PROGRESS REPORT
No. 10

December 1, 1984 – February 28, 1985

MMS Contract 14-08-001-21169, Mod. 3
( LSU Project No. 127-45-5115 )
Effective Date: August 26, 1982
Expiration Date: October 1, 1987

on

THE DEVELOPMENT OF
IMPROVED BLOWOUT PREVENTION SYSTEMS
FOR OFFSHORE DRILLING OPERATIONS

Submitted to
The Minerals Management Service
United States Department of the Interior
Reston, Virginia

Adam T. Bourgoyne, Jr.

by

Petroleum Engineering Department
Louisiana State University
RESEARCH OBJECTIVES

The primary objectives of the research are:

1. The development of an improved blowout prevention system through the integration of measurements while drilling (MWD) and well control technologies.

2. The development of improved diverter systems for offshore operations.

Funding to date has included the following subtasks:

1.1.1 Determine the data requirements (parameters and speed of transmission) for automated well control system. Experimental study, (without secondary kicks) of parameters needed, time urgency, accuracy requirements, redundancy requirements, and trade offs.

1.1.2 Determination of additional data requirements for overall well control strategy including surface data.

1.2.1 Evaluate electrical telemetering technique as data rate alternative to conventional mud pulse telemetry.

1.2.2 Select best MWD approach

1.3.1 Define and develop appropriate new hardware for control of system

2.1 Review of available technology and current field practices on design and use of diverters on offshore drilling rigs.

2.2 Review failures and cause of failures that have occurred in offshore diverter systems.

2.3 Use of systems analysis approach to develop computer model of reservoir/well/diverter system.
2.4 Experimental verification of computer model of diverter system.

2.6 Literature and experimental study of erosion reduction techniques in diverter system (including bends).

2.7 Experimental and computer study of diverter plugging by produced solids.

3.1 Improved surface and near surface kick detection for floating drilling operations.

PROGRESS

Work on the various phases of the project has continued without major problems. Two budget planning updates were prepared during this period which addresses the progress made to date and proposes what is needed for next years funding. Copies of these proposals are attached in Appendix A.

The 10,000 ft. buried flow loop has been completed. The vertical storage cylinders for gas compression and for the model diverter system have been successfully drilled and cased. The acquisition of surface well head equipment needed for these cased boreholes are still in progress.

The cost of preparing the experimental flow loop and vertical boreholes is running about 30% higher than anticipated. However, some additional funding in the form of unrestricted grants and equipment donations have been obtained, and it is still anticipated that the projects can be completed within the contract costs.
SIGNIFICANT CHANGES

No significant changes have been required during the reporting period.
BUDGET PLANNING UPDATE

for

MMS Contract 14-08-001-21169, Mod. 3
(LSU Project No. 127-45-5115)

on

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FOR OFFSHORE DRILLING OPERATIONS

Submitted to
The Minerals Management Service
United States Department of the Interior
Reston, Virginia

by
Petroleum Engineering Department
Louisiana State University

January, 1985
BUDGET PLANNING UPDATE

for

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(LSU Project No. 127-45-5115)

on

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IMPROVED BLOWOUT PREVENTION SYSTEMS
FOR OFFSHORE DRILLING OPERATIONS

Submitted to
The Minerals Management Service
United States Department of the Interior
Reston, Virginia

by

Adam T. Bourgoyne, Jr.
Principal Investigator

Julius P. Langlinais
Co-Principal Investigator

Board of Supervisors
of
LOUISIANA STATE UNIVERSITY
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I. INTRODUCTION

The Petroleum Engineering department at LSU has played an active role over the past decade in well control research and in training of industry personnel in present-day methods of well control. With the help of both industry and government modern training and research facilities centered around two 6000 ft wells were equipped to model well control operations conducted both in the shallow water marine environment of the continental slope and in deepwater offshore operations. A three million dollar expansion of this facility was recently achieved through the combined support of a consortium of 60 companies in the petroleum industry and through a research grant funded by the U. S. Minerals Management Service (MMS).

On March 24, 1982, a workshop was conducted at LSU to assist in the formulation of a long range plan for future well control research. The participants included (1) members of the industry advisory panel to the LSU Blowout Prevention Research Center (2) researchers currently being supported by MMS, and (3) representatives of various MMS districts. Twenty-one desirable projects were identified by this group. The top ten projects are listed in Table 1 along with a composite priority level assigned by the workshop panel.

A five year research plan was made in a proposal to MMS for developing improved well control systems for deep water offshore drilling operations. The proposed five year plan incorporates many of the high priority items identified at the LSU Well Control Workshop. In October, 1983, MMS Contract No. 14-12-001-21169, Mod. 2 was issued for LSU to
Table 1 - Recommendations made at March 24, 1982 LSU Well Control Workshop

<table>
<thead>
<tr>
<th>Priority Level</th>
<th>Research Area</th>
<th>Votes Received Assuming Funding For following number of projects:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>One, Two, Three, Four, or Five</td>
</tr>
<tr>
<td>.1</td>
<td>Feasibility Study on Use of MWD Technology in Well Control Operations on Floating Vessels</td>
<td>6 9 9 10 11</td>
</tr>
<tr>
<td>2</td>
<td>Study of Well Control Operations with Simultaneous Formation Fracture</td>
<td>3 10 12 16 17</td>
</tr>
<tr>
<td>3</td>
<td>Well Control Operations for Short Casing Strings (Diverter Systems)</td>
<td>3 5 8 12 14</td>
</tr>
<tr>
<td>4</td>
<td>Improved Procedures for Handling Upward Gas Migration during stripping or Snubbing Operations</td>
<td>1 3 5 5 8</td>
</tr>
<tr>
<td>5</td>
<td>Improved System for Detecting Gas in Mud at Depth (as opposed to present surface detectors)</td>
<td>2 3 5 5 7</td>
</tr>
<tr>
<td>6</td>
<td>Study of Upward Gas Migration in Slant (Directional) Boreholes</td>
<td>1 2 3 5 7</td>
</tr>
<tr>
<td>7</td>
<td>Scale-up of Fluidic Pulse Telemetry System to longer systems with varying mud properties</td>
<td>0 1 3 4 5</td>
</tr>
<tr>
<td>8</td>
<td>Determination of Minimum Number of Requisite Parameters via MWD for safe drilling operations</td>
<td>1 1 1 3 5</td>
</tr>
<tr>
<td>9</td>
<td>Scale-up of Ongoing Fire Suppression System Development for Offshore Drilling</td>
<td>2 3 3 4 4</td>
</tr>
<tr>
<td>10</td>
<td>Study of Potential Problems due to Gas Hydrate Formation in Subsea Well Control Equipment in Deep Water</td>
<td>0 3 4 4 4</td>
</tr>
</tbody>
</table>
begin work on the first year of the five year plan. In October, 1984, the second year of the proposed plan was funded. In this document, the progress which has been made is summarized, and a budget update is provided for maintaining the project through the third year.
II. GENERAL RESEARCH PROGRAM OBJECTIVES AND TIMETABLE

The primary objective of the research project is to increase the efficiency and safety of offshore drilling operations. This would be accomplished through the development of improved blowout prevention systems. The two main systems included in the study are (1) the high pressure emergency circulating system and choke used to circulate formation fluids from a well under pressure, and (2) the diverter system which must be employed prior to setting sufficient casing to allow use of the high pressure system. Additional objectives deal with improved kick detection systems and complications that can develop as a result of formation fracture, directional drilling operations, or off-bottom kicks.

The overall research plan can be divided into six overall tasks. Several of these tasks can be subdivided into a number of subtasks. These tasks and subtasks are:

<table>
<thead>
<tr>
<th>Task</th>
<th>Subtask</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td>Development of an improved blowout prevention system through the integration of measurements while drilling (MWD) and well control technologies.</td>
</tr>
<tr>
<td>1.1</td>
<td></td>
<td>Determine the data requirements (parameters and speed of transmission) for automated well control system.</td>
</tr>
<tr>
<td>1.1.1</td>
<td></td>
<td>Experimental study, (without secondary kicks) of parameters needed, time urgency, accuracy requirements, redundancy requirements, and trade offs.</td>
</tr>
<tr>
<td>1.1.2</td>
<td></td>
<td>Determination of additional data requirements for overall well control strategy including surface data.</td>
</tr>
<tr>
<td>Task</td>
<td>Subtask</td>
<td>Description</td>
</tr>
<tr>
<td>------</td>
<td>---------</td>
<td>-------------</td>
</tr>
<tr>
<td>1.2</td>
<td></td>
<td>Selection of MWD System compatible with well control application.</td>
</tr>
<tr>
<td>1.2.1</td>
<td></td>
<td>Evaluate electrical telemetry technique as high data rate alternative to conventional mud pulse telemetry.</td>
</tr>
<tr>
<td>1.2.2</td>
<td></td>
<td>Select best available MWD approach.</td>
</tr>
<tr>
<td>1.3</td>
<td></td>
<td>Engineering development of improved Blowout Prevention System.</td>
</tr>
<tr>
<td>1.3.1</td>
<td></td>
<td>Define and develop appropriate new hardware for control of system.</td>
</tr>
<tr>
<td>1.3.2</td>
<td></td>
<td>Develop Process Control Computer and computer logic.</td>
</tr>
<tr>
<td>1.3.3</td>
<td></td>
<td>Integrate Process Control Computer into Well Control System.</td>
</tr>
<tr>
<td>1.3.4</td>
<td></td>
<td>Experimental verification of Process Control Computer logic with risk of secondary kicks included in experimental programs.</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>Development of improved Diverter System for offshore operations.</td>
</tr>
<tr>
<td>2.1</td>
<td></td>
<td>Review of available technology and current field practices on design and use of diverters on offshore drilling rigs.</td>
</tr>
<tr>
<td>2.2</td>
<td></td>
<td>Review failures and cause of failures that have occurred in offshore diverter systems.</td>
</tr>
<tr>
<td>2.3</td>
<td></td>
<td>Use of systems analysis approach to develop computer model of reservoir/well/diverter system.</td>
</tr>
<tr>
<td>2.4</td>
<td></td>
<td>Experimental verification of computer model with scaled model of diverter system.</td>
</tr>
<tr>
<td>2.5</td>
<td></td>
<td>Computer study of feasibility of maintaining an optimal backpressure during operation of diverter system.</td>
</tr>
<tr>
<td>2.6</td>
<td></td>
<td>Literature and experimental study of erosion reduction techniques in diverter system (including bends).</td>
</tr>
<tr>
<td>Task</td>
<td>Subtask</td>
<td>Description</td>
</tr>
<tr>
<td>------</td>
<td>---------</td>
<td>-------------</td>
</tr>
<tr>
<td>2.7</td>
<td></td>
<td>Experimental and computer study of diverter plugging by produced solids.</td>
</tr>
<tr>
<td>2.8</td>
<td></td>
<td>Experimental evaluation of alternative diverter designs.</td>
</tr>
<tr>
<td>2.9</td>
<td></td>
<td>Study of marine riser as part of diverter system.</td>
</tr>
<tr>
<td>2.10</td>
<td></td>
<td>Design of improved diverter systems for bottom supported rigs and floating drilling vessels.</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>Development of improved system for kick detection for floating drilling vessels.</td>
</tr>
<tr>
<td>3.1</td>
<td></td>
<td>Improved surface and near surface kick detection system for floating drilling operation.</td>
</tr>
<tr>
<td>3.2</td>
<td></td>
<td>Pore pressure determination and kick detection assisted by MWD technology.</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>Study of well control with simultaneous formation fracture.</td>
</tr>
<tr>
<td>4.1</td>
<td></td>
<td>Development of computer model.</td>
</tr>
<tr>
<td>4.2</td>
<td></td>
<td>Experimental verification of computer model.</td>
</tr>
<tr>
<td>4.3</td>
<td></td>
<td>Computer study to identify cases where well control with simultaneous formation fracture are feasible or even beneficial.</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td>Study of upward gas migration in slant (directional) boreholes.</td>
</tr>
<tr>
<td>5.1</td>
<td></td>
<td>Experimental study.</td>
</tr>
<tr>
<td>5.2</td>
<td></td>
<td>Development of computer model.</td>
</tr>
<tr>
<td>6</td>
<td></td>
<td>Development of improved blowout prevention system for off-bottom kicks.</td>
</tr>
<tr>
<td>6.1</td>
<td></td>
<td>Development of computer model.</td>
</tr>
<tr>
<td>6.2</td>
<td></td>
<td>Use of computer model to develop improved technique for handling upward gas migration during stripping operations.</td>
</tr>
<tr>
<td>6.3</td>
<td></td>
<td>Use of computer model to evaluate multi-stage off-bottom kill procedure.</td>
</tr>
</tbody>
</table>
An updated timetable for accomplishing the general research program is shown in Figure 1. The current year funding (1984-85), for subtasks 1.2.2, 1.3.1, and 2.4, 2.7 and 3.1, was approved and is effective through September 30, 1985.
FIGURE 1. RESEARCH TIMETABLE
III. RESEARCH PROGRAM PROGRESS AND DIRECTION

The research effort to date has been directed into two major blow-out prevention areas. The first area (Task 1) includes improved well control systems used for circulating out a kick under pressure. The second area (Task 2) includes improved diverter systems, which must be employed prior to setting sufficient casing to allow use of the high pressure well control system. A third area, dealing with improved kick detection systems, has also been initiated.

Organization of Research Effort

The research program has been organized under the direction of Dr. A. T. Bourgoine, Jr., who has overall supervisory responsibility for both phases of the project. Other co-principal investigators involved in the project include Dr. W. R. Holden, Dr. J. P. Langlinais, and Dr. W. R. Whitehead. In addition, Dr. R. S. Desbrandes, another senior faculty member with considerable expertise in the well control area, has become available for work on the project. Dr. Desbrandes is currently scheduled to do a portion of the work originally scheduled for Dr. A. T. Bourgoine, Jr.

The current organizational structure of the research project is shown in Figure 2. Engineering support is provided by James H. Sykora for assistance in designing, constructing, and carrying out all of the experimental research conducted at the research well facility. Dr. W. R. Holden has been supervising the experimental work aimed at the development of an improved well control system. Assisting him with this work is Don Remson, an M.S. student. All of the currently available automatic choke systems have been installed at the LSU research well
FIGURE 2. ORGANIZATIONAL STRUCTURE FOR CURRENT RESEARCH PROGRAM
facility and tested extensively for possible applications with M.W.D. technology. None of these currently available systems have proven to have the close tolerance control capabilities that are needed. The team is currently working on the development of a novel system which will have the required characteristics. The input/output sensors needed to measure and control the automated well control process are being developed and tested.

Mr. Vincente Casariego, a PhD student under the supervision of Dr. A. T. Bourgoyne, Jr. is working on computer models which will assist in the determination of data requirements for an overall well control strategy. Experimental work is also being done to assist in the development and verification of the computer model. Ultimately, the developed computer programs will permit an accurate prediction of the various well control parameters measured at the surface as a function of down hole kick conditions.

Dr. Eric Softley, of OEA, Inc. was subcontracted to perform a major portion of an evaluation of an electrical telemetry MWD process. This process was explored because of its potential for greatly increasing the rate of data transmission from the bottom of the hole to the surface. Tests of a scale model of the electrical telemetry MWD system have been completed, and this technique shows considerable promise. Work with Al Homes, of Harry Diamond laboratories, on a fluidic mud pulser is scheduled to begin soon.

The installation of a 10,000 ft. mud pulse flow loop at the LSU research well facility was completed in December. This installation will permit the study of any of the existing mud pulse data telemetry systems for safety related applications. Although considerable effort
is being expended in the development of mud pulse telemetry systems, these tools are being developed primarily for use in directional drilling applications, formation evaluation applications, and drilling optimization applications.

A major problem anticipated in the use of existing commercial mud pulse telemetry tools for well control applications are their low data transmission rates. The fluidic mud pulser developed by Al Holmes, under sponsorship of the MMS research program, shows promise of a significantly increased data transmission rate over the existing commercial tools. Evaluation of the Al Holmes device is being done as part of Subtask 1.2.2.

A review of existing diverter technology, including both equipment and procedures (Subtask 1) is was conducted by Mr. Mike Begland, an M.S. student, under the supervision of Dr. W. R. Whitehead. In addition, a study of diverter failures (Subtask 2.2) was also being undertaken. Mr. Steve Rohleder, also an M.S. student, is assisting in the diverter failure study and also working on a study of the erosion and plugging failure mechanisms applicable to diverter systems (Subtask 2.6 and 2.7). Mr. Rohleder is also working under the supervision of Dr. W. R. Whitehead. This group has been working closely with MMS personnel in Metairie, La., and with offshore well operators in obtaining the needed information.

The development of a computer model of the reservoir, wellbore, diverter system (Subtask 2.3) is being done by Mr. Gene Beck, a Ph.D. student, under the supervision of Dr. J. P. Langlinais. The computer model, in conjunction with the other diverter studies, will eventually permit the development of improved diverter design and procedures.
The initial diverter studies has permitted the design of an almost full scale experimental diverter model. Recent expansions of the research and training well facility, including the installation of a $97,000, 6-in. gas pipeline connecting a large gas transmission pipeline to the facility, has made practical the implementation of the diverter model design. Work on the model diverter system was began in late December and is now about 60 percent complete. It will be possible to study supersonic single and two phase flow conditions in the model diverter system.

Subtask 2.4 is the experimental verification of the computer model developed by Mr. Gene Beck and Dr. Langlainais in Subtask 2.3. The model diverter system will be utilized in this portion of the study. The model diverter system would employ diverter design concepts resulting from the diverter studies of Subtasks 2.1, 2.2, and 2.6. This model diverter system would be operated by utilizing the energy of stored compressed gas from the gas storage well. Two phase flow can be simulated by simultaneously displacing liquids from the buried drill pipe loop and gas from the storage well. By utilizing the total available volume from these high pressure systems, quite realistic diverter situations can be simulated. Also, the model diverter system is being constructed so that it could be easily modified to test different diverter arrangements and components. The model diverter system should also prove to be quite valuable in MMS mandated well control training activities.

Subtask 3.1 will involve the development and testing of improved methods for kick detection for floating drilling operations. Early detection is a key element in a successful well control program. Early
kick detection is much more difficult for floating drilling operations because of vessel movement. Work on this subtask is scheduled to begin early this summer.

**Plans for Phase III**

Because of anticipated budgetary constraints, plans for the next phase of the research have been separated into several options and assigned a priority. A base plan for continuing the top priority work at a reduced level of activity will be presented first. Additional research activities which are also highly desirable, but having a lower priority will be summarized in this proposal. A more detailed presentation will be given later in separate proposals.

Recent expansions of the research and training well facility has made possible more extensive research on diverter systems than was originally anticipated. These expansions have been made possible by (1) state funds provided as part of a university quality thrust program in the earth sciences and (2) by grants from industry. As a result, two high priority tasks have been added to the diverter study. These tasks include Task (2.8), the experimental evaluation of alternative diverter designs, and Task (2.9), the study of the marine risers as part of the diverter system. The need for the last task was brought to light by a recent accident in the Gulf of Mexico Region which cost the lives of three people. Task (2.5), the study of the possible use of an optimal backpressure in certain cases of diverter operation, is also included in the top priority category.

Work on Task 1, the development of improved well control systems through the use of MWD and process control technologies has been assigned the second highest priority. Subtask 1.3.2, the development of
the process control computer and computer logic, originally scheduled for the 1985-86 year is the most important aspect of this study. Extensions coming out of the work done in subtasks 1.2.1 on the evaluation of the electrical telemetry technique is given the third highest priority and potential additional work on the fluidic mud pulser is given the fourth highest priority.

It is recommended that implementation of subtasks (3.2) and (5.1) originally scheduled for 1985-86 be delayed. It is felt that subtask (3.2), on pore pressure determination and kick detection assisted by MWD Technology, would be premature, due to a longer period needed to complete the MWD evaluation work. Task (5), dealing with upward gas migration in directional boreholes, is now being addressed by the Drilling Engineering Association, Inc. for work at LSU. It now appears likely that this task will be performed at our research center with industrial funding.

The organizational structure needed for the top priority research tasks is shown in Fig. 3. Lower costs can be achieved only through a reduction in the size of the current research team. Thus, Dr. Holden, Dr. Desbranlde, and Dr. Whitehead are not included in the 1985-86 top priority plan. However, proposals will follow showing how they could be involved in a continuation of Task 1, should funding become available.
FIGURE 3. ORGANIZATIONAL STRUCTURE NEEDED FOR TOP PRIORITY RESEARCH AREAS, 1985-86
IV. BUDGET REQUIREMENTS FOR PHASE III

The budget requirements for the top priority portion of Phase III of the project are shown in Table 2. The total estimated cost for this work is $371,587.

An approximate breakdown of the cost of this work by task is given in Table 3.
### TABLE 2

**BUDGET FOR SUBTASKS**

2.5, 2.8, 2.9

( Extends project through September 30, 1986 )

1. **Direct Costs**
   
a. **Principal Investigators (LSU)**
   
   (1) Adam T. Bourgoyne, Jr., Ph.D., P.E.
   
   6 man-months
   
   $38,000
   
   (2) Julius P. Langliniais, Ph.D., P.E.
   
   4.3 man-months
   
   $18,000
   
   b. **Supporting Personnel - Faculty**
   
   (1) Jim Sykora, P.E.
   
   10 man-months
   
   $29,000
   
   (2) Allen Kelly, M.S., P.E.
   
   10 man-months
   
   $25,000
   
   c. **Supporting Personnel - Clerical**
   
   Mary Haynes
   
   2.0 woman-months
   
   $4,000

   **Faculty and Staff Subtotal**

   $114,000

   d. **Supporting Personnel - Graduate Students**
   
   (1) Ph.D. Candidates
   
   15.0 man-months
   
   $31,500
   
   (2) M.S. Students
   
   4.5 man-months
   
   $7,000

   **Graduate Student Subtotal**

   $38,500

   e. **Supporting Personnel - Undergraduate Students**

   4000 man-hours

   $18,000

   f. **Services**

   (1) Engineering Research Services

   (a) Machine Shop
   
   (70 hours)
   
   $1,000
   
   (b) Welding
   
   (400 hours)
   
   $6,000
PROFESSIONAL RESUME

Adam T. (Ted) Bourgoyne, Jr.
Professor and Chairman
Petroleum Engineering Department
Louisiana State University
Baton Rouge, Louisiana 70803
Office Phone: 504-388-5215

PERSONAL INFORMATION

Born: July 1, 1944, Baton Rouge, Louisiana
Married: Kathryn Daspit of Baton Rouge, La., January 22, 1966
Children: Two girls and four boys
Home Address: 6006 Boone Drive
Baton Rouge, Louisiana 70808
Home Phone: 504-766-7507

EDUCATION

B.S. in Petroleum Engineering, Cum Laude, 1966
Louisiana State University

M.S. in Petroleum Engineering, 1967
Louisiana State University

Ph.D. in Petroleum Engineering, 1969
University of Texas at Austin

PROFESSIONAL EXPERIENCE SUMMARY

Industrial Experience

1. Mobil Oil Company; Opelousas, Louisiana
   Summer, 1963
   
   Title: Roustabout
   Supervisor: Plant Foreman
   Duties: Maintenance of plant equipment of gas cycling operations
   in Opelousas field.

2. Mobil Oil Company; Cameron, Louisiana
   Summer, 1964
   
   Title: Offshore Roustabout
   Supervisor: Production Foreman
   Duties: Installation of automation equipment on offshore produc-
   tion platforms.
3. Mobil Oil Company; Morgan City, Louisiana  
   Summer, 1965
   
   Title: Assistant Production Engineer
   Supervisor: District Production Engineer
   Duties: Assisted with well workover planning and economic justification of well workovers.

4. Texaco, Inc.; Morgan City, Louisiana  
   Summer, 1966
   
   Title: Assistant Drilling Engineer
   Supervisor: District Drilling Engineer
   Duties: a) Assisted with well planning and cost estimates
           b) Designed jet bit hydraulics programs for ongoing drilling operations
           c) Assisted company representative in supervision of drilling operations

5. Chevron Oil Research Laboratory; LaHabra, California  
   Summer, 1967
   
   Title: Reservoir Engineer
   Supervisor: Reservoir Simulation Group Leader
   Duties: a) History Matching reservoir behavior using reservoir simulators (computer models)
           b) Developing new programs for interpreting drill stem test data and well interference test data

6. Continental Oil Research Laboratory; Ponca City, Oklahoma  
   Summer, 1968
   
   Title: Research Engineer
   Supervisor: Enhanced Oil Recovery Group Leader
   Duties: Experimental evaluation of a new surfactant system for enhanced oil recovery

7. Continental Oil Company; Houston, Texas  
   June, 1969 to December, 1970
   
   Title: Senior Systems Engineer
   Supervisor: Manager, Production Engineering Services Group
   Duties: Computer applications in drilling and production. Work included drilling data acquisition, abnormal pressure detection, optimization of drilling hydraulics, optimization of bit weight and rotary speed, design of flowline networks involving simultaneous flow of gas and liquids, and design of submersible electric pump installations.
8. Baroid Division of N.L. Industries, Inc.; Houston, Texas
   Summer, 1972
Title: Senior Research Engineer
Supervisor: Manager, Well Information Services and Engineering Group
Duties: Design of new computerized well monitoring unit for determining formation pressure while drilling

Academic Experience

1. University of Texas; Austin, Texas
   September, 1968 to May, 1969
Title: Teaching Assistant
Supervisor: Chairman, Petroleum Engineering Department
Duties: Teaching undergraduate petroleum engineering laboratory courses

2. Louisiana State University; Baton Rouge, Louisiana
   December 10, 1970 to present
Titles: Assistant Professor
December 10, 1970 to August 22, 1974
Associate Professor
August 22, 1974 to May 22, 1977
Associate Professor and Chairman
May 22, 1977 to August 15, 1979
Professor and Chairman
August 15, 1979 to May 31, 1983
Campanile Professor
June 1, 1983 - Present

Duties:

a) Undergraduate Courses Taught
1) CSC 1241, FORTRAN Programming
2) PetE 2020, Introduction to Petroleum Engineering
3) PetE 3031, Reservoir Fluid Flow
4) PetE 3032, Phase Behavior of Hydrocarbon Systems
5) PetE 3033, Petrophysics Laboratory
6) PetE 3034, Phase Behavior Laboratory
7) PetE 3990, Undergraduate Special Projects
8) PetE 3035, Economic Aspects of Petroleum Production
9) PetE 4045, Drilling Engineering
10) PetE 4046, Well Design - Production
11) PetE 4051, Reservoir Engineering
12) PetE 4086, Advanced Drilling Engineering
b) Graduate Courses Taught

1) PetE 7201, Advanced Reservoir Engineering
2) PetE 7241, Advanced Drilling Fluid Rheology
3) PetE 7242, Risk Analysis in the Petroleum Industry
4) PetE 7256, Special Problems in Petroleum Engineering
5) PetE 8000, Thesis Research

c) Extension Courses Taught


d) Short Course Taught

Have participated extensively since 1971 as instructor in Blowout Control Training Center. Have also participated in Well Completion Short Courses and Drilling Engineering Practicum.

e) Committees

1) Departmental Graduate Program Committee, 1976-68
2) Engineering Self-Study Committee, 1969-70
3) Engineering Policy Committee, 1976-77
4) Engineering Student Affairs Committee, 1970-77 (Chairman, 1976-77)
5) Engineering Committee on Faculty Evaluations
6) University Commencement Exercise Committee, 1974-77
7) LWRRI Advisory Board, 1977-present

f) Grants and Contracts


4) "Development of Improved Laboratory and Field Procedures for Determining the Carrying Capacity of Drilling Fluids," Milchem, Incorporated, $12,071.83, 1977-78.


g) Theses Directed


5) McKenzie, Michael F.: "Factors Affecting Surface Casing Pressure During Well Control Operations" (August, 1974).


9) Ofoh, Ebere Paulinus: "The Effect of Flood Rate on Displacement Efficiency When Using Oil Soluble Surface Active Agents to Enhance Oil Recovery" (May, 1978).


14) Redmann, Kerry P.: "Flow Characteristics of Commercially Available Drilling Chokes Used In Well Control Operations" (May, 1982).

PROFESSIONAL SOCIETIES AND ACTIVITIES

1. Registered Profession Engineer (Petroleum) in Louisiana, No. 15776

2. AIME-SPE (Presently charged with writing SPE sponsored textbook on drilling, also serving as Chairman of the Engineering Manpower Committee)

3. API (Presently serving on national committee concerning the determination of formation pore pressures and fracture gradients)

4. ABET (Presently serving on Education and Accreditation Committee and serving on adhoc visiting committee)

5. Minerals Management Service (Conducted Well Control Research Workshop to recommend long range research plan for research program of MMS, March 26, 1982)

HONORARY SOCIETIES AND AWARDS

1. Tau Beta Pi

2. Pi Epsilon Tau

3. SPE Distinguished Achievement Award for Petroleum Engineering Faculty, 1981

CONSULTING ACTIVITIES

1. Continental Oil Company, Drilling Data Acquisition Project, 1971

2. Mobil Oil company, Computer Assisted Design of Jet Bits, 1973


5. Grumman Houston Corporation, Automated Well Logging System Evaluation, 1977-78

7. Superior Oil Company, Drilling Cost Analysis, 1980-81

8. Wemco Division of Envirotec Corporation, Expert witness in Patent Infringement suit, 1982-83

PUBLICATIONS

a. Refereed Journal Articles:


b. Books and Chapters of Books:

2) Applied Drilling Engineering, A. T. Bourgoyne and F. S. Young, Society of Petroleum Engineers of AIME, Dallas, Texas 75206 (accepted for publication by SPE textbook committee).


c. Conference Proceedings:


6) "The Dynamics of Well Control," Proceedings of the Second Research and Development Conference for OCS Oil and Gas Operations; Reston, Virginia (April, 1980).


d. Trade Journal Articles:


4) "A New Approach to Overpressure Detection While Drilling," **Petroleum Engineer** (Sept., 1971).


e. Selected Reports


2) "A Critical Examination of the Graduate Program in Petroleum Engineering at Louisiana State University" (March, 1977).

3) "Department of Petroleum Engineering Five Year Plan" (Feb., 1978).

4) "Department of Petroleum Engineering, Five Year Plan 1982-87" (Sept. 1982).
PROFESSIONAL RESUME

Julius Patrick Langlinais
Assistant Professor
Petroleum Engineering Department
Louisiana State University
Baton Rouge, Louisiana 70803
Office Phone: 504-388-5215

PERSONAL INFORMATION

Born: September 5, 1945, New Iberia, Louisiana
Married: Betty Musumeche of New Iberia, La., November 26, 1966
Children: Two girls
Home Address: 968 Bromley Drive
            Baton Rouge, Louisiana 70808
Home Phone: 504-766-0203

EDUCATION

B.S. in Physics (With Distinction), 1967
University of Southwestern Louisiana

M.S. in Physics, 1970
Louisiana State University

Ph.D. in Physics, 1971
Louisiana State University

PROFESSIONAL EXPERIENCE

Industrial Experience

1. Construction Company, New Iberia, Louisiana
   Summer, 1963
   Title: Laborer
   Supervisor: Foreman
   Duties: Construction Labor

2. Central Louisiana Electric Company, New Iberia, Louisiana
   Summer, 1964 and Summer, 1966
   Title: Shop Helper
   Supervisor: District Engineer
   Duties: Transformer maintenance and repair

3. Grisby Brothers, New Iberia, Louisiana
   Summer, 1965
   Title: Offshore Roustabout
   Supervisor: Foreman
   Duties: Platform sandblasting and painting crew
4. E. I. DuPont Company, Aiken, South Carolina  
   Summer, 1967  
   Title: Summer Assistant  
   Supervisor: Director of Theoretical Physics Group  
   Duties: Computer applications in Nuclear Reactor loading

5. Continental Oil Company, New Orleans, Louisiana  
   Title: Production Engineer and Reservoir Engineer  
   Supervisor: District Engineer  
   Duties: Surface and subsurface aspects of offshore production  
   engineering, including compressor installation, gas lift  
   design, workover operations, and others. Reservoir  
   included economic appraisal, reservoir studies, open hole  
   logging and others.

6. Superior Oil Company, Lafayette, Louisiana  
   March, 1978 to August, 1980  
   Title: Production Engineer and Drilling Engineer  
   Supervisor: District Engineer  
   Duties: Production included various aspects of that area, spe-  
   cifically in inland waters and land operations. Drilling  
   included cost estimates, well design, pressure detection  
   and general activities of that area.

Academic Experience

1. University of Southwestern Louisiana, Lafayette, Louisiana  
   January, 1966 to May, 1967  
   Title: Laboratory Instructor  
   Supervisor: Chairman, Physics Department  
   Duties: Teaching undergraduate Physics labs

2. Louisiana State University, Baton Rouge, Louisiana  
   September, 1967 to May, 1968  
   Title: Teaching Assistant  
   Supervisor: Chairman, Physics Department  
   Duties: Teaching senior-level Modern Physics Laboratory

3. Louisiana State University, Baton Rouge, Louisiana  
   June, 1968 to August, 1971  
   Title: NDEA Fellowship Recipient  
   Supervisor: Chairman, Physics Department  
   Duties: Research fellowship culminating in Ph.D. degree
4. University of Tampa, Tampa, Florida
   September, 1971 to May, 1975

   Title: Assistant and Associate Professor of Physics and Mathematics
   Supervisor: Dean of the Faculty
   Duties: Teach courses in undergraduate Mathematics (Calculus, Complex Variables, Computer programming) and Physics (Introductory Physics, Optics, Electronics).

5. Louisiana State University, Baton Rouge, Louisiana
   August, 1980 to present

   Title: Assistant Professor
   Supervisor: Chairman, Petroleum Engineering Department

   Duties:

   a) Undergraduate Courses Taught

      1) PetE 3035, Economic Aspects of Petroleum Production
      2) PetE 3033, Petrophysics Laboratory
      3) PetE 3031, Petrophysics
      4) PetE 4045, Drilling
      5) PetE 4046, Well Design-Production

   b) Graduate Courses Taught

      1) PetE 7242, Selected Topics in Production Engineering

   c) Extension Courses Taught

      1) PetE 3035, Economic Aspects of Petroleum Production USGS, Metairie, Louisiana - 1980

   d) Short Courses Taught

      Have been involved as instructor in Blowout Control Training Center since Spring, 1981.

   e) Committees

      1) College of Engineering Scholarship Committee
      2) Organization Relief Fund (Student Affairs) Committee

   f) Grants and Contracts

      1) "Waste Disposal Well Integrity Testing and Formation Pressure Build-up Study," Louisiana Department of Natural Resources, $30,587.00, 1981.
g) Thesis Directed


2) Elfaghi, Fawzi A.: "Pressure Losses in Subsea Choke Lines During Well Control Operations" (May, 1982).


PROFESSIONAL SOCIETIES AND ACTIVITIES

1. Registered Professional Engineer (Petroleum) in Louisiana, No. 17000

2. AIME - Society of Petroleum Engineers

3. Sigma Pi Sigma (Physcis)

4. Kappa Mu Epsilon (Math)

5. Phi Kappa Phi

CONSULTING ACTIVITIES

1. Superior Oil Company, Drilling Cost Analysis, 1980 to present

2. Louisiana Department of Natural Resources, 1981 to present

PUBLICATIONS

a. Refereed Journal Articles


b. Trade Journal Articles


c. Reports


d. Conferences

Priority Two

BUDGET PLANNING UPDATE

for

MMS Contract 14-08-001-21169, Mod. 3
(LSU Project No. 127-45-5115)

on

THE DEVELOPMENT OF
IMPROVED BLOWOUT PREVENTION SYSTEMS
FOR OFFSHORE DRILLING OPERATIONS

Submitted to
The Minerals Management Service
United States Department of the Interior
Reston, Virginia

by
Petroleum Engineering Department
Louisiana State University

February, 1985
Priority Two

BUDGET PLANNING UPDATE

for

MMS Contract 14-08-001-21169, Mod. 3
(LSU Project No. 127-45-5115)

on

THE DEVELOPMENT OF
IMPROVED BLOWOUT PREVENTION SYSTEMS
FOR OFFSHORE DRILLING OPERATIONS

Submitted to
The Minerals Management Service
United States Department of the Interior
Reston, Virginia

by

Adam T. Bourgoyne, Jr.
Principal Investigator

William R. Holden
Co-Principal Investigator

Robert Desbranides
Co-Principal Investigator

Board of Supervisors
of
LOUISIANA STATE UNIVERSITY
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</tr>
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<td>4</td>
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<td>34</td>
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</tbody>
</table>
I. INTRODUCTION

The Petroleum Engineering department at LSU has played an active role over the past decade in well control research and in training of industry personnel in present-day methods of well control. With the help of both industry and government modern training and research facilities centered around two 6000 ft wells were equipped to model well control operations conducted both in the shallow water marine environment of the continental slope and in deepwater offshore operations. A three million dollar expansion of this facility was recently achieved through the combined support of a consortium of 60 companies in the petroleum industry and through a research grant funded by the U. S. Minerals Management Service (MMS).

On March 24, 1982, a workshop was conducted at LSU to assist in the formulation of a long range plan for future well control research. The participants included (1) members of the industry advisory panel to the LSU Blowout Prevention Research Center (2) researchers currently being supported by MMS, and (3) representatives of various MMS districts. Twenty-one desirable projects were identified by this group. The top ten projects are listed in Table 1 along with a composite priority level assigned by the workshop panel.

A five year research plan was made in a proposal to MMS for developing improved well control systems for deep water offshore drilling operations. The proposed five year plan incorporates many of the high priority items identified at the LSU Well Control Workshop. In October, 1983, MMS Contract No. 14-12-001-21169, Mod. 2 was issued for LSU to
<table>
<thead>
<tr>
<th>Priority Level</th>
<th>Research Area</th>
<th>Votes Received Assuming Funding For Following number of projects:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>One, Two, Three, Four, or Five</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Feasibility Study on Use of MWD Technology in Well Control Operations on Floating Vessels</td>
<td>6, 9, 9, 19, 11</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Study of Well Control Operations with Simultaneous Formation Fracture</td>
<td>3, 10, 12, 16, 17</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Well Control Operations for Short Casing Strings (Diverter Systems)</td>
<td>3, 5, 8, 12, 14</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Improved Procedures for Handling Upward Gas Migration during stripping or Snubbing Operations</td>
<td>1, 3, 5, 5, 8</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Improved System for Detecting Gas in Mud at Depth (as opposed to present surface detectors)</td>
<td>2, 3, 5, 5, 7</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Study of Upward Gas Migration in Slant (Directional) Boreholes</td>
<td>1, 2, 3, 5, 7</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Scale-up of Fluidic Pulse Telemetry System to longer systems with varying mud properties</td>
<td>0, 1, 3, 4, 5</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Determination of Minimum Number of Requisite Parameters via MWD for safe drilling operations</td>
<td>1, 1, 1, 3, 5</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Scale-up on Ongoing Fire Suppression System Development for Offshore Drilling</td>
<td>2, 3, 3, 4, 4</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Study of Potential Problems due to Gas Hydrate Formation in Subsea Well Control Equipment in Deep Water</td>
<td>0, 3, 4, 4, 4</td>
<td></td>
</tr>
</tbody>
</table>
begin work on the first year of the five year plan. In October, 1984, the second year of the proposed plan was funded. Because of anticipated budgetary problems in continuing all aspects of the research program, the request for next years funds has been broken into various subcategories according to a recommended priority system. In early January, 1985 a priority one budget planning update was submitted. In this previously submitted document, the progress which has been made was summarized, and a budget update is provided for maintaining only the top priority research tasks of the project through the third year. Now in this proposals, the funding requirements needed to continue the other portions of the project are presented. These tasks are viewed as highly desirable and show good promise for success, but have a slightly lower priority than the items addressed in the previous proposal. Also the cost figures are incremental costs derived assuming that the previously submitted top priority items are funded. The work proposed here could not be done at the cost level given for stand-alone projects.
II. GENERAL RESEARCH PROGRAM OBJECTIVES AND TIMETABLE

The primary objective of the research project is to increase the efficiency and safety of offshore drilling operations. This would be accomplished through the development of improved blowout prevention systems. The two main systems included in the study are (1) the high pressure emergency circulating system and choke used to circulate formation fluids from a well under pressure, and (2) the diverter system which must be employed prior to setting sufficient casing to allow use of the high pressure system. Additional objectives deal with improved kick detection systems and complications that can develop as a result of formation fracture, directional drilling operations, or off-bottom kicks.

The overall research plan can be divided into six overall tasks. Several of these tasks can be subdivided into a number of subtasks. These tasks and subtasks are:

<table>
<thead>
<tr>
<th>Task</th>
<th>Subtask</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.1</td>
<td>Development of an improved blowout prevention system through the integration of measurements while drilling (MWD) and well control technologies.</td>
</tr>
<tr>
<td></td>
<td>1.1.1</td>
<td>Determine the data requirements (parameters and speed of transmission) for automated well control system.</td>
</tr>
<tr>
<td></td>
<td>1.1.2</td>
<td>Experimental study, (without secondary kicks) of parameters needed, time urgency, accuracy requirements, redundancy requirements, and trade offs.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Determination of additional data requirements for overall well control strategy including surface data.</td>
</tr>
<tr>
<td>Task</td>
<td>Subtask</td>
<td>Description</td>
</tr>
<tr>
<td>------</td>
<td>---------</td>
<td>-------------</td>
</tr>
<tr>
<td>1.2</td>
<td>Selection of MWD System compatible with well control application.</td>
<td></td>
</tr>
<tr>
<td>1.2.1</td>
<td>Evaluate electrical telemetry technique as high data rate alternative to conventional mud pulse telemetry.</td>
<td></td>
</tr>
<tr>
<td>1.2.2</td>
<td>Select best available MWD approach.</td>
<td></td>
</tr>
<tr>
<td>1.2.3</td>
<td>Extended Study of MWD Techniques.</td>
<td></td>
</tr>
<tr>
<td>1.3</td>
<td>Engineering development of improved Blow-out Prevention System.</td>
<td></td>
</tr>
<tr>
<td>1.3.1</td>
<td>Define and develop appropriate new hardware for control of system.</td>
<td></td>
</tr>
<tr>
<td>1.3.2</td>
<td>Develop Process Control Computer and computer logic.</td>
<td></td>
</tr>
<tr>
<td>1.3.3</td>
<td>Integrate Process Control Computer into Well Control System.</td>
<td></td>
</tr>
<tr>
<td>1.3.4</td>
<td>Experimental verification of Process Control Computer logic with risk of secondary kicks included in experimental programs.</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Development of improved Diverter System for offshore operations.</td>
<td></td>
</tr>
<tr>
<td>2.1</td>
<td>Review of available technology and current field practices on design and use of diverters on offshore drilling rigs.</td>
<td></td>
</tr>
<tr>
<td>2.2</td>
<td>Review failures and cause of failures that have occurred in offshore diverter systems.</td>
<td></td>
</tr>
<tr>
<td>2.3</td>
<td>Use of systems analysis approach to develop computer model of reservoir/well/diverter system.</td>
<td></td>
</tr>
<tr>
<td>2.4</td>
<td>Experimental verification of computer model with scaled model of diverter system.</td>
<td></td>
</tr>
<tr>
<td>2.5</td>
<td>Computer study of feasibility of maintaining an optimal backpressure during operation of diverter system.</td>
<td></td>
</tr>
<tr>
<td>2.6</td>
<td>Literature and experimental study of erosion reduction techniques in diverter system (including bends).</td>
<td></td>
</tr>
<tr>
<td>Task</td>
<td>Subtask</td>
<td>Description</td>
</tr>
<tr>
<td>------</td>
<td>---------</td>
<td>-------------</td>
</tr>
<tr>
<td>2.7</td>
<td></td>
<td>Experimental and computer study of diverter plugging by produced solids.</td>
</tr>
<tr>
<td>2.8</td>
<td></td>
<td>Experimental evaluation of alternative diverter designs.</td>
</tr>
<tr>
<td>2.9</td>
<td></td>
<td>Study of marine riser as part of diverter system.</td>
</tr>
<tr>
<td>2.10</td>
<td></td>
<td>Design of improved diverter systems for bottom supported rigs and floating drilling vessels.</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>Development of improved system for kick detection for floating drilling vessels.</td>
</tr>
<tr>
<td>3.1</td>
<td></td>
<td>Improved surface and near surface kick detection system for floating drilling operation.</td>
</tr>
<tr>
<td>3.2</td>
<td></td>
<td>Pore pressure determination and kick detection assisted by MWD technology.</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>Study of well control with simultaneous formation fracture.</td>
</tr>
<tr>
<td>4.1</td>
<td></td>
<td>Development of computer model.</td>
</tr>
<tr>
<td>4.2</td>
<td></td>
<td>Experimental verification of computer model.</td>
</tr>
<tr>
<td>4.3</td>
<td></td>
<td>Computer study to identify cases where well control with simultaneous formation fracture are feasible or even beneficial.</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td>Study of upward gas migration in slant (directional) boreholes.</td>
</tr>
<tr>
<td>5.1</td>
<td></td>
<td>Experimental study.</td>
</tr>
<tr>
<td>5.2</td>
<td></td>
<td>Development of computer model.</td>
</tr>
<tr>
<td>6</td>
<td></td>
<td>Development of improved blowout prevention system for off-bottom kicks.</td>
</tr>
<tr>
<td>6.1</td>
<td></td>
<td>Development of computer model.</td>
</tr>
<tr>
<td>6.2</td>
<td></td>
<td>Use of computer model to develop improved technique for handling upward gas migration during stripping operations.</td>
</tr>
<tr>
<td>6.3</td>
<td></td>
<td>Use of computer model to evaluate multi-stage off-bottom kill procedure.</td>
</tr>
</tbody>
</table>
An updated timetable for accomplishing the general research program is shown in Figure 1. The current year funding (1984-85), for subtasks 1.2.2, 1.3.1, and 2.4, 2.7 and 3.1, was approved and is effective through September 30, 1985.
FIGURE 1. RESEARCH TIMETABLE
III. PROPOSED PROJECTS

The research effort to date has been directed into two major blow-out prevention areas. The first area (Task 1) includes improved well control systems used for circulating out a kick under pressure. The second area (Task 2) includes improved diverter systems, which must be employed prior to setting sufficient casing to allow use of the high pressure well control system. A third area, dealing with improved kick detection systems, has also been initiated.

Plans for Phase III

Because of anticipated budgetary constraints, plans for the next phase of the research have been separated into several options and assigned a priority. A base plan for continuing the top priority work at a reduced level of activity has already been presented. Additional research activities which are also highly desirable, but having a lower priority will be presented in this proposal.

Work on Task 1, the development of improved well control systems through the use of MWD and process control technologies has been assigned the second highest priority. Subtask 1.3.2, the development of the process control computer and computer logic, originally scheduled for the 1985-86 year is the most important aspect of this study. Subtask 1.2.3 includes additional work extending the work done in subtasks 1.2.1 on the evaluation of the electrical telemetry technique and additional work on the fluidic mud pulser. This subtasks is given the third highest priority.

The organizational structure needed for adding subtask 1.3.2 and subtask 1.2.3 to the top priority research tasks is shown in Fig. 3.
FIGURE 2. ORGANIZATIONAL STRUCTURE NEEDED FOR ALL RESEARCH AREAS, 1985–86
The equipment needed to evaluate different process control algorithms under varying well control conditions will be in place by the end of this fiscal year. In subtask 1.3.2, Dr. Holden would supervise the evaluation of different process control algorithms for reducing the pressure fluxuations experienced when circulating out a kick. This would be done by placing gas kicks in the LSU B-7 research well, and then pumping out the kick under computer control while monitoring pressures at several points in the system. It is envisioned that many experiments would be necessary to perfect the process control algorithms needed for the various choke designs. Preliminary work indicates that the different choke designs will require different control techniques. Once successfully completed, the choke operator would have a much greater chance of pumping out a kick successfully in one circulation with a reduced risk of fracturing a subsurface strata and causing an underground blowout.

Subtask 1.2.3, would be a continuation of the development of the use of MWD technology for safety related applications. This work would be done under the supervision of Dr. Desbrandes. A portion of the work would be subcontracted to OEA, Inc. as proposed in Appendix B. This subcontract work would be a continuation of subcontract work started by Dr. Softley of OEA, Inc., in 1983, based on several novel ideas which he had proposed. Dr. Softley would focus his efforts on developing an electronics and computer package for installation at LSU where the experiments would be performed. Dr. Desbrandes would also oversee these experiments as well as begin work on the problems associated with insulating the drill string.
IV. BUDGET REQUIREMENTS FOR PHASE III

The budget requirements for the second and third priority items of Phase III of the project are shown in Table 2 and Table 3. The total estimated cost for this work is $188,918.
<table>
<thead>
<tr>
<th>1. Direct Costs</th>
<th></th>
<th>18,000</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Principal Investigators</td>
<td>William R. Holden</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3 man-months</td>
<td></td>
</tr>
<tr>
<td>b. Supporting Personnel</td>
<td>M.S. Student</td>
<td>7,000</td>
</tr>
<tr>
<td></td>
<td>4.5 man months</td>
<td></td>
</tr>
<tr>
<td>c. Supplies</td>
<td>Misc. Computer Electronics</td>
<td>3,000</td>
</tr>
</tbody>
</table>

| 2. Fringe Benefits                  | (18% of Faculty and Staff Subtotal)  | 3,240  |
|                                      |                                      |        |
| 3. Indirect Costs                   | MTDC, 31,240                         | 12,184 |
|                                      | (39% of MTDC)                        |        |
| 4. Tuition Remission                | (17% of Graduate Student Subtotal)   | 1,190  |
|                                      |                                      |        |
| Total                               |                                      | $44,614|
### TABLE 3

**BUDGET FOR SUBTASK 1.2.3**

*(Priority 3)*

1. **Direct Costs**
   a. **Principal Investigators**
      Robert Desbrandes
      3.2 man months  
      $20,000
   b. **Supporting Personnel**
      M.S. Student
      4.5 man months  
      $7,000
   c. **Supplies and Services**
      (1) 4-Joints Drill-Pipe
      N/C
      (2) Internal Coating of Drill-Pipe
      $10,000
      (3) Tool Joint Modifications
      $8,000
      (4) Misc.
      $4,000
      **Subtotal** $22,000

2. **Fringe Benefits**
   *(18% of Faculty and Staff Subtotal)*  
   $3,600

3. **Indirect Costs**
   MTDC, 52,600
   *(39% of MTDC)*  
   $20,514

4. **Tuition Remission**
   *(17% of Graduate Student Subtotal)*  
   $1,190
   **Subtotal** $74,304

5. **Continuation of Subcontract to OEA, Inc.**
   *(1,2)*  
   $70,000
   **Total** $144,304

---

1 Continuation subcontract to OEA documented in Appendix B.

2 Indirect Costs for OEA subcontract charged in previous year.
APPENDIX A

Resume's of Key Personnel
PROFESSIONAL RESUME

William R. Holden
Professor
Petroleum Engineering Department
Louisiana State University
Baton Rouge, Louisiana 70803
Office Phone: 504-388-5215

PERSONAL INFORMATION

Born: December 20, 1928, Fort Worth, Texas
Married: Barbara Ann Babin, 1957
Children: Two daughters
Home Address: 2066 Columbine
            Baton Rouge, Louisiana 70808
Home Phone: 504-766-2515

EDUCATION

B.S. Engineering Physics, 1953
University of Oklahoma

M.S. Engineering Physics, 1957
University of Oklahoma

Ph.D. Petroleum Engineering, 1969
University of Texas

PROFESSIONAL EXPERIENCE-SUMMARY

Industrial Experience

Related Experience


   Invited guest lecturer at Research and Development Center of Petrobras, Rio de Janeiro, Brazil.

3. 1973 - Special lecturer in Reservoir Engineering School for Texaco, Inc.

4. 1969 and 1970 - Special lecturer in Reservoir Engineering School for Mobil Oil Company.

6. Summers


2) 1957 - Drilling Engineer, The California Co., Venice, Louisiana.

3) 1956 - Production Engineer, The California Co., Brookhaven, Mississippi.


5) 1952 - Engineering Aid, GS-4, Development and Proof Services Branch, Aberdeen Proving Grounds, Maryland.

Academic Experience

1. Louisiana State University, Baton Rouge, Louisiana
   September 13, 1955 to present

   Titles: Assistant Professor
           September 13, 1955 to September 11, 1963

           Associate Professor
           September 12, 1963 to August 22, 1973

           Professor
           August 23, 1973 to present

   Duties:

   a) Undergraduate Courses Taught

      1) ENGR 2060, FORTRAN programming
      2) PetE 3031, Petrophysics
      3) PetE 3032, Phase Behavior of Hydrocarbon Systems
      4) Gas Production Measurement and Transmission
      5) PetE 3033, Petrophysics Laboratory
      6) PetE 3036, Introductory Well Logging
      7) PetE 4045, Drilling Engineering
      8) PetE 4046, Well Design - Production
      9) PetE 4051, Reservoir Engineering
     10) PetE 4052, Reservoir Engineering
     11) PetE 4085, Production Engineering
     12) PetE 4088, Well Logging

   b) Graduate Courses Taught

      1) Experimental Studies of Non-Newtonian Fluids
      2) PetE 7201, Advanced Reservoir Engineering
      3) PetE 7280, Mathematical Simulation of Petroleum Reservoir Performance
c) Extension Courses Taught

1) A 15-week evening course in Reservoir Engineering at LSU Shreveport at request of Lou-Ark Section, Society of Petroleum Engineers of AIME - 1967.

2) A 15-week evening course in Reservoir Engineering at LSU Medical School, New Orleans, at request of Delta Section, Society of Petroleum Engineers of AIME - 1971.

d) Short Courses Taught

Special Instructor in International Association of Drilling Contractors Blowout Training School since 1973.

Special Instructor in LSU Advanced Well Control School for Deepwater Floating Drilling Operations since Oct., 1981.

e) Committees

1) General Editorial Committee, SPE of AIME (1967-1968)
2) Education and Professionalism Committee, Fall Meeting SPE 1970
3) E & A Standing Committee of SPE (1974-1978)
4) Faculty Advisor to LSU Student Chapter SPE (1968-1977)
5) Member of Committee to prepare three years of examinations for professional licensing of Petroleum Engineers for NCEE-1972
6) Advisory Committee, Division of Continuing Education (past)
7) Freshman Counseling (past)
8) Faculty Policy Committee (past)
10) Student Affairs Committee (past)
11) Computer-Oriented Academic Program (past)
12) Admission, Standards and Honors (past)
13) Senior Academic Advisor, Petroleum Engr. Dept.
15) Graduate Program Committee, Petroleum Engr. Dept.
16) Annual High School Seminar (since 1969)
17) COE Ad-Hoc Faculty Promotion and Tenure Review Committee (AY 1979-80 through AY 1981-82)
18) Departmental Promotions and Tenure Committee, 1979 to present (Chairman since 1980)
19) Search Committee for LSU Foundation Chaired Professorship in Petroleum Engineering
20) COE Task Force on Microcomputers (since August 1983)

f) Grants and Contracts

Principal Investigator, Louisiana Water Resources Research Institute Projects:


5) Co-Investigator with A. T. Bourgoyne and J. P. Langlinais, unsolicited research grant from Minerals Management Service of U.S. Dept. of Interior" The Development of Improved Blowout Prevention Systems for Offshore Drilling Operations," $1,862,000 (5-yr. program).


g) Theses Directed


8) Bender, Catherine Vosin: "Pressure Gradient Reversals in Shut-in Wells" (August 1980).

PROFESSIONAL SOCIETIES AND ACTIVITIES

1. Registered Professional Engineer in Louisiana - No. 9085
2. Society of Professional Well Log Analysts - No. 704
3. Society of Petroleum Engineers of AIME - No. 07796
4. Tau Beta Pi (Engr.)
5. Sigma Tau (Engr.)
6. Pi Epsilon Tau (Petr. Engr.)
7. Sigma Pi Sigma (Physics)
8. Pi Mu Epsilon (Math)
9. Sigma Xi (Physics)
10. B.S. Degree with Distinction (University of Oklahoma, 1953)
11. National Science Foundation, Faculty Fellowship (June 64-Nov. 65)
12. Pan American Oil Company Fellowship (Sept. 65-Aug. 66)
13. Continental Oil Company Scholarship (Sept. 66-Dec. 66)
15. LSU College of Engineering Outstanding Faculty Recognition (1963 and 1968)
16. Lafayette Society of LSU Petroleum Engineers Outstanding Faculty Member Award (1982)

CONSULTING ACTIVITIES

5. Mrs. G. S. Dickerson - Technical Expert: Civil action over plant accident with salt cavern storage of LPG.
7. Mr. Munsel M. Mayeus - Mathematical simulation of LPG flow in pipelines to include phase changes (flashing flow).

PUBLICATIONS


PROFESSIONAL RESUME

Robert DESBRANDES
Professor
Department of Petroleum Engineering
Louisiana State University
Baton Rouge, LA. 70803
Phone: 504 - 388-5215

PERSONAL INFORMATION

Date of Birth          September 25, 1924
Nationality           French
Marital Status        Married, three children (28, 25 and 23)
Home Address          2100 College Dr. #194
                      Baton Rouge, La. 70808
Home Phone            504 - 928-4622
Foreign Languages     English (fluent spoken and written)
                      Spanish (spoken and written)
                      German (7 years of classes)
                      Russian (1 year of classes)
                      Chinese (1 year of classes)

EDUCATION

Ecole Nationale Superieure d'Arts et Metiers, Cluny, 1944 Silver Medal
Ph.D. in Spectromony, Faculty of Science, University of Lyon, France, 1965.

MILITARY SERVICE

1967                  Received commission
1956                  Promoted to Lieutenant of the reserves
1946                  Officer of reserves at Equipment Applications
                      School in Bourges, France
1945                  Fought on the Atlantic front (La Rochelle)
1944                  Enlisted in French Home Forces

PROFESSIONAL EXPERIENCE

1984-                  Professor
                      Louisiana State University
Teaching assignment:

PETE 3036 (1)

PETE 3036 (2) Introductory to Well Logging

Research assignment:

Head of Well Logging Research and teaching facilities

1982-1984

Visiting Professor at the University of Houston, Department of Electrical Engineering

Teaching assignment:

ELEE 5340: Introduction to well Logging

ELEE 7397: Well Log Interpretation

ELEE 6111: Advanced Well Logging Seminar

Research assignment:

Participation in the Well Logging Laboratory work

1966-1981

Lecturer of well logging at Ecole Nationale Superieure du Petrole et des Moteurs, France

Teaching of borehole measuring methods and their interpretation.

In charge of training:

10 to 15 economists
20 to 30 geologists-geophysicists
20 to 30 drilling-production engineers
3 to 4 foreign trainees per year

Leading contributions:

Two text books published in 1968 and 1981
Exercise book in 1970
Simplified book in 1970

1960-1966

Head of Direct Prospection Project at the French Petroleum Institute, France

Fundamental research on direct prospection

Responsibility for two research scientists and two technicians

Contact with two university laboratories

In 1960, appointed Senior Research Scientist
1958-1960
Head of Mud-Logging Laboratory at the French Petroleum Institute, France
Measurements of parameters during drilling
Directly responsible for:
3 well-logging teams
2 scientists and 2 technicians
development of new equipment

1952-1958
Research Scientist with Schlumberger South America Corporation in Houston, Texas
Designing and building new well-logging equipment
Chief of Formation Tester project
Project led to commercial success

1947-1952
Field Engineer with Schlumberger Well Surveying Corporation
Successively:
Field Engineer in Trinidad, Columbia
Chief of Center in Colombia
Chief of Division in Venezuela

1946-1947
Engineer with Etablissements SADER
Miscellaneous construction jobs

PUBLICATIONS

Articles
37 articles in different magazines in the field of borehole geophysics, physics of solids and fundamental physics

Books
Five books on borehole geophysics

Patents
Several patents taken out in France and/or abroad

REFERENCES
Attached.
LIST OF TEXTBOOKS
Authored or Co-Authored by
Dr. Robert DESBRANDES


7. **Ge li liu he jie shi**, Desbrandes R., In print, Petroleum Exploration and Exploitation Research Institute Peking, China Chinese translation and adaptation of "Theory and Interpretation of Well Logs".


LIST OF PUBLICATIONS
Authored or Co-Authored by
Dr. Robert DESBRANDES


LIST OF PATENTS
Dr. Robert DESBRANDES


2. "Short Duration Pulse Energy Measuring Device Using a Gas Tube Whose Degree of Ionization is Varied by the Pulse Itself" U.S. no 3.173.090 (March 1965), France no 1.313.726, W. Germany 1 261.598, Austria 22 750, Canada 714 719, Brazil 71 710, (Nov. 1962).


ELECTRICAL TELEMETRY IN THE MUD IN A DRILL PIPE WHILE DRILLING

Dr. Eric J. Softley 12/21/84

OCEAN ELECTRONIC APPLICATIONS INC.
ELECTRICAL TELEMETRY IN THE MUD IN A DRILL PIPE

WHILE DRILLING

Subcontract Proposal To

Louisiana State University
Petroleum Research Institute
Baton Rouge, LA

By
Dr. Eric J. Softley
Ocean Electronic Applications
50 West Mashta Drive
Key Biscayne
FL, 33149

21 December 84
1. Introduction

The need for data telemetry during drilling has been recognized for some time. The availability of data at the surface allows for rapid monitoring of the drilling process and more importantly provides valuable information before a kick takes place and during subsequent shut-in and circulation of the kick.

Most of the work on MWD to date has concentrated on pressure pulse or continuous wave pressure telemetry systems. These have provided valuable support for the drilling process. The pressure telemetry systems, however, have some significant drawbacks. First attenuation of the signal increases rapidly with increasing acoustic frequency. As a result the inherent data rate is essentially limited to a few baud and this in turn provides quite slow effective information rates. Secondly the signal attenuation increases with increasing mud weight. Therefore if the mud weight is increased, a typical action which can follow taking a kick, the telemetry is likely to be lost at a very critical time.

To understand the data rate requirement it is important to consider the overall system requirements. For a MWD system to be practical in both engineering and financial terms the system should provide sufficient information for drilling efficiency and safety considerations. To that end it should provide information usually provided by well logging as well as bore hole pressures, drill angle and direction. Hence a typical system might provide the following:

- Bore hole pressure (2 values)
- Bore hole Deviation
- Bore hole azimuth
- Tool face gravity angle
- Tool face magnetic angle
- Downhole weight on bit
- Annulus temperatures
- Formation resistivity
- Formation radioactivity
- Downhole sonic velocity

If this information is available on a continuous and reasonably rapid basis then three information needs can be at least partially satisfied. Drilling efficiency can be monitored and controlled. Secondly the last four data items above can be combined to give an early indication of gas influx into the
return mud. Thirdly if the well is shut in and the kick circulated out the direct measurement of bore hole pressure provides valuable control information during this process.

In summary a set of typical data requirements can be estimated. The data can be organized into frames of words and a single frame would be logically about 16 words in length with each word 16 bits in length. Overhead might add about 50% to grow in size and complexity so that data frames of length 600 bits are not unreasonable.

If the data is sent in complete form a data rate of 1/2 baud would require 20 minutes to transmit a complete set. Since acoustic telemetry, either pulse or continuous wave, has data rates of this order it is necessary to limit the data transmitted to a few parameters at any one time. This does not satisfy the overall requirement of providing information for all three functions.

If a data rate of 300 baud were possible then it would take 2 seconds for each complete frame of data. Three such frames would take 6 seconds and allow demonstration and self checking for data consistency. Using the four indicated parameters for kick detection it would then be possible to identify a kick in about 10 seconds. This response is adequate to warn the drill operators and to allow human intervention.

Thus for a system which can satisfy multiple functions for drilling efficiency and safety the acoustic telemetry does not provide a sufficiently fast response. As a result the acoustic telemetry now in use must still be supported by conventional wire logging. Also early kick detection is really not feasible.

A more promising approach to obtaining higher data rates has recently been examined by the author in conjunction with work at the Petroleum Research Institute at Louisiana State University. The concept involves using electrical propagation in the mud if the mud is insulated from the drill pipe.

The system in simplified form is shown in figure 1. Some form of insulation is placed on the inside surface of the drill pipe. This insulation is assumed to extend from a short distance above the drill bit to the top of the Kelly. At a distance above the insulation lower limit a transmitter is installed with electrodes contacting the mud. Similar receive electrodes are located at the lower end of the Kelly. The electrical signal passes through the mud from the transmitter to the receiver.

In the system the drill bit and the swivel assembly above the Kelly are both considered as uninsulated. Also the drill pipe insulation is also considered imperfect.
It is possible to make some statements about the system.

1. The signal will attenuate due to the electrical resistance of the mud in conjunction with capacitive loading from the finite insulation thickness and resistive loading from insulation leaks.

2. The transmitter will be loaded by the electrical path to the drill bit or to where the drill pipe or collars are no longer insulated.

3. The receiver electrode impedance will depend in part on the electrical path to the swivel assembly.

The design of such a system will involve engineering effort for the transmitter design and packaging, design for the receiver and the electrodes, and design and development of a suitable insulation technique. Before this activity was initiated it was felt that examination of the physical processes was important so that the signal attenuation, electrical noise, the effect of insulation thickness and leakage could be reliably estimated. A feasibility study has been performed for this purpose. This feasibility study allowed the development of a computer model to calculate signal strengths and a small scale telemetry experiment to evaluate the model and to determine the effects of insulation leakage, changing mud parameters, etc. on the telemetry.
2. Results of Work To Date – Propagation Study

A typical field application might have the following parameters.

Pipe - 4 1/2 inch 3.8 inch inside dia.
Length 20,000 feet.

For the electrical propagation in such a pipe (when insulated) a simple electrical model can be devised. This is shown in figure 2. The resistive elements refer to the mud resistance per unit length and the capacitance is the shunt capacitance between the inner conductor, the mud, and the outer conductor, the pipe.

To calculate the attenuation these values must be known. The mud electrical conductivity can be measured using a test cell. A typical sample of mud is placed in a tube and using two outer electrodes a current is induced in the mud. The voltage across a sample is then measured using two inner electrodes. A variation of this approach is used in the mud probe shown in figure 3. The circuit shown uses a ten turn calibrated potentiometer to balance a bridge such that if the bridge is in balance the resistance of the potentiometer is equal to the resistance of the mud sample.

Using both this probe and a test cell samples of field muds were evaluated for their specific resistivity. Table 1 shows the results. For the field muds tested the specific resistivity varied from 0.5 to 2.2 ohms/meter/sq.meter in most cases with oil based muds having much higher values > 13.

The capacitance of the system can be calculated from the known geometry for different insulating materials. Material variations are not very large but the insulation thickness does strongly influence the values. Insulation thicknesses of 1/16 to 1/8 inch were calculated.

It became apparent during some early experiments that the simple model shown is not adequate. The problem lies in the electrical connection between the electrodes and the mud. If the mud is stationary (with respect to the electrode) the impedance of the electrode is relatively low but if the mud is flowing over the electrode a higher resistance value is observed and this value is frequency dependent.

To evaluate this problem a small test cell was fabricated. This cell uses a stationary electrode at the bottom of the cell and a rotating plate for the upper electrode. As such there will be a small center section which is not slipping and this section is insulated. The results with a single mud sample are reasonably consistent and are shown in figure 4. It is possible
to devise a formula for the electrode impedance. In fact the electrode can be represented closely by a capacitance and resistance in parallel with both a function of surface area.

The electrical model then appears as in figure 5. In addition to the electrode impedance at the transmitting and receiving electrodes the influence of leaks at the insulation joints can now be handled. These leaks will occur due to the end fits of each drill pipe section and for our purposes the area of such a leak is the unknown parameter.

2.1 Small Scale Telemetry Experiment

It is apparent from the model that it is possible to perform an experiment on mud electrical telemetry on a smaller scale than the fullsize. Since the principal parameter is the resistance then a small diameter pipe will have higher linear resistance and can be simulated by a shorter length. To simulate the 4 1/2 inch pipe of 20,000 foot length a 1/2 inch diameter pipe of 400 foot length was used. In fact PVC pipe was used and the scale (based on internal diameter) was about 50 to 1. Using a heavy wall pipe working pressures of 800 lbs. were possible allowing realistic velocities (of order 20ft/sec) to be achieved and with Reynolds numbers well into the turbulent flow regime.

Since a thick wall PVC pipe in any configuration will have negligibly small shunt capacitance, electrodes were placed in the pipe every 10 feet to allow the electrical insertion of capacitors into the experiment. At the ends of the pipe sections of copper pipe were used to electrically simulate the drill bit and swivel sections. The transmitting and receiving electrodes were placed 0.6 feet from these ends to simulate a 30 foot pipe length as a typical offset. To simulate the drill pipe a length of 10 gage wire was strung along the experiment. All capacitive returns and simulated shorts were made to this wire.

This experiment was set up at LSU Blowout Prevention School during July 1984. Fluids for the experiment were pumped from a small mixing tank. This enabled relatively easy changes to the fluid. Initial experiments used water with salt added in stages to change the specific resistivity. Then light weight mud (8.9#) was used and salt also added to this in stages. The fluids used in the experiment are summarized in Table II. Note that specific resistances were the same order as the field muds. Note also that the addition of salt to the mud only made a slight change in the resistivity. The values are also shown in figure 7 and compared with sea water. The electrical conductivities of the experiment fluids is much lower than sea water.
The electrical telemetry was performed using the equipment shown in figure 8. A small transmitter based on a standard modem integrated circuit was fabricated. A square wave was used to simulate a typical NRZ data string. The resulting FSK signal was amplified and sent to the transmitting electrode. No attempt at impedance matching was made since power consumption was not important. Typical signals at the transmitting electrodes were 10 v p/p and 1 to 2 KHz with data modulation rates up to 325 baud.

The receiver used a two stage amplifier and combined low pass and high pass filters to provide low Q filtering of the signal. A phase locked loop squared the waveform and this was inputted to a matching demodulator.

Transmitting and receiving signals were measured and a check on the data telemetry made were pertinent. The results are shown in Table III. Typical attenuation values for the simulated drill string were 70 to 100 dB which allows a satisfactory level of received signal. In even the worst case a data rate equal to a maximum for the carrier frequency was achieved. Over 300 baud was always achieved.

To test the effect of leaks (shorts) in the insulation some of the electrodes were connected directly to the 'drill pipe'. As each section was shorted a small additional attenuation was observed.

It is interesting to compare the calculated values for the attenuation with those observed experimentally. Figure 9 shows this comparison. Using the improved model values of the calculated attenuation were within a few dB of the experimental values. Note that this calculation is valid for the small scale 1/2 inch pipe as well as the full size 4 1/2 inch pipe, 20,000 ft.

For a typical full size system with suitable power matching circuitry and with low level signal detection and decoding the calculated signals are shown in figure 10.

The effects of leaks can also be calculated. The leak calculation will depend only on the total surface area exposed to the drill pipe. For each leak equivalent in length to a single pipe diameter the attenuation is about 1 dB. While this does not appear great it should be noted that in a pipe length of 20,000 feet there are 667 joints and if each of these has a 1/16 inch gap there would be some 12 diameters of pipe exposed and an additional loss of 12 dB of signal. It is a measure of how good the end fits must be. The leak calculation is also shown in figure 10.
3. Proposed Study

The activity performed to date has indicated that the telemetry in the drill pipe would be expected to have reasonable signal levels. The noise levels, in as much as they are influenced by fluid flow and pump activity would also appear to be quite reasonable. At this point several unanswered questions remain. The key electronic questions are:

1. How to design the transmitter to maximize the signal
   a. Design of the electrodes and coupling signals.
   b. Design of a self adjusting output coupler.
   c. Packaging of the transmitter.

2. How to design a receiver for minimum error rate.
   a. Optimum data error rate for low signal to noise.

To evaluate two of these problems a study is proposed. The transmitter and receiver designs will be developed in the laboratory and tested using simulated noise and attenuation. In addition the laboratory setup will include local attenuation nodes to simulate leaks. The results will be examined parametrically.

Figure 11 shows the basic components. A small computer will be used to format data similar to a final system but with some engineering parameters set to preset values. Sensors for the measurement of pressure and temperature in the mud will be included and the data from these included in the data string.

The receiver design will include a front end that uses a probability detector to discriminate against noise. This design which was developed for satellite telemetry provides error free data transmission with signal to noise ratios as low as -4 dB.

The data from the receiver will be sent to a specially programmed microcomputer. A single board 80 computer will be used and this will receive and store the data and calculate error rates. The computer can also be used to calculate engineering values from the data and to indicate such derived events as kick detection.

The installation used for the earlier experiments will be used for system evaluation. The computer, transmitter and receiver components will be installed at LSU and a series of experiments on data telemetry performed. Particular attention will be given to actual error rates under widely varying conditions.
4. Work Statement

The above activity can be summarised into a work statement:

1. Design and laboratory test of self adjusting output amplifier.
2. Design and construct data computer and transmitter assembly.
3. Design and fabricate receiver electronics and integrate with programmed microcomputer.
4. Test transmitter/receiver/computer system.
5. Assemble three components into system at LSU.
6. Perform mud flow tests for telemetry and error rates.
7. Analyse and report results.
5. **Budget**

<table>
<thead>
<tr>
<th>Description</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct Labor (Principal Investigator)</td>
<td>$26,000</td>
</tr>
<tr>
<td>(Engineering Support)</td>
<td>$8,000</td>
</tr>
<tr>
<td></td>
<td>$34,000</td>
</tr>
<tr>
<td>Expendable Materials</td>
<td>2,000</td>
</tr>
<tr>
<td>Travel and Living</td>
<td>2,400</td>
</tr>
<tr>
<td>Engineering Overhead 83.2% of direct labor</td>
<td>31,949</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$ 70,349</strong></td>
</tr>
</tbody>
</table>

6. **Principal Investigator**

The Principal Investigator will be Dr. Eric J. Softley.

7. **Period Of Activity**

The period of this study will be 8 months starting as soon as possible after January 1, 1984.
SIMPLE MODEL

RESISTANCE IS \( \frac{\sigma L}{\lambda} \)
CAPACITANCE IS \( \frac{2\pi \varepsilon L}{\ln(D_2/D_1)} \)
ATTENUATION COEFFICIENT IS
\[ \text{Re} \left( (R+ivL)(G+iwC) \right) \]

NOTE.
1. For low frequencies (<100KHz) L and G insignificant
2. Attenuation is per unit length and therefore can scale problem by matching R and C per unit scale length.

Figure 2. Simple Electrical Model
Figure 3. Use Of Insertable Probe For Mud Conductivity Measurement.
**Figure 4. Effect of Slipping Electrode**

- Cell Resistance (Ω)
- Electrode Stationary
- Rotating Electrode
- Mud Sample
- Fixed Electrode

- Frequency Range: 10 Hz to 10 KHz
IMPROVED MODEL

ELECTRODE IMPEDANCE IS COMPLEX AND DEPENDS ON THE STATE OF THE MUD. FOR MOVING MUD THE MODEL BECOMES

NOTE:

1. Insulation leaks at the pipe junctions become less important since they are shielded by the electrode impedance.

2. The capacitive component in the electrode impedance reduces the applied signal. This reduction can be partially overcome by adding a carrier to the signal.

Figure 5. Improved Electrical Model
Figure 6. Arrangement For Small Scale Telemetry Experiment.
Figure 7. Variation Of Electrical Conductivity
In Experiment Fluids.
Figure 8. Electronics For Telemetry Experiment
Figure 9. Comparison Of Calculated And Measure Attenuations For Experiment.
FULL SIZE SYSTEM CONSIDERATIONS

- 20,000 FT.
- 4 1/2 inch Pipe
- 2.1 KHz
- 300 Baud
- 30 ft. electrode offset
- 1 Watt Power

Figure 10. Typical Received Signals For Telemetry
Figure 11. Electrical Telemetry Demonstration.
TABLE I

EXAMPLES OF MUD RESISTIVITY

Samples of field muds were analysed for resistivity to determine typical values. In some cases mud analyses are available.

<table>
<thead>
<tr>
<th>SAMPLE NO</th>
<th>SAMPLE</th>
<th>TEST CELL</th>
<th>PROBE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>9.2 lb. KCL</td>
<td>2.3</td>
<td>2.23</td>
</tr>
<tr>
<td>2.</td>
<td>9.0 lb KOH</td>
<td>1.31</td>
<td>1.25</td>
</tr>
<tr>
<td>3.</td>
<td>10.0 lb LIGNO</td>
<td>0.98</td>
<td>1.00</td>
</tr>
<tr>
<td>4.</td>
<td>11.4 lb LIGNO/LIME</td>
<td>0.594</td>
<td>0.594</td>
</tr>
<tr>
<td>5.</td>
<td>12.5 lb OIL BASE</td>
<td>0.528</td>
<td>0.502</td>
</tr>
<tr>
<td>6.</td>
<td>14.5 lb OIL BASE</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>7.</td>
<td>11.0 lb LIGNO</td>
<td>0.506</td>
<td>0.568</td>
</tr>
<tr>
<td>8.</td>
<td>12.5 lb LOW LIME</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>9.</td>
<td>13.8 lb LIGNO</td>
<td>1.15</td>
<td>1.15</td>
</tr>
<tr>
<td>10.</td>
<td>14.9 lb DENSIMIX</td>
<td>8.63</td>
<td>*</td>
</tr>
<tr>
<td>11.</td>
<td>15.0 lb LIGNO</td>
<td>0.713</td>
<td>0.726</td>
</tr>
<tr>
<td>12.</td>
<td>17.3 lb LIGNO</td>
<td>0.713</td>
<td>0.752</td>
</tr>
</tbody>
</table>

Resistance shown is specific resistance in ohms/meter/sq.meter. * means the value was greater than 13.
# Table II

## Experiment Fluids

<table>
<thead>
<tr>
<th>No.</th>
<th>Base Material</th>
<th>Salt Added</th>
<th>% Salt by St.</th>
<th>Specific Resistivity</th>
<th>Specific Conductivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Water</td>
<td>0</td>
<td>?</td>
<td>11.7</td>
<td>0.08</td>
</tr>
<tr>
<td>2</td>
<td>Water</td>
<td>8</td>
<td>.28</td>
<td>2.27</td>
<td>0.44</td>
</tr>
<tr>
<td>3</td>
<td>Water</td>
<td>16</td>
<td>.56</td>
<td>1.21</td>
<td>0.83</td>
</tr>
<tr>
<td>4</td>
<td>Water</td>
<td>20</td>
<td>.72</td>
<td>0.92</td>
<td>1.09</td>
</tr>
<tr>
<td>5</td>
<td>Mud</td>
<td>0</td>
<td>0</td>
<td>1.49</td>
<td>0.67</td>
</tr>
<tr>
<td>6</td>
<td>Mud</td>
<td>12</td>
<td>.31</td>
<td>1.41</td>
<td>0.71</td>
</tr>
<tr>
<td>7</td>
<td>Mud</td>
<td>28</td>
<td>.73</td>
<td>1.33</td>
<td>0.75</td>
</tr>
</tbody>
</table>

By comparison:

- Sea water: 3.6, 0.21, 4.74
### TABLE III

**TABLE OF TEST RESULTS**

<table>
<thead>
<tr>
<th>No.</th>
<th>Sample Matl.</th>
<th>Flow (psi)</th>
<th>Elec. Res. (KHz)</th>
<th>Input (V)</th>
<th>Output (uV)</th>
<th>Noise (uV)</th>
<th>Attenu (dB)</th>
<th>Data Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Water</td>
<td>300</td>
<td>2/3</td>
<td>11.7</td>
<td>1.0</td>
<td>2.9</td>
<td>370</td>
<td>75</td>
</tr>
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<td>2</td>
<td>1</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Water +</td>
<td>2.27</td>
<td>1.0</td>
<td>0.5</td>
<td>150</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Salt</td>
<td>1.21</td>
<td>1.0</td>
<td>4.3</td>
<td>700</td>
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<td>2.1</td>
<td>4.1</td>
<td>300</td>
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</tr>
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<td>Salt</td>
<td>0.92</td>
<td>1.0</td>
<td>4.3</td>
<td>900</td>
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<tr>
<td>8</td>
<td>Salt</td>
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<td>4.3</td>
<td>740</td>
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<td>1.4</td>
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<tr>
<td>11</td>
<td>Salt</td>
<td></td>
<td></td>
<td>1.0</td>
<td>1.5</td>
<td>150</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Shorted #11, #28 and then both electrodes*

| 13  | Water        | 250        | 1/4              | 0.92      | 2.1         | 3.6        | 370         |           | 80        |
| 14  | Water        |            |                  |           | 2.1         | 3.6        | 360         |           | 81        |
| 15  | Water        |            |                  |           | 2.1         | 3.6        | 150         |           | 88        | 325       |

*Mud tests*

| 16  | Mud          | 1/4        | 1.49             | 2.1       | 3.6        | 150        | 45          |           | 88        | 325       |
| 17  | Mud          | 2/4        |                  | 2.1       | 3.6        | 300        |             |           | 82        |
| 18  | Mud          | 2/3        |                  | 2.1       | 3.6        | 1120       |             |           | 70        | 325       |

*Installed capacitors in all electrode positions*

| 21  | Mud          | 2/3        | 1.49             | 2.1       | 4.3        | 75          | 45          |           | 95        | 325       |
| 22  |             |            |                  | 1.5       | 4.3        | 75          |             |           | 95        | 260       |
| 23  |             |            |                  | 1.2       | 4.3        | 67          |             |           | 96        | 180       |
| 24  |             |            |                  | 1.0       | 4.3        | 52          |             |           | 98        | 100       |

*Increase salt content of mud in stages*

| 25  | Mud          | 2/3        | 1.41             | 2.1       | 4.3        | 82          |             |           |           |           |
| 27  | +            | 1.33       | 2.1              | 4.3       | 90         |             |             |           |           |           |

*Reverse transmitting direction*

| 29  | Mud          | 3/2        | 1.33             | 2.1       | 4.3        | 90          |             |           |           |           |
| 30  |             |            |                  |           |            |             |             |           |           |           |

*Increase flow*

| 31  | Mud          | 550        | 3/2              | 1.33      | 2.1        | 4.3        | 75          | 75        | 95        | 325       |

*Electrode #11 shorted*

| 32  | 550          | 3/2        | 1.33             | 2.1       | 4.3        | 60          | 75          |           | 97        | 325       |

*Shorten pipe 70*

| 33  | 550          | 3/2        | 1.33             | 2.1       | 4.3        | 300         | 75          |           | 82        | 325       |