length can represent the surface area of 100 or more feet of reservoir.

Milestone 5—Two CT-monitored corefloods are in progress to determine the effect on oil-bank formation and propagation when the slug-injection size is altered. Both cores have been waterflooded to residual oil saturation and are ready for chemical injection. For one core, 0.4 PV of 0.4% total concentration of surfactant will be injected and, for the second core, 0.2 PV of surfactant will be injected. Results will be compared with a previous experiment where 0.75 PV of the same surfactant formulation was used.

A paper, entitled "CT-Imaging of Surfactant/Polymer EOR Corefloods," was presented at the ACS Symposium on Enhanced Oil Recovery, 205th National American Chemical Society Meeting, March 28-April 2, 1993, in Denver, CO.

Milestone 6—Work on the surfactant data base is continuing. Twenty recent references were added to the data base this month. Approximately 175 references now comprise the subset of publications to be considered for critical review. The review process is underway.

Milestone 7—For the NIPER final report, a first draft of the state-of-the-art analysis of chemical flooding processes and project BE4A accomplishments over the FY84-92 time frame has been assembled. Accomplishments for FY93 are being prepared. The final report chapter on chemical flooding will include surfactant flooding, alkaline-surfactant-polymer flooding, and polymer research.

Manpower and Financial Status

Manpower and financial expenditures are on schedule.

Status of Project Milestones

Project milestones are on schedule.

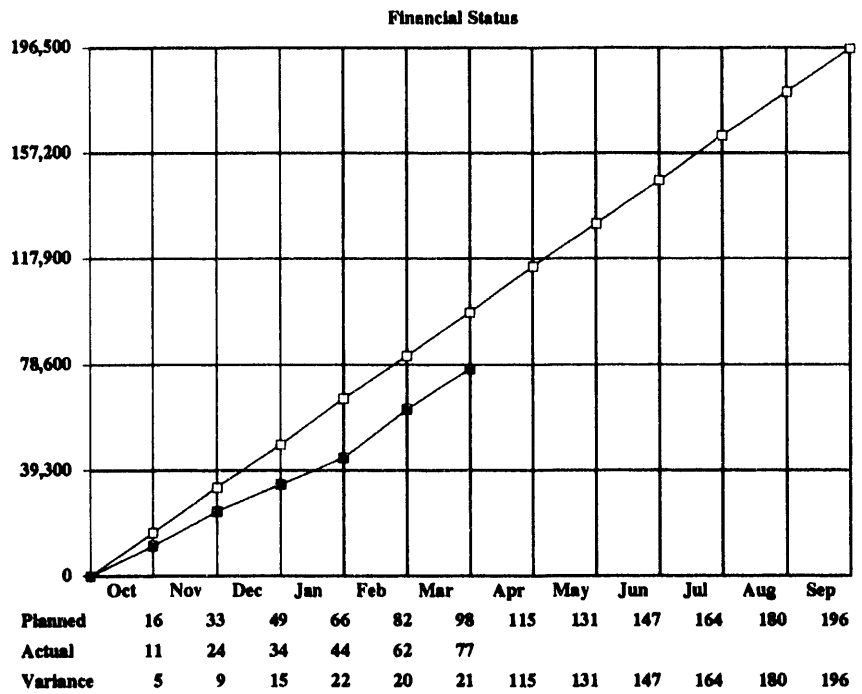
BE4B

FINANCIAL STATUS OF THE PROJECT FOR MARCH

Total Appropriation:	200,000
Less Capital Equipment:	3,500
Appropriation Balance:	196,500
Expenditures for the Month:	15,549
Total Expenditures to Date:	77,254
Net Available:	122,746
Capital Equipment Expenses and Commits:	2,665

Annual Plan Project BE4B

Development of Improved Alkaline Flooding Methods



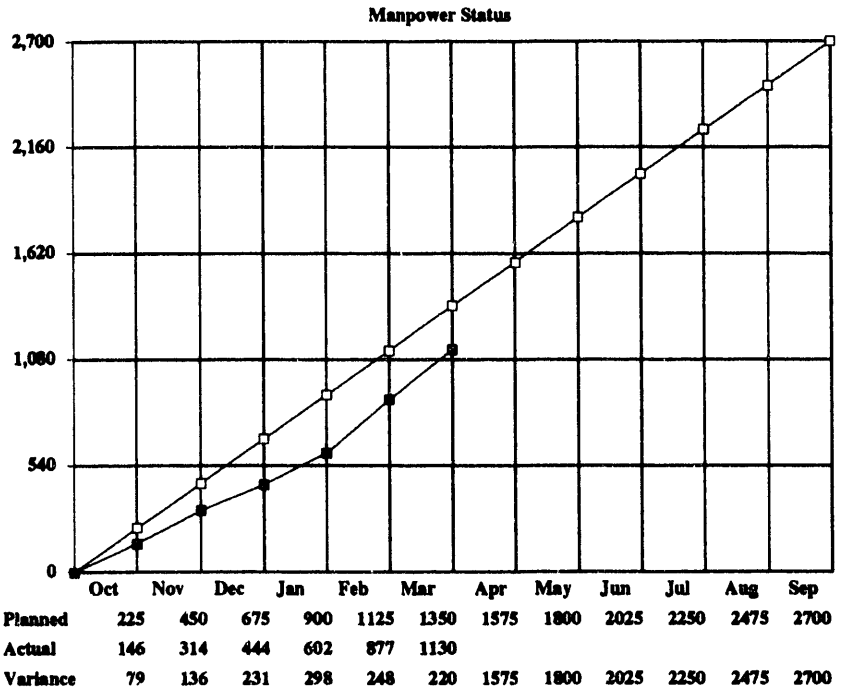
MANPOWER STATUS OF THE PROJECT FOR MARCH

Total Man-hours:	2,700
Man-hours used this Month:	253
Total Man-hours used to Date:	1,130
Net Available:	1,570

Legend for Key Milestones

- X = Work Completed
- C = Planned Completion Date
- C' = Revised Completion Date
- C'' = Completed Ahead of Schedule

Key Milestone Status



- 1 Submit Status Report on Project Environmental, Safety, and Health Assessment
- 2 Conclude Study on Dispersion/Interactions Associated with Surfactant-Enhanced Alkaline Flooding Systems
- 3 Complete Transfer of Surfactant-Enhanced Alkaline Flooding Technology to Independent Oil Producers
- 4 Prepare Chapter for NIPER Final Report Summarizing Accomplishments of Project BE4B (Draft Complete by April 15)
- 5 Topical Report Describing Characteristics of Dispersions Associated with Surfactant & Alkaline Chemical Systems

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BE4B. DEVELOPMENT OF IMPROVED ALKALINE FLOODING METHODS

Accomplishments

The objectives of this project are to develop improved alkali-surfactant flooding systems and to provide support for an SGP field project. The specific objectives for FY93 are to improve the stability of alkali-surfactant flooding systems by designing combinations of chemicals that will curtail the loss of surfactant from chemical interactions. Most of the tests are being performed with crude oil from the Tucker sand (a Cherokee group sand) of Hepler (KS) oil field, the site of a alkaline/surfactant/polymer field project.

Milestone 2—Completion of this milestone on the characterization of dispersions that are typical of surfactant-enhanced alkaline systems, has proven to be more complicated and time intensive than anticipated. The results from light-scattering techniques employed in this research have been found to be extremely sensitive to polymer molecule shape—a shape in which changes are dependent on parameters such as extremely small variations in the ionic character of the solutions. The acquired laboratory data has been reviewed by an expert in light scattering techniques, and this has resulted in consensus of opinion that there is not sufficient time remaining in FY93 to obtain laboratory data that will provide a quality report on this subject. Thus, a memo has been submitted to the BPO requesting a change in the scope of work for this milestone.

The proposed new direction for the work for milestone 2 would focus on the use of computerized tomography (CT) imaging to accurately determine oil saturations in field cores swept with surfactant-enhanced alkaline chemical formulations. It has recently been determined that this type of research is necessary because of the difficulty in accurately predicting heterogeneities in midcontinent field cores and in estimating final oil saturations that result after application of chemical flooding methods in midcontinent fluvial-dominated (DOE Class 1) reservoirs.

Milestone 3—Results from Project BE4B were used in the design of the field test in Hepler (KS) field. They were also included in part of the data presented at the Tenth TORP conference in Wichita, KS, and at the FDD sandstone reservoir workshop in Norman, OK. Both meetings were held in March.

Milestone 4—Final report preparation was continued with a written section on the accomplishments of surfactant-enhanced alkaline flooding research during the past 9 years, which will be a part of Chapter 4 of the report.

Manpower and Financial Status

Manpower and financial expenditures are below projections due to staff involvement in the SGP41 alkaline/surfactant/polymer flooding field project.

Status of Project Milestones

As explained above, a request has been submitted to the BPO requesting a change in scope for milestone 2. The other project milestones are on schedule.

BE4C

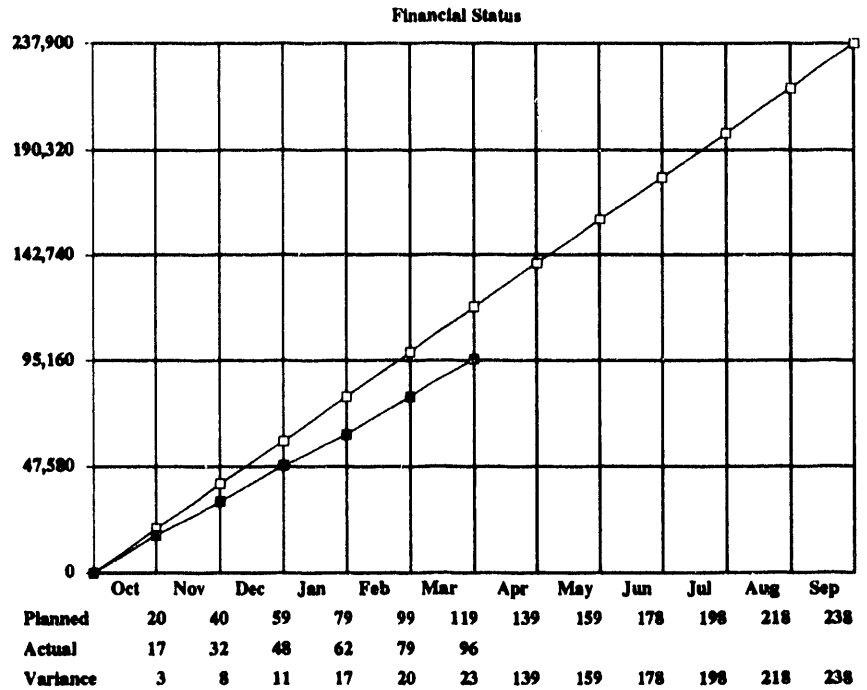
FINANCIAL STATUS OF THE PROJECT FOR MARCH

Total Appropriation:	240,000
Less Capital Equipment:	2,100
Appropriation Balance:	237,900
Expenditures for the Month:	17,259
Total Expenditures to Date:	96,012
Net Available:	143,988

Capital Equipment Expenses and Commits: 0

Annual Plan Project BE4C

Mobility Control and Sweep Improvement
in Chemical Flooding



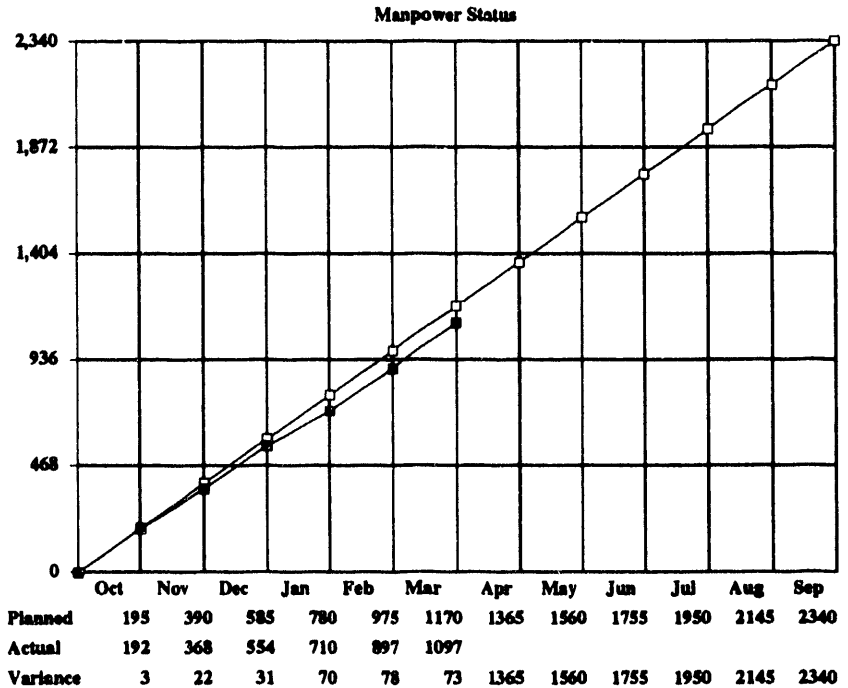
MANPOWER STATUS OF THE PROJECT FOR MARCH

Total Man-hours:	2,340
Man-hours used this Month:	200
Total Man-hours used to Date:	1,097
Net Available:	1,243

Legend for Key Milestones

- X = Work Completed
- C = Planned Completion Date
- C' = Revised Completion Date
- C'' = Completed Ahead of Schedule

Key Milestone Status



- 1 Submit Status Report on Environmental, Safety, & Health Review
- 2 Complete Determination on the Effect of Lamination Angle & Pore Size Distribution on Polymer Retention
- 3 Finalize Comparison of Simulation Results from Permeability Modification Simulator with Field Performance Data
- 4 Finalize Adaptation of Permeability Modification Simulator to IBM-PC/80386 Microcomputer
- 5 Prepare Chapter for NIPER Final Report (Draft by April 15)
- 6 Status Report Describing the Simulation & Prediction of Oil Recovery from Field Permeability Modification Treatments
- 7 Topical Report Describing the Effect of Lamination Angle & Pore Size Distribution on Polymer in Unfired Berea Cores
- 8 Complete Source Code, Executable Code, & User's Manual for IBM-PC/80386 Version of Permeability Modification Simulator

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BE4C. MOBILITY CONTROL AND SWEEP IMPROVEMENT IN CHEMICAL FLOODING

Accomplishments

The objectives of this project are to develop improved methods for maintaining effective mobility control throughout the reservoir in chemical flooding and to use NIPER's permeability modification simulator to design a cost-effective gel treatment employing polymer gel systems. Specific objectives in FY 93 are (1) to determine the effect of lamination angle on polymer retention in unfired Berea cores, (2) to compare simulation results using the permeability modification simulator with field performance, and (3) to convert the permeability modification simulator for use with an IBM-PC/80386 or compatible microcomputer.

Milestone 2—Computed tomography (CT) scans were conducted on an unfired rectangular Berea sandstone core, before and after it was saturated with 2% KCl, to determine the locations, directions, and porosity contrast of the laminations. This core had dimensions of 23.88 x 3.81 x 3.81 cm and was cut at 30° from the direction of laminations. Calculated CT porosity was 18.8%, compared with 19% from a brine saturation method. Tracer tests were conducted at 5.4 mL/hr (1.54 ft/d or 47 cm/d) by injecting a slug (0.3 PV) of tagged brine (7% KI) into the core followed by 2% KCl. The flow behavior of the tagged brine was monitored throughout its advance through the core by conventional CT and topogram scanning. The resulting images are being analyzed and will be compared with those after the polymer flow. Corefloods will be started upon completion of the brine permeability measurements.

Milestone 3—Converting the field data from a pilot field that had been treated with gelled polymer to an input data file for NIPER's permeability modification simulator is in progress.

Milestone 5— The first draft of the research activities and accomplishments from FY85 to FY93 has been completed and is in review.

A paper (SPE 25453), entitled "The Effects of Layer Permeability Contrast and Crossflow on the Effectiveness of Polymer Gel Treatments in Polymer Floods and Waterfloods," was presented at the 1993 SPE Production Operations Symposium in Oklahoma City, March 21-23, 1993.

Manpower and Financial Status

Manpower utilization is on schedule, but financial expenditures are low due to the temporary allocation of senior staff to other DOE priority projects.

Status of Project Milestones

Project milestones are on schedule.

BESA

FINANCIAL STATUS OF THE PROJECT FOR MARCH

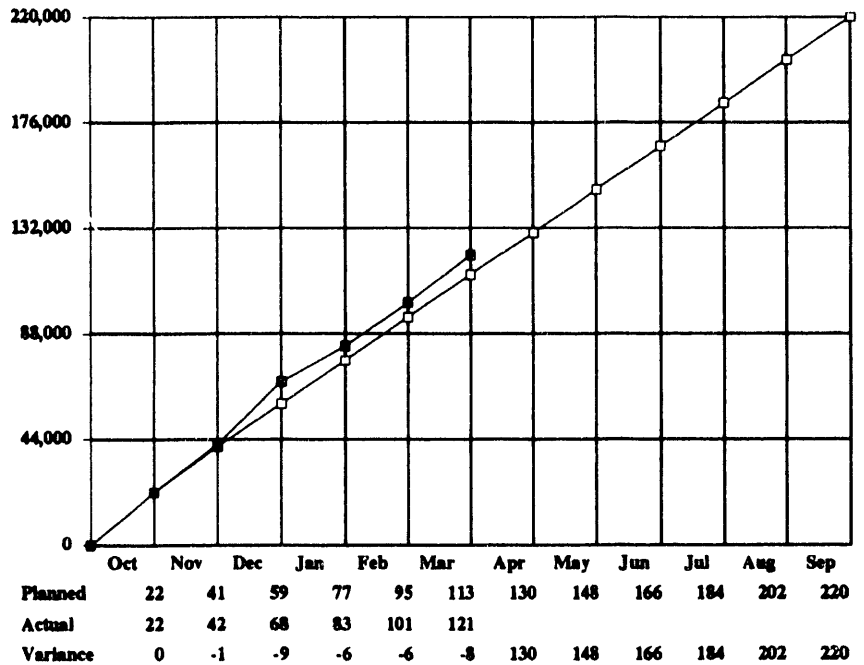
Total Appropriation:	250,000
Less Capital Equipment:	30,000
Appropriation Balance:	220,000
Expenditures for the Month:	20,228
Total Expenditures to Date:	120,882
Net Available:	129,118

Capital Equipment Expenses and Commts: 7,916

Annual Plan Project BESA

Gas Flood Performance Prediction Improvement

Financial Status



MANPOWER STATUS OF THE PROJECT FOR MARCH

Total Man-hours:	2,560
Man-hours used this Month:	214
Total Man-hours used to Date:	1,128
Net Available:	1,432

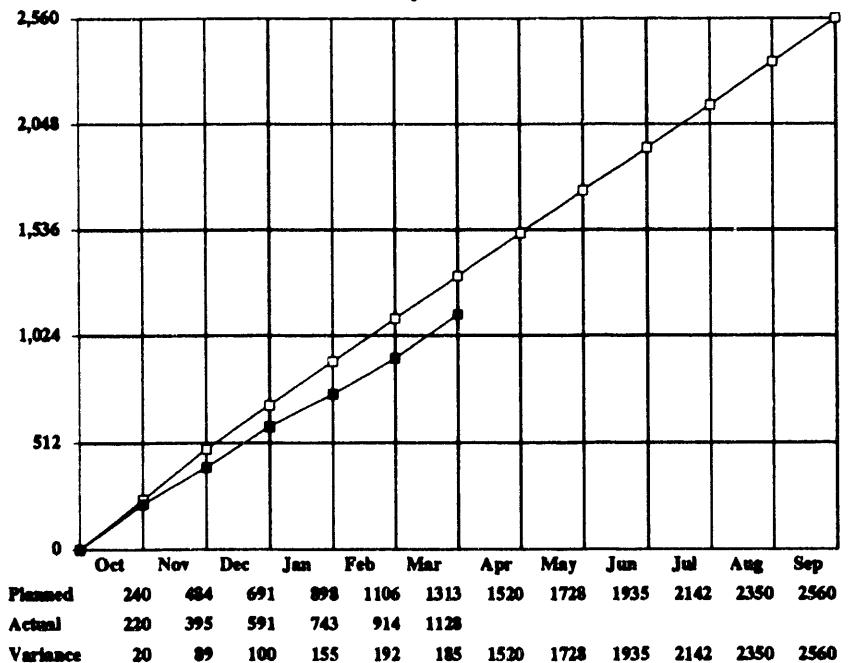
Legend for Key Milestones

- X = Work Completed
- C = Planned Completion Date
- C' = Revised Completion Date
- C'' = Completed Ahead of Schedule

Key Milestone Status

- 1 Submit Status Report on Environmental, Safety, and Health Review
- 2 Complete Construction & Testing of High-Pressure IFT Measurement Apparatus
- 3 Finalize Studies on PVT Determination of Carbon Dioxide Partitioning Between Hydrocarbon & Water Phases at Selected Temperature & Pressure Conditions
- 4 Complete IFT Measurements for Water-Hydrocarbon Systems
- 5 Prepare Chapter for NIPER Final Report Summarizing Accomplishments of Project BESA (Draft Complete by April 15)
- 6 Topical Report Describing Experimental Techniques & Correlations Developed for IFT and Carbon Dioxide-Partitioning Measurements

Manpower Status



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BESA. GAS FLOOD PERFORMANCE PREDICTION IMPROVEMENT

Accomplishments

The objective of this project is to improve prediction techniques for gas miscible displacement through fundamental research in displacement mechanisms. The FY93 studies are to determine (1) the effects of CO₂ partitioning in oil and water phases and (2) the significance of CO₂ dissolution on water-oil interfacial tension (IFT) and relative permeability.

Milestone 2—The construction and testing of the high-pressure IFT measurement apparatus have been completed.

Milestone 3—Before completing IFT measurements of CO₂ systems, the solubilities of CO₂ in the aqueous and oil phases have to be determined. To this end, the literature is being examined in an attempt to find equations of state that can be used in developing techniques to predict CO₂ solubility in water and brine. However, none of the available equations of state examined to date have been acceptable.

Milestone 4—A calibration of the IFT measuring equipment has been conducted for pure water. The water sample was obtained from the distillation of deionized water with the oxidation agent (KMnO₄). The measured surface tension for pure water at 30° C was determined to be 71.46 dyne/cm and in close agreement with the literature reported value of 71.4 dyne/cm. The calibration work will be continued to assure the IFT measuring equipment continually produces reliable and reproducible data. Once all testing has been completed, a calibration procedure will be established for future measurements.

Milestone 5—A draft of the chapter on gas flooding research has been prepared for the final report and submitted for review.

Manpower and Financial Status

Financial expenditures are on schedule, but manpower is low by 14%. Additional laboratory support was required in the installation and operation of the new IFT measuring equipment.

Status of Project Milestones

Milestone 2 has been completed. The other project milestones are on schedule.

BESB

FINANCIAL STATUS OF THE PROJECT FOR MARCH

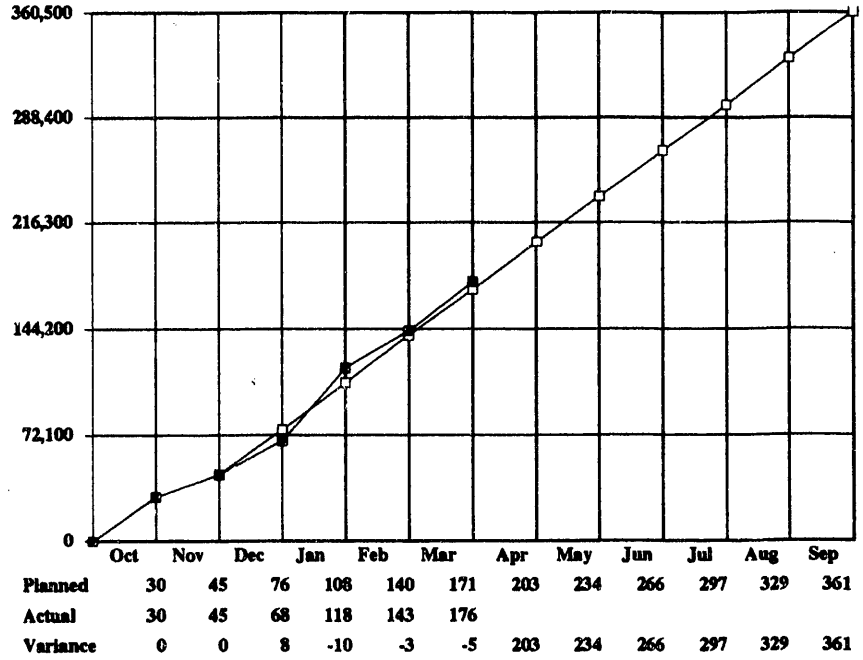
Total Appropriation:		375,000
Less Capital Equipment:	14,500	
Appropriation Balance:	360,500	
Expenditures for the Month:		32,908
Total Expenditures to Date:		175,532
Net Available:		199,468

Capital Equipment Expenses and Commits: 0

Annual Plan Project BESB

Mobility Control, Profile Modification, and Sweep Improvement in Gas Flooding

Financial Status



MANPOWER STATUS OF THE PROJECT FOR MARCH

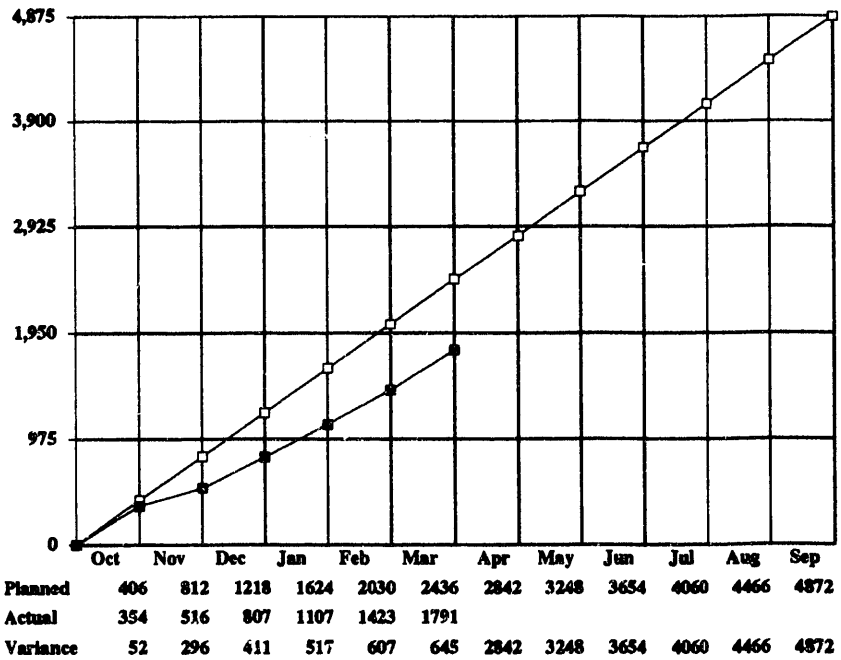
Total Man-hours:		4,872
Man-hours used this Month:	368	
Total Man-hours used to Date:		1,791
Net Available:		3,081

Legend for Key Milestones

- X = Work Completed
- C = Planned Completion Date
- C' = Revised Completion Date
- C* = Completed Ahead of Schedule

Key Milestone Status

Manpower Status



- 1 Submit Status Report on Project Environmental, Safety, and Health Assessment
- 2 Complete Feasibility Evaluation on Use of Alcohol-Induced Salt Precipitation for Profile Modification; Determine Phase Behavior & Salt Precipitation of Alcohol-brine Systems
- 3 Complete Studies on Plugging of Porous Media by Alcohol-Induced Salt Precipitation
- 4 Prepare Chapter for NIPER Final Report Summarizing Accomplishments of Project BESB (Draft Complete by April 15)
- 5 Complete Profile Modification Determinations Using Polymer Gels and/or Alcohol-Induced Salt Precipitation
- 6 Status Report Describing Results of Profile Modification Studies

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BE5B. MOBILITY CONTROL, PROFILE MODIFICATION, AND SWEEP IMPROVEMENT IN GAS FLOODING

Accomplishments

The objective of this project is to develop methods for improving sweep efficiency in gas flooding. Proposed methods for profile modification include the use of polymers, in situ formation of polymer gels, and by precipitation of salts and chemicals.

Milestone 3—Mercury invasion tests were made with cores to determine the size of pore throats and the particle size of precipitated salt necessary to block pore throats. For a high-permeability core of 700 to 800 mD, the median diameter of the larger pore throats was about 24 μm . Previously, the particle size of precipitated salt with ethanol was measured from bottle tests. These observations indicated that most of the precipitates ranged in size from 3 to 12 microns. The observations indicated that most the salt crystals were not sufficiently large enough to plug a pore throat of this size and, therefore, pore throats of lower permeability cores were more effectively plugged by the salt crystals.

Several corefloods were conducted with Berea cores to measure permeability reduction using salt precipitation. For the corefloods, three parameters were observed that affect the degree of permeability reduction: the quantity of alcohol injected, the original core permeability, and the shut-in time after brine and alcohol injection. Alternating slugs of alcohol and NaCl-saturated brine were injected at a rate of 7.5 ft/d. It was observed, that for cores having the same permeability a 10 to 15% higher permeability reduction was obtained when injecting 0.3 PV of ethanol as compared with 0.2 PV. The permeability reduction of a 500 mD core was about 25% lower than observed with a 800 mD core. In addition, as stated last month, greater permeability reduction was obtained by shutting in the core for about one week.

Additional corefloods were conducted to determine the persistence of salt precipitation on permeability reduction by a conventional waterflood. A lower salinity brine (5% NaCl) was used rather than fresh water to reduce salinity shock and to prevent the possibility of clay swelling. For two corefloods, the permeability increased 5 to 10% after injecting two PV of 5% brine. The corefloods indicated a good persistence of salt precipitation to maintain blocked pores after the injection of low salinity brines.

Milestone 4—A draft of the final report describing work accomplished for gas flooding is being prepared.

Manpower and Financial Status

Financial expenditures are on schedule. Manpower is below planned projections due to laboratory staff commitments to other DOE projects.

Status of Project Milestones

Project milestones are on schedule.

BE9

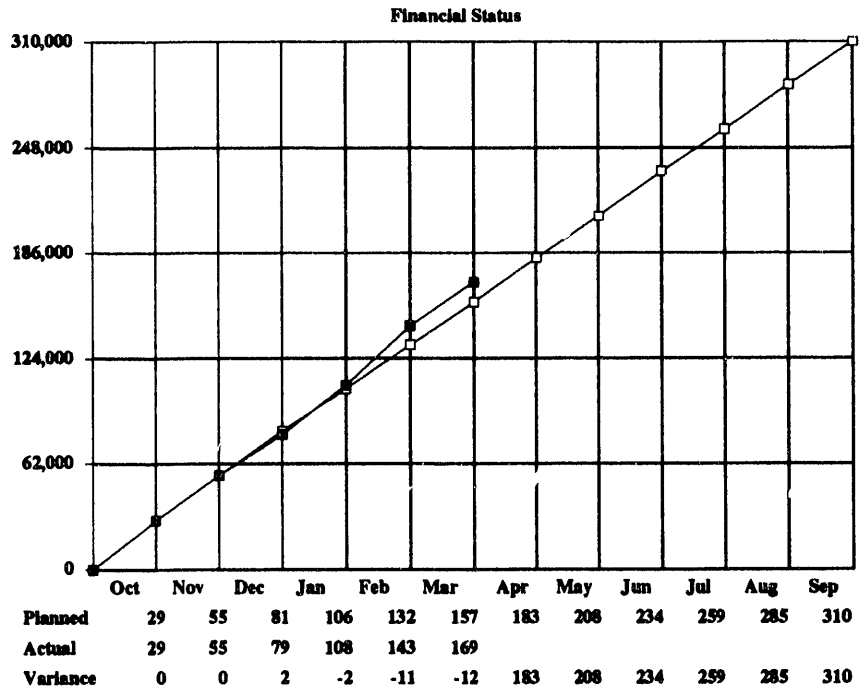
FINANCIAL STATUS OF THE PROJECT FOR MARCH

Total Appropriation: 340,000
 Less Capital Equipment: 30,000
 Appropriation Balance: 310,000
 Expenditures for the Month: 26,039
 Total Expenditures to Date: 169,494
 Net Available: 170,506

Capital Equipment Expenses and Commits: 4,745

Annual Plan Project BE9

Three-Phase Relative Permeability Research



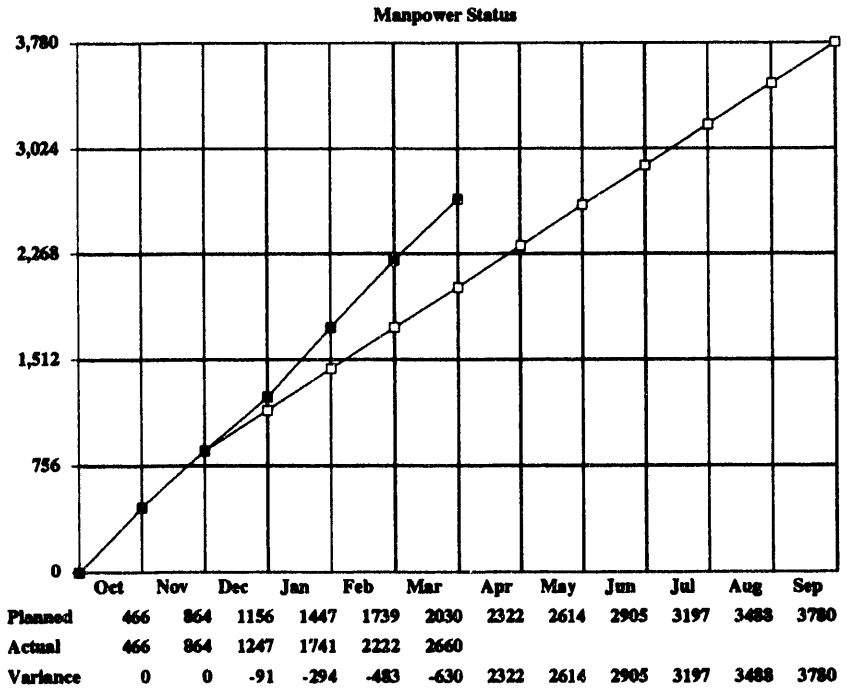
MANPOWER STATUS OF THE PROJECT FOR MARCH

Total Man-hours: 3,780
 Man-hours used this Month: 438
 Total Man-hours used to Date: 2,660
 Net Available: 1,120

Legend for Key Milestones

- X = Work Completed
- C = Planned Completion Date
- C' = Revised Completion Date
- C'' = Completed Ahead of Schedule

Key Milestone Status



- 1 Submit Status Report on Environmental, Safety, and Health Assessment
- 2 Complete Multiphase Relative Permeability Tests at 150 Degrees F on Almond Formation Rock
- 3 Select & Characterize Rock for FY93 Experimental Program
- 4 Complete Design of Test Fluid & Equipment for Use in Measuring IFT Under Selected Conditions of Temperature & Pressure
- 5 Conclude FY93 Multiphase Relative Permeability Experiments at Elevated Conditions of Temperature & Pressure
- 6 Complete Development of Coreflood Simulator
- 7 Prepare Chapter for NIPER Final Report Summarizing Project Accomplishments (Draft Complete by April 15)
- 8 Topical Report Describing Two- and Three-Phase Relative Permeability & Other Experimental Results

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BE9. THREE-PHASE RELATIVE PERMEABILITY RESEARCH

Accomplishments

The objectives of this project are (1) to improve the reliability of laboratory measurements of three-phase relative permeability for steady- and unsteady-state conditions in core samples; (2) to investigate the influence of rock, fluid, and rock-fluid properties on two- and three-phase relative permeabilities; and (3) to expand the state of the art for measuring relative permeabilities at higher temperatures and pressures.

Milestone 2—Two-phase steady-state oil/brine reservoir condition relative permeability measurements were recorded for Almond Formation plug 4953. The test was conducted with 1,000 psig confining pressure at a temperature of 120° F. Compared to ambient temperature results for plug 4959, the oil relative permeability curves were similar, while the brine relative permeabilities from the 120° F test were higher than those of the 74° F condition. This may indicate an increase in wetting-phase relative permeability with an increase in temperature. Additional tests are required to verify this observation as time and funds permit; however, the majority of work scheduled for this milestone has been completed.

Milestone 3—Thin-section, XRD, and SEM analyses; mercury injection porosimetry; and routine permeability and porosity tests were conducted on Fontanbleau sandstone samples. Routine permeabilities ranged from 80 to 130 mD while porosities were in the range of 9 to 11.3%. The XRD results indicate that the rock is 99% quartz, with 1% clay (illite). SEM and thin-section analyses indicate that the rock is comprised of medium-grained, very well sorted, well rounded, quartz-cemented, quartzarenitic sandstone. The mean grain diameter is about 0.60 mm. Quartz overgrowth cement is the dominant authigenic constituent within this sandstone, accounting for approximately 19% of the bulk volume. Porosities may be considered lower than normal compared to the permeability range. The pores are large and are well connected.

Milestone 4—The bubble point characteristics of bromopropane were measured this month and were found to be different from predicted values. A fluid system consisting of methane, propane, and bromopropane is in design. PVT characteristics of the fluid system will be tested next month.

Milestone 6—The computer to be used in coreflood simulations has arrived. A request was extended to another research laboratory equipped with a coreflood simulator to test some of the laboratory data from this project.

Milestone 7—A first draft of the final report was submitted for secretarial enhancement at the end of the month. Much of the manpower expended during this reporting period was concentrated toward completing the first draft.

Manpower and Financial Status

Manpower and financial expenditures have been high because of milestone 7 efforts.

Status of Project Milestones

Milestone 2 is finished. Milestone 3 is on schedule. Milestone 4 is behind schedule and has proved to be more difficult than anticipated. The first draft of the final report (milestone 7) has been prepared.

BE11A

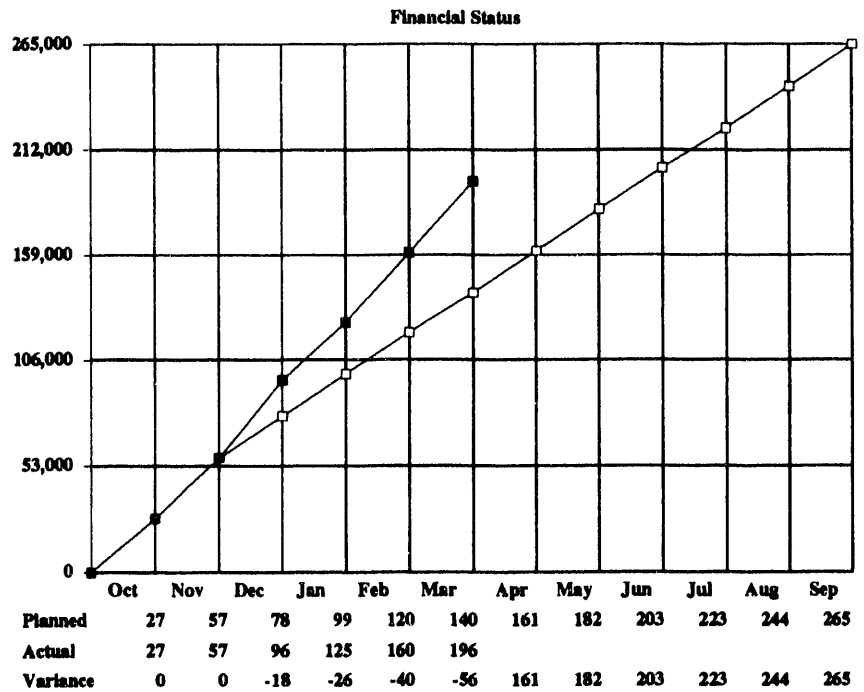
FINANCIAL STATUS OF THE PROJECT FOR MARCH

Total Appropriation:		300,000
Less Capital Equipment:	35,000	
Appropriation Balance:	265,000	
Expenditures for the Month:		35,610
Total Expenditures to Date:		195,509
Net Available:		104,491

Capital Equipment Expenses and Commits: 0

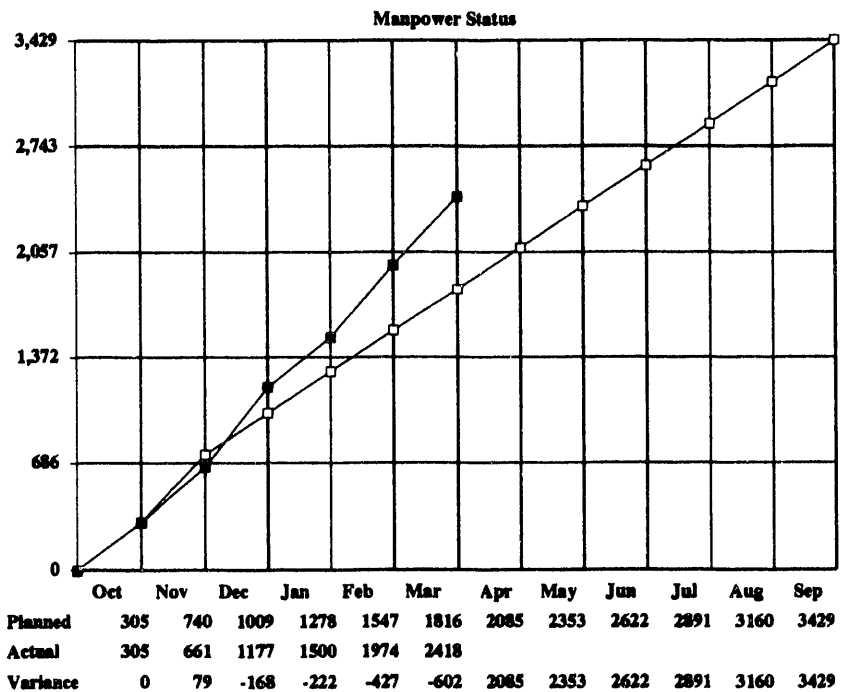
Annual Plan Project BE11A

Thermal Processes for Light Oil Recovery



MANPOWER STATUS OF THE PROJECT FOR MARCH

Total Man-hours:		3,429
Man-hours used this Month:	444	
Total Man-hours used to Date:		2,418
Net Available:		1,011



Legend for Key Milestones

- X = Work Completed
- C = Planned Completion Date
- C' = Revised Completion Date
- C'' = Completed Ahead of Schedule

Key Milestone Status

- 1 Submit Status Report on Project Environmental, Safety, and Health Assessment
- 2 Topical Report on Assessment of NIPER Thermal EOR Research Program Over Past Ten-Year Period
- 3 Complete Supporting Research on Improved Steamflooding at NPR No. 3, Teapot Dome (WY) Field
- 4 Develop Procedures & Apparatus for Measuring Dynamic Saturation Changes in Steamflooding Using X-ray & CT-scanning
- 5 Prepare Chapter for NIPER Final Report Summarizing Accomplishments of NIPER's Thermal EOR Program (Draft by April 15)
- 6 Complete Transfer of Thermal Technology Developmental Research Through ANNEX IV of the DOE/Venezuelan Cooperative Agreement
- 7 Topical Report Describing Research on Thermal Processes for Light Oil Recovery

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BE11A. THERMAL PROCESSES FOR LIGHT OIL RECOVERY

Accomplishments

The FY93 objectives of this project are (1) to perform an environmental, safety, and health (ES&H) analysis on project tasks; (2) to assess the thermal research performed at NIPER; (3) to develop procedure and apparatus for measuring dynamic saturation changes in steamfloods at field conditions using X-ray and CT scanning and incorporate temperature and pressure measurements to calibrate a numerical simulator for predictive purposes; (4) to conduct laboratory research in support of NPR No. 3, Teapot Dome (WY) field light oil steamflood; and (5) to participate in the Annex IV meetings conducted by the DOE and the Venezuelan Ministry of Energy and Mines.

Milestone 2—A draft report on the review of the previous 10 years of research conducted by the thermal group has been reviewed and is to be published as NIPER-675.

Milestone 4—A poster and subsequent paper on NIPER's research on the screening of surfactants as foams for steam diversion was included in the Proceedings (NIPER-669) of the DOE/NIPER Symposium on the Field Application of Foams for Oil Production. The symposium was held in Bakersfield, CA, February 11-12, 1993, as part of project SGP63. The topical report on the data/control/presentation software for the steamflood laboratory is in preparation.

Milestone 5—A draft of the results of the previous 10 years research at NIPER by the thermal group is being prepared as a chapter for inclusion into NIPER final report.

Milestone 6—A report on the results of research on task 58—light oil steamflooding research at NIPER—was presented at the Annex IV meeting held in Caracas, Venezuela, Mar. 2-5. The next meeting, scheduled for October 1993, will be held at Stanford University. This completes milestone 6 ahead of schedule.

Milestone 7—An outline of the topical report describing research on light oil recovery has been prepared.

Manpower and Financial Status

Manpower and financial expenditures are above original projections due to the effort required in preparing the review of the previous 10 years of research conducted by the thermal EOR group (milestone 2) and in preparing the March Annex IV presentation (milestone 6).

Status of Project Milestones

The topical report for milestone 2 has been submitted for review. Milestone 6 has been completed ahead of schedule. All other milestones are on schedule. Problems with location of the steamflood laboratory have not been resolved.

BE11B

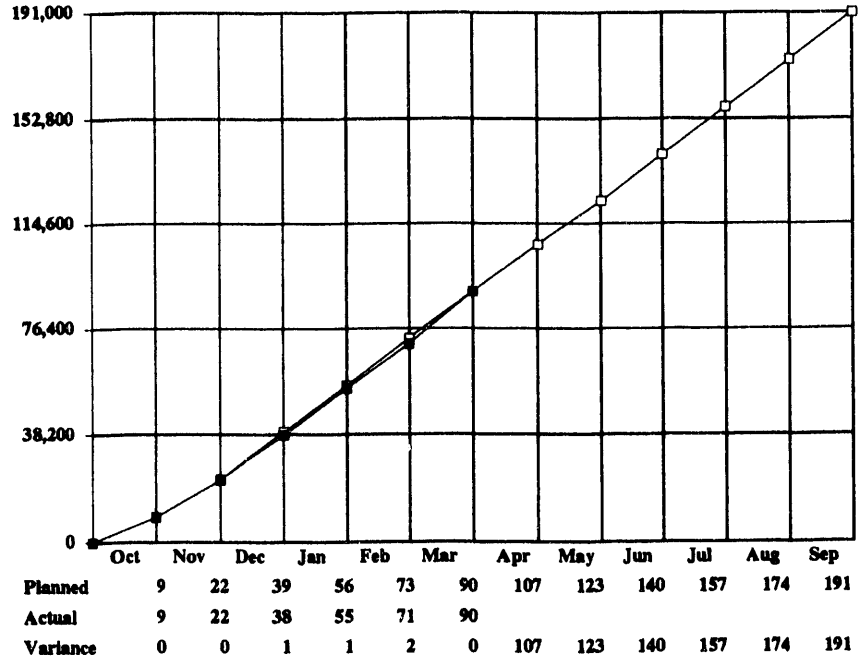
FINANCIAL STATUS OF THE PROJECT FOR MARCH

Total Appropriation:		200,000
Less Capital Equipment:	9,000	
Appropriation Balance:	191,000	
Expenditures for the Month:	18,513	
Total Expenditures to Date:	89,961	
Net Available:	110,039	
Capital Equipment Expenses and Commits:	0	

Annual Plan Project BE11B

Thermal Processes for Heavy Oil Recovery

Financial Status



MANPOWER STATUS OF THE PROJECT FOR MARCH

Total Man-hours:		3,080
Man-hours used this Month:	262	
Total Man-hours used to Date:	1,342	
Net Available:	1,738	

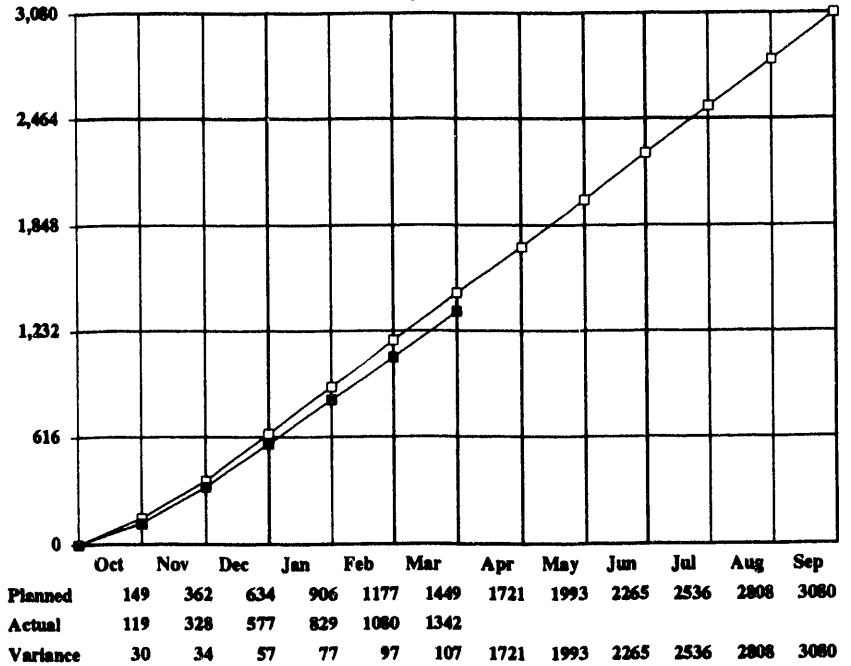
Legend for Key Milestones

- X = Work Completed
- C = Planned Completion Date
- C' = Revised Completion Date
- C'' = Completed Ahead of Schedule

Key Milestone Status

- 1 Submit Status Report on Project Environmental, Safety, and Health Review
- 2 Complete Screening & Identification of Potential Heavy Oil Reservoirs in Texas Gulf Coast Region; Obtain Rock, Fluid, & Reservoir Data on Most Promising Reservoir
- 3 Topical Report on Assessment of NIPER Thermal EOR Research Program Over Past Ten-Year Period
- 4 Complete Evaluation of Mobdl's Steamflood Predictive Model
- 5 Complete Modeling Studies to Determine Applicability of Thermal EOR for Recovery of Heavy Oil in Texas Gulf Coast Reservoirs
- 6 Prepare Chapter for NIPER Final Report (Draft by April 15)
- 7 Status Report on Results of Predictive Model & Simulation Studies

Manpower Status



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BE11B. THERMAL PROCESSES FOR HEAVY OIL RECOVERY

Accomplishments

The project objectives are (1) to analyze the NIPER heavy oil data base and screen Texas Gulf Coast reservoirs for priority ranking and (2) to conduct modeling and reservoir studies to determine the applicability of thermal enhanced oil recovery technique in Texas Gulf Coast heavy oil reservoirs.

Milestone 3—The topical report for the 10-year assessment of thermal EOR research was submitted to BPO and NIPER management for review on March 22, 1993. The report is expected to be finalized next month.

Milestone 4—Mobil's steamflood prediction model software was received on March 23, 1993. Evaluation of the software for its predictive ability will begin next month.

Milestone 5—Most of the wells in the Hutzler "C" lease were hydraulically fractured and sand propped. A preliminary evaluation of the fracture job in a well (Hutzler "C-3") indicated that orientation of the fracture was vertical. The fracture was 0.2 in. wide and 312 ft long. The PI (productivity index) was 6.3. The permeability of the fracture was 2,000 darcies and the porosity was assumed to be the same as that of the matrix (0.32).

Results of the cyclic steam simulation studies indicated that the cyclic steam process would not be effective in this reservoir due to thin pay, hence, numerical simulation of steamflooding (steamdrive) was initiated. A quarter of a 5-spot pattern of 2-acre area was considered for simulating steamflood. The dual porosity model was used to represent the hydraulic fracture. For the injection well, the maximum injection pressure was limited to 1,000 psi and the steam quality was assumed to be 70%. The maximum steam injection rate was limited to 400 bbl/d. In a run, using a 8 x 8 x 3 grid and 15 ft as the width of the block containing fracture, the oil recovery and cumulative oil steam ratio (COSR) were found to be 51% and 0.15, respectively, at the end of 1,058 days of steamflood. Additional runs are underway.

Milestone 6—A chapter on thermal EOR research activities for inclusion in NIPER's 10-year report is nearing completion.

Manpower and Financial Status

Manpower and financial expenditures are on schedule.

Status of Project Milestones

The topical report for milestone 3 is in review. The other project milestones are on schedule.

BE12

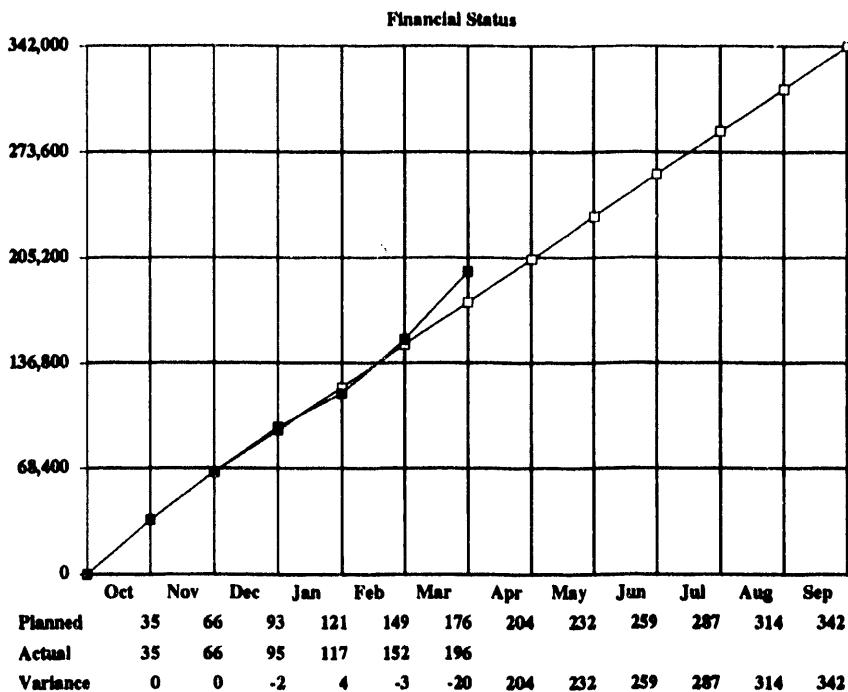
FINANCIAL STATUS OF THE PROJECT FOR MARCH

Total Appropriation:	350,000
Less Capital Equipment:	8,000
Appropriation Balance:	342,000
Expenditures for the Month:	43,169
Total Expenditures to Date:	195,587
Net Available:	154,413

Capital Equipment Expenses and Commits: 0

Annual Plan Project BE12

Imaging Techniques Applied to the Study of Fluids in Porous Media



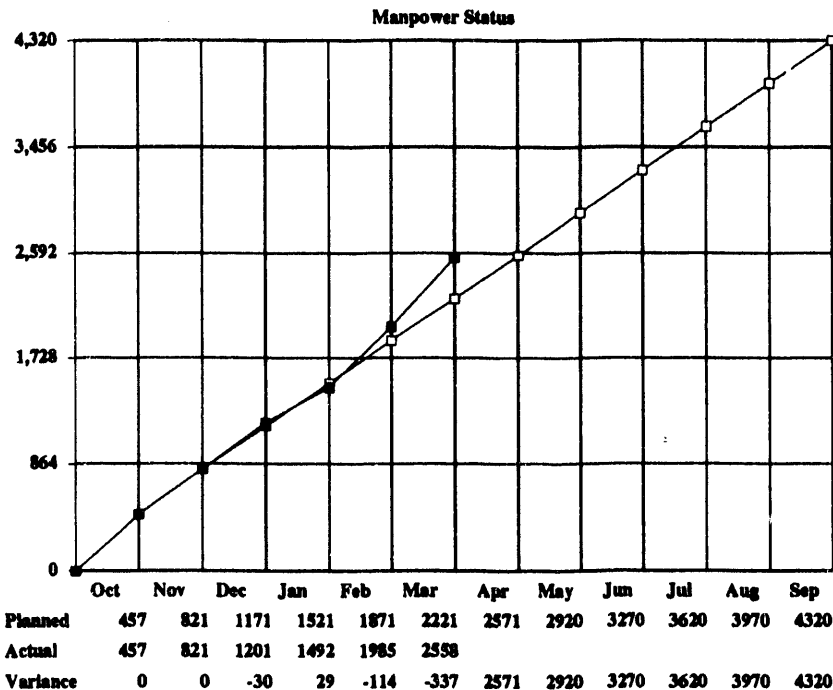
MANPOWER STATUS OF THE PROJECT FOR MARCH

Total Man-hours:	4,320
Man-hours used this Month:	573
Total Man-hours used to Date:	2,558
Net Available:	1,762

Legend for Key Milestones

- X = Work Completed
- C = Planned Completion Date
- C' = Revised Completion Date
- C'' = Completed Ahead of Schedule

Key Milestone Status



- 1 Submit Status Report on Environmental, Safety, and Health Review
- 2 Topical Report Describing Scale-up of Reservoir Rock Types in Class 1 Reservoirs
- 3 Complete Investigation on Use of Single- & Multi-energy Scans for Rapid Characterization of Core Samples
- 4 Derive Scale-up Procedures for Determining Permeability & Relative Permeability Values in Large, Heterogeneous Core Samples
- 5 Complete Investigation on the Applicability of NMR Spectroscopy & Microscopy for Studying Rock-Fluid Interactions Affecting Wettability
- 6 Prepare Chapter for NIPER Final Report (Draft by April 15)
- 7 Complete Development of Technology Transfer Activity
- 8 Status Report Describing the Application of NMR Spectroscopy to the Study of Wettability

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BE12. IMAGING TECHNIQUES APPLIED TO THE STUDY OF FLUIDS IN POROUS MEDIA

Accomplishments

The objectives of this project are: (1) to develop and correlate reservoir engineering parameters from petrographic image analysis, computed tomography (CT) scanning, and nuclear magnetic resonance imaging (NMRI); (2) to investigate the applicability of imaging technologies in the development of scale-up procedures from core plug to whole core to interwell scale; (3) to develop an industry consortium or industrial advisory panel to help plan, review, and participate in the research through the Work-For-Others program and to provide for effective technology transfer and (4) to strongly encourage collaborative research by industrial participants.

Milestone 2—A topical report, entitled "Imaging Techniques Applied to the Study of Fluids in Porous Media: Scaling Up in Class 1 Reservoir Type Rock," has been completed and submitted to BPO as NIPER-663.

Milestone 3—In investigating the use of single and multi-energy scans for rapid characterization of cores, topograms and CT reconstructed images were compared for 5-in. diameter core of strongly consolidated sandstone containing millimeter-scale layers. Although the topograms showed the general sedimentary features, the quality generated by the images reconstructed from 2-mm sections taken at 141 kV was clearly superior. To use the topogram mode for large core diameters or high-attenuation rock, higher X-ray energies as found in industrial X-ray equipment are needed. When a medical CT scanner is available, which has the maximum energy in the 140-150 kV range, the CT reconstructed images can provide the needed detailed core information but at larger time investment and equipment utilization than when the topogram mode is used.

Milestone 4—The imbibition cycle for relative permeability measurements in a heterogeneous Tallant sample has been completed for fractional water flow rates of 0.0, 0.05, 0.1, 0.2, 0.4, 0.7, 0.9, 1.0 for the 26 cP oil viscosity. Preliminary analysis indicates the presence of correlations between the porosity of various rock laminations and the saturation distributions at the various fractional flow conditions. The drainage process will be performed in April.

Milestone 5—Improved NMR images of the pores in Fontainebleau sandstone were generated using the surface rendering capability of the latest upgrade of Spyglass Dicer. Mercury injection data and computer-assisted petrographic image analysis of thin-sections data were obtained and used in combination with NMRI data to study the correlations between pores and pore throats in Fontainebleau, Tallant, and Bentheimer sandstones. Qualitative preliminary agreement was observed between the thin section and the NMRI observations.

Milestone 6—The first draft for the rock fluid imaging research chapter (containing results and accomplishments of project BE12 and earlier projects BE12A, BE12B) has been prepared for the NIPER final report.

Milestone 7—A paper, entitled "Pore Scale Fluid Imaging in Reservoir Rock by NMR Microscopy," by Daryl A. Doughty, Liviu Tomutsa, and Michael P. Madden has been prepared and presented at the ACS National Spring Meeting Symposium on Applications of Magnetic Resonance Imaging in Enhanced Oil Recovery, Denver, CO, March 28-April 2, 1993. Contacts have continued with two major oil companies regarding research cooperation and formation of an imaging consortium.

Manpower and Financial Status

Manpower and financial expenditures are on schedule.

Status of Project Milestones

The milestone 2 topical report has been submitted to BPO as NIPER-663. Milestone 3 is running behind schedule. The other milestones are on schedule.

BFR2

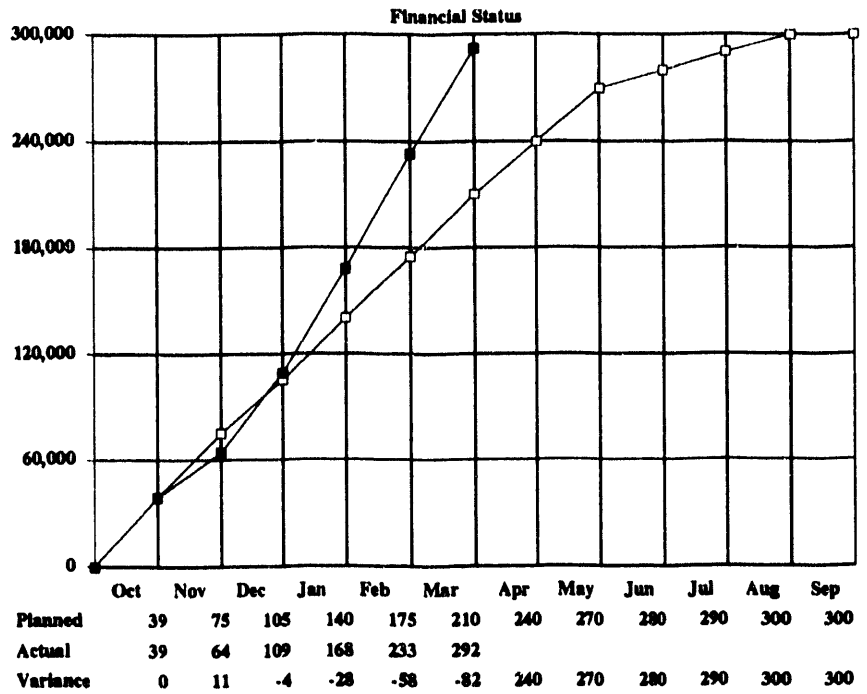
FINANCIAL STATUS OF THE PROJECT FOR MARCH

Total Appropriation: 300,000
 Less Capital Equipment: 0
 Appropriation Balance: 300,000
 Expenditures for the Month: 59,256
 Total Expenditures to Date: 291,927
 Net Available: 8,073

Capital Equipment Expenses and Commits: 0

Annual Plan Project BFR2

Development of Analytical Methodology
 for Analysis of Heavy Crudes



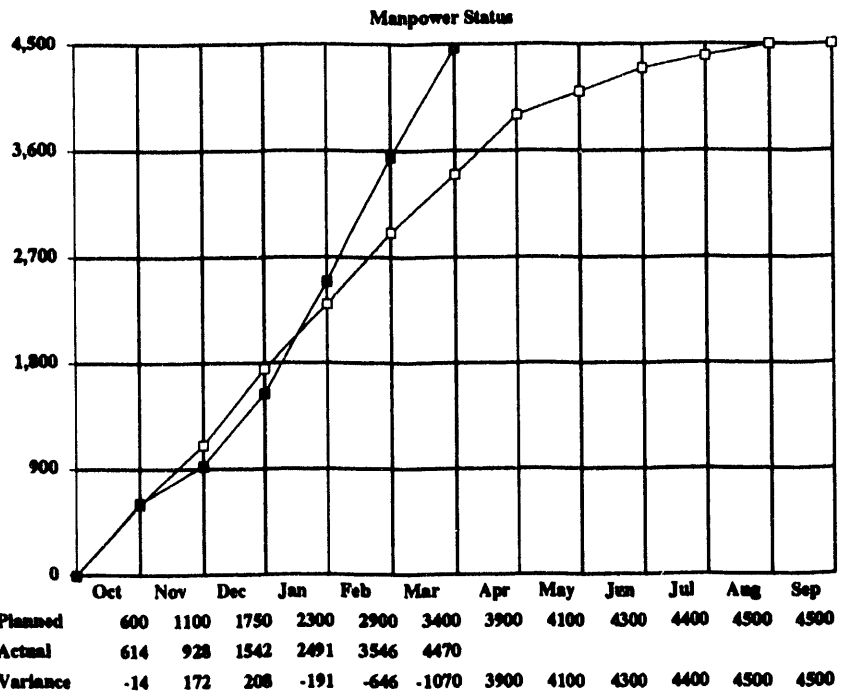
MANPOWER STATUS OF THE PROJECT FOR MARCH

Total Man-hours: 4,500
 Man-hours used this Month: 924
 Total Man-hours used to Date: 4,470
 Net Available: 30

Legend for Key Milestones

- X = Work Completed
- C = Planned Completion Date
- C' = Revised Completion Date
- C'' = Completed Ahead of Schedule

Key Milestone Status



- 1 Submit Status Report on Project Environmental, Safety, and Health Assessment
- 2 Prepare Chapter for NIPER Final Report Summarizing Accomplishments of Project BFR2 (Draft complete by July 30)
- 3 Complete FY93 Research on Catalytic Cracking of 650 Degree F Resids and Fractions; Submit Topical Report on the Research Results

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FUELS RESEARCH

BFR2. DEVELOPMENT OF ANALYTICAL METHODOLOGY FOR ANALYSIS OF HEAVY CRUDES

Accomplishments

Cat-cracking of Lagomedio >650° F resid, and chromatographic fractions thereof, was completed. Solid and liquid products from those runs are currently being analyzed. Analysis of Brass River products was completed; those data are being entered into the computer for calculation of material balances for those runs.

Several cross-blending, cat-cracking experiments were carried out this month. A given acid or base fraction was blended with neutral fractions from several resids to determine if any interaction would occur between acidic or basic components and neutrals. Also, a Wilmington base fraction was diluted with a gas oil at levels from 3 to 50 wt % to determine the concentration dependence for base inhibition of gas oil cracking.

Work on the 10-year summary report (milestone 2) was initiated.

Manpower and Financial Status

Experimental work has essentially ceased due to the exhaustion of available funds. One more series of experiments with Meroy >650° F resid and its fractions remains to be completed.

Status of Project Milestones

Milestone 2 is on schedule; milestone 3 is ahead of schedule.

BFR3

FINANCIAL STATUS OF THE PROJECT FOR MARCH

Total Appropriation:	350,000
Less Capital Equipment & Sub:	0
Appropriation Balance:	350,000
Expenditures for the Month:	21,385
Total Expenditures to Date:	183,626
Net Available:	166,374

Capital Equipment/Subcontract Exp & Comm 0

Annual Plan Project BFR3

Thermochemistry & Thermophysical Properties of Organic Nitrogen- and Dihalogen-Containing Compounds

MANPOWER STATUS OF THE PROJECT FOR MARCH

Total Man-hours:	4,022
Man-hours used this Month:	175
Total Man-hours used to Date:	2,227
Net Available:	1,795

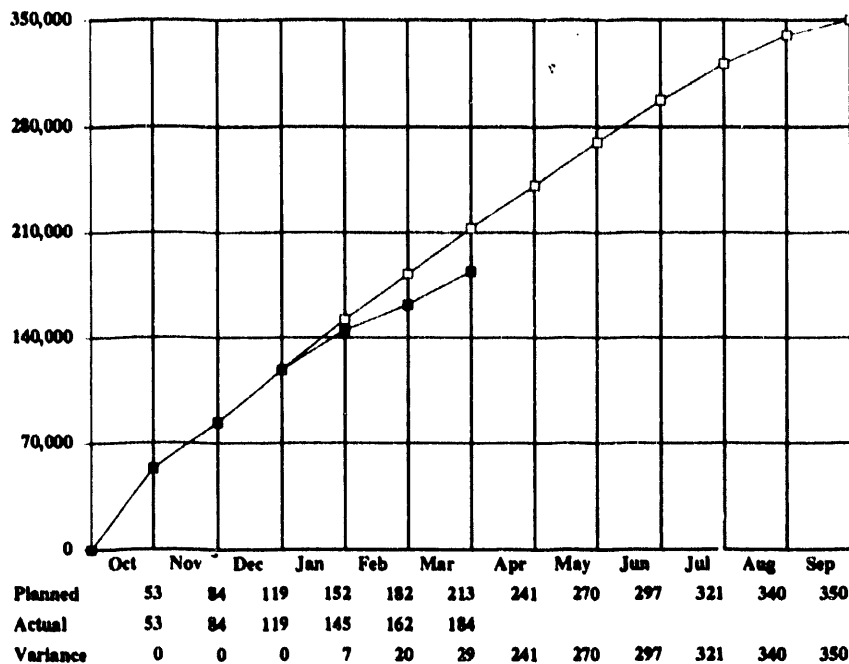
Legend for Key Milestones

- X = Work Completed
- C = Planned Completion Date
- C' = Revised Completion Date
- C'' = Completed Ahead of Schedule

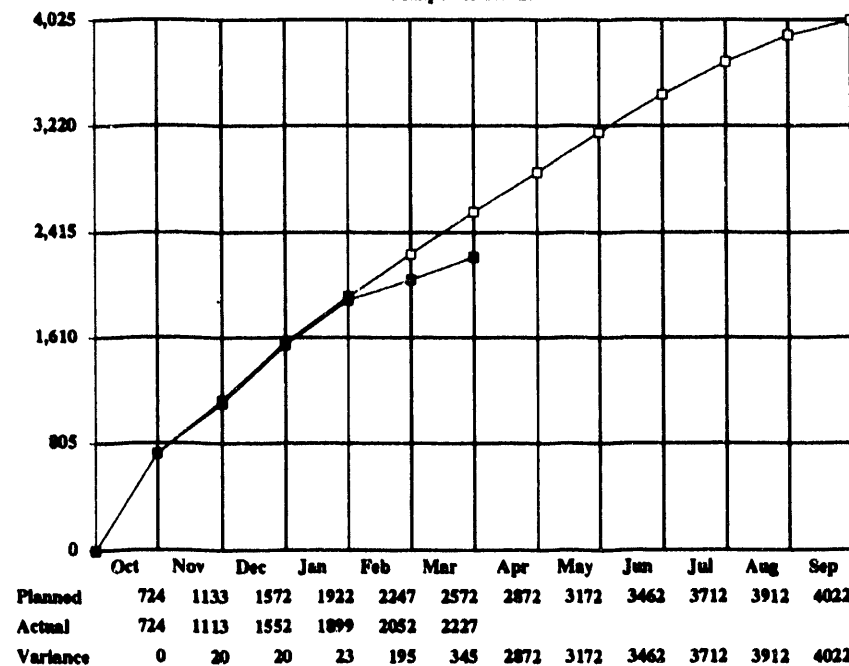
Key Milestone Status

- 1 Submit ES&H Report for DOE Review and Action
- 2 Conduct Review Meeting with DOE Headquarters
- 3 Complete Three Journal Articles on the Thermodynamic Properties of Nitrogen-Containing Compounds Measured in this Research
- 4 Prepare Chapter for NIPER Final Report Summarizing Accomplishments of Project BFR3 and State of the Art of Fossil Energy Thermodynamics Research
- 5 Topical Report and Computer Software for EPCoP

Financial Status



Manpower Status



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BFR3. THERMOCHEMISTRY AND THERMOPHYSICAL PROPERTIES OF ORGANIC NITROGEN- AND DIHETEROATOM-CONTAINING COMPOUNDS

Accomplishments

Preparation of a journal article on the thermodynamic properties of the compounds 2-methylaniline and trans-decahydroquinoline continued. Data analysis is now complete. Updating of all of the relevant tables continues. The article will be submitted to the *Journal of Chemical Thermodynamics* in the coming month.

Heat capacity and enthalpy measurements by adiabatic calorimetry were completed for 2-methylquinoline. Measurements extended over the temperature range 4 to 450 K.

Last month adiabatic calorimetry on 5-methylbenzimidazole was halted due to an impurity in the sample that hindered rapid measurement. The problem was assessed, and it was decided that the compound required further purification. If measurements were continued with the present sample they would require a time extension of 6 to 9 months.

Heat capacity and enthalpy studies on 8-methylquinoline were halted for cryostat repairs. After operating for approximately 50 years, the insulation on one of the calorimeter shields finally deteriorated beyond repair. Rewiring of that shield is in progress, and it is probable that measurements on 8-methylquinoline will recommence by the end of April.

Enthalpy of combustion studies on 2-methyl and 8-methylquinolines continued. These compounds are included in a series of measurements scheduled for completion in this quarter.

Ebulliometric vapor pressure measurements in the temperature range 394 K to 569 K (2 kPa to 270 kPa) were completed for 2-methylquinoline.

High-temperature heat capacity and critical property determinations by differential scanning calorimetry (DSC) were completed for 2-methyl- and 8-methylquinoline. Critical temperature and critical density values were determined for both compounds. (The critical properties are key engineering-design parameters.)

Writing of the chapter for the NIPER final report on the accomplishments in this research continued and will be completed by mid-April (milestone 4).

A status report for research completed in FY92 will be completed this month.

Manpower and Financial Status

Manpower and financial expenditures are below original estimates. Development of the computer software scheduled for milestone 5 has been delayed pending direction on the exact design, and which was to be determined at the milestone 2 review meeting.

Status of Project Milestones

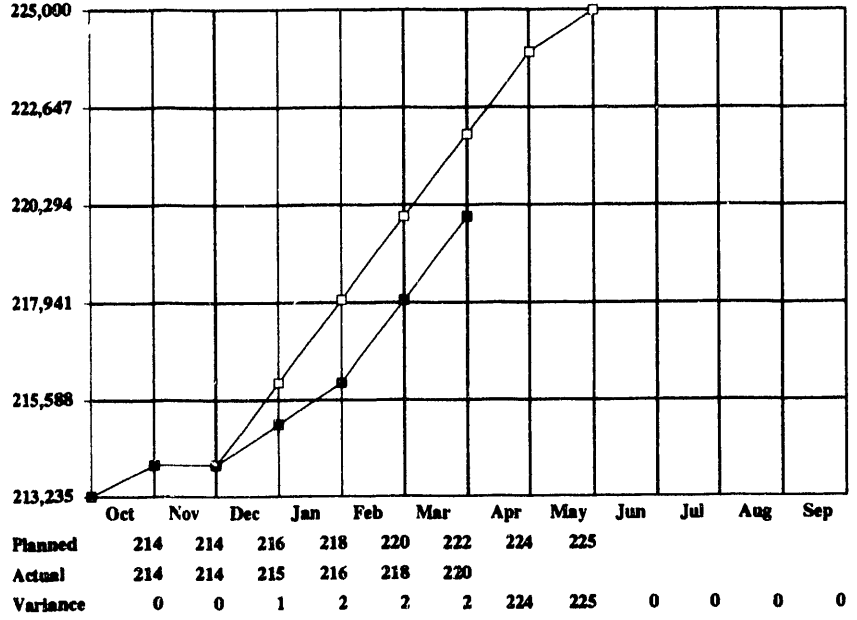
The status report to complete the FY92 milestones is in preparation. FY93 project milestones are on schedule.

SGP13

FINANCIAL STATUS OF THE PROJECT FOR MARCH

Financial Status

Total Appropriation:	419,000
Less Subcontracts:	194,050
Appropriation Balance:	224,950
Expenditures for the Month:	1,619
Total Expenditures to Date:	413,881
Net Available:	5,119
Subcontract Expenses:	194,050



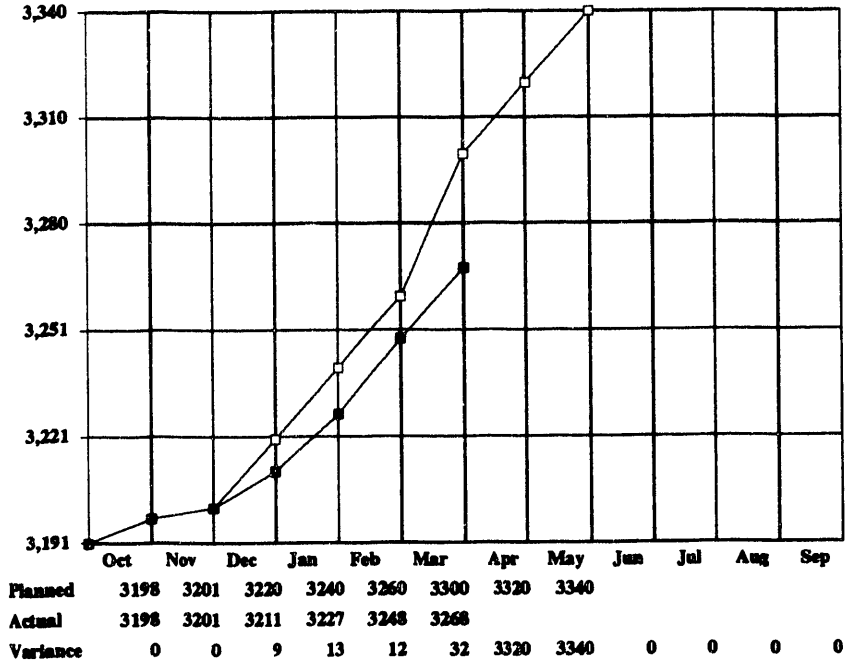
Annual Plan Project SGP13

Microbial-Enhanced Waterflooding Field Project

MANPOWER STATUS OF THE PROJECT FOR MARCH

Total Man-hours:	3,340
Man-hours used this Month:	20
Total Man-hours used to Date:	3,268
Net Available:	72

Manpower Status



Legend for Key Milestones

- X = Work Completed
- C = Planned Completion Date
- C' = Revised Completion Date
- C'' = Completed Ahead of Schedule

Key Milestone Status

1 Complete Oil Recovery Monitoring Phase; Submit Topical Report Describing Performance of MEOR Field Project

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SUPPLEMENTAL GOVERNMENT PROGRAM

SGP13. MICROBIAL-ENHANCED WATERFLOODING FIELD PROJECT

Accomplishments

The objectives of this project are to determine the feasibility of improving oil recovery in an ongoing waterflood using microorganisms; to expand the initial pilot and determine the economics of microbial enhanced waterflooding.

The site for the expanded MEOR pilot is located in Section 8, Township 24 North, Range 17 E, of Rogers County. This site is part of the Chelsea-Alluwe field in the Bartlesville formation and was initially developed shortly after Delaware-Childers field. The site is currently under waterflood and is owned by Phoenix Oil and Gas Ltd. This field is in a very isolated area, with virtually no other oil-producing leases nearby. Although this field has much in common with the Mink Unit, there are some significant differences. The Phoenix field is not a freshwater flood; the water is recycled and injected and has an average total dissolved solids value of 3%. The permeability of the formation is about 20 mD.

Milestone 1— Oil production data through December 1992, indicated an improvement in oil production of 16% over waterflooding alone. No new oil production data has been received.

A paper detailing the results of this field test was presented March 11, 1993, at the Tenth Oil Recovery Conference sponsored by TORP in Wichita, KS.

Manpower and Financial Status

Manpower and financial expenditures are on schedule.

Status of Project Milestones

Milestone 1 is on schedule.

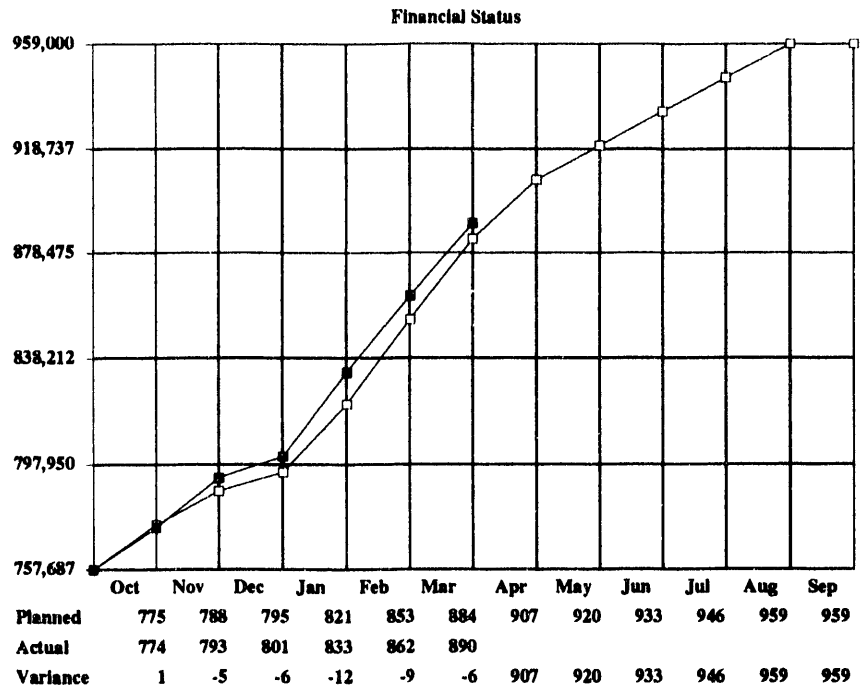
SGP37

FINANCIAL STATUS OF THE PROJECT FOR MARCH

Total Appropriation:	1,099,440
Less Subcontracts:	131,463
Appropriation Balance:	967,977
Expenditures for the Month:	28,216
Total Expenditures to Date:	1,013,968
Net Available:	85,472
Subcontract Expenses:	131,463

Annual Plan Project SGP37

Feasibility Study of Heavy Oil Recovery
in the Midcontinent Region: Oklahoma, Kansas, & Missouri

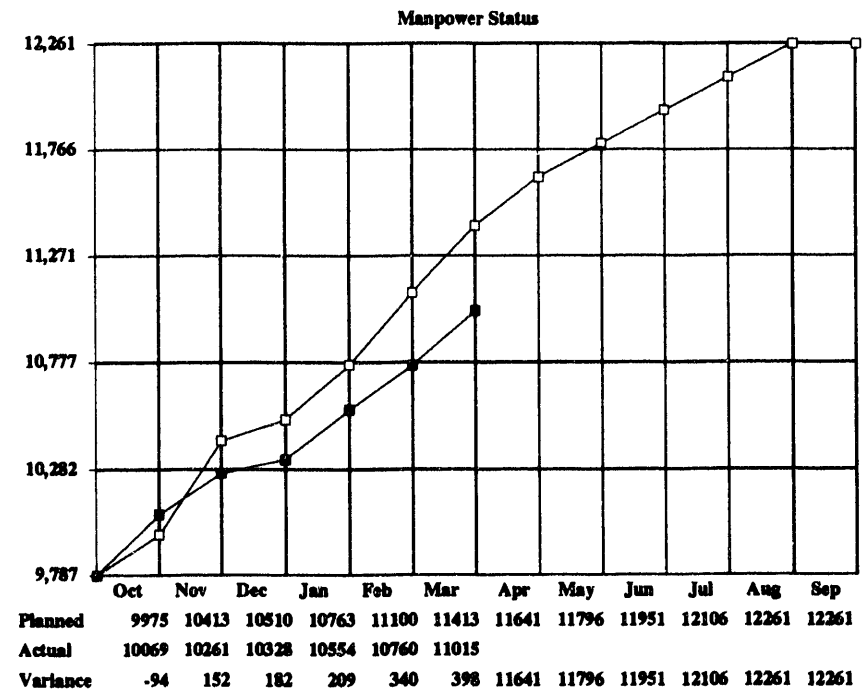


MANPOWER STATUS OF THE PROJECT FOR MARCH

Total Man-hours:	12,655
Man-hours used this Month:	255
Total Man-hours used to Date:	11,015
Net Available:	1,640

- Legend for Key Milestones**
- X = Work Completed
 - C = Planned Completion Date
 - C' = Revised Completion Date
 - C'' = Completed Ahead of Schedule

Key Milestone Status



- 1 Status Report Describing Results of Computer Modeling Study on Potential for Heavy Oil Recovery
- 2 Complete Detailed Review of Heavy Oil Potential For Gulf Coast Region
- 3 Status Report Discussing Results of U. S. Heavy Oil Reservoir Data Study

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SGP37. FEASIBILITY STUDY OF HEAVY OIL RECOVERY IN THE MIDCONTINENT REGION: OKLAHOMA, KANSAS, AND MISSOURI

Accomplishments

The objectives of this research project are (1) to determine the known heavy oil resources of the United States, (2) to evaluate the various economic constraints that may impact development of this resource, and (3) to determine if steam or other EOR processes are applicable to economic production of this resource.

Milestone 1—An approved version of the heavy oil data base was sent through the TORIS recovery and economic model to analyze each reservoir for its recovery potential using steam, in situ combustion, and alkaline/surfactant/polymer (ASP) flooding processes. These reservoir data were approved by the DOE Technical Project Officer in February for this computer study but are still considered preliminary. The data will be refined and additional data will be collected as part of another milestone before this project is completed.

Reservoir information on 505 reservoirs, representing 68.6 billion barrels of original oil in place, was put into the type of format necessary for the modeling runs, and additional information was added. Early computer runs indicated numerous reservoirs with input data that estimated unreasonable EOR potential. For example, information on gross pay—as it relates to net pay—is used by the model to estimate steam efficiency, but this relationship was not emphasized in the compilation of the reservoir information. Another problem was found in the computer model itself in estimating potential for in situ combustion. A subroutine in the model was setting oil saturation to the value of the residual oil saturation when a current water saturation was not entered—even if the current oil saturation was input. After corrections were made to the input data and model, final runs were made for steam, in situ combustion, and alkaline flooding recovery processes.

The results showed an 11.5 billion barrel potential for implemented steam technology, a 15.8 billion barrel potential for advanced steam technology, a 1.3 billion barrel potential for implemented in situ combustion, and a 1.0 billion barrel potential for advanced alkaline flooding technology at \$20/barrel (e.g., reference price for 40° API—price for modeling is adjusted for °API and location) and at 10% rate of return without considering mutually excluding results. The results were consistent with the 1984 EOR study by the National Petroleum Council (NPC), since roughly 50% more oil and improvements in recovery technology are included in the current estimate. The NPC study estimated 4.4 billion barrels for implemented thermal recovery technologies at the same economics and the 10.5 billion barrel estimate for advanced thermal technology at \$30/barrel. The NPC study did not estimate alkaline-surfactant-polymer (ASP) potential for heavy oil but estimated 9.9 billion barrels for surfactant and 0.07 billion barrels for alkaline at \$30/barrel. The NPC study did not estimate ASP potential for heavy oil but estimated 9.9 billion barrels for surfactant and 0.07 billion barrels for alkaline at \$30/barrel. Last year, the criteria for implemented technology was broadened to include reservoir characteristics of technically and economically successful steam projects. Therefore, some of the reservoirs classified as the advanced technology target by the NPC are now classified as targets for implemented steam technology.

This task was completed in March and the results were delivered to the BPO Technical Project Officer by memorandum. The scheduled status report will be delayed beyond the scheduled April completion. A request to extend this completion date is being prepared.

Milestone 2—The report on the feasibility of heavy oil recovery from the U.S. Gulf Coast is being prepared. An additional analysis of select Texas heavy oil reservoirs is underway.

Manpower and Financial Status

Manpower and financial expenditures are on schedule.

Status of Project Milestones

Two earlier project reports have gone through a second DOE/NIPER review. Report NIPER-606, "Estimates of Future Heavy Oil Production at Three Production Rates—Background Information for Assessing Effects on the U.S. Refining Industry," is being reviewed by DOE Headquarters. NIPER-560, "Feasibility Study of Heavy Oil Recovery in the Midcontinent Region," is scheduled for delivery in April. A request to extend the completion date of milestone 1 beyond April is being prepared for submittal to the BPO.

SGP41

FINANCIAL STATUS OF THE PROJECT FOR MARCH

Total Appropriation:		618,000
Less Subcontracts:	111,000	
Appropriation Balance:	507,000	
Expenditures for the Month:	12,209	
Total Expenditures to Date:	296,670	
Net Available:	321,330	
Subcontract Expenses:	17,900	

Annual Plan Project SGP41

**Surfactant-Enhanced Alkaline Flooding
Field Project**

MANPOWER STATUS OF THE PROJECT FOR MARCH

Total Man-hours:		6,000
Man-hours used this Month:	104	
Total Man-hours used to Date:	3,720	
Net Available:	2,280	

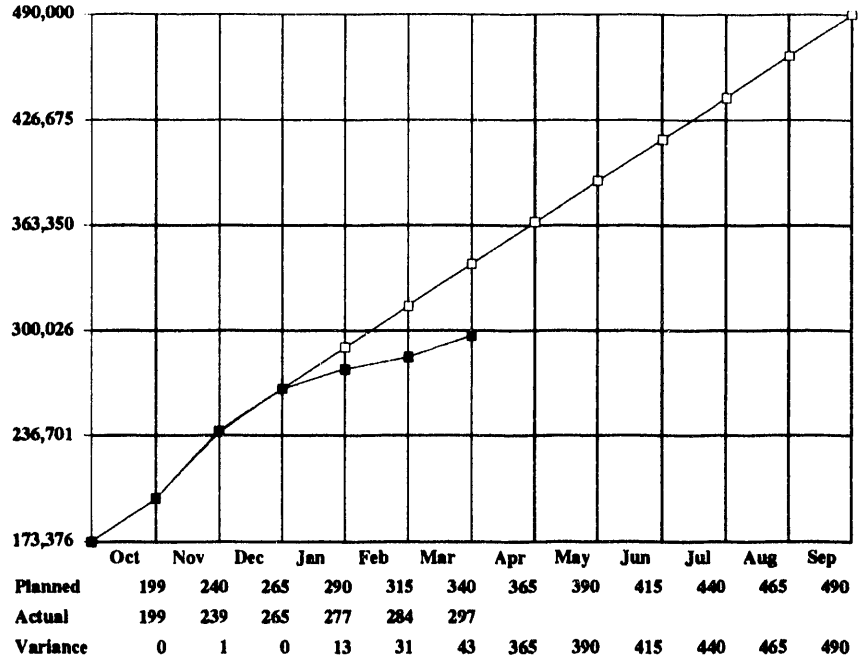
Legend for Key Milestones

- X = Work Completed
- C = Planned Completion Date
- C' = Revised Completion Date
- C'' = Completed Ahead of Schedule

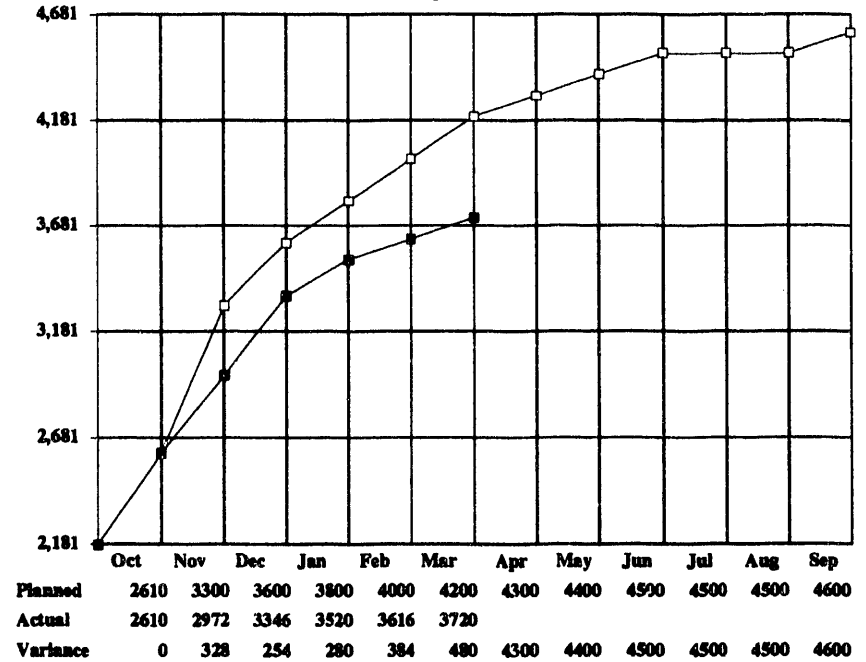
Key Milestone Status

- 1 Complete Environmental Assessment
- 2 Finalize Geological Evaluation of Field Core
- 3 Test Chemical System in Field Core; Finalize Design of Chemical System Based on Results Obtained with Field Core
- 4 Prepare Presentation on Comparison of Methods for Evaluating Core from a Midcontinent Fluvial-Dominated Deltaic Sandstone Reservoir
- 5 Inject Chemicals
- 6 Complete Oil Recovery Monitoring Phase; Submit Final Report (FY95 Completion Date)

Financial Status



Manpower Status



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SGP41. SURFACTANT-ENHANCED ALKALINE FLOODING FIELD PROJECT

Accomplishments

The objectives of this pilot project are (1) to obtain information and data that will help to demonstrate the applicability of surfactant-enhanced alkaline flooding as a cost-effective EOR method, (2) to transfer the surfactant-enhanced alkaline flooding technology that has been developed under the sponsorship of the DOE to the petroleum industry, and (3) to obtain information regarding procedures for designing and applying this technology that will assist independent producers in sustaining production from mature producing oil fields rather than abandoning marginal wells.

The site selected for the surfactant-enhanced alkaline flooding pilot test is Hepler (KS) oil field, which is located in Crawford and Bourbon Counties. This near-term application of a promising EOR technology in a fluvial-dominated deltaic type reservoir is consistent with the strategy outlined in DOE's oil research program implementation plan.

Milestone 2—Plans for field implementation of the project were discussed at a meeting in Wichita on March 10. Routine core analyses and wireline log data indicate that the Tucker Sand is heterogeneous. Special core analyses showed that the heterogeneities extend to microscale. Microscale heterogeneities adequately explain the less than ideal laboratory coreflooding results. Extrapolation of results from laboratory scale to field scale is difficult due to the lack of information on the lateral extent of compartmentalization. Therefore, the effect of reservoir heterogeneity on chemical flooding will not be known until the field project is implemented. It was decided that a better estimate of the final oil saturation in the area swept by chemical flooding is needed. This has been difficult to estimate from coreflooding experiments due to channeling of fluids through high permeability streaks in the field cores. In an attempt to better estimate oil saturation in the zone swept by chemicals, corefloods are being performed while monitoring flow patterns with CT scanning. These experiments are being performed under Project BE4B, which is supporting the SGP project with some laboratory experiments.

Milestone 3—One remaining task is to ensure that the sodium bicarbonate, which will be acquired from western Colorado or Wyoming (North American Chemical Co.), is compatible with the other EOR chemicals. A test sample of the sodium bicarbonate has been shipped.

Milestone 4—In completing this task, a presentation on comparison of methods for evaluating core from a midcontinent fluvial-dominated deltaic sandstone reservoir was presented at the Tenth Oil Recovery Conference held in Wichita, KS, and at the Fluvial-Dominated Deltaic Reservoirs in the Southern Midcontinent workshop in Norman, OK. The Tucker sand is a local-equivalent Bartlesville sand and is typical of many reservoirs in the area that are operated by independent oil companies. The presentation showed that there is extremely good agreement between routine and advanced analytical methods that can be used for reservoir evaluation: computerized tomography, minipermeameter measurements, and thin section analysis.

Manpower and Financial Status

Manpower and financial expenditures are behind schedule due to delays that have resulted from unfavorable core results in the area of the field that was originally selected for the pilot site.

Status of Project Milestones

As described above, milestone 4 has been completed. Milestones 2 and 3 are behind schedule due to lower than predicted oil recovery from reservoir cores during coreflood. Additional information on possible channeling of injected fluids will be obtained through CT monitoring of the reservoir core during coreflood. A request to extend the completion dates of these milestones is being prepared for submittal to BPO.

SGP49

FINANCIAL STATUS OF THE PROJECT FOR MARCH

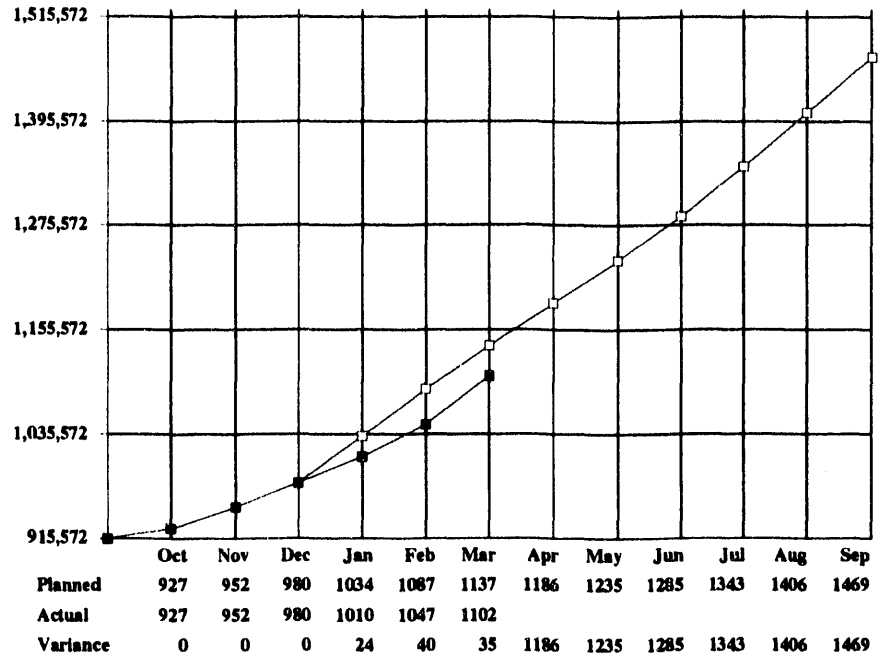
Total Appropriation:	1,523,572
Less Cap Equip & Subs:	90,115
Appropriation Balance:	1,433,457
Expenditures for the Month:	55,025
Total Expenditures to Date:	1,102,250
Net Available:	421,322

Cap Equip/Subcontract Exp & Commits: 90,115

Annual Plan Project SGP49

Process-Engineering Property Measurements on Heavy Petroleum Components

Financial Status



MANPOWER STATUS OF THE PROJECT FOR MARCH

Total Man-hours:	18,085
Man-hours used this Month:	706
Total Man-hours used to Date:	13,517
Net Available:	4,568

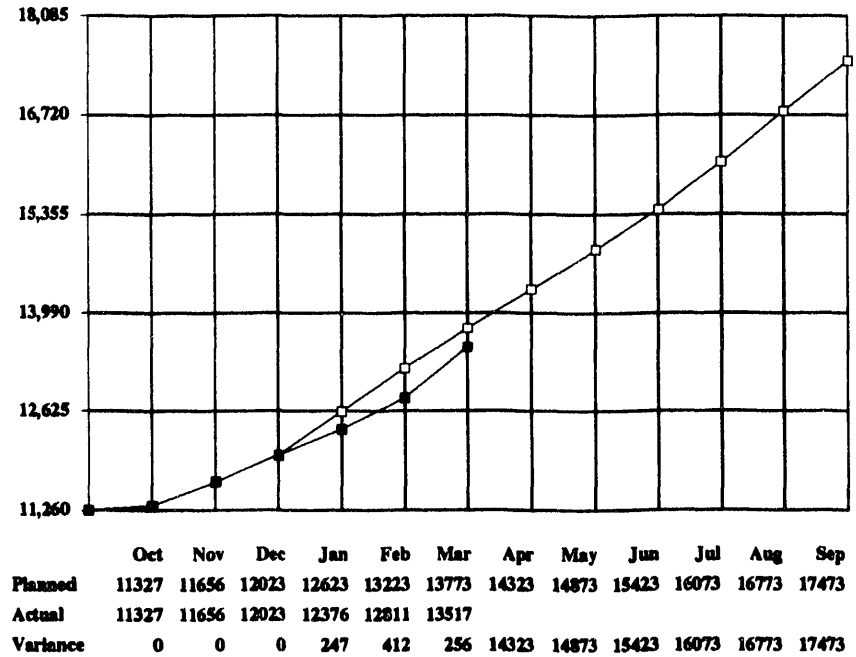
Legend for Key Milestones

- X = Work Completed
- C = Planned Completion Date
- C' = Revised Completion Date
- C'' = Completed Ahead of Schedule

Key Milestone Status

- 1 Topical Report/Journal Article on the Thermochemical & Thermophysical Properties at High Temperature (Approaching the Critical Region) of Phenanthrene & the Products of Its Hydrogenation
- 2 Prepare a Minimum of Three Journal Articles on the Thermodynamic Properties of Aromatic & Hydroaromatic Compounds Measured in This Research
- 3 Status Report on the Synthesis & Purification of Key Compounds (FY94 Completion Date)
- 4 Status Report Summarizing Data Acquired, Its Utility, & Updated Assessment of Needs for Future Work (FY94 Completion Date)

Manpower Status



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SGP49. PROCESS-ENGINEERING PROPERTY MEASUREMENTS ON HEAVY PETROLEUM COMPONENTS

Accomplishments

A topical report, entitled "The Thermodynamic Properties to 700 K of Naphthalene and 2,7-Dimethylnaphthalene," NIPER-678, was completed this month and fulfills the requirements of FY92 milestone 5. The report will be submitted to the BPO following internal review. Work on a topical report on phenanthrene and its hydrogenation products continues (milestone 1).

The topical report in which the thermodynamics of hydrogen shuttling are compared for pyrene, phenanthrene, and anthracene is near completion. These reports were not part of the original milestones for this project but will be completed due to the important insights they give to the controversy existing in the literature over the mechanism(s) of hydrogen shuttling. Work on the organometallics report (FY92 milestone 3) is also near completion.

Enthalpy of combustion studies on 1,2-dihydronaphthalene and 1,10-trimethylenepheneanthrene continued. These compounds are included in a series of measurements scheduled for completion this quarter.

Heat capacity and enthalpy studies by adiabatic calorimetry on 1,2-dihydronaphthalene were started this month. Early results confirm the very high purity of the calorimetric sample (>99.97 mole per cent).

High-temperature measurements by differential scanning calorimetry (DSC) were completed on 1,10-trimethylenepheneanthrene. The DFC results extended the range of heat capacity and enthalpy studies on this compound to 700 K. Thermodynamic property calculations for this four-ring hydroaromatic await completion of the vapor pressure and enthalpy of combustion studies mentioned above.

The status reports for research completed in FY92 (FY92 milestones 7 and 8) are near completion.

Manpower and Financial Status

Manpower and financial expenditures are on schedule.

Status of Project Milestones

Details of project milestones are given above. Milestone 1 is running behind schedule.

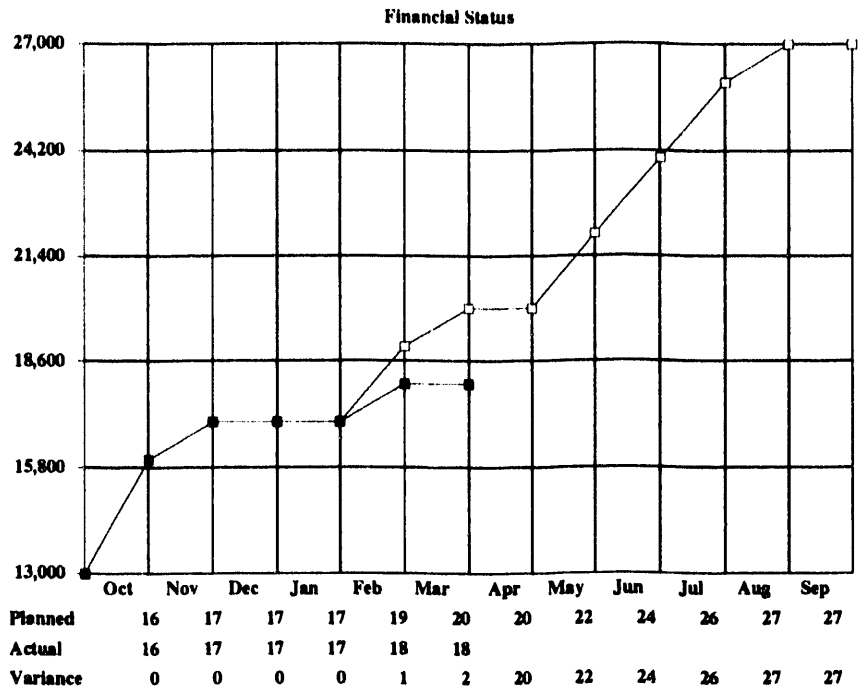
SGP50

FINANCIAL STATUS OF THE PROJECT FOR MARCH

Total Appropriation:		296,000
Less Subcontracts:	269,000	
Appropriation Balance:	27,000	
Expenditures for the Month:		626
Total Expenditures to Date:		193,589
Net Available:		102,411
Subcontract Expenses:		178,237

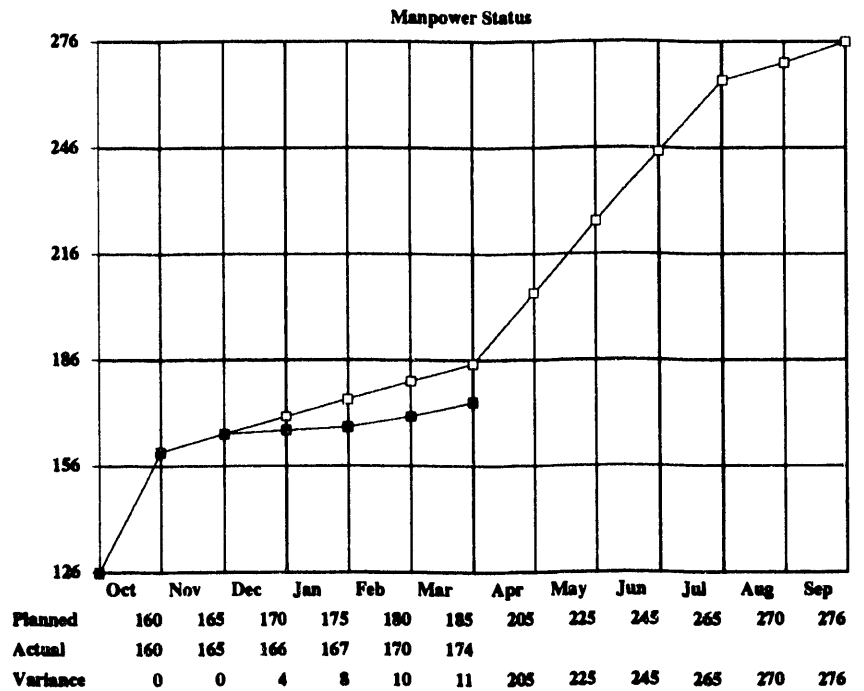
Annual Plan Project SGP50

Training in Development & Application
of Petroleum Production Technologies



MANPOWER STATUS OF THE PROJECT FOR MARCH

Total Man-hours:		276
Man-hours used this Month:	4	
Total Man-hours used to Date:		174
Net Available:		102



Legend for Key Milestones

- X = Work Completed
- C = Planned Completion Date
- C' = Revised Completion Date
- C'' = Completed Ahead of Schedule

Key Milestone Status

- 1 Submit Final Report on Development & Application of Petroleum Production Technologies
- 2 Recruit Summer Interns
- 3 Interview and Select Summer Interns
- 4 Supervise and Teach Summer Interns
- 5 Complete Final Report

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SGP50. DEVELOPMENT AND APPLICATION OF PETROLEUM PRODUCTION TECHNOLOGIES

Milestones 2 and 3—Thirty-five application forms from students attending the University of Oklahoma, Oklahoma State University, University of Central Oklahoma, Baylor University, University of Missouri at Rolla, University of Kansas, Purdue University, Rice University, Stanford University, Harvey Mudd University, Texas Christian University, Bartlesville Wesleyan College, Villanova University, California State University at Fresno, Tulsa University, and Ohio State University were received. After reviewing their resumes and transcripts, offers were made to 11 students after interview. The reviewing and interviewing process will be continued in April.

Manpower and Financial Status

Manpower and financial expenditures are on schedule.

Status of Project Milestones

Although milestone 2 was scheduled for completion in March, the decision has been made to continue the recruitment of students through the month of April. The other project milestones are on schedule.

SGP56

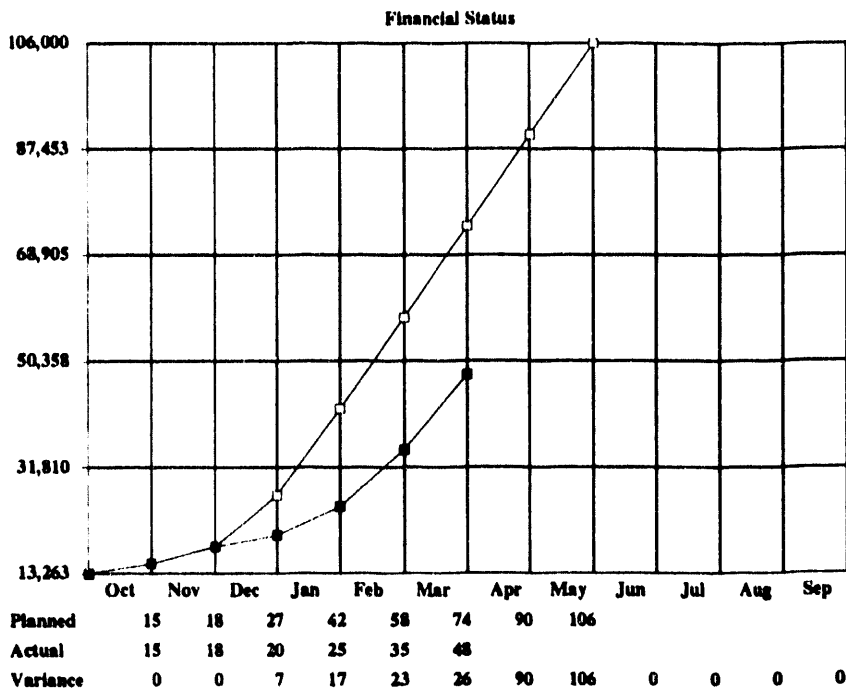
FINANCIAL STATUS OF THE PROJECT FOR MARCH

Total Appropriation:	106,000
Less Subcontracts:	0
Appropriation Balance:	106,000
Expenditures for the Month:	12,491
Total Expenditures to Date:	47,563
Net Available:	58,437

Subcontract Expenses: 0

Annual Plan Project SGP56

Upgrade BPO Crude Oil Analysis Data Base

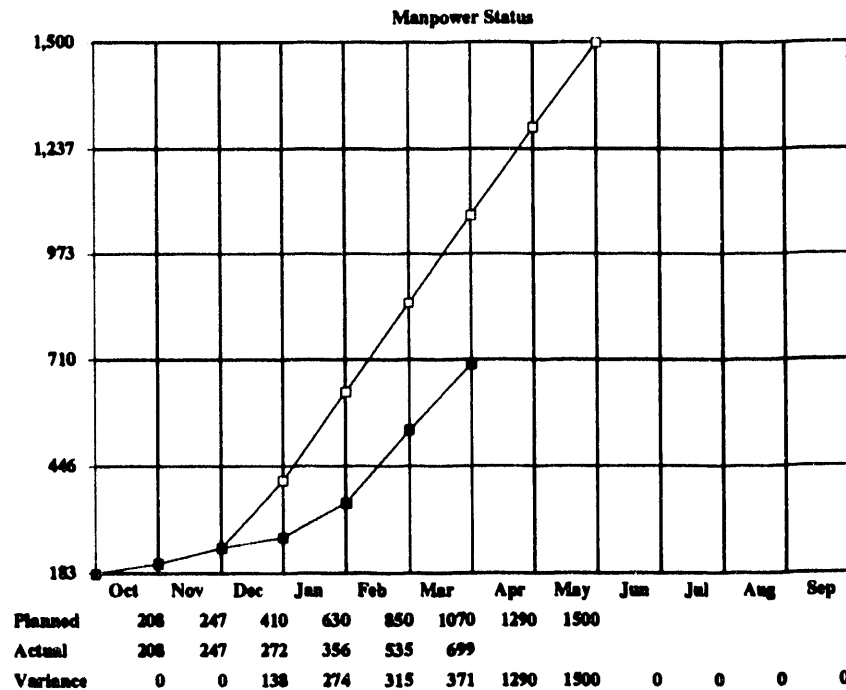


MANPOWER STATUS OF THE PROJECT FOR MARCH

Total Man-hours:	1,500
Man-hours used this Month:	164
Total Man-hours used to Date:	699
Net Available:	801

- Legend for Key Milestones**
- X = Work Completed
 - C = Planned Completion Date
 - C' = Revised Completion Date
 - C'' = Completed Ahead of Schedule

Key Milestone Status



- 1 Participate in UNITAR Crude Oil Analysis Round Robin
- 2 Complete Development of Crude Oil Analysis (COA) Data Management System
- 3 Upgrade Data in Data Base
- 4 Prepare a New COA Data Base User's Guide

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SGP56. UPGRADE BPO CRUDE OIL ANALYSIS DATA BASE

Accomplishments

The objectives of this project are (1) to develop and maintain a high-integrity, on-line, crude oil analysis (COA) data base that is available to the public; (2) to upgrade and update crude oil analyses for inclusion in this data base; and (3) to participate in the UNITAR analysis round robin.

Milestone 1—The UNITAR Round-Robin conference was postponed and has not been rescheduled.

Milestone 2—The data base system design is progressing. The bulletin board software and a doorway program were configured to work with an xBase program. A test program was written to determine the best user interface for the new COA. The test results showed that an interface design that did not include cursor control would be most appropriate. This type of user interface will allow use of the most basic terminals (TTY) to access the data base. The planned interface will be an interactive dialogue that scrolls as a session progresses. The use of more advanced protocols that use ANSI standards, and would allow arrow keys to be used, might be a future enhancement. Work has started on programming for generic queries by the user.

Milestone 3—Approximately 50 crude oil samples will be analyzed for trace metals and approximately 30 samples will be analyzed for hydrocarbon type. One additional sample was analyzed for hydrocarbon type this month. Sixteen samples have now been analyzed for hydrocarbons and fifteen for trace metals. Results will be reported in the next Technical Quarterly Report.

Manpower and Financial Status

Manpower and financial expenditures are behind schedule. Selection and analyses were started later than originally planned.

Status of Project Milestones

Milestone 1 is behind schedule because the review meeting was canceled and has not been rescheduled. All other project milestones are on schedule.

SGP58

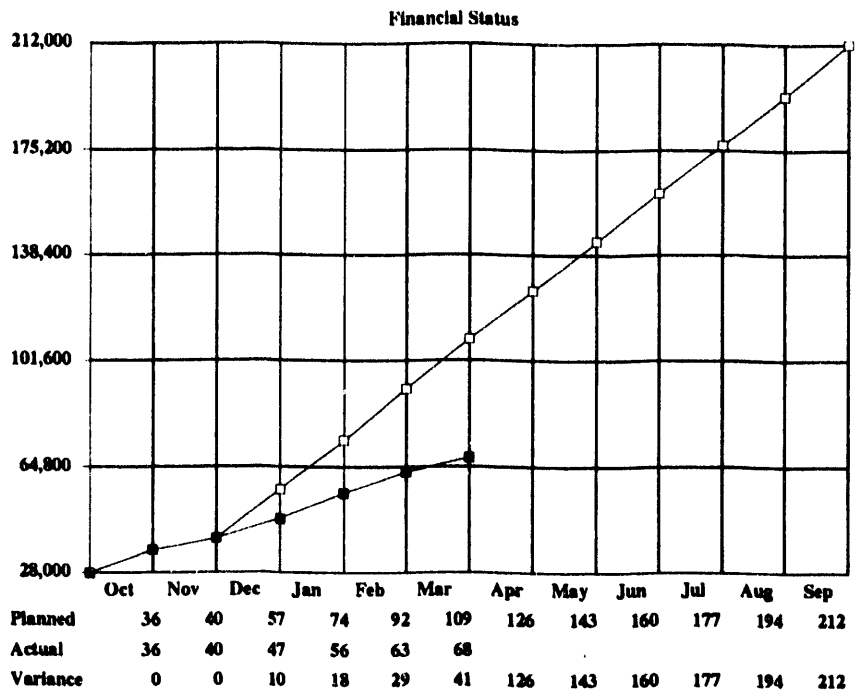
FINANCIAL STATUS OF THE PROJECT FOR MARCH

Total Appropriation: 350,000
Less Subcontracts: 0
Appropriation Balance: 350,000
Expenditures for the Month: 5,396
Total Expenditures to Date: 67,955
Net Available: 282,045

Subcontract Expenses: 0

Annual Plan Project SGP58

Simulation Analysis of Steam-Foam Projects



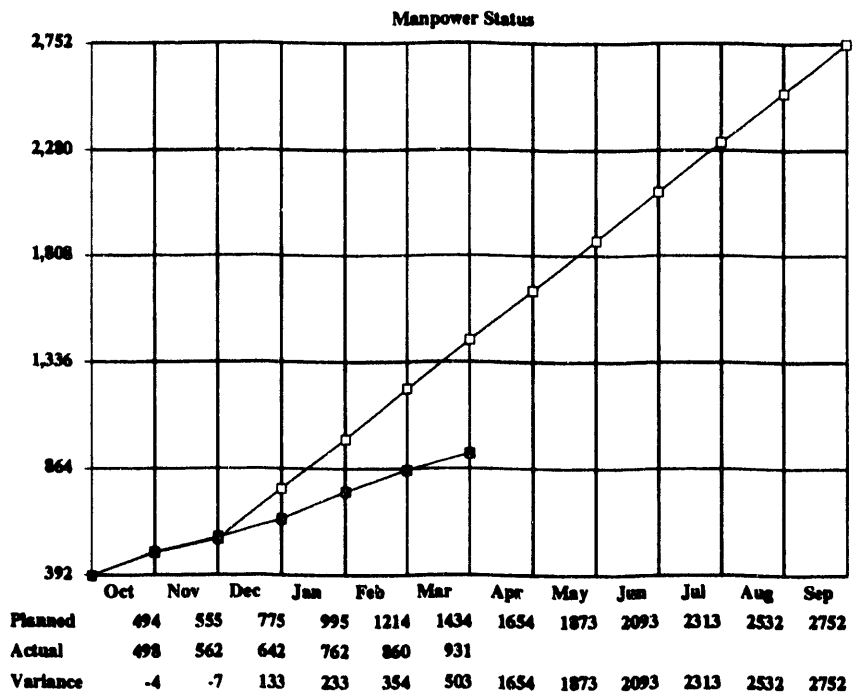
MANPOWER STATUS OF THE PROJECT FOR MARCH

Total Man-hours: 4,410
Man-hours used this Month: 71
Total Man-hours used to Date: 931
Net Available: 3,479

Legend for Key Milestones
X = Work Completed
C = Planned Completion Date
C' = Revised Completion Date
C'' = Completed Ahead of Schedule

Key Milestone Status

- 1 Complete Review of Data from Previous Steamflood Projects
- 2 Complete Basic History Match
- 3 Finalize Full-Pattern Simulation Study (FY94 Completion Date)
- 4 Final Report on Research Findings (FY94 Completion Date)



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SGP58. SIMULATION ANALYSIS OF STEAM-FOAM PROJECTS

Accomplishments

The objectives of this research project are (1) to study the viability of the steam-foam process by analyzing data from selected completed steam-foam projects and (2) to assess conditions under which the process likely to succeed, both technically and economically.

Milestone 2—The history match of Chevron's Section 26-C Steam-Foam Pilot is continuing. Matching of the pressure profile was successfully accomplished, but the temperature match was less than satisfactory. While the simulation predicts significant temperature response after 45 days of foam injection, field observation indicated significant response after 80 days of foam injection. Attempts to match the temperature profile caused the pressure profile to deviate significantly from the observed value, and the oil production rate was reduced. This was attributed to an inability to match the temperature to the basic assumption of the simple foam model employed, namely that foam (pressure pulse) and surfactant propagate at the same rate. Observation in the field indicates this is not the case and that foam significantly lags surfactant propagation. Additional simulation runs are planned with increased surfactant adsorption to obtain better history matching.

Manpower and Financial Status

Manpower and financial expenditures are below planned estimates due to senior staff commitments to other DOE priority projects.

Status of Project Milestones

Project milestones are on schedule. The March completion date for milestone 2, as shown in previous Monthly Reports, was in error. The approved completion date is May 1993, as shown on the facing page.

SGP61

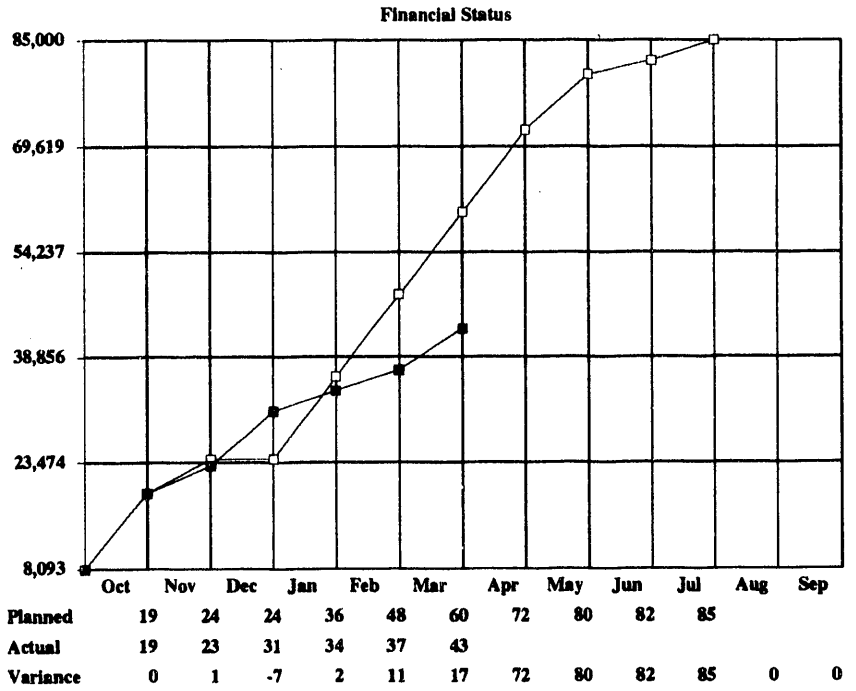
FINANCIAL STATUS OF THE PROJECT FOR MARCH

Total Appropriation: 110,000
 Less Subcontracts: 24,900
 Appropriation Balance: 85,100
 Expenditures for the Month: 5,910
 Total Expenditures to Date: 43,246
 Net Available: 66,754

Subcontract Expenses: 18,005

Annual Plan Project SGP61

DOE Educational Initiative Project



MANPOWER STATUS OF THE PROJECT FOR MARCH

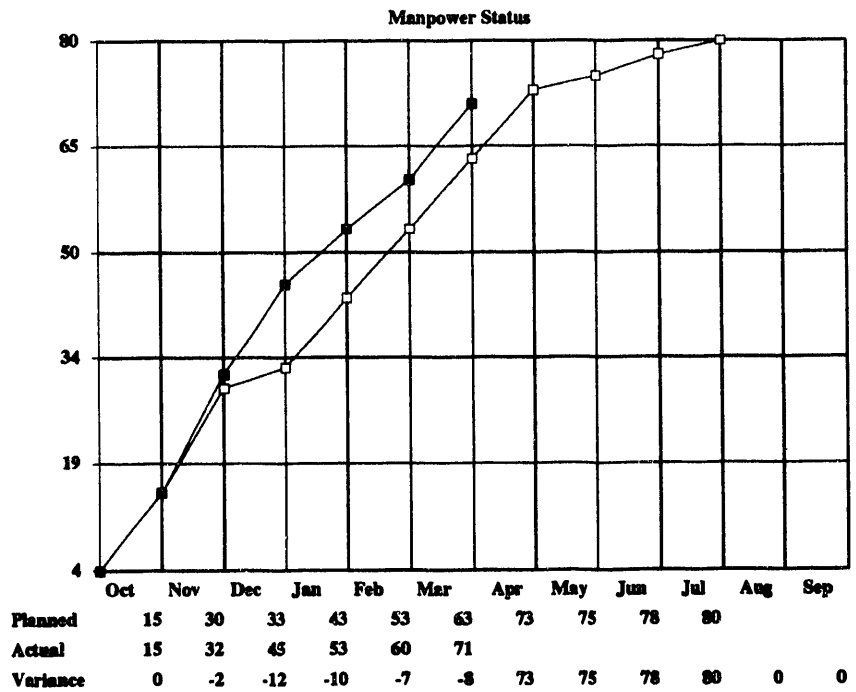
Total Man-hours: 80
 Man-hours used this Month: 11
 Total Man-hours used to Date: 71
 Net Available: 9

Legend for Key Milestones

- X = Work Completed
- C = Planned Completion Date
- C' = Revised Completion Date
- C'' = Completed Ahead of Schedule

Key Milestone Status

- 1 Complete Assessment of School Needs & Community Resources
- 2 Complete Development of Science Classroom Support Bureau
- 3 Coordinate Staff Development Opportunities for Teachers



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SGP61. DOE EDUCATION INITIATIVE PROJECT

Accomplishments

The objective of the DOE Education Initiative project is to enrich the science programs of public schools in the northeastern part of Oklahoma by developing partnerships between the schools, communities, businesses, and other interested groups.

Milestone 3—Evaluation forms were sent to students, coaches, moderators, and Science Bowl volunteers. Approximately 180 forms were mailed, and 64 responses have been received as of this writing. Results will be tabulated in April.

Liaison is provided between the Oklahoma Science Bowl team and National Science Bowl organizers to ensure all information is made available and that arrangements are made for the Oklahoma team to participate in the National Science Bowl, April 16-19.

Judy Kokesh assisted with regional "Train the Trainers" session in the Oil and Gas Exploration module of the Denver Earth Science Project. Ms. Kokesh met with Milt Jarrett, Dean of Continuing Education, University of Tulsa, to discuss the University's participation in the regional "Train the Trainers," July 11-21. TU will provide classroom space, resource people, housing, and meals for participants.

Planning has begun for the "Oil and Gas Exploration" module workshop to be held in Oklahoma City, during the summer. Ms. Kokesh met with Dr. Edna Manning, President, Oklahoma School of Science and Mathematics to discuss their participation in the workshop and completed preliminary discussions with the Curriculum Director of Oklahoma City Public Schools relating to the distribution of workshop information to science teachers. Discussions were also conducted with the Education/Career Development Committee (ECDC) and Phillips Petroleum Company regarding a joint teacher internship program for Phillips and NIPER during the summer of 1993.

NIPER will provide one teacher internship in Energy Production Research, and Phillips will provide three. Application information will be mailed to 60 teachers in Bartlesville and surrounding districts. Teacher applications will be reviewed by supervising researchers. Teacher interns will be invited to attend NIPER's weekly seminar program offered for summer students.

Manpower and Financial Status

Financial expenditures are low by 28%, and manpower is high by 13%. This is due to the inability to plan accurately for the type of activities involved.

Status of Project Milestones

Project milestones are on schedule.

SGP63

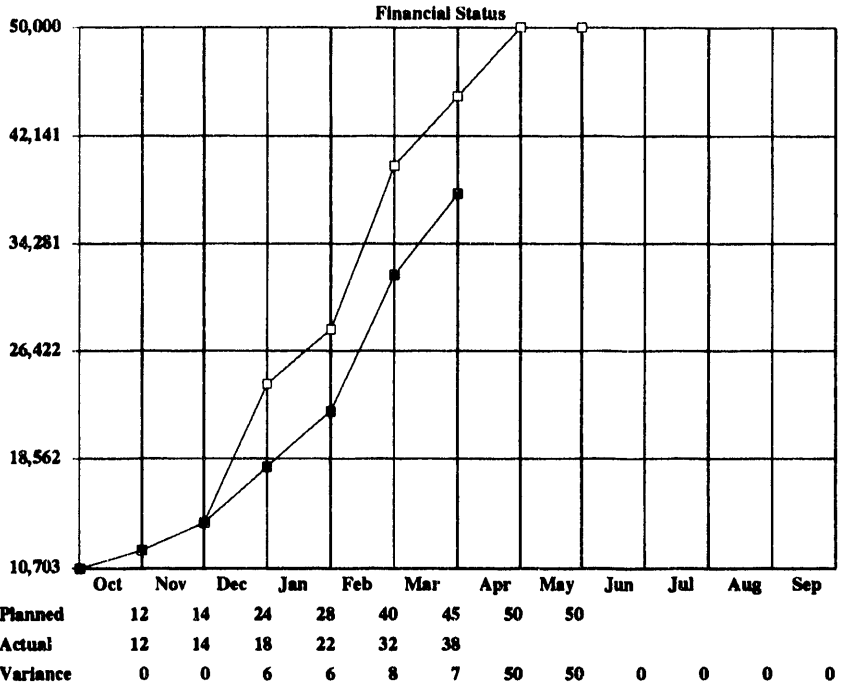
FINANCIAL STATUS OF THE PROJECT FOR MARCH

Total Appropriation: 50,000
 Less Subcontracts: 0
 Appropriation Balance: 50,000
 Expenditures for the Month: 5,320
 Total Expenditures to Date: 37,769
 Net Available: 12,231

Subcontract Expenses: 0

Annual Plan Project SGP63

**Field Application of Foams for Oil
 Production Symposium**



MANPOWER STATUS OF THE PROJECT FOR MARCH

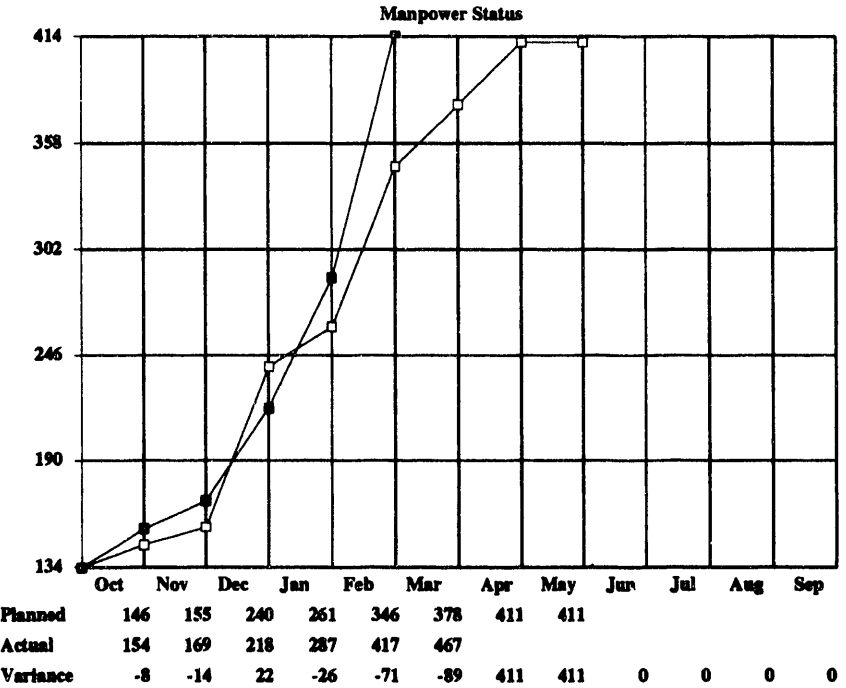
Total Man-hours: 475
 Man-hours used this Month: 50
 Total Man-hours used to Date: 467
 Net Available: 8

Legend for Key Milestones

- X = Work Completed
- C = Planned Completion Date
- C' = Revised Completion Date
- C'' = Completed Ahead of Schedule

Key Milestone Status

- 1 Organize & Conduct a Symposium on Field Application of Foams
- 2 Compile Summary of Technical Comments Obtained During Symposium
- 3 Compile Proceedings for DOE Fossil Energy Report



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SGP63. FIELD APPLICATION OF FOAMS FOR OIL PRODUCTION SYMPOSIUM

Accomplishments

The DOE and NIPER cosponsored a day and a half symposium on the field application of foams for oil production at the Red Lion Inn, Bakersfield, CA, Feb. 11-12, 1993. Seventy-two individuals from seven countries were in attendance and actively participated in the discussions and panel presentations on the current status of foam technology. The agenda included 13 technical papers and 8 poster sessions. Responses from the participants indicated that the symposium was an overwhelming success, and many wanted to see additional process-specific meetings of this type.

Milestones 2 and 3—The papers, extended abstracts of poster session presentations, and summary of the panel discussion, have all been assembled into the Proceedings of the symposium and designated as NIPER report number 699. The report has been submitted for review and comment. The Proceedings will be distributed following publication as a DOE/FE report.

Manpower and Financial Status

Financial expenditures are below schedule because all invoices associated with the symposium have not been paid. Manpower is high and reflects the considerable amount of secretarial help required in preparing for the symposium.

Status of Project Milestones

Milestone 2 has been completed. Milestone 3 is on schedule.

SGP64

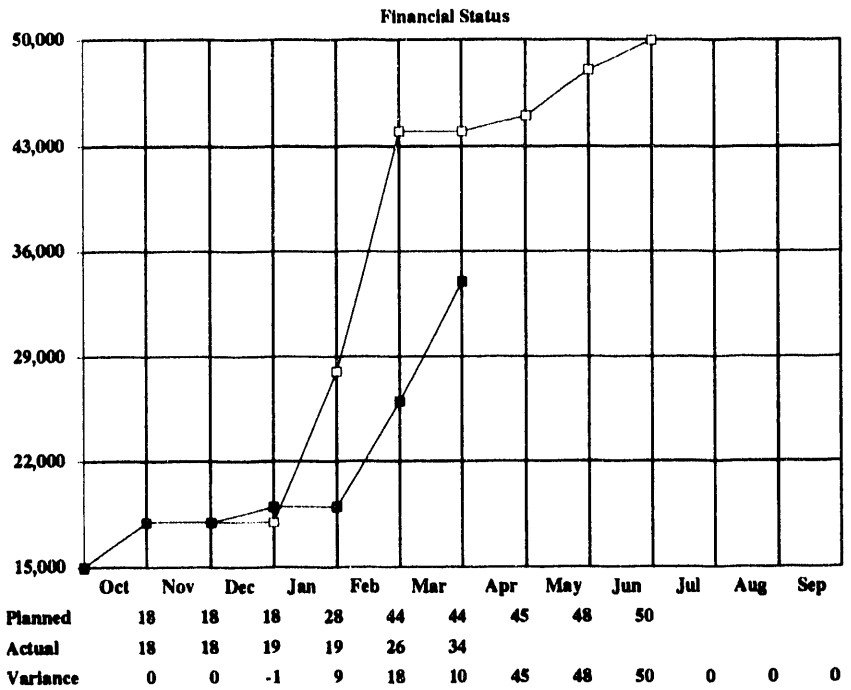
FINANCIAL STATUS OF THE PROJECT FOR MARCH

Total Appropriation: 174,350
Less Subcontracts: 124,350
Appropriation Balance: 50,000
Expenditures for the Month: 8,255
Total Expenditures to Date: 34,186
Net Available: 140,164

Subcontract Expenses: 0

Annual Plan Project SGP64

Technology Transfer to Independent Producers



MANPOWER STATUS OF THE PROJECT FOR MARCH

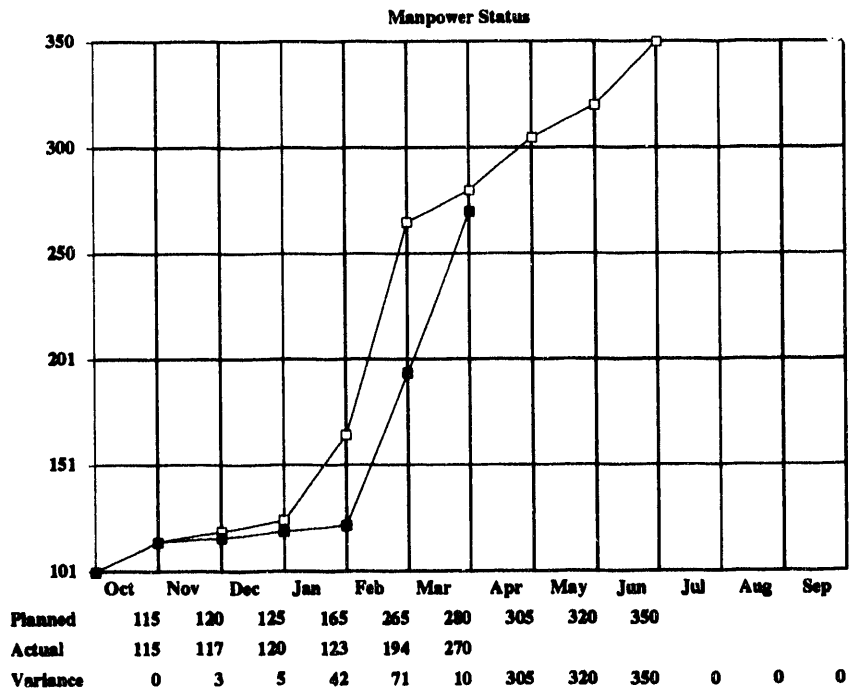
Total Man-hours: 350
Man-hours used this Month: 76
Total Man-hours used to Date: 270
Net Available: 80

Legend for Key Milestones

- X = Work Completed
- C = Planned Completion Date
- C' = Revised Completion Date
- C'' = Completed Ahead of Schedule

Key Milestone Status

- 1 Review Response to First Seminar; Complete Design for Additional Seminars
- 2 Conduct Series of One-Day Seminars
- 3 Submit Final Report Describing Project Results



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SGP64. TECHNOLOGY TRANSFER TO INDEPENDENT PRODUCERS

Accomplishments

The objective of this project is to transfer information, through a series of seminars, on oil and gas related subjects which have been identified by independent operators as having the highest priority.

Milestone 2—The current series of lectures developed by Texas Independent Producers and Royalty Owners (TIPRO) and the Bureau of Economic Geology at the University of Texas at Austin has concluded. Lectures were given in the following Texas cities: Dallas (January 28, attendance 85), Amarillo (February 12, attendance 38), Abilene (February 17, attendance 60), Midland (February 18, attendance 77), Houston (February 24, attendance 77), and Wichita Falls (March 3, attendance 85). A scheduled meeting in Corpus Christi was canceled due to low registration; however, potential attendees from the Corpus area were urged to attend the Houston meeting. NIPER personnel attended and monitored each of these meetings.

Luncheon speakers included Jeff Jones (Jones Company Ltd., Abilene meeting), Julian Martin (TIPRO, Amarillo meeting), T. D. Coffman (President TIPRO, Midland meeting), R. Earley (Chairman, House Energy Committee, Houston meeting), and V. Okorokov (Federation of Energy & Electrotechnical Societies, U. Texas at Richardson, Wichita Falls meeting).

Evaluation of these meetings has begun in terms of a cross section on types of company participation (e.g., were attendees from large or small independent companies), comments by attendees, appropriateness of materials, and recommendations for future technology transfer activities. A data base containing information received from the survey forms provided at these meetings was prepared for evaluation.

Manpower and Financial Status

Manpower and financial expenditures are below planned estimates. Staff expenditures associated with the late-February workshops were not all posted for the month. These charges should be accounted for in the April Monthly Report.

Status of Project Milestones

Milestones 1 and 2 have been completed. Milestone 3 is on schedule.

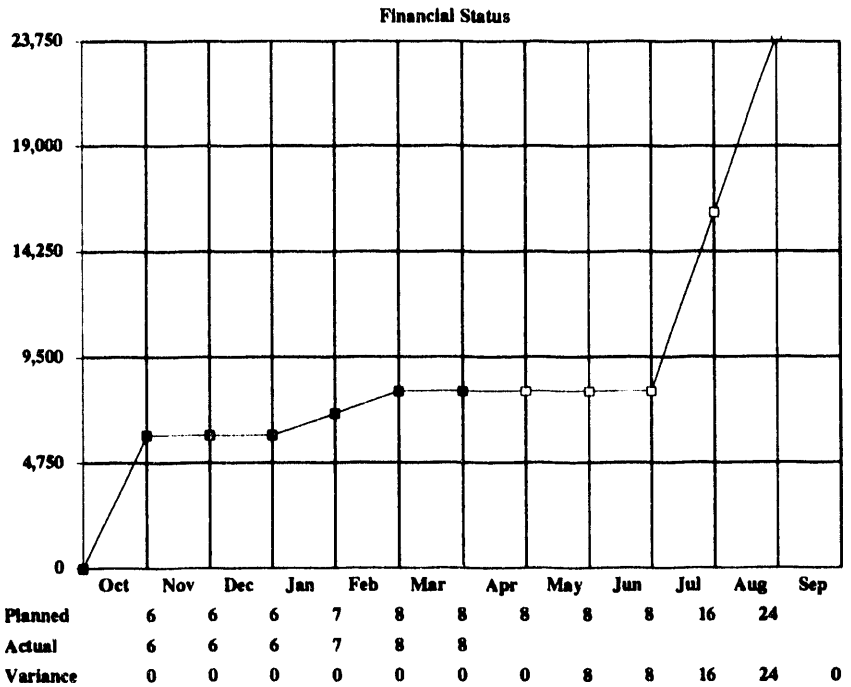
SGP69

FINANCIAL STATUS OF THE PROJECT FOR MARCH

Total Appropriation:	23,750
Less Subcontracts:	0
Appropriation Balance:	23,750
Expenditures for the Month:	714
Total Expenditures to Date:	8,401
Net Available:	15,349
Subcontract Expenses:	0

Annual Plan Project SGP69

Completions and Analysis of Outcrop Data from the Muddy and Almond Formations



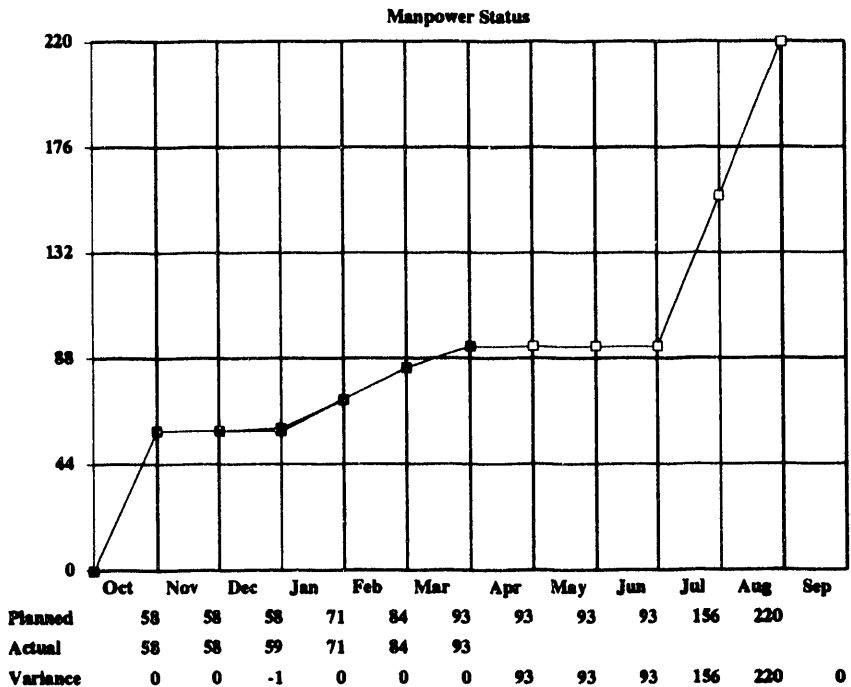
MANPOWER STATUS OF THE PROJECT FOR MARCH

Total Man-hours:	212
Man-hours used this Month:	9
Total Man-hours used to Date:	93
Net Available:	119

Legend for Key Milestones

- X = Work Completed
- C = Planned Completion Date
- C' = Revised Completion Date
- C'' = Completed Ahead of Schedule

Key Milestone Status



- 1 Supply Missing Data, Interpretations, & Analyses of Outcrop Data Collected
- 2 Correlate Minipermeameter & CT Density Data with Sedimentological Features in Core Well No. 2
- 3 Compile Almond & Muddy Formation Outcrop Data into Transferable Format & Prepare Illustrations & Documentation of Data Files
- 4 Topical Report Containing a Compilation of Data Collected & Analyzed from Muddy & Almond Formation Outcrops & Providing Descriptions, Sedimentological Interpretations, Correlations, & Analyses of Muddy & Almond Formation Outcrop Sections Studied
- 5 Submit Electronic Files of Permeability & Porosity Data, Grain Size, & Facies Data from Muddy & Almond Formation Outcrops

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SGP 69. COMPILATION AND ANALYSIS OF OUTCROP DATA FROM THE MUDDY AND ALMOND FORMATIONS

Objectives

The objectives of this project are (1) to compile outcrop data from the Muddy and Almond Formations; (2) supply missing data, interpretations, and analyses where needed; and (3) put data in a transferable format for use by interested parties.

Accomplishments

No work was performed on this project this month. Work will resume in June.

Manpower and Financial Status

Financial expenditures and manpower have been rescheduled with permission of the BPO.

Status of Project Milestones

Milestones have been extended to accommodate manpower and financial rescheduling.

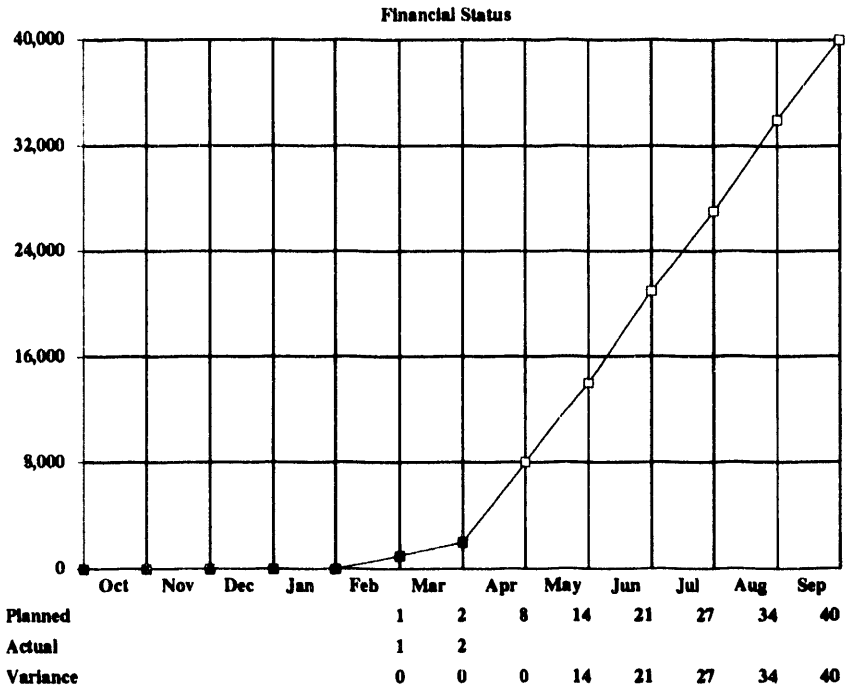
SGP73

FINANCIAL STATUS OF THE PROJECT FOR MARCH

Total Appropriation:	40,000
Less Subcontracts:	0
Appropriation Balance:	40,000
Expenditures for the Month:	1,645
Total Expenditures to Date:	2,353
Net Available:	37,647
Subcontract Expenses:	0

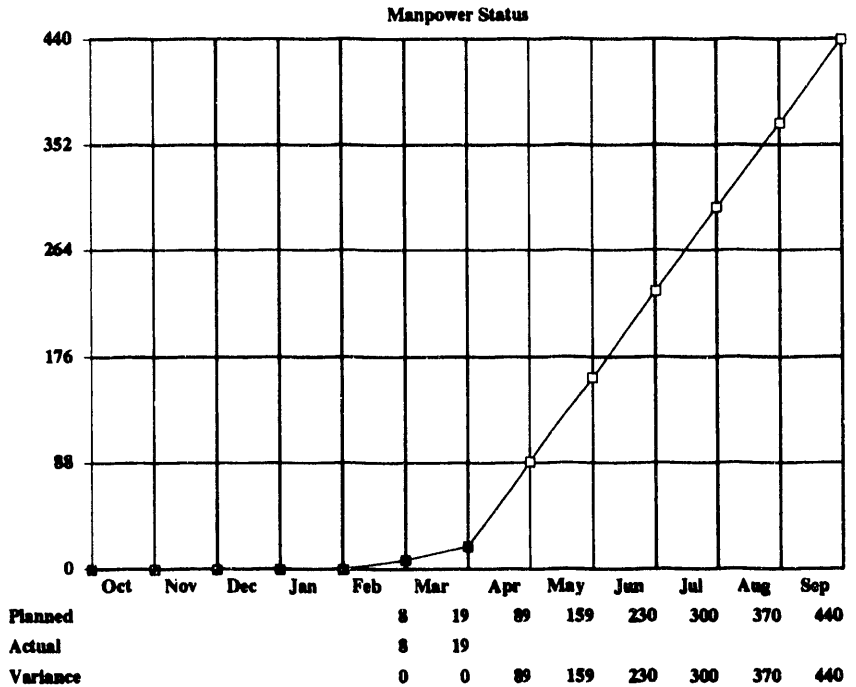
Annual Plan Project SGP73

Horizontal Well Production from Fractured Reservoirs



MANPOWER STATUS OF THE PROJECT FOR MARCH

Total Man-hours:	440
Man-hours used this Month:	19
Total Man-hours used to Date:	27
Net Available:	413

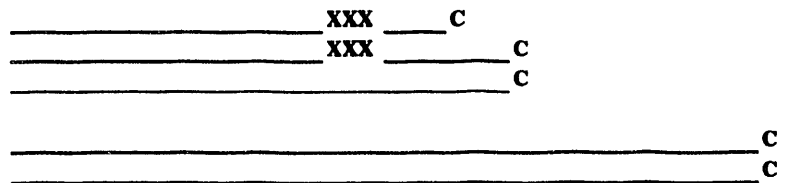


Legend for Key Milestones

- X = Work Completed
- C = Planned Completion Date
- C' = Revised Completion Date
- C'' = Completed Ahead of Schedule

Key Milestone Status

- 1 Complete Fracture Data Collection from Reservoir and Outcrop
- 2 Improve Transfer Function Between Rock Matrix and Fracture
- 3 Finalize Development of Fracture Reservoir Model
- 4 Conduct Numerical Simulation of Horizontal Production from Fractured Reservoirs
- 5 Topical Report Describing Horizontal Production from Reservoir



SGP73. HORIZONTAL WELL PRODUCTION FROM FRACTURED RESERVOIRS

Accomplishments

The objective of this project is to determine effects of natural fractures on horizontal well production using numerical simulation to provide guidelines, screening criteria, or analytical predictions of horizontal well production.

Milestone 1—The fracture density and distribution pattern from outcrops are being collected.

Milestone 2—The shape factor in the transfer function between fracture and rock matrix was investigated. The shape factor σ is defined as

$$\sigma = \frac{q\mu}{kV(p_f - \bar{p}_m)} \quad (1)$$

where k = permeability of rock matrix

p_f = fracture pressure

\bar{p}_m = volumetric average pressure of rock matrix block

q = flow rate between fracture and rock matrix

V = bulk volume of rock matrix block

μ = fluid viscosity

The shape factor formula proposed by Kazemi for the case of a cubic matrix block is $12/d^2$, where d is the length of the matrix block. Kazemi's formula can be derived based on the quasi-steady-state (QSS) flow and the assumption that \bar{p}_m equals the pressure in the center of the matrix block. Warren and Root proposed a formula for the shape factor as

$$\sigma = 4N(N+2)/d^2 \quad (2)$$

where N is the number of normal sets of fractures, 1, 2, or 3 (The basis of this formula is not known).

Based on material balance and darcy flow in QSS, the shape factor was derived in this study as

$$\sigma = 15/r^2 = 60/d_i^2 \quad \text{for spherical flow} \quad (3)$$

$$\sigma = 8/r^2 = 32/d_i^2 \quad \text{for cylindrical flow} \quad (4)$$

$$\sigma = 12/d^2 \quad \text{for lineal flow} \quad (5)$$

where r and d_i are the radius and diameter of the spherical or cylindrical matrix, respectively, and d is the length of the linear rock matrix.

Formulas (3)-(5) agree with formula (2), if d_i 's in formulas (3)-(5) are replaced by d . The equivalent location of \bar{p}_m from the edge of rock matrix is back-calculated as $0.1d$, $0.125d$, and $0.167d$ for cases in formulas (3), (4), and (5), respectively. These values of \bar{p}_m location are different from the assumption of $0.5d$ in Kazemi's formula. Because of this assumption of $0.5d$, Kazemi's shape factor is five times smaller than shown in (3) for the spherical or three-dimensional cubic flow between fracture and rock matrix.

Manpower and Financial Status

Manpower and financial expenditures are on schedule.

Status of Project Milestones

Project milestones are on schedule.

END

**DATE
FILMED**

5 / 27 / 93

