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ANNUAL REPORT

NO. 2

# DEVELOPMENT OF IMPROVED BLOWOUT PREVENTION PROCEDURES TO BE USED IN DEEP WATER DRILLING OPERATIONS

Submitted To

THE UNITED STATES GEOLOGICAL SURVEY

Department of the Interior

Reston, Virginia

PETROLEUM ENGINEERING DEPARTMENT

Louisiana State University

Baton Rouge, Louisiana 70803

February 15, 1981

ANNUAL SUMMARY REPORT

August, 1979 - July, 1980

# Development of Improved Blowout Prevention Procedures for Deep Water Drilling Operations

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Petroleum Engineering Department

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Petroleum Engineering Department

February 15, 1981

## RESEARCH OBJECTIVES

The primary objective of this research program is the development of improved blowout prevention procedures to be used in deep water floating drilling operations. The overall research plan was divided into eight tasks which will take approximately four years for completion at a total cost to the USGS of $822,962. These tasks are as follows:

1. Design of a research well facility for accurately modeling blowout control operations on a floating drilling vessel in deep water.
2. Construction of research well facility.
3. Documentation of blowout control equipment configuration and procedures currently used on deep water floating drilling vessels.
4. Experimental study of shut-in procedures for blowout control on deep water floating drilling vessels.
5. Experimental study of procedures for handling upward gas migration during the shut-in period.
6. Experimental study of pump start-up procedures.
7. Experimental study of pump out procedures with emphasis on problems occurring when a gas kick reaches the seafloor.
8. Development of a mathematical model of well behavior during the control of gas kicks on floating drilling vessels.

It should be pointed out that this research project is being jointly sponsored by industry, and the total cost of the project is approximately two million dollars. At the end of this reporting period, the second year on this project has been completed with USGS funding to date totaling $197,096.00 for Tasks 1, 3, and 5 and a portion of Task 4.

This report is intended to be a concise and credible discussion of our technical progress, findings, and accomplishments by task.

## Task 1 - Research Well Facility Design

Significant modifications in blowout prevention equipment and procedures are required for floating drilling vessels used in deep water drilling operations. The current trend of the oil industry to much greater water depths (shown in Figure 1) emphasizes the importance of working towards improvements in blowout control equipment and procedures for these vessels. Future plans by the National Science Foundation call for scientific ocean drilling in up to 13,000 ft of water during the next decade. The NSF Ocean Margin Drilling Program will be a joint venture between government and industry.

As part of the USGS-sponsored research at LSU, a new research well facility has been designed to allow improved blowout prevention procedures to be experimentally investigated under simulated threatened blowout conditions in an actual well. Construction of the new facility is being accomplished under the dual support of industry and the USGS. Task 1, the design of the new research well facility, has been completed. The location of the new well facility is the site of the Goldking LSU No. 1 well on the southwestern edge of the LSU Campus, as shown in Figure 2. A scale model of the facility has been constructed and is shown in Figure 3.

Details of the completed design are given in Appendix A. The heart of the new facility will be an actual well for modeling well control operations in deep water. Shown in Appendix A as Figure A-1 is the well design which will be used. A water depth of approximately 3000 ft will

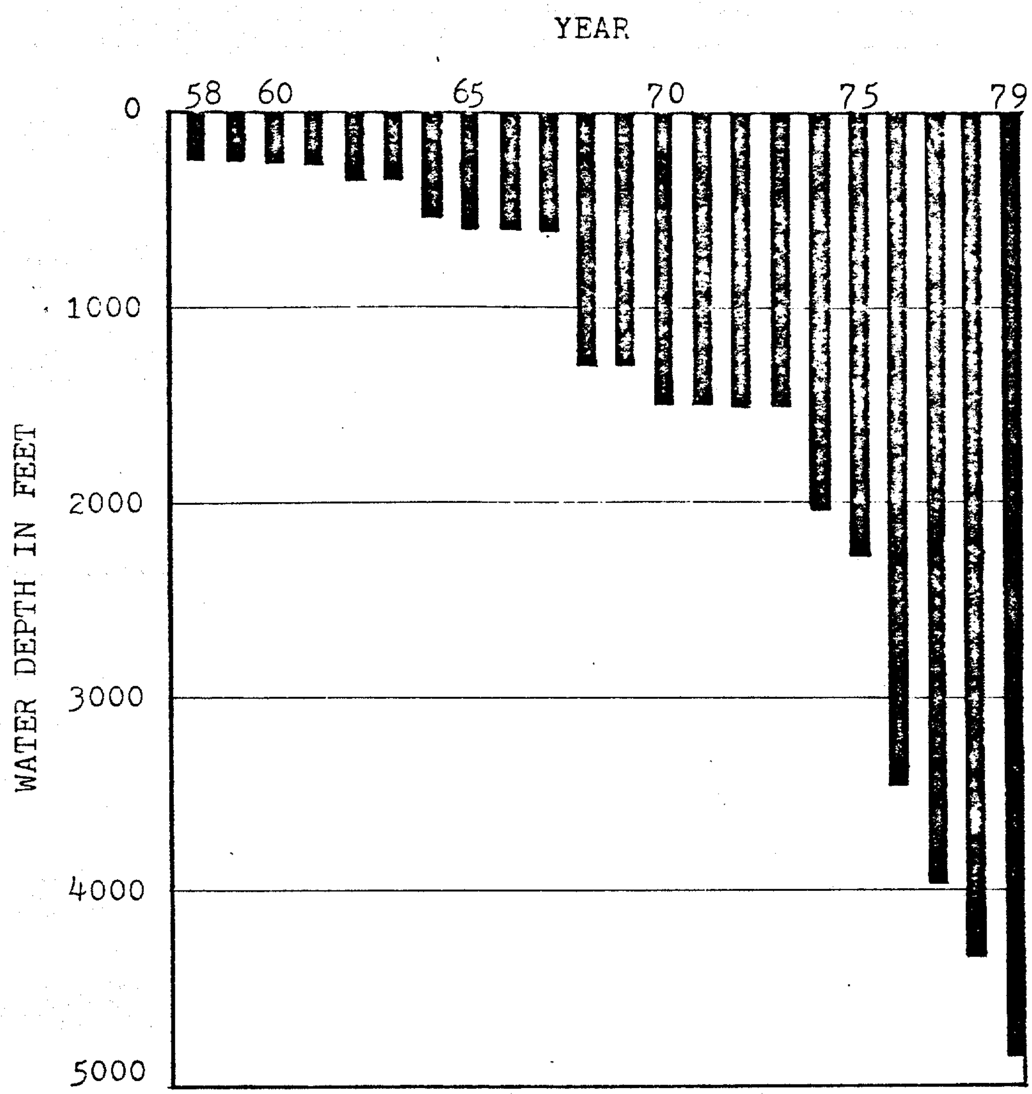



**Figure 1 - History of Water Depth Record for Floating Drilling Vessels**

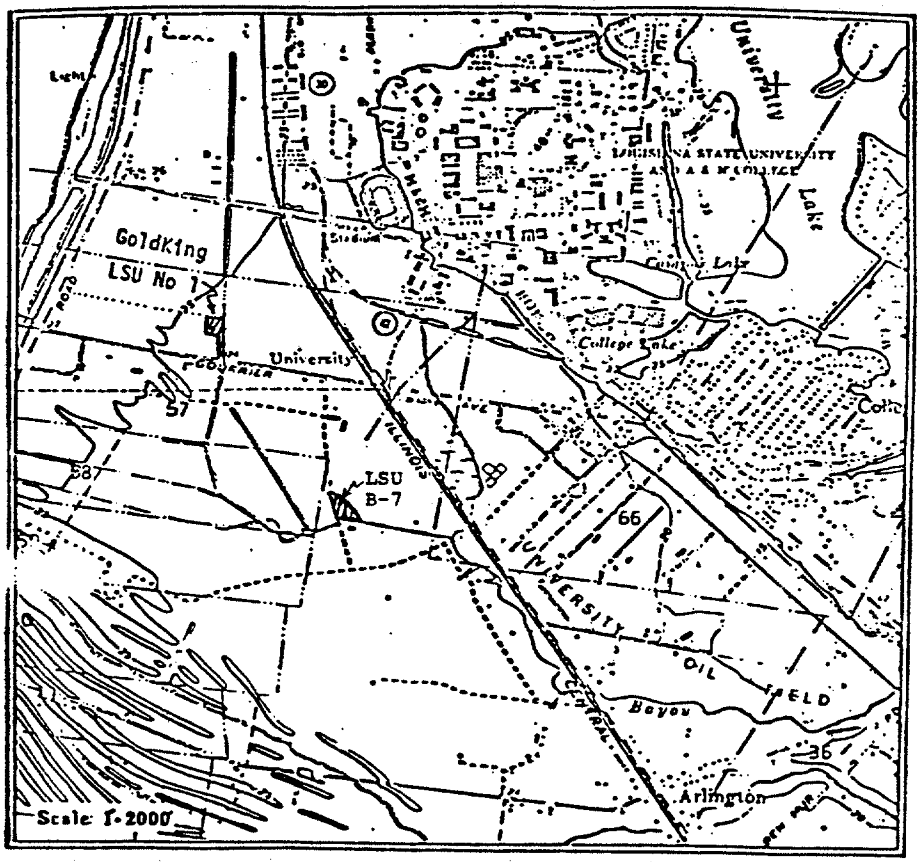



Figure 2 - Location of Research

Well Facility

Figure 3 - Scale Model of New Research Well Facility

be simulated using a Baker packet and triple parallel flow tube placed in the well at this depth. A total well depth of 6000 ft has been chosen. The lengths and sizes of the well tubulars were selected after extensive computer simulations of both actual and model well behaviors under various assumed kick conditions. The new well facility should allow a range of pressure behaviors under simulated well control conditions which are very similar to the behavior of an offshore well being drilled by a floating drilling vessel.

A detailed schematic of the surface and subsurface piping of the new facility is shown in Figure A-2. This arrangement will allow the realistic duplication of pressure control operations using the most modern well control equipment available. The piping will also allow several flow options not normally available on a drilling rig in order to allow the collection of experimental data needed to define more precisely the operating characteristics of several of the drilling chokes used. The piping arrangement will also allow several innovative pressure control procedures to be tested.

The most complex portion of the surface pressure control piping used on drilling rigs is the choke manifold, which contains the high pressure, remote operated, adjustable chokes. The Choke Manifold design is documented in Figures A-3 and A-4. The manifold being used will be one of the largest in the world and will allow several flow options not usually available in current practice.

Considerable surface pit volume will be required to simulate the pressure control operations and conduct the experimental research program. The plans for two 300 bbl mud tanks are shown in Figure A-5. The surface layout plan showing the physical arrangement of the mud tanks, choke manifold, and associated pumps, mud gas separators, and degassers are shown in Figure A-6. A site plan showing the placement of the access road, shell mats, and concrete equipment foundations is shown in Figure A-7. The site electrical plans are shown in Figure A-8. Plans for the control house foundations and metal shell are shown in Figure A-9.

Task 3 - Documentation of Current Practice

There exist considerable differences among the various well operators as to the best equipment configuration and pressure control procedures which should be used on floating drilling vessels in deep water. As a first step in the development of improved blowout prevention procedures, a study documenting the existing equipment and procedures currently in use has been initiated. This study is being documented by Mr. Bob Surcouf in an M.S. Thesis entitled, "An Examination of Blowout Prevention Equipment and Procedures Used on Floating Drilling Vessels." The topical outline he has constructed is as follows:

1. Introduction
2. Description of Available Well Control Equipment
   (a) Subsea Blowout Preventer Stacks
   (b) Blowout Preventer Control Systems
   (c) Marine Risers
   (d) Diverter Systems
   (e) Choke and Kill Manifolds
   (f) Drilling Chokes
   (g) API Recommended Equipment Configurations
   (h) Government Regulations

3. Survey of Deep Water Drilling Vessels
   (a) Deep Water Rig Availability
   (b) Survey Sample
   (c) Survey Results
   (d) Typical Piping Diagrams
4. Current Well Control Procedures
   (a) Government Regulations
   (b) Approved Well Control Manuals for Subsea BOP Stacks
   (c) Well Shut-in Procedures
   (d) Pump Start-up Procedures
   (e) Pump Out Procedures
5. Theoretical Limitations of Well Control Operations
   (a) Computed Deep Water Fracture Gradients
   (b) Computed Diverter System Capacities
   (c) Computed Choke Pressure Requirements
6. Conclusions and Recommendations

In this study, equipment currently being manufactured was first cataloged. A survey of deep water rigs was then conducted to identify how the available equipment was being configured in actual practice. A number of drillships and semi-submersible rigs were visited in conjunction with this study. Next, all USGS approved subsea well control manuals were surveyed in order to catalog the various recommended procedures for use of the existing equipment. Finally, some limitations of existing equipment and procedures were explored through mathematical analysis and computer simulations. Documentation of the results of this study is still in progress.

Photographs taken during one of Mr. Surcouf's offshore visits are shown in Figures 4 and 5. Example well control piping diagrams for a typical diverter system used for drilling the shallow portion of a well and the blowout preventer system used for drilling the deeper portion of a well are shown in Figures 6 and 7.

For the past two years, the record water depth for floating drilling has been advanced by the Discoverer Seven Seas Drillship. In 1978 a well was drilled by this vessel off the African coast in 4342 ft of water, and in 1979 a well was drilled offshore Newfoundland in 4876 ft of water. Special emphasis was placed in this study on these two wells. Well data obtained from the well operators was obtained to allow computer simulations of pressure control operations for various assumed kick conditions. Shown in Figure 8 is a photograph of the Discoverer Seven Seas, and shown in Figure 9 are the results of computer simulations of pressure control operations computed for this vessel using well data from the 1979 record water depth well drilled off the African coast. The results of computer simulations of this type proved very valuable in designing the new research well facility.

Task 4 - Improved Shut-In Procedures

Task 4 is not scheduled for completion until after construction of the new research well facility. However, work which could be done using existing facilities has been initiated. This initial work includes the following subtasks:

4a. An experimental determination of frictional area coefficients for modern drilling chokes used in pressure control operations.

4b. An experimental determination of frictional area coefficients of a modern annular blowout preventer during closure.

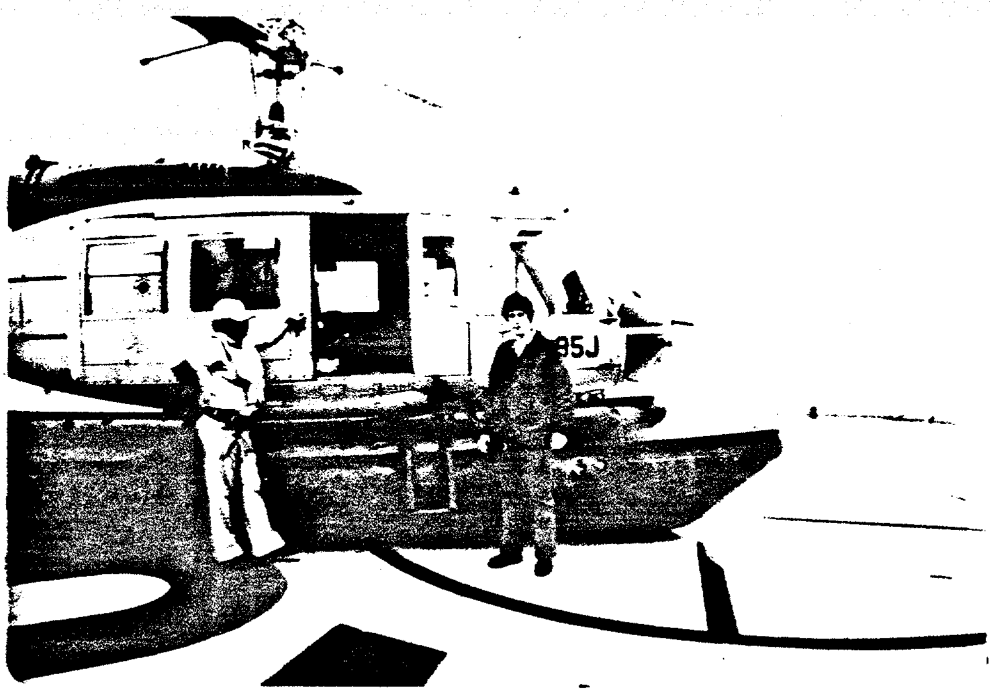



Figure 4

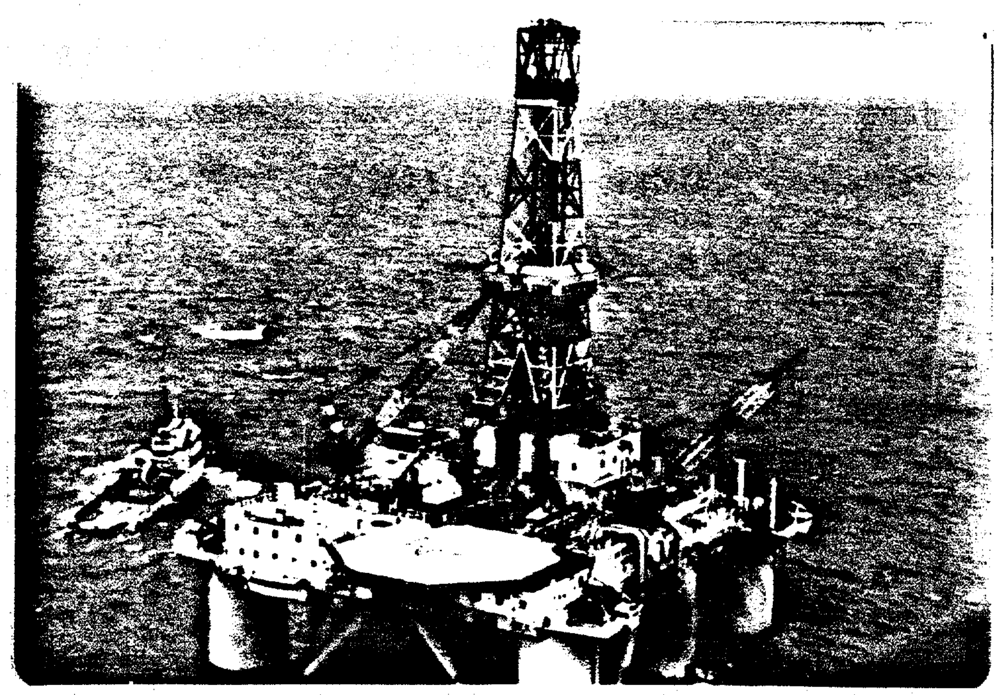


Figure 5

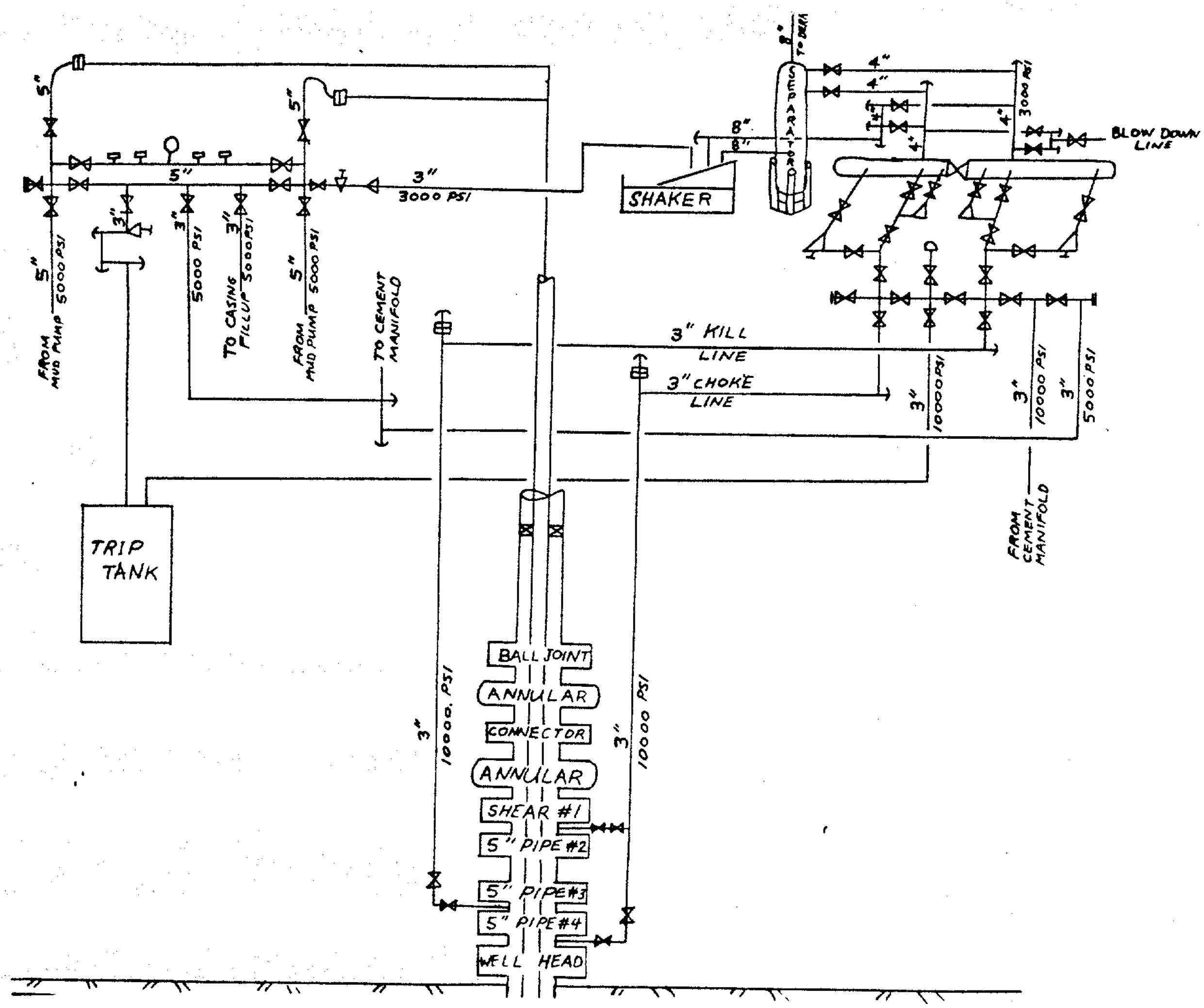



Figure 7 - Typical Well Control System

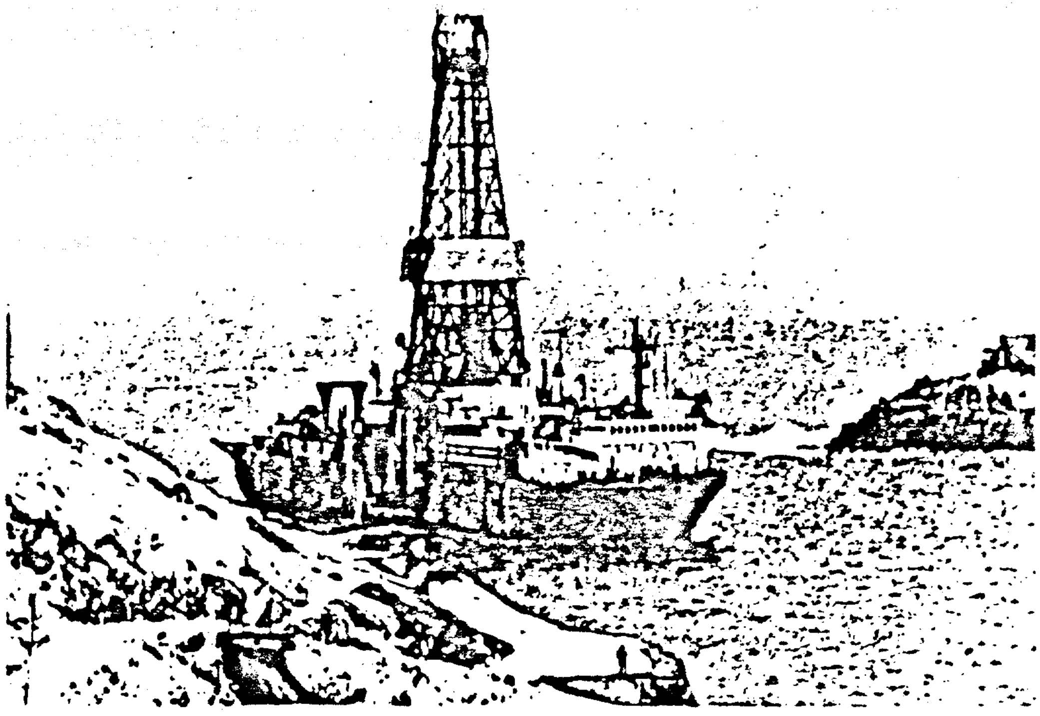


Figure 8 - Discoverer Seven Seas Drillship

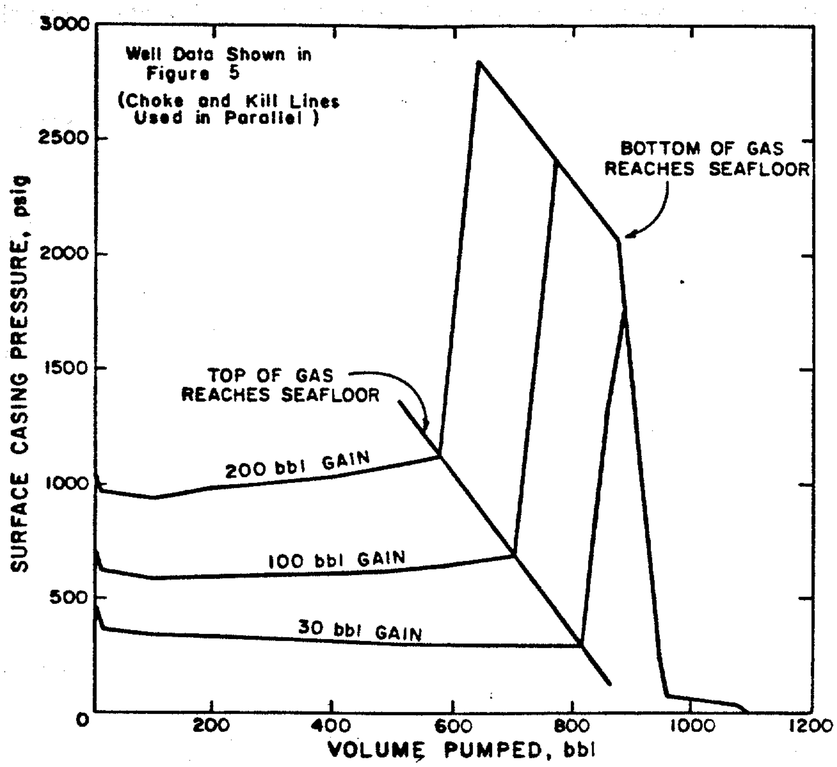



Figure 9 - Pressure Control Simulation Results for

Well Drilled by Discoverer Seven Seas

Subtask 4a is being accomplished by Mr. Kerry Redmann and Subtask 4b is being accomplished by Mr. Scott Doyle. These two individuals are performing these tasks as part of their M.S. thesis research.

One goal of this research is the development of much improved algorithms for predicting the response of a well to actions taken by the rig crew during pressure control operations. It is hoped that the frictional area coefficient data collected on each of the commercially available drilling chokes will lead to greatly improved algorithms for computing the changes in well pressures and flow rates with time associated with incremental changes in choke position by the choke operator. The incorporation of more realistic choke response algorithms in pressure control simulation programs is needed to allow a more valid comparison of alternative well control procedures. Similarly, it is hoped that the frictional area coefficient data collected on an annular blowout preventer will lead to more accurate algorithms for predicting initial pressure surges during well closure and ultimately to improved shut-in procedures.

A schematic of the experimental flow loop used for Subtask 4a is shown in Figure 10. Drilling fluid having the desired rheological characteristics is first mixed in the available pits. By opening a bypass valve (6) and closing the normal drill pipe valve (7), drilling fluid could be circulated from one pit directly through any of the available chokes (1), (2), (3), or (4) and returned to a second pit. Flow rates were computed both from the recorded stroke rate of the positive displacement triplex pump and from the observed change in pit level. For some of the runs, a magnetic flow meter had been installed in return line (10), providing a third check on the measured flow rates.

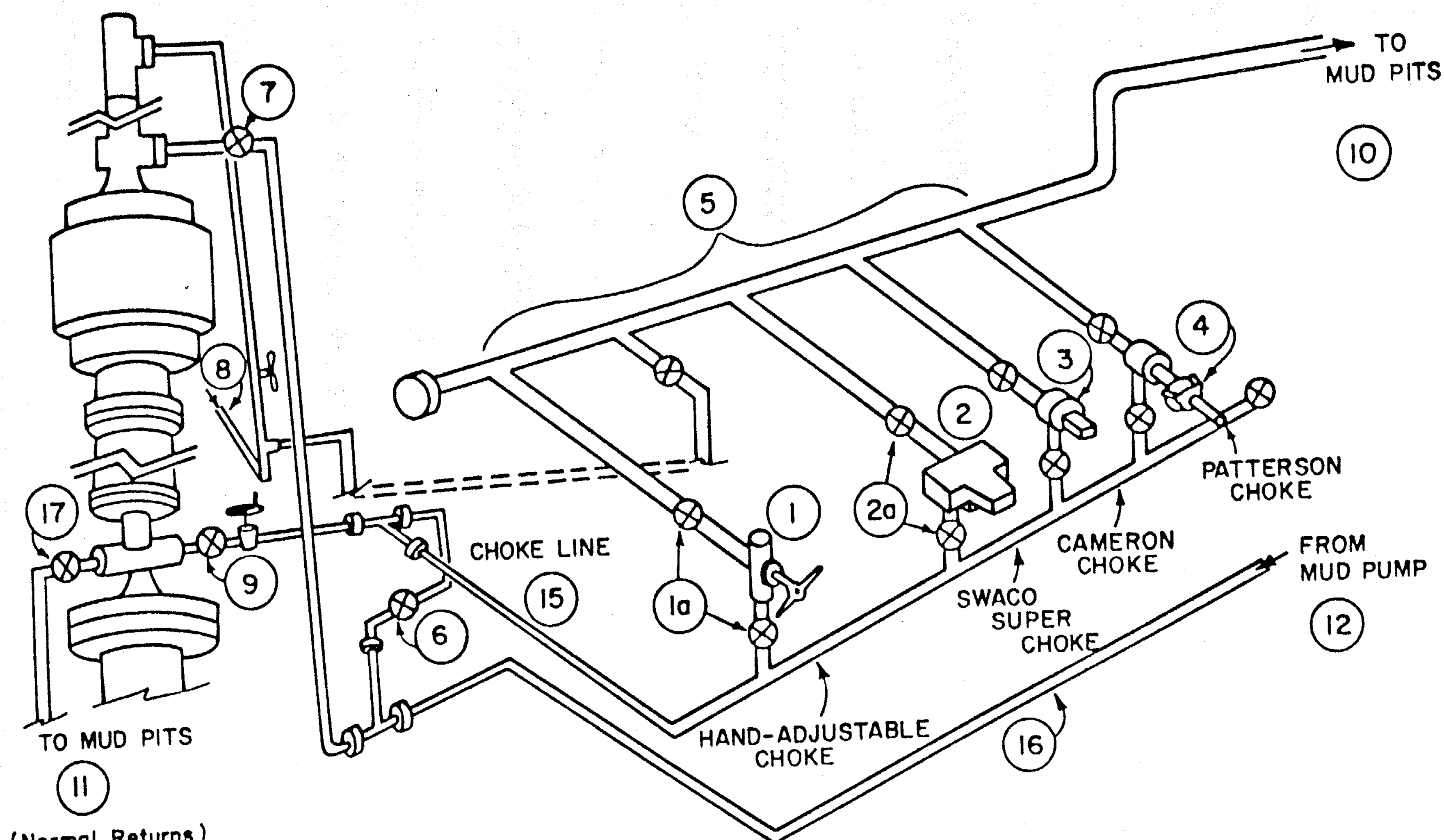



Figure 10 - Surface Layout of LSU Training Well

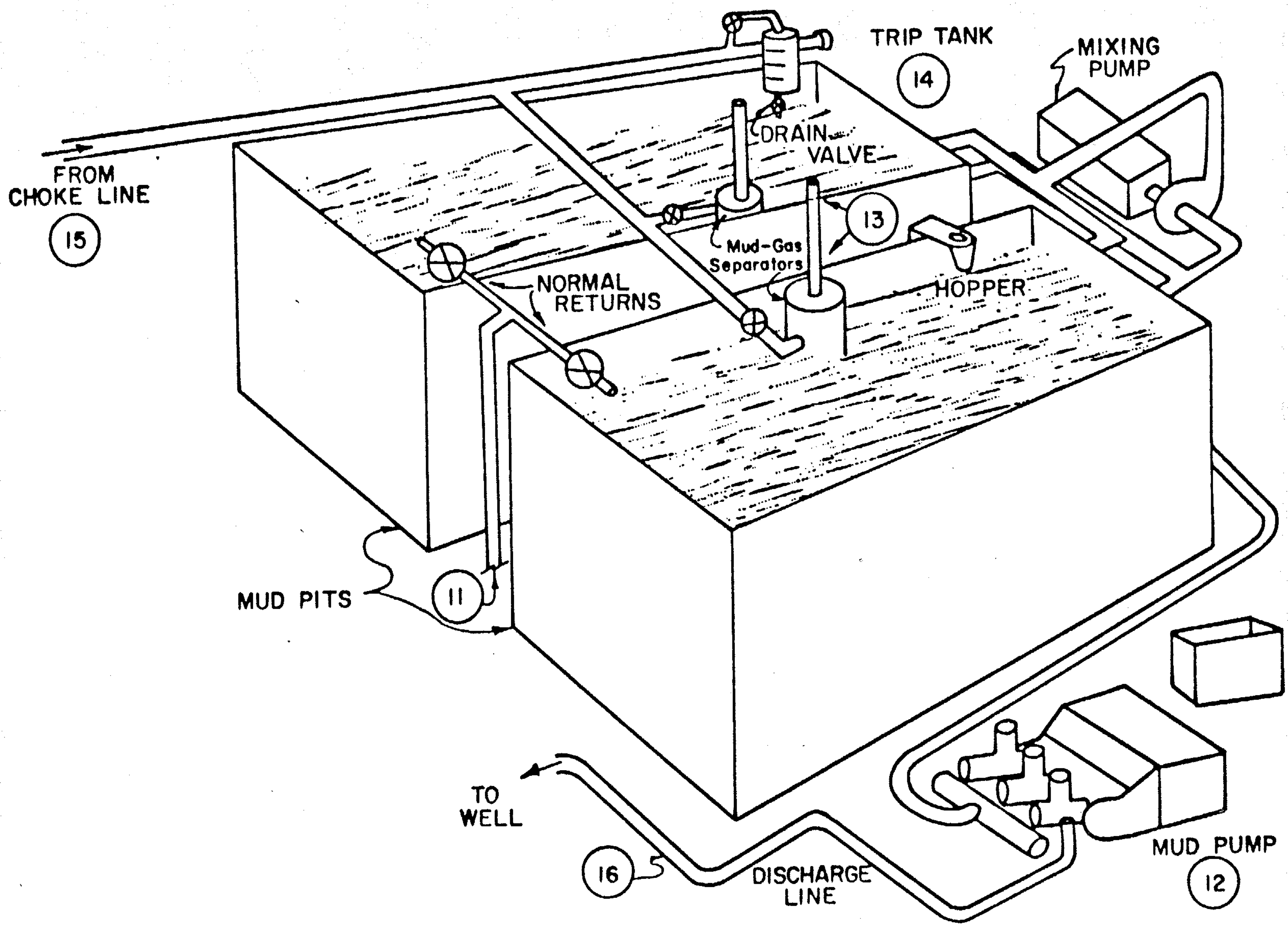



Figure 10 - Continued

Pressures upstream of the chokes were monitored using a recording pressure gauge, and pressures downstream of the choke were essentially atomspheric.

Example drilling choke data obtained on the cameron hand-adjustable drilling choke, cameron remote-adjustable drilling choke, swaco high-pressure drilling choke, and Patterson drilling choke are shown in Appendix B. Drilling fluid properties used in these tests are also given in this appendix. Documentaion of the results of Subtask 4a is now underway by Mr. Kerry Redmann in an M.S. thesis entitled, "Flow Characteristics of Adjustable Drilling Chokes Used in Well Control Operations."

A schematic of the experimental flow loop used for Subtask 4b is shown in Figure 11. Flow could be directed through the annular preventer in the same manner as previously described for the drilling choke flow loop used for Subtask 4a, and the same equipment was used to monitor the pressures and flow rates. The flow characteristics of the annular blowout preventer are being determined at various stages of blowout preventer closure. These data should greatly assist us in developing improved algorithms for determining inertial pressure surges during well closure. Example data obtained using this apparatus are shown in Appendix C.

Task 5 - Improved Procedures for Handling Gas Migration

After a well has been shut-in due to the flow of a gas kick into the wellbore, there may be a considerable lapse of time until conventional well control procedures can be implemented. This time lapse can be due to mechanical difficulties or to weighting up the mud to the

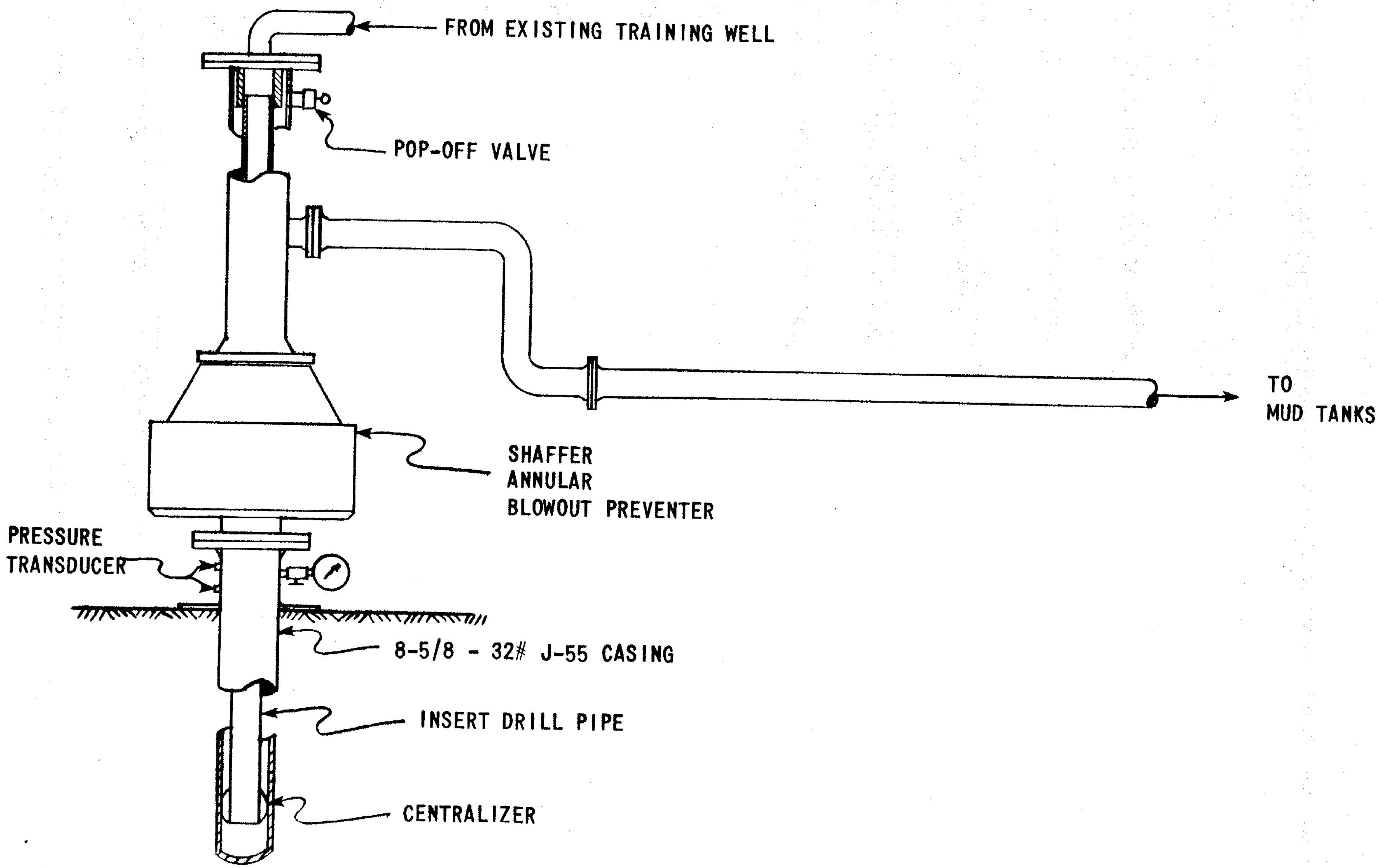



Figure 11 - Experimental Apparatus for Measuring Flow Characteristics of Annular Preventer During Shut-In

required kill value. During this time, upward migration of the gas occurs due to the large density difference between the mud and the gas. As this gas rises on the shut-in well, wellbore pressures continuously increase until 1) pressure is bled off at the surface, or 2) formation fracture and the resulting underground blowout occurs at the weakest zone in the open hole, usually at the casing seat.

The basic problem, as earlier stated, is that gas rising in the shut-in well can cause excessive wellbore pressures. Refer to the real gas equation of state,

$$PV = ZnRT \tag{1}$$

where

$P$ = pressure, psia

$V$ = volume, $ft^3$

$Z$ = gas compressibility factor

$n$ = number of lb-moles of gas

$R$ = 10.732 psia-$ft^3$/lb-mole-°R

$T$ = temperature, degrees Rankine

Since the well remains shut-in, the gas volume and number of moles remains constant, assuming an incompressible system. Since the value for Z does not change very much over relatively large pressure and temperature variations, and assuming constant temperature of the gas, the result is that the pressure of the gas remains essentially constant at the initial shut-in bottomhole pressure as it rises upward.

Figure 12 illustrates the detrimental aspects of maintaining the well shut-in during this period. At initial shut-in conditions, the gas (bottomhole) pressure is 5220 psig. The fracture gradient at the

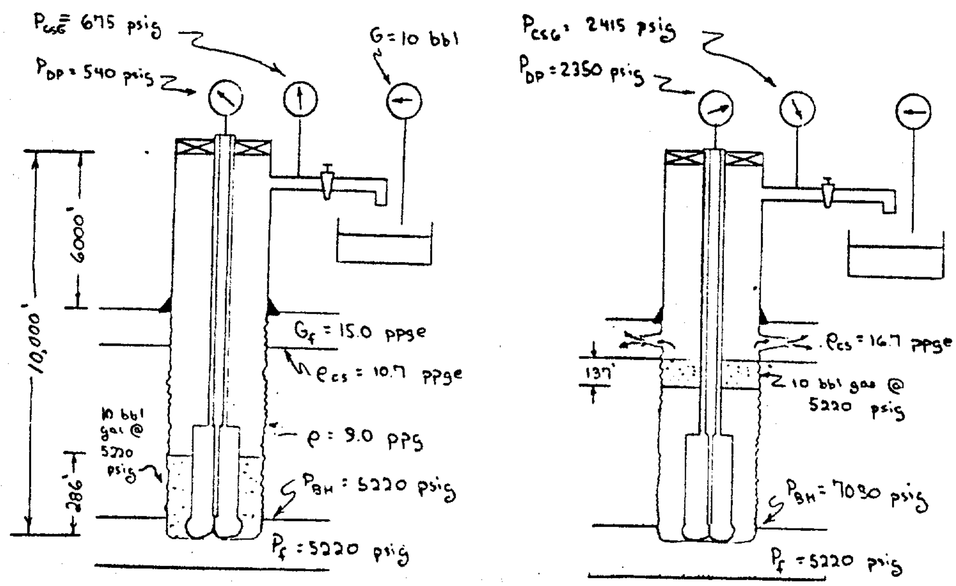



Figure 12 - Problem of Upward Gas Migration
in a Shut-In Well

casing shoe was established at 15 ppg, and at initial conditions it has not been exceeded, since the equivalent shut-in density at the shoe is 10.7 ppg. However, at a later time the gas has migrated to the casing shoe with a 16.7 ppg resulting equivalent density at the shoe. This is in excess of the formation strength, and fracturing of the formation and an underground blowout will occur. It can also be seen that the bottom-hole pressure has increased to over 7000 psig. This is for in excess of the pressure required to maintain well control. Also, the surface drillpipe and annular pressures have also increased, signifying that the gas is migrating upwards.

The usual procedure for handling upward gas migration prior to normal well control operations is to maintain a constant drillpipe pressure, slightly greater than the initial shut-in value. This procedure maintains the bottomhole pressure at a value slightly greater than the formation pore pressure, since a continuous column of mud lies between the surface and the formation.

To maintain a constant, drillpipe pressure mud is bled periodically through a surface choke to allow the migrating gas to expand and subsequently reduce its pressure.

However, situations can arise when a meaningful drillpipe pressure is not available. In one case, the bit could be plugged, preventing pressure communication between the drill string and formation. In another instance, the drill string could be off-bottom with the bit initially well above the intruding gas. The drillpipe would "see" the same fluid column - mud and gas - as the casing, resulting in the drillpipe and casing pressure reading the same. In the extreme case, the pipe could be out of the hole entirely.

In all the above cases, a meaningful drillpipe pressure would not be available. It is for these instances that a volumetric method was proposed by several authors. The method utilizes casing pressure-pit level changes, theoretical in nature, and had been largely untested in the field. For these reasons work was conducted at LSU to test the theory and see if it had application to field practices.

The procedure suggested by the earlier authors is as follows:

1) Allow the casing pressure to rise to a value slightly above initial shut-in pressure to allow for a margin of safety.
2) Let the casing pressure rise by a selected pressure increment. Usually 50 psi is adequate.
3) Bleed at constant casing pressure the volume of mud which would generate a hydrostatic pressure equal to the selected pressure increment.
4) Once the mud has been bled at the surface, repeat steps 2 and 3 as necessary until gas is produced at the surface.

The procedure outlined above is known as the static procedure, since no circulation of mud occurs in any manner. A second procedure, called the dynamic method, utilizes the rig pumps and the kill line to pump across the top of the annulus. Mud is pumped through the kill line, across the annulus, and into the choke line to the metering pit. This procedure has the advantage that it is easier to hold casing pressure constant. Mud is now "kicked" from the well by the expansion of the gas. Once sufficient mud has been bled, pump pressure is increased as required.

In order to evaluate experimentally the volumetric methods of well control, the 6000 ft LSU B-7 training well was utilized. Experimental runs were made for a wide variety of conditions. The results of these experiments are summarized in the May, 1980 M.S. thesis by Jeff Matheras entitled "Upward Augration of Gas Kicks in a Shut-In Well." One copy of this thesis, enclosed with this annual report, was sent to Mr. John Gregory, the technical coordinator of this project.

As a result of the experimental work done in this study, the following conclusions were made:

1. The assumption that the gas kick remains as a continuous slug during upward gas migration was found to be invalid.
2. The trailing edge of a gas bubble was found to rise much slower than predicted due to gas fragmentation.
3. In spite of a portion of the gas reaching the surface prematurely, the modified volumetric procedure for handling upward gas migration was found to ba a valid and practical technique.
4. Contrary to previously accepted practices, the venting of gas that reaches the surface prematurely was found not to cause any significant problems in maintaining well control, as long as a portion of the gas is still rising in the well.

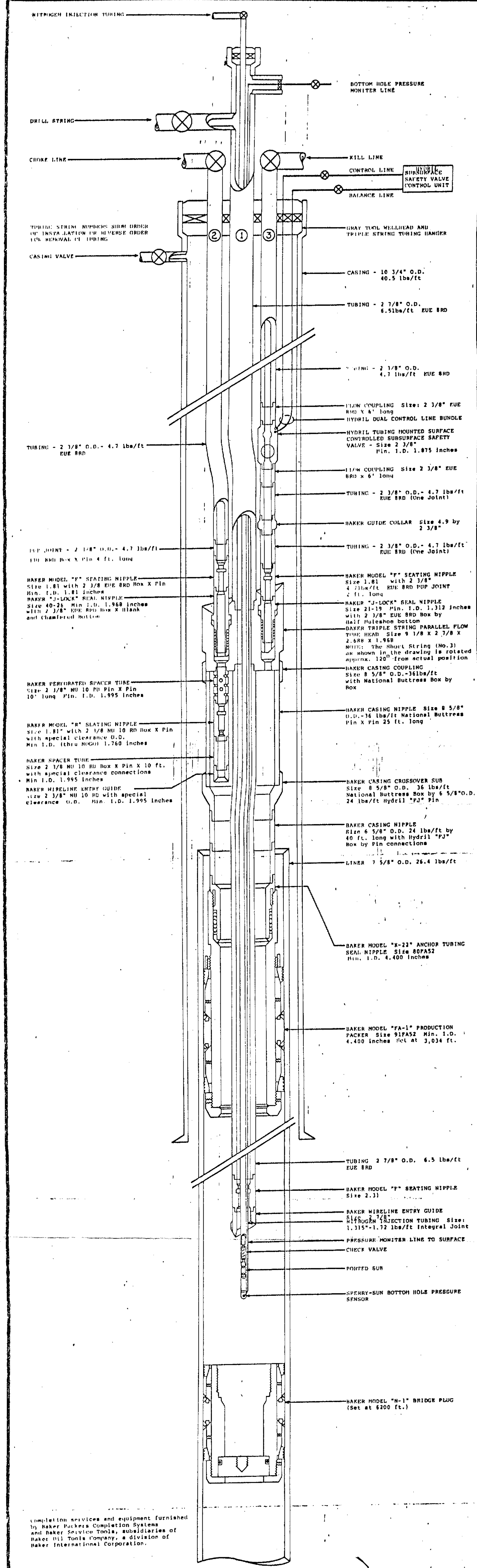
# Appendix A

## Detailed Design for New Well Facility

Figure A-1 - Design of Research Well

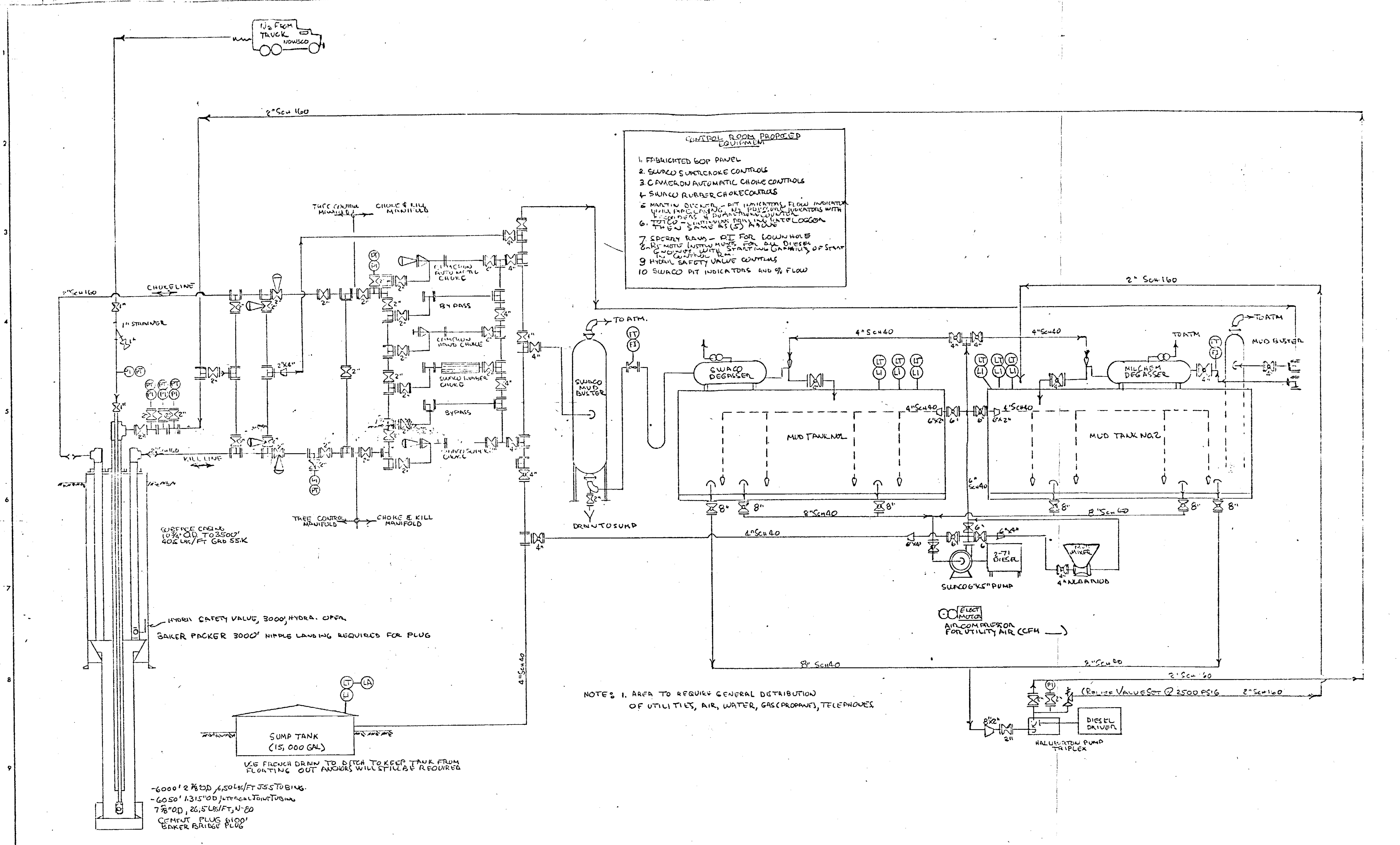
BAKER PACKERS

ILLUSTRATIVE 'ING
OF SPEC
TOOLS AND ME..ODS




Completion services and equipment furnished by Baker Packers Completion Systems and Baker Service Tools, subsidiaries of Baker Oil Tools Company, a division of Baker International Corporation.

Figure A-2 - Piping Diagram

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| DRAWN | J.H.SYKCRA | 9/80 | |
| CHECKED | W.HOLDEN | 9/80 | |
| APPROVED | A.T BOURGCYNE | 9/80 | |
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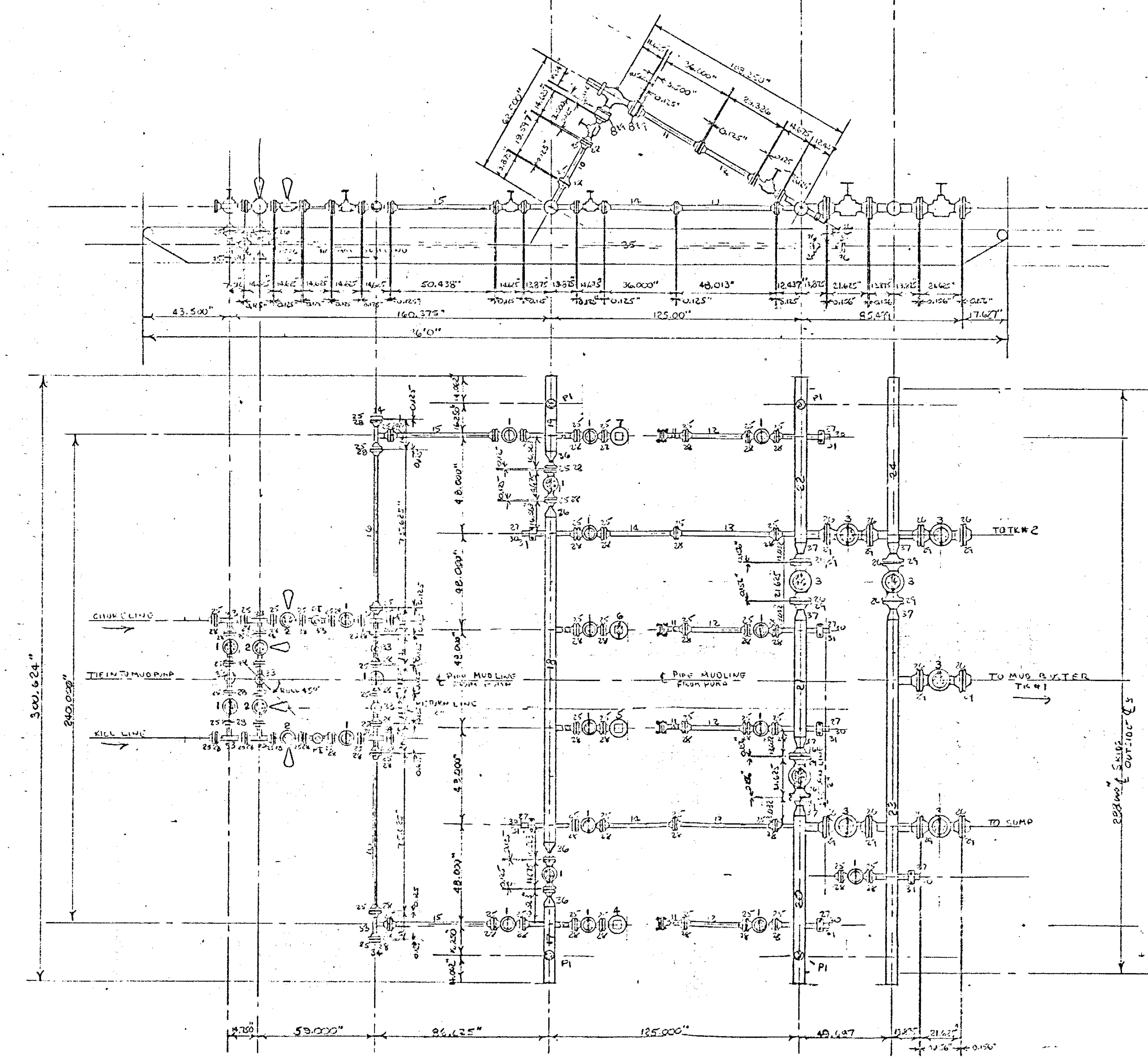
Figure A-3 - Choke Manifold Design




# BILL OF MATERIALS

| ITEM NO. | NO. REQ'D | IN STK. | UNIT PRICE | PART NUMBER | DESCRIPTION | AMOUNT |
|---|---|---|---|---|---|---|
| 1 | 20 | | | | VALVE CAMERON F GATE 2-1/16" API 5000 PSI WOG (10,000 PSI TEST) END TO END FLANGED, RING JOINT # 24 | |
| 2 | 4 | | | | VALVE CAMERON F GATE 2-1/16" API 5000 PSI WOG (10,000 PSI TEST) END TO END FLANGED RING JOINT # 24 AIR OPERATED W/ [illegible] | |
| 3 | 8 | | | | VALVE CAMERON F GATE 4-1/16" API 5000 PSI WOG (10,000 PSI TEST) END TO END FLANGED, RING JOINT # 39 | |
| 4 | 1 | | | | CHOKE HYDRAULIC W/ POSITION INDICATOR 3-1/8" 5000 PSI WP X 3-1/8" 5000 PSI WP, [illegible] ORIFICE CAMERON. RING JOINT # [illegible] | |
| 5 | 1 | | | | CHOKE CAMERON H-2 ADJUSTABLE 2-1/16" NOM 5000 PSI WP 2" MAX ORIFICE INLET AND OUTL FLGD 2-1/16 RING JOINT # 24 NEEDLE & [illegible] WITH TUNGSTEN CARBIDE TIP SEAT ST/STL TUNGSTEN CARBIDE TRIM [illegible] ALLOY STEEL BONNET ASSY. | |
| 6 | 1 | | | | CHOKE NL SWACO, HYDRAULIC W/ POSITION INDICATOR, 2-1/16" 5000 PSI WP (2-1/16" 5000 PSI WP), 2" MAX ORIFICE RING JOINT # [illegible] | |
| 7 | 1 | | | | CHOKE [illegible] HYDRAULIC W/ POSITION INDICATOR 2-1/16" 5000 PSI WP X 2-1/16" 5000 PSI WP, 2" MAX ORIFICE RING JOINT # [illegible] | |
| 8 | 6 | | | | SPOOL SPACER ADAPTER 2-1/16" 5000 PSI WP X 3-1/8" 5000 PSI WP RING JOINTS # 24 X # 35 - 3.500" LONG | |
| 9 | 2 | | | | SPOOL SPACER ADAPTER [illegible] 5000 PSI WP X 2-1/16 5000 PSI WP RING JOINTS | |
| 10 | 4 | | | | SPOOL SPACER 2-1/16 X 2-1/16 API 5000 WP D/F R-24, 19.597" LONG | |
| 11 | 4 | | | | SPOOL SPACER 2-1/16 X 2-1/16 API 5000 WP D/F R-24, 36" LONG | |
| 12 | 4 | | | | SPOOL SPACER 2-1/16 X 2-1/16 API 5000 WP D/F R-24, 20.336" LONG. | |
| 13 | 2 | | | | SPOOL SPACER 2-1/16 X 2-1/16 API 5000 WP D/F R-24, 48.013" LONG. | |
| 14 | 2 | | | | SPOOL SPACER 2-1/16 X 2-1/16 API 5000 WP D/F, R-24, 36.000" LONG | |
| 15 | 2 | | | | SPOOL SPACER 2-1/16 X 2-1/16 API 5000 WP D/F, R-24, 50.438" LONG | |
| 16 | 2 | | | | SPOOL SPACER 2-1/16 X 2-1/16 API 5000 WP D/F, R-24, 75.625" LONG | |
| 17 | 1 | | | | BUFFER TANK 5000 PSI WP ONE END SOLID, OTHER END 2-1/16" 5000 WP R-24 INLETS ONE 2-1/16 5000 WP R-24 OUTLETS ONE 2-1/16 5000 WP R-24 46.875" LONG. | |
| 18 | 1 | | | | BUFFER TANK 5000 PSI WP BOTH ENDS 2-1/16 5000 WP R-24, INLETS [illegible] 2-1/16 5000 WP R-24 OUTLETS TWO 2-1/16 5000 WP. [illegible] CIW CLAMP [illegible] 177.126" LONG | |
| 20 | 1 | | | | BUFFER TANK 5000 PSI WP ONE END [illegible] AND ONE END 4-1/16 5000 WP R-39, INLETS TWO 2-1/16 5000 WP [illegible] ONE 4-1/16 5000 WP [illegible] OUTLETS 2-1/16 5000 WP BX 152 CIW CLAMP APPROXIMATELY [illegible] LG. | |
| 21 | 1 | | | | BUFFER TANK, 5000 PSI WP BOTH ENDS 4-1/16" 5000 WP R-39 INLETS TWO 2-1/16 5000 WP R-24 OUTLETS TWO 2-1/16" 5000 WP BX 152 CIW CLAMP APPROXIMATELY 74.[illegible]" LG. | |
| 19 | 1 | | | | BUFFER TANK 5000 PSI WP ONE END SOLID, OTHER END 2-1/16 5000 WP R-24 INLETS ONE 2-1/16 5000 WP R-24 OUTLETS ONE 2-1/16 5000 WP R-24 46.875" LONG. | |
| 22 | 1 | | | | BUFFER TANK 5000 PSI WP ONE END SOLID, OTHER END 4-1/16 5000 WP R-39 INLETS TWO 2-1/16" 5000 WP R-24 OUTLET ONE 4-1/16 5000 WP R-39 OUTLET ONE 2-1/16 5000 WP BX 152 CLAMP CIW APPROXIMATELY [illegible] LG. | |
| 23 | 1 | | | | BUFFER TANK 5000 PSI WP ONE END SOLID, OTHER END 4-1/16 5000 WP R-39, INLETS [illegible] R-39 INLET ONE [illegible] R-24 OUTLET [illegible] 5000 WP R-24 OUTLET ONE [illegible] 5000 WP [illegible] CIW CLAMP [illegible] 157.[illegible]" LG. | |
| 24 | 1 | | | | BUFFER TANK 5000 PSI WP ONE END SOLID, OTHER [illegible] 5000 WP R-24 [illegible] OUTLET [illegible] 5000 WP R-24 | |
| 25 | 99 | | | | GASKET, SELF SEALING RING R-24 | |
| 26 | 16 | | | | GASKET, SELF SEALING RING R-39 | |
| 27 | 9 | | | | GASKET, SELF SEALING RING BX 152 | |
| 28 | 792 | | | | STUD 7/8 X 6-1/4 W/ 2 HEX NUTS EACH [illegible] B-7 | |
| 29 | 128 | | | | STUD 1-1/8 X [illegible] W/ 2 HEX NUTS EACH [illegible] B-7 | |
| 30 | 9 | | | | HUB, BLIND, [illegible] BUFFER 2-1/16 5000 WP BX 152 CIW CLAMP | |
| 31 | 9 | | | | CLAMP ASSY CIW 2-1/16" 5000 WP CIW HUB, [illegible] | |
| 32 | 2 | | | | CROSS, 2-1/16" 5000 PSI WP R-24 | |
| 33 | 16 | | | | TEE, 2-1/16" 5000 PSI WP R-24 | |
| 34 | 4 | | | | FLANGE, BLIND 2-1/16" 5000 PSI WP R-24 | |
| 35 | 9 | | | | SPOOL SPACER 2-1/16 X 2-1/16 API 5000 WP D/F R-24, [illegible] LONG | |
| 36 | 4 | | | | [illegible] 6" X [illegible] X X | |
| 37 ORIGINAL B/M NO. | | | | | [illegible] X X | |

| | | |
|---|---|---|
| DESIGNED | JIM SYKORA | 10-80 |
| DRAWN | JIM SYKORA | 10-80 |
| CHECKED | | |
| APPROVED | | |
| NOTED | | |

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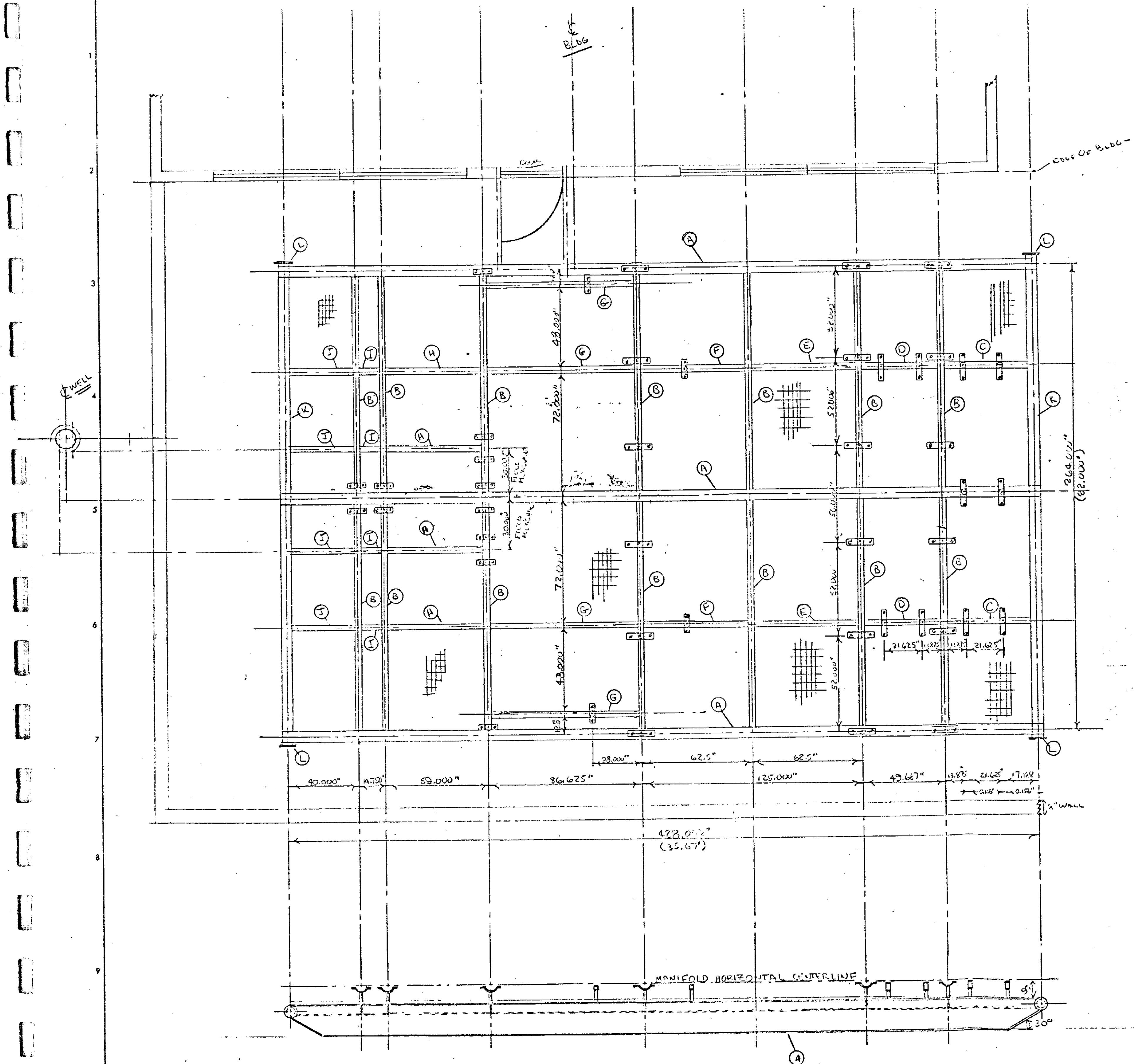
FOR CONSTRUCTION

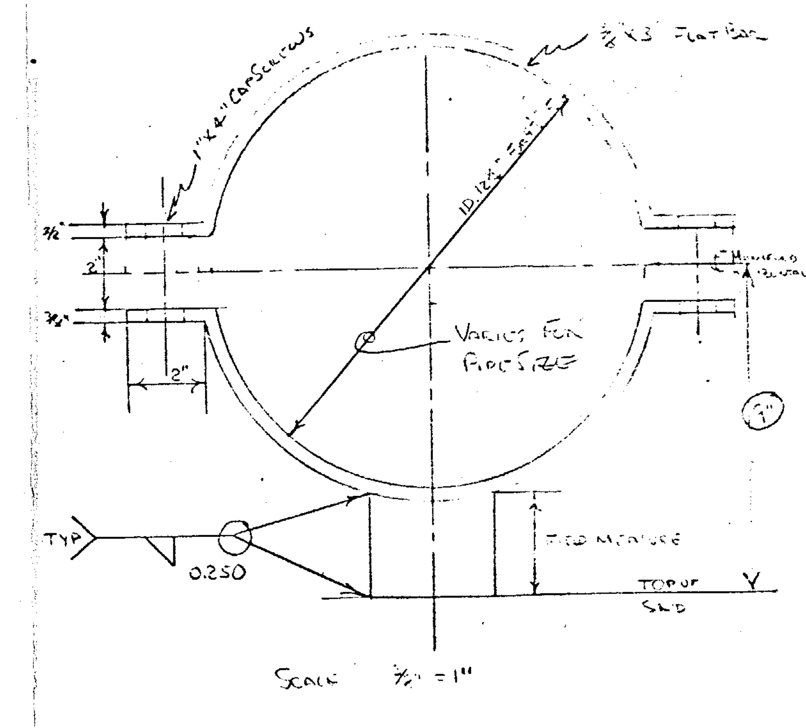
LOUISIANA STATE UNIVERSITY

CHOKE & KILL MANIF[illegible]

SHEET NO.

Figure A-4 - Choke Manifold Skid Design




- BILL OF MATERIALS

| ITEM | QTY. | MATERIAL |
|---|---|---|
| A | 3 | 15" x 6" x 54.7# I-BEAM 4[illegible] LONG |
| B | 14 | 6" x 3-3/8 x 17.25# I-[illegible] 13[illegible]" LONG |
| C | 2 | 6" x 3-3/8 x 17.25# I-BEAM 53" LONG |
| D | 2 | 6" x 3-3/8 x 17.25# I-BEAM [illegible] LONG |
| E | 2 | 6" x 3-3/8 x 17.25# I-BEAM 62.[illegible] LONG |
| F | 2 | 6" x 3-3/8 x 17.25# I-BEAM 62.5" LONG |
| G | 4 | 6" x 3-3/8 x 17.25# I BEAM [illegible] LONG |
| H | 4 | 6" x 3-3/8" x 17.25# I BEAM 59.0" LONG |
| I | 4 | 6" x 3-3/8 x 17.25# I BEAM 14.75" LONG |
| J | 4 | 6" x 3-3/8 x 17.25# I BEAM 40.0" LONG |
| K | 2 | 6XX PIPE - 274" LONG |
| L | 4 | 8" O.D. x 0.500" THK. MILD STEEL PLATE |
| M | 792 FT² | GRATING GALV TO COVER TOP OF SKID |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |

ORIGINAL B'M NO

| | | |
|---|---|---|
| DESIGNED | JHS | 11/[illegible] |
| DRAWN | JHS | 11/[illegible] |
| CHECKED | JHS | 11/[illegible] |
| APPROVED | | |
| NOTED | | |
| MFG. REP. | | |

ORIGINAL DWG. ISSUED WITH

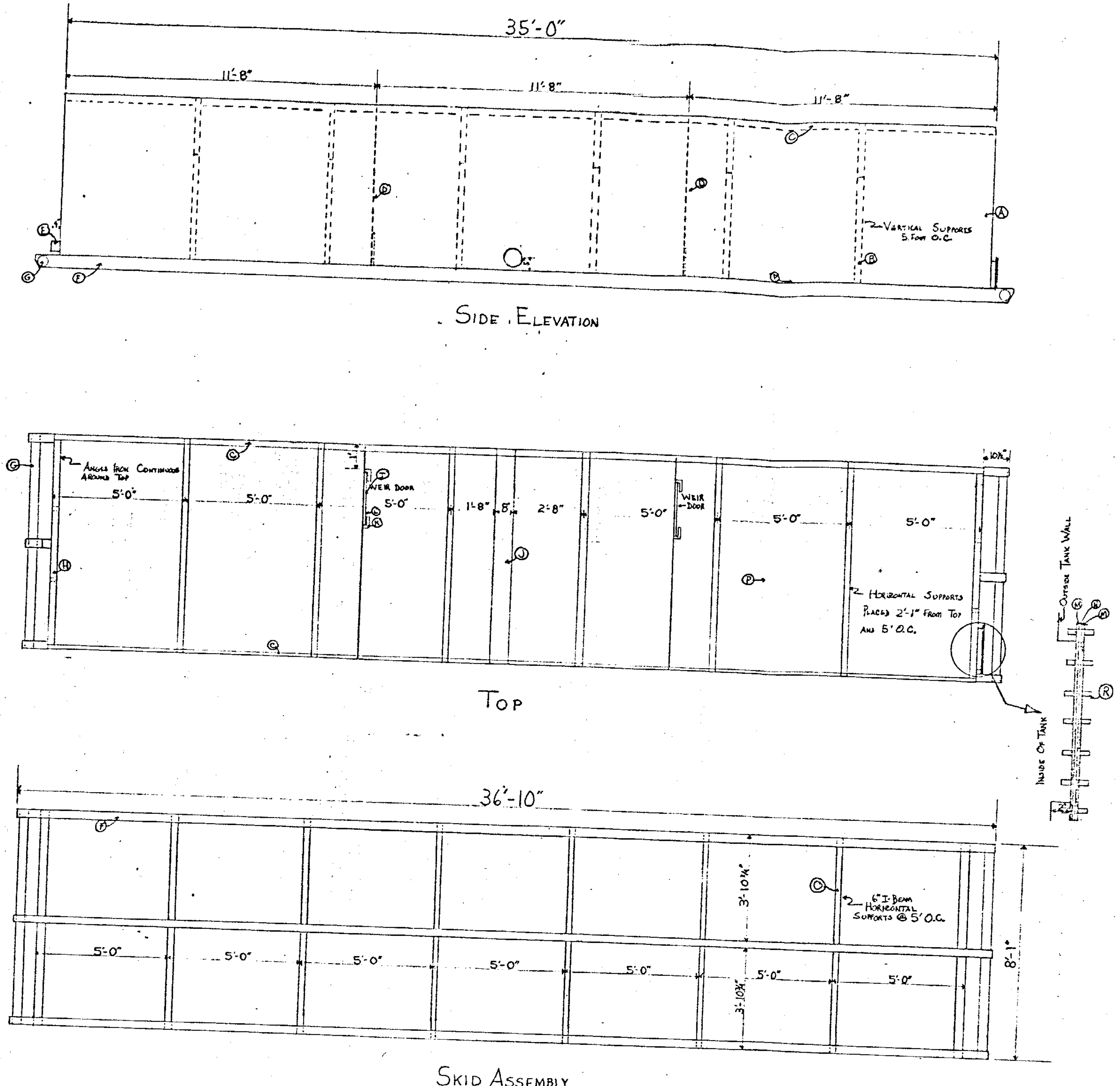
FOR BID PURPOSES ONLY
FOR CONSTRUCTION
FOR [illegible]

LSU SUBSEA RESEARCH WELL
MANIFOLD SKID

JOB NUMBER
SCALE

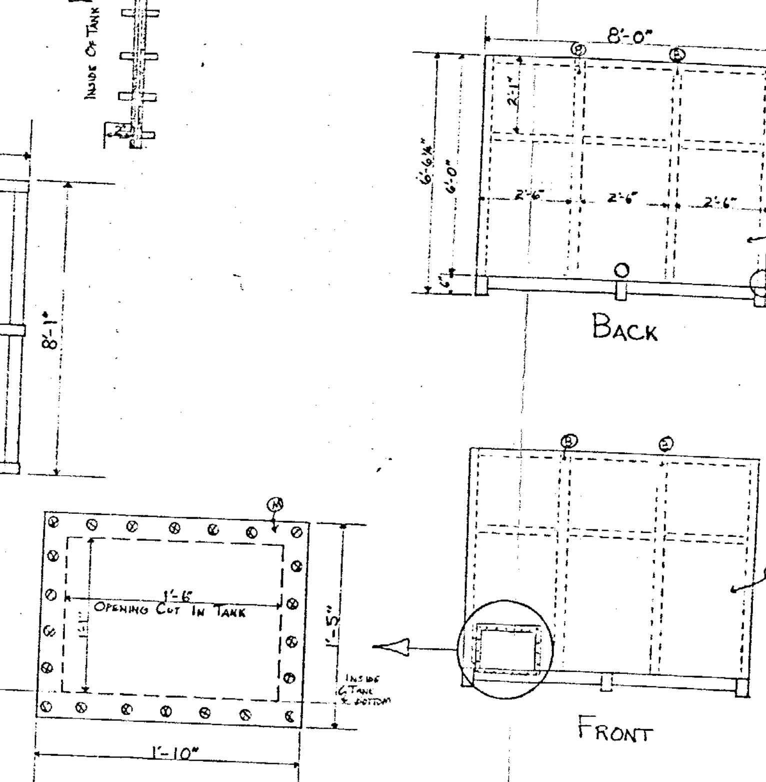
REV. | DWG. | REVISION | BY | DATE | APP
REV. | DWG. | REVISION | BY | DATE | APP
REVISION

Figure A-5 - Mud Tank Design




| ITEM | QUAN | DESCRIPTION |
|---|---|---|
| A | 2 | 6'-0" x 35'-0" x ¼" Plate C.S. |
| B | 16 | 2½" x 2½" x ¼" Angle 5'-11½" Long |
| C | 2 | 2½" x 2½" x ¼" Angle 35'-0" Long Placed Along Top Of Tank |
| D | 2 | 6'-0" x 7-11½" x ¼" Plate C.S. With Weir Door |
| E | 1 | 4" O.D. Drain Pipe With Inside Thread |
| F | 3 | 6" x 3½" x # I Beam 36'-10" Long |
| G | 2 | 4½" XX Pipe 8'-0" Long |
| H | 8 | 2½" x 2½" x ¼" Angle 7'-11" Long Placed Along Top Of Tank |
| I | 2 | 1'-0" x 2'-0" x ¼" Weir Door Plate |
| J | 1 | 8" XX Pipe 8'-0" Long |
| K | 8 | Guides 1" x 3/8" x 12" Long Flat Bar |
| L | 2 | Guides 1" x 3/8" x 24" Long Flat Bar |
| M | 2 | 1'-10" x 1'-5" x 3/4" Plate C.S. |
| N | 1 | ¼" x 1'-10" x 1'-5" Rubber Seal |
| O | 8 | 6" x 3½" x # I Beam 8'-1" Long |
| P | 1 | 8'-0" x 35'-0" x ¼" Plate C.S. |
| Q | 2 | 8'-0" x 6'-0" x ¼" Plate C.S. |
| R | 22 | Bolts |

Note: Weir Doors Are To Be Chain Operated From Above.
All Seams To Be Welded.




Note: All Wall Panes To Be Inset ½" For Welding Fillets

ORIGINAL B'M NO.

| | | |
|---|---|---|
| REV. DWG. MARK CUORD | REVISION | BY DATE APP |
| REV. DWG. MARK CUORD | REVISION | BY DATE APP |
| | REVISION | |

| | |
|---|---|
| DESIGNED | |
| DRAWN | |
| CHECKED | |
| APPROVED | |
| NOTED | |
| MFG. REP. | |

ORIGINAL DWG. ISSUED WITH

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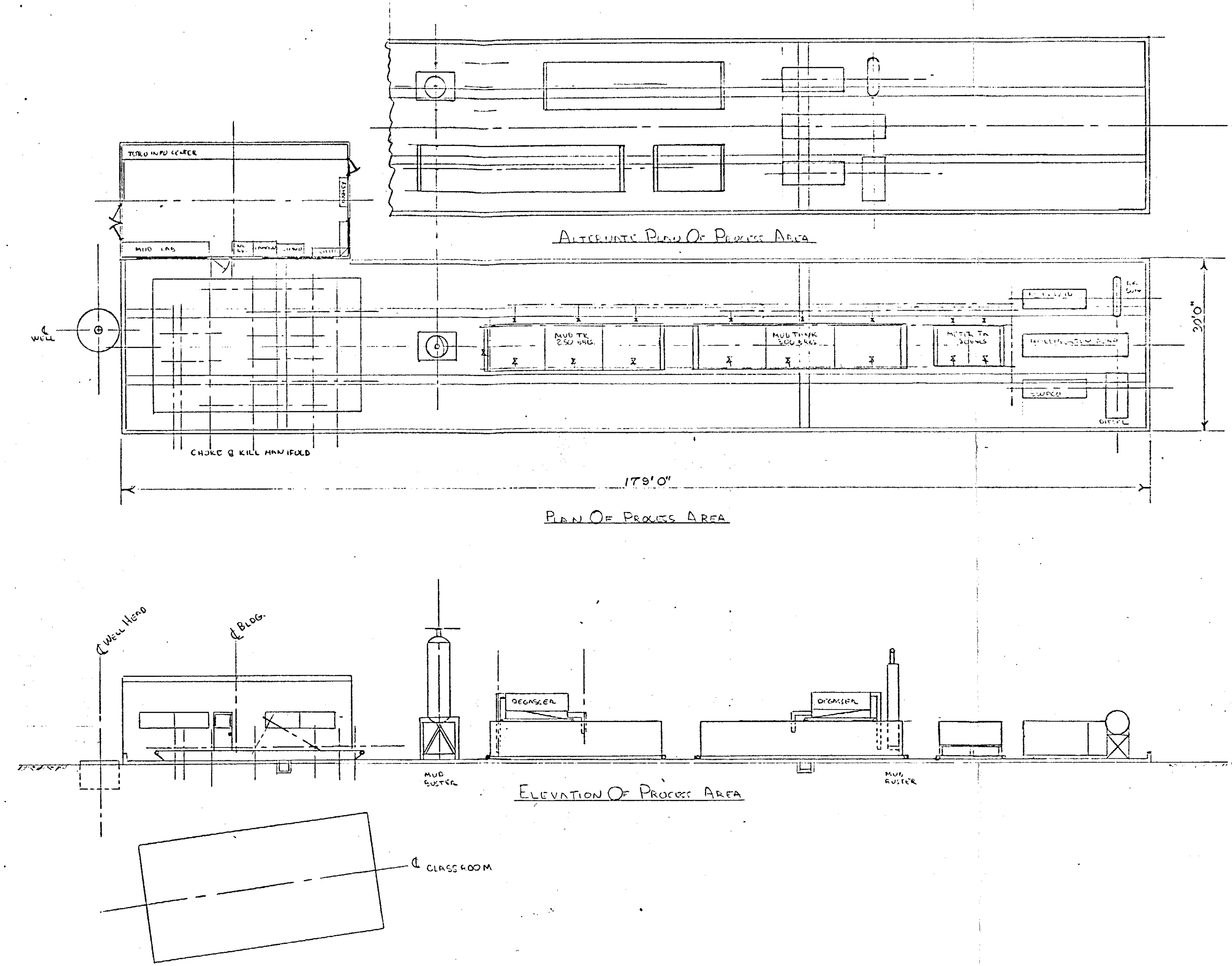
FOR CONSTRUCTION
FOR REFERENCE ONLY

LSU SUBSEA RESEARCH FACILITIES
MUD TANK 300 BBL CAPACITY

JOB NUMBER | SCALE

PRINTED

Figure A-6 - Surface Layout Plan




ORIGINAL B'M NO.

| | | | |
|---|---|---|---|
| DESIGNED | J.R. SYKORA | 1/01 | ORIGINAL DWG. ISSUED WITH |
| DRAWN | J.R. SYKORA | 1/01 | |
| CHECKED | | | |
| APPROVED | | | |
| NOTED | | | FOR BID PURPOSES ONLY ☐ |
| MFG. REP. | | | FOR CONSTRUCTION ☐ |
| | | | FOR REFERENCE ONLY ☒ |

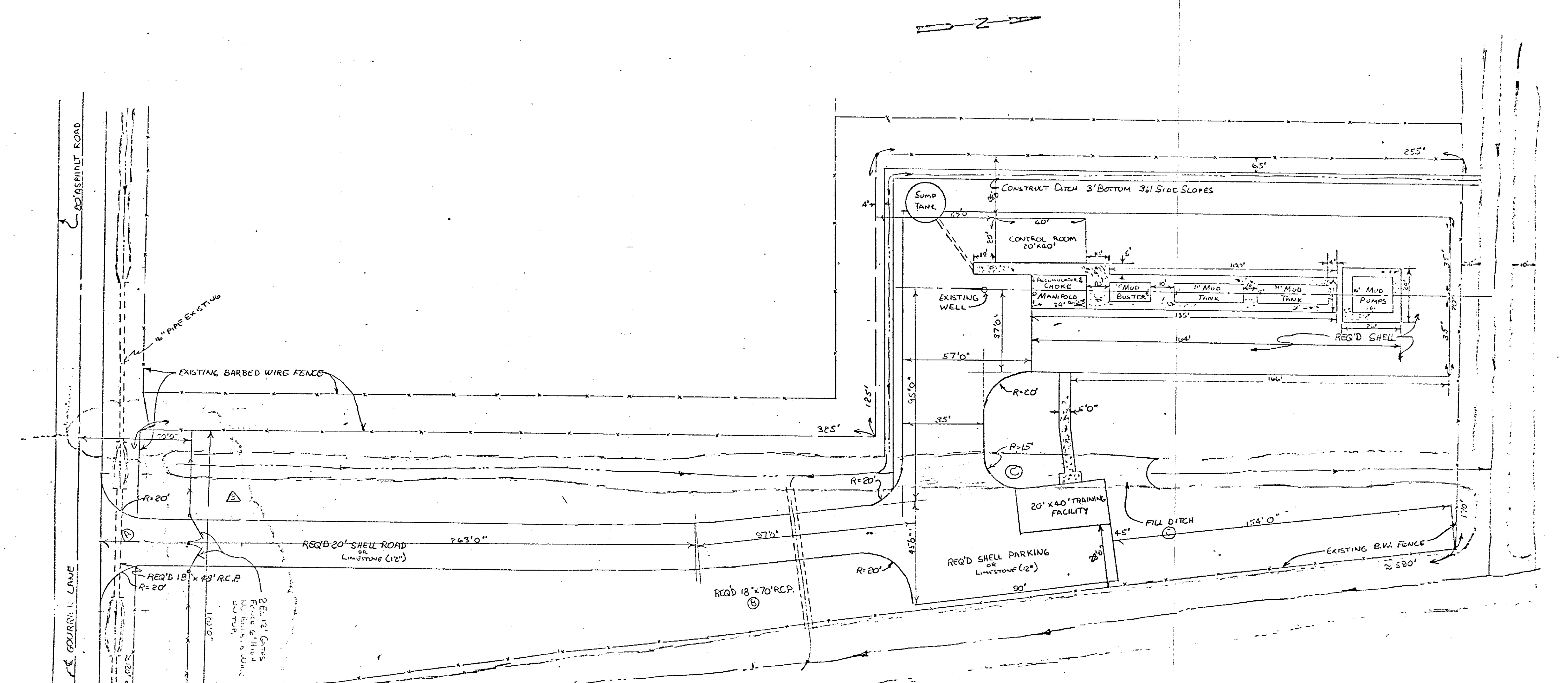
LSU SUBSEA RESEARCH WELL
PLAN OF AREA

JOB NUMBER | SCALE 1" = 10'0"

REV. DWG. MARK COORD. | REVISION | BY DATE APP.

PRINTED

Figure A-7 - Site Plan




NOTES: FIRST PHASE OF CONSTRUCTION

1. FROM CENTERLINE OF ROAD & PARKING REMOVE ROOTS TOP 4 TO 6" AND FEATHER TO DITCHES
2. INSTALL CULVERTS AT POINTS Ⓐ & Ⓑ AS SHOWN. USE CONCRETE CULVERT FURNISHED BY CONTRACTOR.
3. PLACE FIBRE GLASS MATTS (20' WIDE & OVERLAPPED) IN AREAS SHOWN FOR LIMESTONE PLACEMENT. MATTS FURNISHED BY CONTRACTOR.
4. TWELVE (12") INCHES OF LIMESTONE TO BE PLACED IN AREAS SHOWN FOR PHASE I, FURNISHED BY LSU.
5. DITCH AS SHOWN TO BE BACKFILLED AND COMPACTED TO GRADE, POINT Ⓒ. DITCH AS SHOWN TO BE CUT ON 3:1 SLOPE WITH 3' WIDE BOTTOM, DIRT TO BE USED TO FILL DITCH @ POINT Ⓒ
6. PRICE TO BE QUOTED ON COST PLUS NOT TO EXCEED QUOTATION. QUOTATION TO BE IN MONDAY, SEPTEMBER 29, 1980 TO JIM SYKORA @ TRAILER BY 12:00 PM
7. ANY QUESTIONS CALL JIM SYKORA 383-4173

| MARK | DATE | REVISIONS | BY | MARK | DATE | REVISIONS | BY |
|---|---|---|---|---|---|---|---|

| APPROVALS | | |
|---|---|---|
| DATE | BY | DEPT. |
| PROD. | | |
| SAFETY | | |
| TECH. | | |

THIS DRAWING IS THE PROPERTY OF DEPT. OF PETE

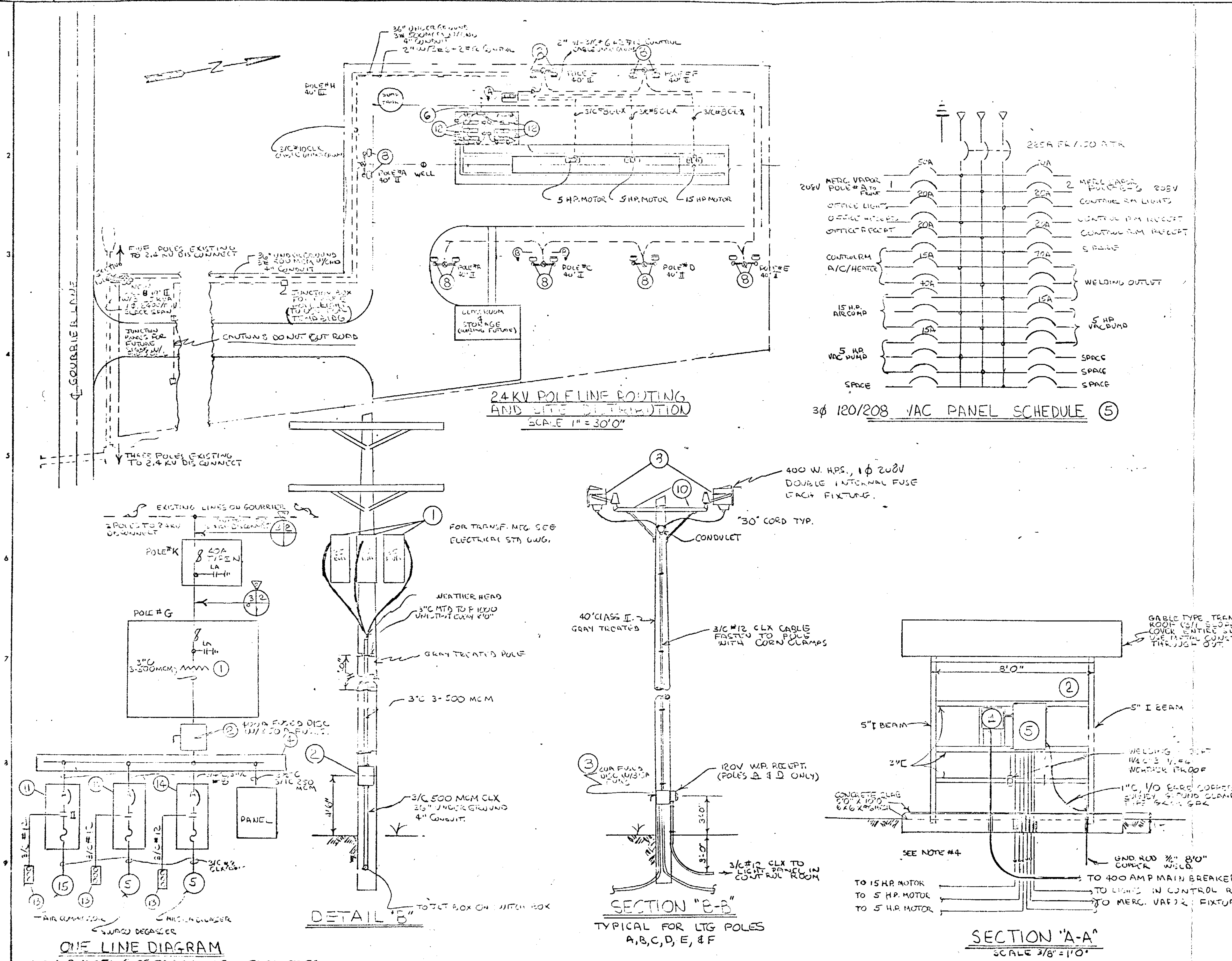


ENGINEERS AND CONSTRUCTORS
Baton Rouge, Louisiana

PROPOSED RESEARCH FACILITY

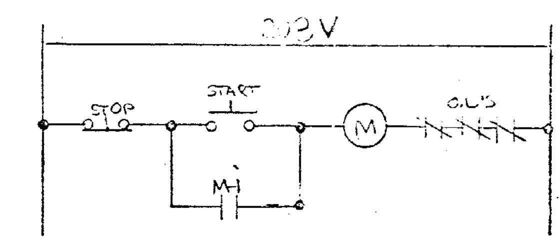
SCALE 1" = 200' DRAWN J.H.S.

Figure A-8 - Electrical Site Plans




## MATERIAL SCHEDULE

| MRK | QTY | DESCRIPTION |
|---|---|---|
| 1 | 3 | [illegible] KVA, POLE TOP TRANSFORMER [illegible] V, 1φ COMPLETE WITH BRACKETS |
| 2 | 1 | 400 A FUSED DISC, W/ [illegible] FUSES |
| 3 | 7 | [illegible] A FUSED DISC W/ [illegible] FUSES |
| 4 | 1 | LOW VOLTAGE BUS BOX, [illegible] NEMA [illegible] ENCLOSURE [illegible] |
| 5 | 1 | PANELBOARD ITE TYPE NHB [illegible] VAC [illegible] AMP MAINS W/ [illegible] BREAKER [illegible] CKT W/BREAKERS [illegible] |
| 6 | 1 | LOAD CENTER ITE NEMA 1, [illegible] VAC 60 AMP MAINS 12 CKT, SURFACE W/BREAKERS SHOWN IN SCHEDULE |
| 7 | — | — DELETE |
| 8 | 14 | 400 W H.P.S., 1φ 208V DOUBLE INTERNAL FUSE EACH FIXTURE |
| 9 | — | — DELETE |
| 10 | 7 | POLE MOUNT ASSEMBLY |
| 11 | 1 | SIZE II STARTER, ITE CLASS A31 BREAKER EF, NEMA 4 ENCLOSURE |
| 12 | 6 | FLUORESCENT FIXTURE, - 4 LAMP |
| 13 | 3 | START-STOP WIRED PILOT LIGHT PUSH BUTTON STATION ITE NEMA 4 ENCLOSURE |
| 14 | 2 | SIZE 0 STARTER, ITE CLASS A31 BREAKER EF, NEMA 4 ENCLOSURE |




MOTOR CONTROL DIAGRAM

NOTES:

1. ALL CABLES TO BE A MINIMUM OF 36" BELOW FINISHED GRADE
2. ALL 1/C INSULATION TO BE TYPE THW.
3. CLX INDICATES [illegible] CABLE TYPE CLX SPEC [illegible]
4. CONTRACTOR TO INSTALL [illegible] CONDUIT THIMBLES FOR CLX CABLES [illegible] THRU SLAB
5. C/H INDICATES CROUSE-HINDS CO. OR APPROVED (EQUAL)
6. ALL NEMA 4 ENCLOSURES TO BE EQUIPPED WITH DRAIN & BREATHER
7. ALL STEEL TO BE COATED WITH TWO COATS OF CORROSION RESISTANT PAINT (WHITE FINAL COAT)
8. ALL UNDERGROUND CABLE [illegible] WITH RED CONCRETE.

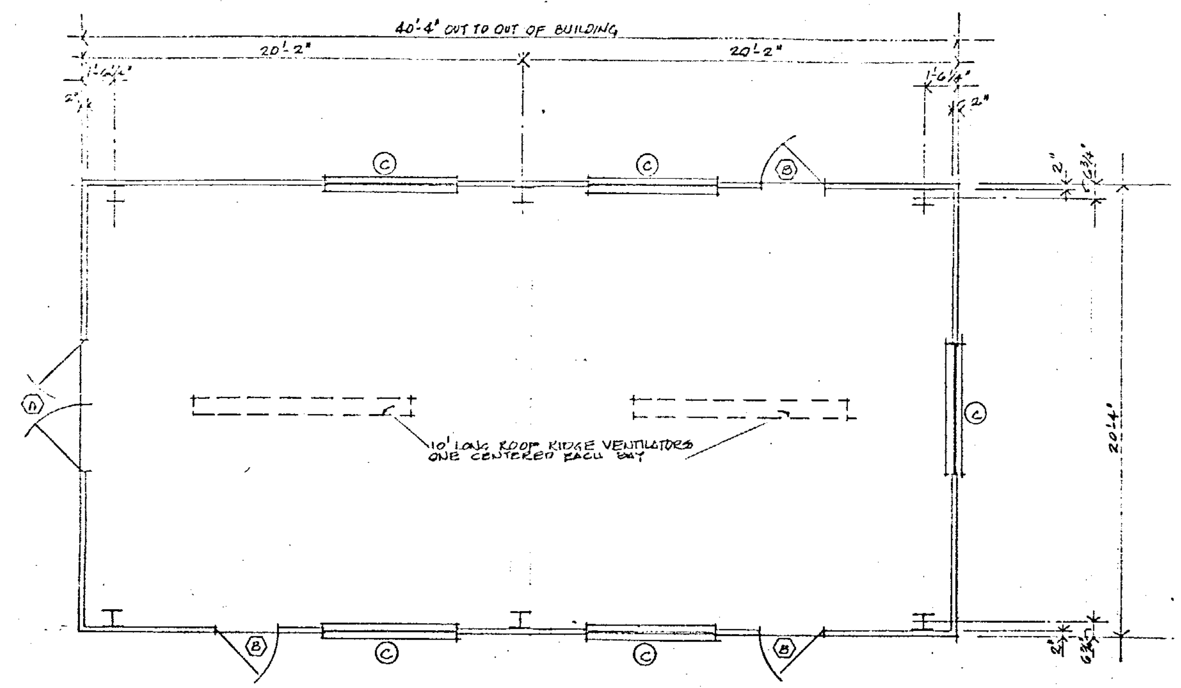
| | | |
|---|---|---|
| DESIGNED | J.H. SYKORA | 10/[illegible] |
| DRAWN | J.H. SYKORA | 10/[illegible] |
| CHECKED | W. HOLDEN | 10/[illegible] |
| APPROVED | A.J. BOURGOYNE | 10/[illegible] |
| NOTED | | |
| MFG. REF. | | |

ORIGINAL B/W NO.

LOUISIANA STATE UNIVERSITY
LSU SUBSEA RESEARCH WELL FACILITIES
ELECTRICAL PLAN AND DETAILS

REVISION REVISION REVISION

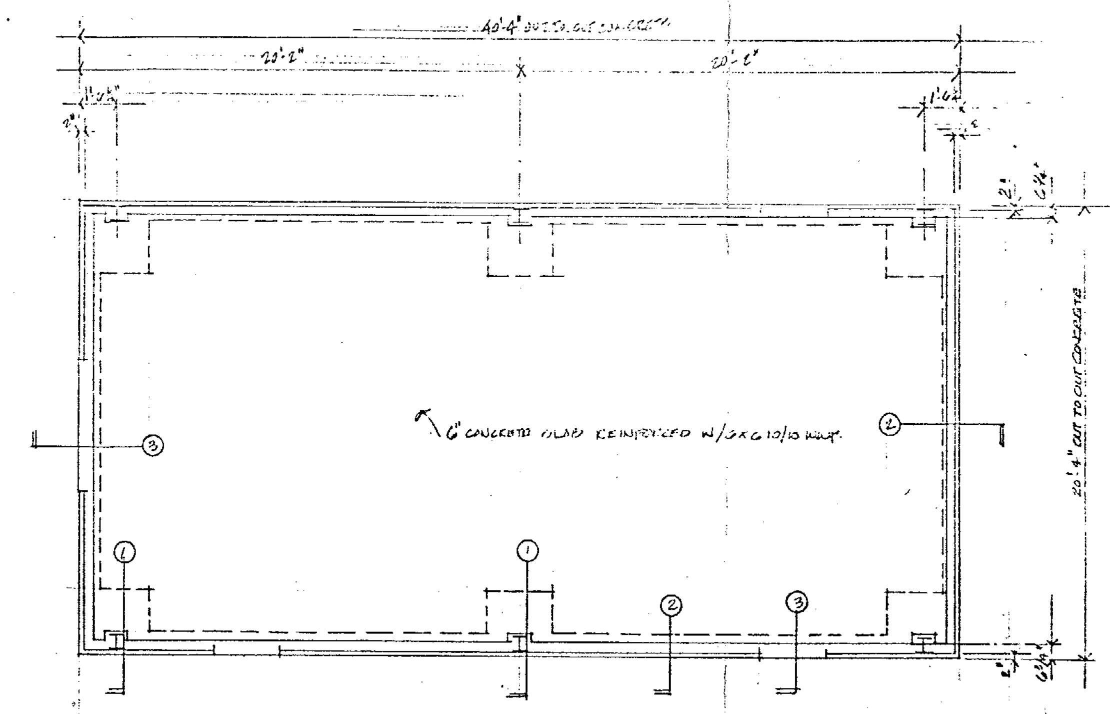
Figure A-9 - Control House Design



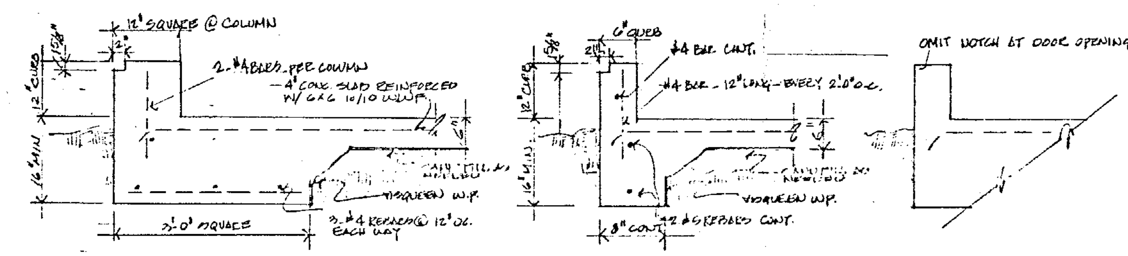

FLOOR PLAN BUILDING "A" (BUILDING "B", SIMILAR)
SCALE: 1/4" = 1'-0"

GENERAL NOTES!

1. BUILDING TO BE ALL STEEL STRAIGHT RIGID FRAME, DIMENSIONS AS SHOWN ABOVE WITH A 12' EAVE HEIGHT.
2. WALLS AND CEILING TO BE INSULATED WITH 3" VINYL BACKED FIBERGLASS BATTS.
3. GALVANIZED ROOF AND WALL PANELS SHALL BE COLOR FINISHED WITH DOUBLE-LAM, OR APPROVED EQUAL, WITH A MINIMUM 20 YEAR GUARANTEE.
4. EACH BUILDING TO HAVE TWO ROOF VENTS, ONE EACH BAY.
5. MARKED OPENINGS, AS SCHEDULED BELOW, ARE TO BE LOCATED IN THE FIELD AS APPROVED BY OWNER:
   - (A) 6'-0" x 7'-0" PAIR, DOUBLE DOORS, STEEL WITH HALF GLASS — 1/4" SAFETY GLASS. (ONE, EACH BUILDING)
   - (B) 3'-0" x 7'-0" STEEL DOOR, WITH HALF GLASS, 1/4" SAFETY GLASS (THREE, EACH BUILDING)
   - (C) 6'-0" x 3'-0" ALUMINUM SLIDING GLASS WINDOW (FIVE, EACH BUILDING)
6. BASE BID TO INCLUDE: BUILDING "A", BUILDING "B", AND SITE WORK AS INDICATED ON PLOT PLAN, SHT. 2. ALTERNATE 1 TO INCLUDE BUILDING "C".
7. ALL INTERIOR PARTITIONS & FINISHES ARE TO BE BY OWNER.

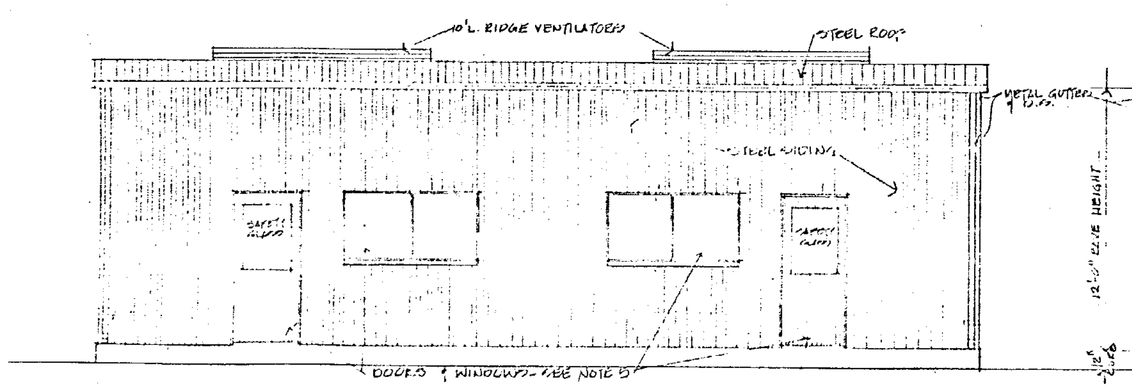



FOUNDATION PLAN - BUILDING "A" (BUILDING "B" - SIMILAR)
SCALE: 1/4" = 1'-0"

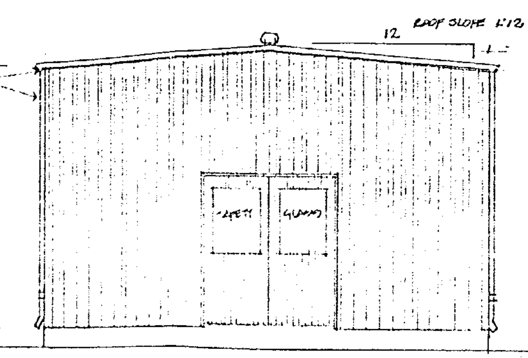



SECTION 1 SECTION 2 SECTION 3

FOUNDATION SECTIONS
SCALE: 1/4" = 1'-0"



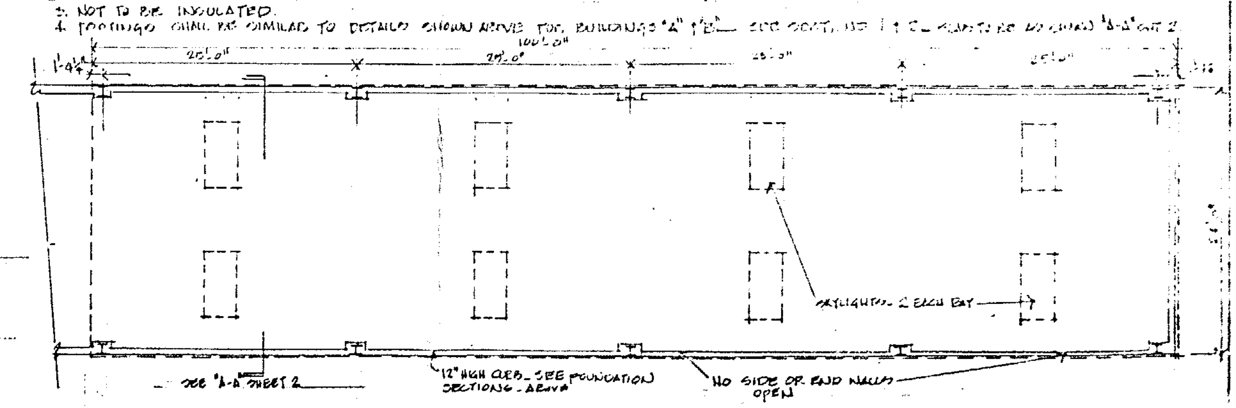

SIDE ELEVATION (TYPICAL)
SCALE: 1/4" = 1'-0"



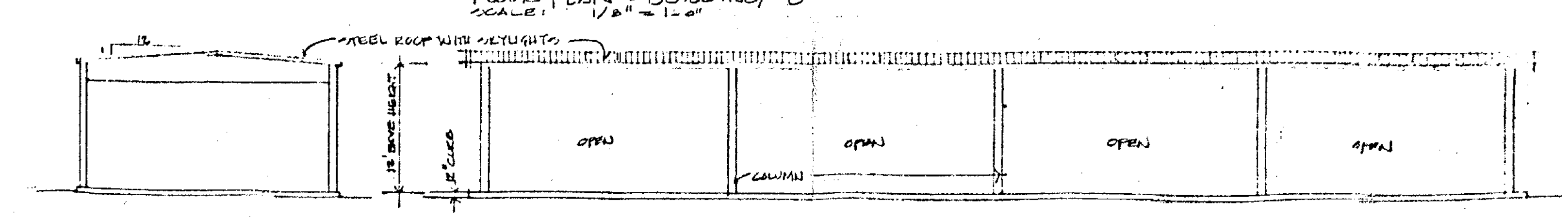

END ELEVATION (TYPICAL)
SCALE: 1/4" = 1'-0"

ALTERNATE NUMBER 1

1. ALTERNATE NUMBER ONE IS DESCRIBED BELOW AS BUILDING "C" — ALSO SEE SITE PLAN ON SHT. 2.
2. A PRICE FOR ALTERNATE NUMBER 1 SHALL BE SHOWN SEPARATE FROM THE BASE BID.
3. NOT TO BE INSULATED.
4. FOOTINGS SHALL BE SIMILAR TO DETAILS SHOWN ABOVE FOR BUILDINGS "A" & "B" [illegible]




FLOOR PLAN - BUILDING "C"
SCALE: 1/8" = 1'-0"




END ELEVATION (TYPICAL) BLDG. "C" SIDE ELEVATION (TYPICAL) BUILDING "C"
SCALE: 1/8" = 1'-0"

# PROPOSED RESEARCH FACILITY
LOUISIANA STATE UNIVERSITY
BATON ROUGE, LOUISIANA

SEPTEMBER 8, 1960

SHEET 1 OF 2

# Appendix B

## Flow Coefficient Data on Commercial Drilling Chokes

Table A-1 - Flow Data for Cameron Manually Adjustable Drilling Choke (2 in diameter)

| Drilling Fluid Sample | Choke Position (fraction open) | Flow Rate (GPM) | Upstream Pressure (PSIG) | Valve Capacity Coefficient Cv |
|---|---|---|---|---|
| 1 | 0.500 | 280 | 20 | 63.80 |
| | | 285 | 80 | 32.47 |
| | | 305 | 180 | 23.17 |
| | | 315 | 220 | 21.64 |
| | | 320 | 285 | 19.32 |
| | 0.375 | 270 | 50 | 38.91 |
| | | 285 | 100 | 29.04 |
| | | 295 | 150 | 24.54 |
| | | 307 | 220 | 21.09 |
| | | 315 | 300 | 18.53 |
| | 0.313 | 275 | 105 | 27.35 |
| | | 285 | 180 | 21.65 |
| | | 290 | 250 | 18.69 |
| | | 300 | 340 | 16.58 |
| | | 310 | 440 | 15.06 |
| 2 | 0.281 | 270 | 100 | 27.51 |
| | | 275 | 190 | 20.33 |
| | | 285 | 280 | 17.36 |
| | | 295 | 400 | 15.03 |
| | | 307 | 630 | 12.46 |
| | 0.250 | 263 | 120 | 24.47 |
| | | 275 | 320 | 15.67 |
| | | 285 | 460 | 13.54 |
| | | 295 | 620 | 12.07 |
| | | 300 | 800 | 10.81 |
| | 0.219 | 260 | 180 | 19.75 |
| | | 270 | 380 | 14.11 |
| | | 280 | 570 | 11.95 |
| | | 285 | 820 | 10.14 |
| | | 290 | 1070 | 9.03 |

Table A-1 (Continued)

| Drilling Fluid Sample | Choke Position (fraction open) | Flow Rate (GPM) | Upstream Pressure (PSIG) | Valve Capacity Coefficient Cv |
|---|---|---|---|---|
| 3 | 0.188 | 255 | 265 | 15.96 |
| | | 265 | 600 | 11.02 |
| | | 270 | 820 | 9.61 |
| | | 275 | 1120 | 8.37 |
| | | 280 | 1400 | 7.63 |
| | 0.156 | 250 | 360 | 13.43 |
| | | 255 | 690 | 9.89 |
| | | 260 | 1180 | 7.71 |
| | | 262 | 1520 | 6.85 |
| | | 265 | 1870 | 6.24 |
| | 0.125 | 245 | 350 | 13.34 |
| | | 250 | 850 | 8.74 |
| | | 255 | 1250 | 7.35 |
| | | 260 | 1900 | 6.08 |

Table A-2 - Flow Data for Patterson Remote Adjustable Drilling Choke

| Drilling Fluid Sample | Choke Position (fraction open) | Flow Rate (GPM) | Upstream Pressure (PSIG) | Valve Capacity Coefficient Cv |
|---|---|---|---|---|
| 4 | 0.750 | 282 | 15 | 74.20 |
| | | 290 | 17 | 71.67 |
| | | 303 | 19 | 70.84 |
| | | 305 | 20 | 69.50 |
| | 0.625 | 278 | 15 | 73.15 |
| | | 285 | 20 | 64.94 |
| | | 295 | 25 | 60.12 |
| | | 300 | 30 | 55.81 |
| | 0.500 | 258 | 240 | 16.97 |
| | | 265 | 660 | 10.51 |
| | | 273 | 1230 | 7.93 |
| | | 280 | 1640 | 7.05 |
| 5 | 0.333 | 252 | 260 | 15.93 |
| | | 256 | 610 | 10.56 |
| | | 267 | 1200 | 7.85 |
| | | 270 | 1880 | 6.35 |
| | 0.250 | 245 | 630 | 9.95 |
| | | 248 | 1100 | 7.62 |
| | | 250 | 1340 | 6.96 |
| | | 252 | 1920 | 5.86 |
| 6 | 0.200 | 240 | 560 | 10.33 |
| | | 243 | 890 | 8.30 |
| | | 245 | 1340 | 6.82 |
| | | 247 | 1790 | 5.95 |
| | 0.167 | 240 | 650 | 9.59 |
| | | 242 | 1040 | 7.65 |
| | | 244 | 1480 | 6.46 |
| | | 246 | 1960 | 5.66 |

Table A-3 - Flow Data for Swaco Super Remote Adjustable Drilling Choke

| Drilling Fluid Sample | Choke Position (fraction open) | Flow Rate (GPM) | Upstream Pressure (PSIG) | Valve Capacity Coefficient Cv |
|---|---|---|---|---|
| 7 | 0.750 | 280 | 20 | 63.62 |
| | | 285 | 23 | 60.38 |
| | | 300 | 42 | 47.04 |
| | | 312 | 62 | 40.26 |
| | | 320 | 70 | 38.86 |
| | | 323 | 80 | 36.69 |
| | 0.625 | 277 | 27 | 54.17 |
| | | 295 | 55 | 40.42 |
| | | 308 | 70 | 37.40 |
| | | 320 | 80 | 36.35 |
| | | 328 | 100 | 33.33 |
| | 0.500 | 275 | 40 | 44.18 |
| | | 295 | 80 | 33.52 |
| | | 305 | 105 | 30.24 |
| | | 315 | 120 | 29.22 |
| | | 320 | 135 | 27.98 |
| | 0.333 | 265 | 40 | 42.57 |
| | | 270 | 50 | 38.80 |
| | | 273 | 70 | 33.15 |
| | | 275 | 100 | 27.94 |
| | | 277 | 130 | 24.69 |
| | 0.250 | 267 | 90 | 28.60 |
| | | 271 | 170 | 21.12 |
| | | 273 | 270 | 16.88 |
| | | 275 | 370 | 14.53 |
| | | 277 | 540 | 12.11 |
| | 0.200 | 265 | 360 | 14.19 |
| | | 270 | 870 | 9.30 |
| | | 273 | 1200 | 8.01 |
| | 0.167 | 251 | 830 | 8.85 |
| | | 255 | 1120 | 7.74 |
| | | 260 | 1500 | 6.82 |

Table A-3 (Continued)

| Drilling Fluid Sample | Choke Position (fraction open) | Flow Rate (GPM) | Upstream Pressure (PSIG) | Valve Capacity Coefficient Cv |
|---|---|---|---|---|
| 14 | 0.500 | 265 | 450 | 12.73 |
| | | 269 | 950 | 8.89 |
| | | 272 | 1460 | 7.25 |
| | 0.333 | 255 | 480 | 11.86 |
| | | 260 | 1060 | 8.14 |
| | | 264 | 1410 | 7.16 |
| | | 267 | 1880 | 6.28 |
| | 0.250 | 252 | 520 | 11.26 |
| | | 257 | 920 | 8.63 |
| | | 261 | 1340 | 7.27 |
| | | 264 | 1920 | 6.14 |
| | 0.200 | 250 | 320 | 14.24 |
| | | 253 | 940 | 8.41 |
| | | 257 | 1300 | 7.26 |
| | | 260 | 1840 | 6.18 |
| | 0.167 | 246 | 340 | 13.60 |
| | | 250 | 880 | 8.59 |
| | | 254 | 1400 | 6.92 |
| | | 257 | 1820 | 6.14 |

Table A-4 - Flow Data for Cameron High Pressure Remote Adjustable Drilling Choke

| Drilling Fluid Sample | Choke Position (fraction open) | Flow Rate (GPM) | Upstream Pressure (PSIG) | Valve Capacity Coefficient Cv |
|---|---|---|---|---|
| 8 | 0.500 | 163 | 20 | 37.03 |
| | | 190 | 50 | 27.30 |
| | | 237 | 100 | 24.08 |
| | | 263 | 140 | 22.58 |
| | | 273 | 160 | 21.93 |
| 9 | 0.375 | 160 | 40 | 25.70 |
| | | 210 | 130 | 18.71 |
| | | 220 | 170 | 17.14 |
| | | 247 | 220 | 16.92 |
| | | 265 | 280 | 16.09 |
| 10 | 0.250 | 96 | 120 | 8.90 |
| | | 121 | 250 | 7.78 |
| | | 149 | 380 | 7.77 |
| | | 173 | 580 | 7.30 |
| | | 192 | 750 | 7.12 |
| 11 | 0.125 | 13 | 390 | 0.699 |
| | | 19 | 700 | 0.730 |
| | | 20 | 1020 | 0.636 |
| | | 39 | 1380 | 1.067 |
| | | 40 | 1850 | 0.945 |
| 12 | 0.188 | 67 | 290 | 4.000 |
| | | 73 | 700 | 2.804 |
| 13 | 0.188 | 86 | 1070 | 2.671 |
| | | 105 | 1320 | 2.936 |
| | | 111 | 1670 | 2.760 |

| Drilling Fluid Sample | Density ppg | Plastic Viscosity cp | Yield Point lb/100 ft$^2$ | Temperature F | Gel Strength lb/100 ft$^2$ @ 10 sec | @ 10 min | Fann Viscometer Dial Readings 600 rpm | 300 rpm | 200 rpm | 100 rpm | 6 rpm | 3 rpm |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 8.65 | 20.0 | 9.5 | 60 | 4.0 | 14.0 | 49.5 | 29.5 | 22.5 | 13.5 | - | - |
| 2 | 8.65 | 14.0 | 14.5 | 85 | 2.5 | 12.0 | 42.5 | 28.5 | 21.0 | 12.5 | - | - |
| 3 | 8.65 | 12.5 | 15.0 | 108 | 2.5 | 11.0 | 40.0 | 27.5 | 20.5 | 11.0 | - | - |
| 4 | 8.65 | 10.5 | 4.0 | 73 | 3.0 | 3.5 | 25.0 | 14.5 | 11.0 | 6.5 | 1.0 | 0.5 |
| 5 | 8.65 | 11.5 | 5.0 | 83 | 3.5 | 4.0 | 28.0 | 16.5 | 12.7 | 7.5 | 1.5 | 1.0 |
| 6 | 8.65 | 12.0 | 4.5 | 76 | 3.0 | 4.0 | 28.5 | 16.5 | 12.0 | 7.0 | 1.5 | 1.0 |
| 7 | 8.60 | 20.0 | 10.0 | 72 | 2.0 | 7.0 | 50.0 | 30.0 | 23.0 | 15.0 | - | - |
| 8 | 8.60 | 11.5 | 10.5 | 98 | 2.0 | 15.0 | 33.5 | 22.0 | 17.0 | 11.5 | - | - |
| 9 | 8.60 | 11.0 | 10.5 | 104 | 2.0 | 15.0 | 32.5 | 21.5 | 17.0 | 11.5 | - | - |
| 10 | 8.60 | 12.5 | 10.5 | 86 | 2.0 | 15.0 | 35.5 | 23.0 | 17.5 | 11.5 | - | - |
| 11 | 8.60 | 11.0 | 11.5 | 98 | 2.0 | 15.0 | 33.5 | 22.5 | 17.0 | 11.0 | - | - |
| 12 | 8.60 | 13.0 | 10.0 | 85 | 3.0 | 16.0 | 36.0 | 23.0 | 17.5 | 12.5 | - | - |
| 13 | 8.60 | 13.0 | 10.0 | 88 | 3.0 | 15.0 | 36.0 | 23.0 | 17.5 | 12.5 | - | - |
| 14 | 8.65 | 21.0 | 16.0 | 58 | 11.0 | 30.0 | 58.0 | 37.0 | 28.5 | 19.0 | 8.0 | 6.5 |

Table A-5 - Properties of Drilling Fluids Used in Determining Flow Characteristics of Drilling Chokes

# Appendix C

## Flow Coefficient Data on NL-Shaffer Annular Blowout Preventer

| Drilling Fluid Sample | Temp. (°F) | Density (lb/gal) | Plastic Viscosity (cp) | Yield Point ($lb/100\ ft^2$) | Gel Strength @ 1 min | Gel Strength @ 10 min | Fann Dial Readings 600 rpm | 300 rpm | 200 rpm | 100 rpm | 6 rpm | 3 rpm |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 70 | 8.33 | 1.0 | 0.0 | 0.0 | 0.0 | 2.0 | 1.0 | .67 | 0.33 | - | - |
| 2 | 80 | 8.6 | 6.5 | 2.0 | 1.0 | 2.0 | 15.0 | 8.5 | 6.0 | 4.0 | 1.0 | - |
| | 86 | 8.6 | 7.0 | 1.0 | 1.0 | 3.0 | 15.0 | 8.0 | 6.0 | 4.0 | 1.0 | - |
| | 106 | 8.6 | 7.0 | 3.0 | 1.0 | 3.0 | 17.0 | 10.0 | 8.0 | 5.0 | 1.0 | - |
| 3 | 93 | 8.6 | 20.0 | 22.0 | 29.0 | 44.0 | 62.0 | 42.0 | 35.0 | 27.0 | 12.0 | 12.0 |
| 4 | 89 | 8.6 | 11.0 | 6.0 | 5.0 | 13.0 | 28.0 | 17.0 | 14.0 | 9.0 | 2.0 | 1.0 |
| | 104 | 8.6 | 11.0 | 11.0 | 11.0 | 19.0 | 33.0 | 22.0 | 18.0 | 14.5 | 2.5 | 2.0 |
| 5 | 101 | 8.7 | 17.0 | 16.0 | 8.0 | High | 50.0 | 33.0 | 25.0 | 16.5 | 5.0 | 3.5 |

Table C-1 - Drilling Fluid Properties Used in Determining Flow Characteristics of Annular Blowout Preventer

Table C-2 - Flow Characteristics of 6 in. Annular Blowout Preventer

| Drill Pipe O.D. (in.) | Drilling Fluid Sample | Piston Position (in.) | Piston Position Frac. (open) | Flow Rate (gpm) | Hydraulic Pressure (psig) | Well Pressure (psig) | Value Coefficient Cv |
|---|---|---|---|---|---|---|---|
| 2.375 | 1 | 0 | 1.000 | 162.6 | 0 | 0 | - |
| | | 1.552 | 0.483 | 168.0 | 0 | 20 | 37.6 |
| | | 1.968 | 0.613 | 168.0 | 0 | 30 | 30.7 |
| | | 2.3715 | 0.7386 | 168.0 | 0 | 30 | 30.7 |
| | | 2.7854 | 0.8675 | 130.9 | 0 | 580 | 5.4 |
| | | 2.8840 | 0.8982 | 84.0 | 0 | 1400 | 2.2 |
| | | 3.211 | 0.0 | 0.0 | - | - | 0 |
| 2.375 | 1 | 0.000 | 1.000 | 168.0 | 0 | 0 | - |
| | | | | 122.0 | 0 | 0 | - |
| | | | | 63.0 | 0 | 0 | - |
| | | 2.4458 | 0.7496 | 176.0 | 0 | 0 | - |
| | | | | 116.0 | 0 | 0 | - |
| | | | | 59.0 | 0 | 0 | - |
| | | 2.6507 | 0.8124 | 177.0 | 0 | 60 | 22.9 |
| | | | | 119.0 | 0 | 20 | 26.6 |
| | | | | 48.0 | 0 | 3 | 27.7 |
| | | | | 180.0 | 0 | 40 | 28.46 |
| | | | | 113.5 | 0 | 20 | 25.4 |
| | | | | 48.5 | 0 | 3 | 28.0 |
| | | 2.8546 | 0.8748 | 157.5 | 0 | 320 | 8.8 |
| | | | | 107.5 | 0 | 190 | 7.8 |
| | | | | 46.0 | 0 | 40 | 7.3 |
| | | | | 150.5 | 0 | 420 | 7.3 |
| | | | | 120.0 | 0 | 320 | 6.7 |
| | | | | 47.5 | 0 | 140 | 4.0 |
| | | 3.0585 | 0.9373 | 101 | 250 | 1280 | 2.8 |
| | | | | 54.5 | 250 | 820 | 1.9 |
| | | | | 20.5 | 250 | 560 | 0.87 |
| | | | - Automatic Closure - | | | | |
| 2.375 | 2 | 0.0 | 1.000 | 171.5 | 0 | 0 | - |

Table C-2 (Continued)

| Drill Pipe O.D. (in.) | Drilling Fluid Sample | Piston Position (in.) | Piston Position Frac. (open) | Flow Rate (gpm) | Hydraulic Pressure (psig) | Well Pressure (psig) | Value Coefficient Cv |
|---|---|---|---|---|---|---|---|
| | | 1.6450 | 0.5000 | 171.5 | 0 | 0 | - |
| | | 2.4675 | 0.7500 | 171.5 | 220 | 30 | 31.3 |
| | | 2.6733 | 0.8125 | 168 | 300 | 140 | 14.2 |
| | | | | 158.5 | 300 | 280 | 9.4 |
| | | | | 130.5 | 300 | 60 | 16.9 |
| | | | | 84.0 | 300 | 20 | 18.8 |
| | | 2.8788 | 0.8750 | 120 | 440 | 780 | 4.3 |
| | | | | 117 | 440 | 860 | 4.0 |
| | | | | 90 | 440 | 700 | 3.4 |
| | | | | 77 | 440 | 580 | 3.2 |
| | | | | 46.5 | 440 | 440 | 2.2 |
| 2.375 | 3 | 0 | 1.000 | 118.5 | 0 | 0 | - |
| | | 2.4675 | 0.7500 | 168.0 | 220 | 20 | 37.6 |
| | | 2.6733 | 0.8126 | 157.5 | 300 | 240 | 10.2 |
| | | | | 114.5 | 300 | 160 | 9.1 |
| | | | | 76.0 | 300 | 70 | 9.1 |
| | | 3.0844 | 0.9375 | - Automatic Closure - | | | |
| 3.500 | 4 | 0.0 | 1.000 | 168 | - | 100 | 16.8 |
| | | | | 118.5 | - | 40 | 18.7 |
| | | | | 53 | - | 20 | 11.9 |
| | | | | 42 | - | 10 | 13.3 |
| | | 1.511 | 0.5182 | 168 | - | 100 | 16.8 |
| | | | | 109.5 | - | 60 | 14.1 |
| | | | | 41.0 | - | 40 | 6.4 |

Table C-2 (Continued)

| Drill Pipe O.D. (in.) | Drilling Fluid Sample | Piston Position (in.) | Piston Position Frac. (open) | Flow Rate (gpm) | Hydraulic Pressure (psig) | Well Pressure (psig) | Value Coefficient Cv |
|---|---|---|---|---|---|---|---|
| | | 2.201 | 0.7549 | 168 | - | 120 | 15.3 |
| | | | | 91 | - | 60 | 11.7 |
| | | | | 41 | - | 40 | 6.5 |
| | | 2.558 | 0.8774 | 86 | - | 1380 | 2.3 |
| | | | | 65.5 | - | 1100 | 2.0 |
| | | | | 42.5 | - | 880 | 1.4 |
| 3.500 | 5 | 0.0 | 1.000 | 174.0 | - | 100 | 17.4 |
| | | | | 111.0 | - | 60 | 14.3 |
| | | | | 41.0 | - | 20 | 9.2 |
| | | | | 165.0 | - | 100 | 16.5 |
| | | | | 106.5 | - | 60 | 13.7 |
| | | | | 43.5 | - | 20 | 9.7 |
| | | 2.187 | 0.7500 | 168 | - | 90 | 17.7 |
| | | | | 99.5 | - | 60 | 12.8 |
| | | | | 43.5 | - | 40 | 6.9 |
| | | 2.551 | 0.8750 | 95.5 | - | 1180 | 2.8 |
| | | | | 66.0 | - | 900 | 2.2 |
| | | | | 33.5 | - | 760 | 1.2 |
| | | 2.733 | 0.9375 | - Automatic Closure - | | | |
| 4.500 | 1 | 0.0 | 1.0 | 48 | 0 | 3.4 | 26.0 |
| | | 1.757 | 0.6174 | 50 | 100 | 3.8 | 25.6 |
| | | | | 100 | 100 | 5.2 | 43.8 |
| | | | | 143 | 100 | 7.6 | 51.9 |
| | | | | 185 | 100 | 11.0 | 55.8 |
| | | 1.933 | 0.700 | 19 | 100 | 13.5 | 5.17 |
| | | | | 46 | 100 | 47 | 6.7 |
| | | | | 101 | 100 | 150 | 8.3 |
| | | | | 141 | 100 | 180 | 10.5 |

Table C-2 (Continued)

| Drill Pipe O.D. (in.) | Drilling Fluid Sample | Piston Position (in.) | Piston Position Frac. (open) | Flow Rate (gpm) | Hydraulic Pressure (psig) | Well Pressure (psig) | Value Coefficient Cv |
|---|---|---|---|---|---|---|---|
| | | 2.134 | 0.7500 | 26 | 200 | 250 | 1.6 |
| | | | | 44 | 200 | 280 | 2.6 |
| | | | | 94 | 200 | 325 | 5.2 |
| | | | | 143 | 200 | 350 | 7.6 |
| | | 2.277 | 0.8000 | 8 | 200 | 425 | 0.39 |
| | | | | 45 | 195 | 500 | 2.01 |
| | | | | 87 | 140 | 550 | 3.71 |
| | | | | 141 | 200 | 560 | 5.96 |
| | | 2.423 | 0.851 | 6 | 1150 | 750 | 0.22 |
| | | | | 13 | 1150 | 975 | 0.42 |
| | | | | 51 | 1200 | 1175 | 1.5 |
| | | | | 76 | 1200 | 1300 | 2.1 |
| | | | | 87 | 1200 | 1800 | 2.1 |
| | | 2.561 | 0.8999 | - Automatic Closure - | | | |