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# STUDY OF CEMENTING PRACTICES APPLIED TO THE SHALLOW CASING IN OFFSHORE WELLS

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# FOREWORD

Occasional blowouts caused by annular gas flow has long plagued the petroleum industry. They often occur within the first few hours, sometimes minutes, after cementing a casing string. The objective of this study was to learn the causes of such annular flow problems and, possibly, to identify important research areas, or techniques, that could lead to corrective solutions.

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## ABSTRACT

Survey information shows annular gas flow associated with cementing defects to be a major problem in shallow casing strings offshore as well as in other cemented strings in oil and gas wells. The gas flow hazard to safety, environment, and economics could be reduced by an aggressive program keyed to prevent gas migration. The program components are: 1) historical data base, 2) training, 3) research of cement hydration in a long, thin column, and 4) development of logging-surveillance devices.

## SUMMARY

Failure of cement, particularly with the shallow strings, can result in safety, environmental protection, and economic problems in offshore petroleum production.

Our interviews and surveys show that annular gas flow is a major problem not only in the shallow casing in offshore wells, but also in the other pipe strings in land as well as offshore operations. However, the greatest hazard is the migration of gas behind conductor or surface casing because the gas can reach the surface within hours (within minutes in extreme cases). Well-control measures to halt annular gas flow are difficult to implement.

Thus, the best approach to safety and environmental protection is the prevention of gas migration. The prevention effort can be categorized into two distinct types that address the components of the annular gas flow problem:

1. User projects that can be immediately implemented when reviewed and funded. Examples:

    a. A historical data base software and hardware system for compilation of cementing and well-control information. System users would be the USGS, cementing service companies, drilling contractors and operating companies.

b. A training program on cementing basics, state-of-the-art prevention of annular gas flow, and well control. Users would be from all facets of industry.

2. Research projects that are multi-year studies to simulate and model cementing phenomena as well as to develop gas flow detection devices. Examples:

   a. Study the cement hydration mechanism in a long, thin column and causes for gas entry.

   b. Study the logging devices and develop tool enhancements that can locate behind pipe channels which permit gas flow.

## CONCLUSIONS

1. Annular gas flow through cement defects or flow induced by loss of cement hydrostatic pressure are major hazards to safety, environment, and economics.

2. Statistical data on failure cause and frequency or a historical data base on cementing applications has not been compiled.

3. Less than state-of-the-art hole conditioning and cementing procedures are sometimes used and contribute to failures.

4. Limited study has been done on cement hydration mechanics in a long, thin column.

5. Surveillance/logging tools are available to detect gas flow, but precise locating of wellbore channels for well-control implementation cannot be done with existing equipment.

## INTRODUCTION

Inadequate cement behind casing is a problem that has continuously affected the petroleum industry because the procedures, materials, and equipment used to displace the borehole-casing annulus mud with cement slurry are unsuccessful in a significant percentage of occasions. The cement defects are manifested as an incomplete sheath, commonly called channels, in the annular space (see Figure 1); as a honeycombed structure that has mud, gas, or water as a dispersed phase; or as poor bonding of the cement to the casing.

Intrusion of gas, oil, or water into the annular space is possible when the setting cement loses its capability to maintain hydrostatic pressure on the rock formations. The higher pressured formation fluids

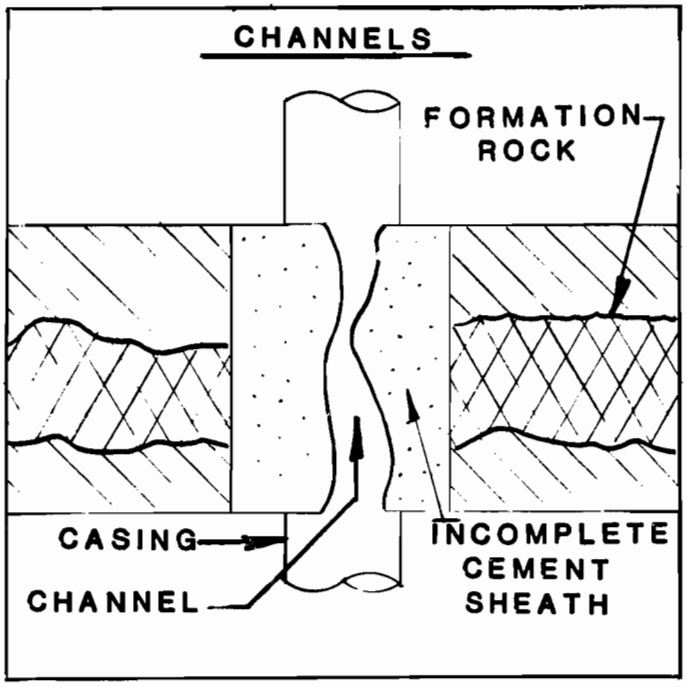


Figure 1

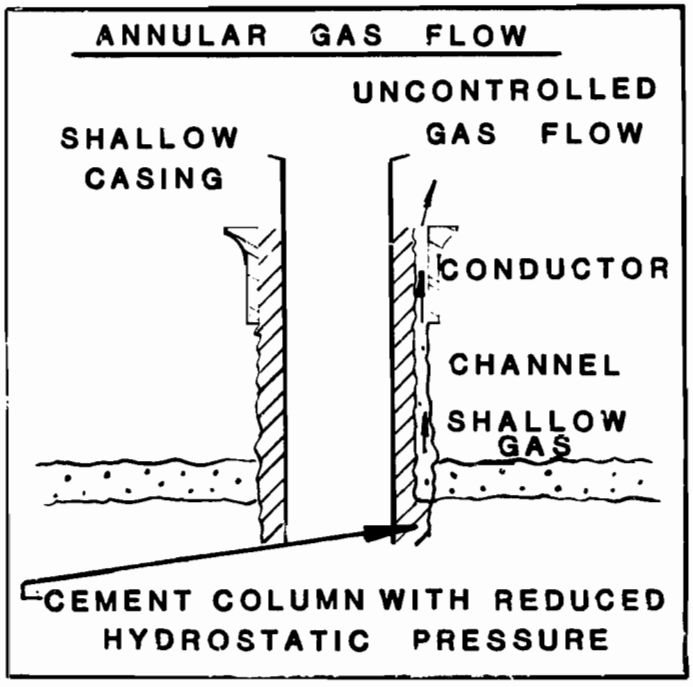


Figure 2

fluids can then flow, either to lower pressured rock zones, or directly to the surface (see Figure 2). This loss of hydrostatic pressure control and the channels are not apparent until fluids are flowing to the surface, or in an uncontrolled flow, such as a leak to the seafloor or gas flowing into and pressurizing a shallow sand. At this point, remedial work is difficult as well as expensive, and severe hazard to life and environment can exist.

Cementing problems and annular gas flow caused or contributed to the hazardous drilling conditions and blowouts reported in Outer Continental Shelf (OCS) Operations Safety Alert Notices 2, 24, 43, and 66 issued by the Gulf of Mexico Area United States Geological Survey (USGS). These defective casing cement jobs (as well as undetected problems) were caused by cementing practices that are inadequate due to lack of information, less than state-of-the-art procedures, and technology weak on cement hydration mechanics.

Successful cementing logically is related to specific practices which should be possible to delineate. Just as important are the surveillance devices and evaluation of their capability to indicate defects. This project and subsequent recommended work can bring about a reduction in hazards and the following benefits:

1. Safety Improved by Reduced Risk from:

   A. Underground Blowouts
   B. Pressurized Shallow Sands
   C. Blowout Adjacent Conductor and Potential Loss of Platform

2. Environmental Protection Enhanced by Reduced Potential for Leaks to the Seafloor or Shallow Formations

3. Economics:

   A. Expensive Blowout Risk is Reduced (as well as Public Loss of Confidence in Industry and Agencies)

   B. Reduced Well Control Problems Save Drilling Time and Cost

   C. Remedial Squeeze Jobs Are Reduced

## STUDY RESULTS

The purpose of the study is to identify the major problems associated with cementing the shallow casing in offshore wells and to recommend actions directed toward improvement. The six major tasks are:

1. Identify Problems
2. Analyze Information
3. Identify Type of Improvements Needed
4. Identify Sources of Technology and Lab Facilities
5. Research and Development Recommendations
6. Report

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### Task 1 IDENTIFY PROBLEMS

We will initiate a literature survey and commence personal interviews with operators, drilling contractors, and cementing company personnel. The research will be used to assess failure modes, frequency, and costs. We will also use USGS reports to accumulate case histories and review regulations for requirements related to cementing practices. A state-of-the-art review of surveillance tools will be done.

Result:

A literature search and verbal discussions with authors and other involved persons provided most of the information for this project. Statements on failure modes and on key items were solicited; however, hard statistical data to support failure frequencies and causes are non-existent or proprietary. From this comes the recommendation for a historical data-base system. Regulation reviews and surveillance tool reviews were more easily accomplished.

## Task 2 ANALYZE INFORMATION

The case histories and interviews will help identify the widespread major problems that have the greatest impact on safety, environmental protection, and economics. Those problems with significant potential for improvement will be identified.

Results:

Technical reports, case histories from USGS problem reports (an example is attached as Appendix 2), coupled with verbal reports lead to an information analysis on the cementing problem: gas (or other formation fluids) flowing in the annulus subsequent to cementing causes the hazard to safety, environment, and economics.

Although safety and environment are primary points, future project justification is aided by the economic impact. The actual cost of events occurring in response to this problem has not been estimated, but included are blowouts, well-control operations, cement mixture experiments, trial/error cement slurry formulations, laboratory cementing models, and theoretical analyses. Further information analysis shows that annular gas flow is really a sequence of distinct occurrences:

A. Insufficient historical information on hazardous locations and on successful cement mixtures/cementing procedures.

B. Inadequate hole preparation prior to cementing and failure to use the mechanical devices plus procedures that aid good cementation.

C. Unreliable cement slurry mixtures resulting from insufficient theoretical and laboratory model simulation of the cement hydration process and the related critical factors.

D. Insufficient cement column hydrostatic pressure for well control occurs during the cement hydration process.

E. Inability to detect the channel location in the annulus and to control the gas flow.

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## Task 3 IDENTIFY TYPE OF IMPROVEMENTS NEEDED

The potential improvements can be categorized as to procedures, equipment or materials, detection devices, training, or reporting requirements. Responsibility for the items can be referred to either the oil companies, drilling contractor, or cementing service company.

Results:

The improvement potential consists of two distinct type efforts:

1. User oriented projects that require only approval and funding to achieve a product that can be immediately implemented. Examples are:

   a. A cementing-well control historical data base software and hardware system for use by the USGS, cementing service companies, and the operator companies; and

   b. A training program on cementing basics, state-of-the-art regarding annular gas flow prevention, and well control in annular gas flow situations.

2. Research oriented projects that are multi-year studies with theoretical models, laboratory experiments, and with joint industry participation in the projects. The examples are:

   a. Research on the cement hydration mechanism in a long, thin column, using both a theoretical model and laboratory experiments to relate the setting mechanism to gas entry; and

   b. Research on logging tools with potential to locate a behind-pipe gas flow path channel in the 360° circumference of the wellbore.

## Task 4 IDENTIFY SOURCES OF TECHNOLOGY AND LAB FACILITIES

Some areas will require additional research and development. Thus, we need to identify sources of expertise and research capability.

Results:

Future projects will necessarily draw on the combined expertise of the public and private sectors. Industry groups such as the API Committee 10 on Standardization of Oilwell Cements and the Offshore Operators Committee are focal points for operating companies and service companies, some which were willing to comment on future work (Appendix 3). National laboratories, universities, and consultants are also sources of technology for the recommended projects.

## Task 5 RESEARCH AND DEVELOPMENT RECOMMENDATIONS

Recommendations for research proposals and research location will be made based on Tasks 2, 3, and 4. Each proposal will be allocated time and money based on its importance to improved cementing practice or detection methods and the benefit gained in safety, environmental protection, or economics.

Results:

These action recommendations stem from the objective of preventing annular gas flow. The recommended projects are two types:

1. User Projects

   a. A cementing-well control historical data base.

   b. A training program on basics, gas-flow prevention, and well control.

2. Research Projects

   a. Cement hydration mechanism in a long, thin column and causes for gas entry.

   b. Logging tool improvements needed to locate behind pipe channels which permit gas flow.

The first group of improvement items are aimed at the often repeated lament that not enough information is compiled on the casing cementing jobs; thus, cementing technology doesn't evolve at a desirable pace. Another often repeated comment concerned the physical/mechanical procedures that, on occasion, are carelessly implemented or are less than state-of-the-art technology. Historical data accumulation and training are the obvious methods to rectify this lack of information.

These projects could provide immediate user application upon task termination; the two previously identified projects are:

1a. A cementing-well control historical data base could be developed by a paid professional working with an industry related group such as the API Committee 10 on Standardization of Oilwell Cements and/or the Offshore Operators Committee. The data base would provide information storage and retrieval on successful/unsuccessful cement slurry mixes, cementing procedures, and well-control methods. Key tasks are the gathering of volunteered information, the development of the computer software storage/retrieval routines, the mating of software to a selected computer (main frame or mini) with terminal access for all parties.

1b. A training program on basics, gas-flow prevention, and well control should be available for contractors/oil companies that have repeated annular gas flow with a subsequent well-control problem. This material could be available on slide/tapes or video cassettes to train interested personnel on potentially hazardous locations, cement contamination, mud conditioning, mechanical procedures, cement hydration mechanics, annular gas flow, slurry mixtures, cementing procedures, logging tools for flow behind pipe, and well-control methods applicable to flow behind pipe.

The above projects improve safety and environmental protection by bringing current information and up-to-date technology to those persons making the operating decisions. A secondary effect is an improved level of expertise among all the personnel involved in this phase of drilling; this benefit is immediate because the programs can be quickly implemented. However, just as important are the research projects that might lead to prevention of annular gas flow and to superior well-control procedures.

The second group of improvement items are the research projects. These are two-to-three year efforts that initially will be theoretical model studies, secondly, experimental studies with laboratory models, and finally, development of commercial products readily available to all, as well as a source of royalties that could partially reimburse the program. Technology and laboratory expertise would be supplied by universities, national laboratories, consultants, cementing service companies, and oil companies. Several have expressed interest but have reserved judgment until a program has been formulated. The programs should be concentrated on that research which will lead to prevention of annular gas flow and to positive well-control techniques should a problem occur; the research proposals are:

2a. A study of the cement hydration mechanism in a long, thin column and causes for gas entry is fundamental to a prevention breakthrough. An intensive effort to develop a theoretical hydration model would be best accomplished by an independent group such as a national laboratory, consultant, or university. This model can be drawn from other cementing research and applied to the wellbore environment, i.e., the long, thin column, with the objective of predicting pressure behavior throughout the column. The hydration process causes a loss of column pressure with subsequent gas entry; thus, the research

should focus on the interdependence of the setting mechanism and pressure in the column.

2b. An investigation should be conducted on logging tool improvements which would provide capability to locate behind pipe channels permitting gas flow and causing well-control problems. Even when annular gas flow is occurring, current practice is to squeeze cement the casing shoe, whereas the gas flow may be entering at a formation some distance above the shoe. A positive method to delineate a channel is needed and potentially is available by making an existing tool into one capable of locating the channel in the 360° circumference of the wellbore. Required is research on the theoretical methods, followed by laboratory wellbore models for tool validation.

Task 6 REPORT

Write a summary report.

## DISCUSSION

A recent review by Tinsley et al[1] describes various types of annular gas flow problems, identifies some of the producing fields with recurring cementing defects and gas flows, and estimates some of the costs of remedial work. A summary of the information:

| Field | Typical Problem | Cost Estimate of Remedial Cementing |
|---|---|---|
| High Island | Gas flow on conductor and surface casing | $20K to $350K per well |
| Katy | Gas flow from high pressure to low pressure zones | $1.2 million over 5 years |
| Wolfcamp/Pennsylvanian | Gas flow on deep liners | $150K to $200K per well |
| Anadarko Basin | Gas flow on liner | $150K to $200K per well |
| Ship Shoal Area | Gas flow on liner | $530K on a well |
| South Texas Area | Gas flow between strings of casing | No estimate given |

Other reports concern the blowouts that have occurred because gas has flowed on the shallow casing after cementing. One of the few documented sources, OCS Operations Safety Alerts (Appendix 2), provides details of offshore well blowouts:

| Notice No. | Cemented Casing Size and Depth | Lapsed Time to Gas Flow | Lapsed Time of Blowout |
|---|---|---|---|
| 43 | 10-3/4" @ 2716' | 5-1/2 hrs | 16 days |
| 66 | surface | several hrs | not given |
| OCS | 13-3/8" @ 4000' | 2 hrs | 5 hrs |

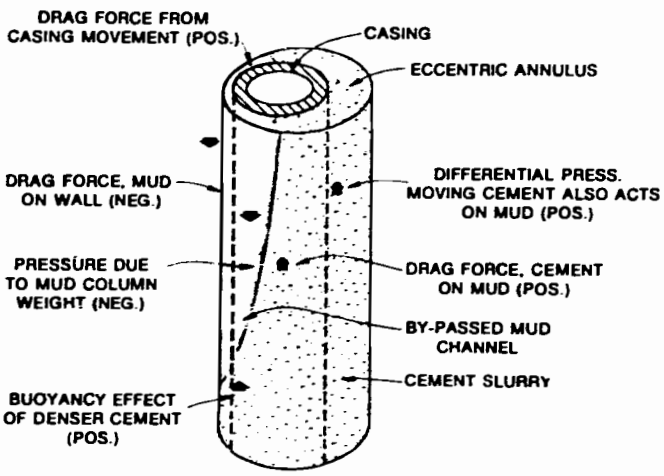
The OCS report is an accident investigation and analysis report on the OCS-G-2934, Well 2 blowout that occurred in June 1979. This report has excellent documentation, but it was the only one in the USGS Public Information file for years 1975 to 1979.

Joint meetings of USGS and Offshore Operators Committee (OOC) members have produced information on drilling problems in the Pleistocene zone. At a meeting[2] on December 28, 1976 the operator's representatives commented on their drilling practices and problem areas. They agreed that cementing was a problem due to the presence of shallow gas sands, and that slurry design was crucial. However, there was difference of opinion on proper slurry design and on cementing techniques.

This group also discussed the need for better communication regarding drilling problems; the OOC representatives were urged to make their reports more informative with regard to operations that were conducted. The company representatives also expressed concern over the problems of personnel turnover and qualifications because of many new, inexperienced hires. They stressed the importance of training.

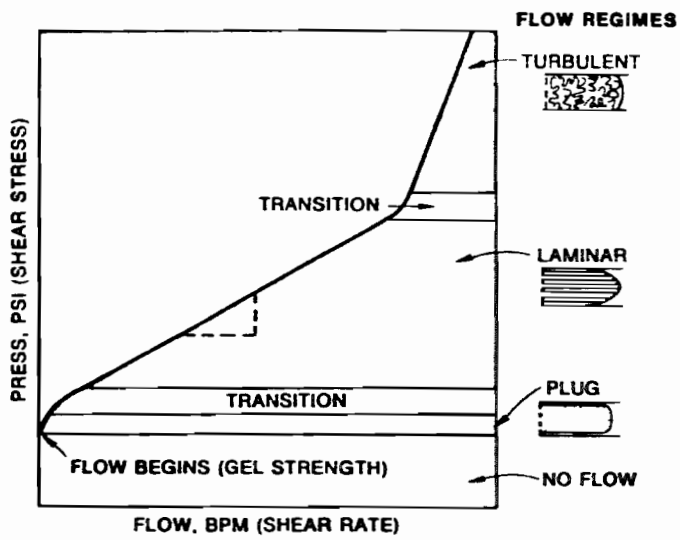
Continuing problems with cementing and annular gas are not surprising because of the numerous facets to the potential cause(s). Mud conditioning, mechanical devices on the casing, casing movement, cementing

techniques, and slurry design all affect mud displacement. Mud that remains in the wellbore-casing annulus is a potential channel once gas enters. Suman and Ellis[3] illustrate the various forces acting to displace (and resist displacement) a by-passed mud column, as shown in Figure 3. Differential pressures and drag forces dominate as displacement mechanisms but these are greatly influenced by velocity changes due to an eccentric annulus, washouts, variable filter cake thickness, and inclined holes.




Suman & Ellis[3] (after McLean[4])

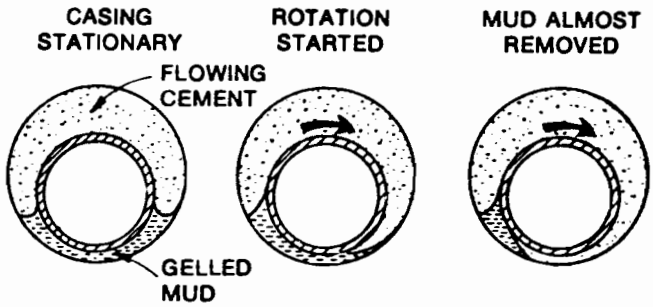
Figure 3




Suman & Ellis[3]

Figure 4

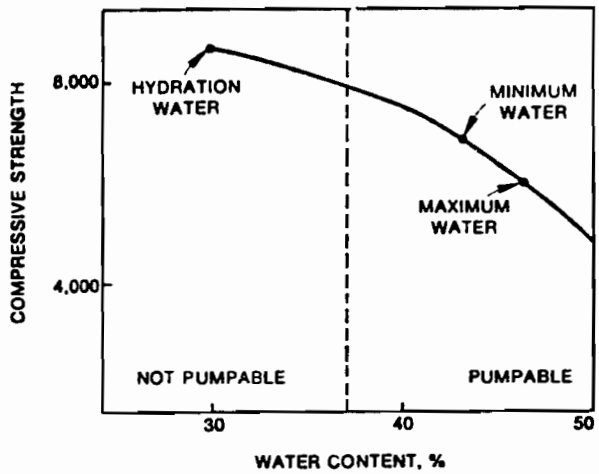
As non-Newtonian fluids, mud and cement slurries exhibit resistance to flow, as illustrated in Figure 4, which require a differential pressure to initiate flow. The displacement efficiency is related to this fluid flow model, but is also dependent on the mechanical conditions, such as the effect of reciprocating or rotating. The work of McLean[4] indicates how rotation can improve displacement, Figure 5.




McLean[4]

Figure 5

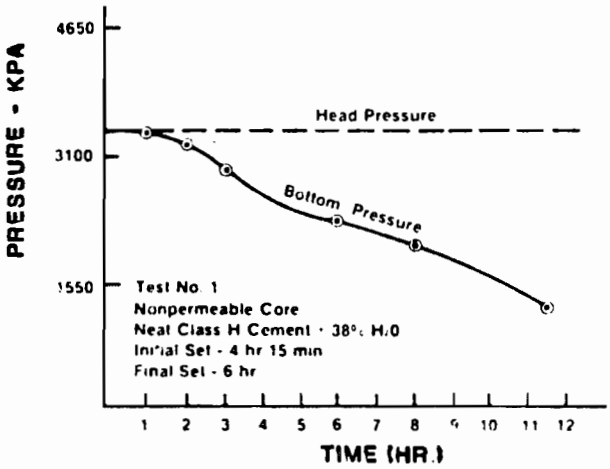
Slurry design is a crucial aspect of displacement and of cement hydration mechanics and its relationship to gas entry. Water content in the slurry and water loss (dehydration) of the slurry have been accorded more importance in recent studies. Water is required for hydration of the cement and for pumpability of the slurry, as illustrated in Figure 6. One major operator has avoided significant problems of annular gas flow by using controlled water-loss cement slurries for many years[5]. Webster et al[6] have related gas entry to excess water.



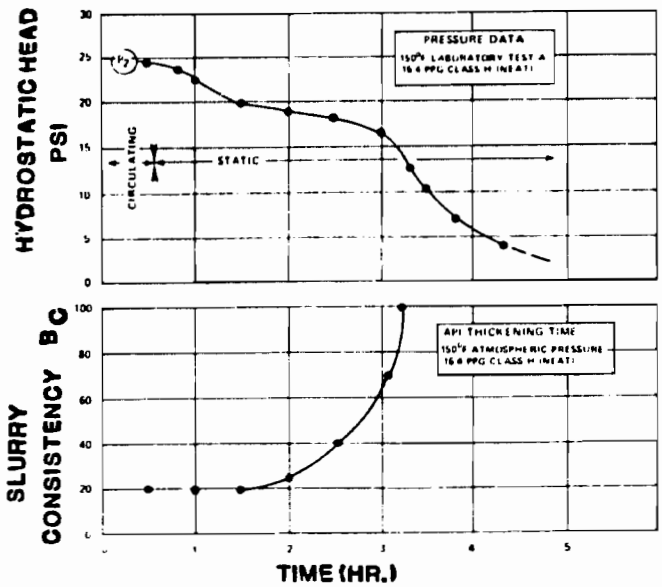

Suman & Ellis[3] (after W. K. Godfrey)

Figure 6

This work probes the effect that free-water has on the slurry density as time lapses; the results qualitatively show that density remains approximately constant at low free-water but density decreases by one-fourth at high free-water. Tinsley[1] and Levine[7] have related slurry designs to cement-column hydrostatic pressure changes. The cement column loses hydrostatic pressure as time lapses, and gas entry is possible since wellbore pressure has decreased to a value less than formation pressure. This pressure response at the bottom of a cement column is illustrated in Figures 7 and 8.




Tinsley[1]




Levine[7]

Figure 7 and Figure 8

This information has been used to modify slurry compositions[1] as well as to alter field cementing practices.[7]

However, gas flows have not been eliminated, possibly because there has not been an extensive study of the cement hydration mechanics in a long, thin column and its relationship to gas entry.

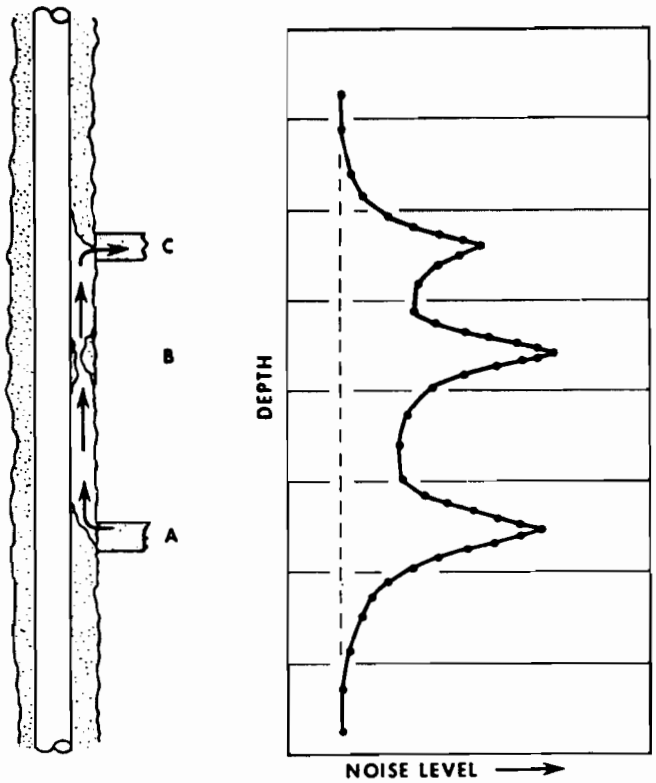
Detection logging devices have application in this study as:

a. Devices to detect that gas is flowing behind pipe

b. Devices to detect the precise location of a behind-pipe channel for subsequent perforating and well-control implementation

McKinley et al[8,9] have shown the noise log to be an excellent tool for confirming flow in channels behind pipe, as illustrated in Figure 9.

**NOISE LOGGER DETECTS BEHIND — PIPE LEAKS**




McKinley[8]

Figure 9

However, a log capable of 360° rotation with focusing to detect the channel location is needed for this problem. The noise log probably is the best prospect, but a neutron log potentially could be used. When flow is occurring, this tool would be used in tandem with a perforating gun for establishing communication with the channel.

Technology sources range from national laboratories such as Brookhaven, to universities such as Texas A & M, and consultants such as Maurer Engineering/Production Associates. Joint participation by the industry groups is desirable because the oil companies and service companies would then have peer pressure to contribute technology to an industry problem.

## PROJECT PROPOSALS
## TASKS REQUIRED

### Computer Data Base of Historical Information

1. Organize data collection method

2. Develop format for categorizing information
   a. cementing data
   b. well-control data

3. Select computer system for information storage and retrieval

4. Write code for accessing data

5. Start data collection

6. Enter data, test storage and retrieval

7. Provide terminals to users, provide seminars

### Training

1. Develop acceptable cementing procedures
   a. preconditions
   b. running casing
   c. cementing
   d. cement formulations
   e. logging
   f. well control

2. Formulate level of training to proposed student

3. Develop guidebooks and visual aids

4. Assemble course material in format for instruction by others

5. Provide instruction to trainers, provide assistance and equipment as needed

Cementing Research

1. In-depth review of current published research
2. On-site reviews with cementing service companies and oil companies that have previously conducted research
3. Formulation of theoretical model
4. Enhancement of model with cementing research from other users of cement technology
5. Formulation of model for long, thin columns
6. Causes for loss of pressure on column
7. Effects of imposed environments
8. Development of laboratory model
9. Study of basic mechanism and data match to lab model
10. Study of imposed conditions and data match to lab model
11. Extensive report on project

Logging Device Research

1. Collection of published material and reviews with developers of logging devices and with logging service companies
2. Theoretical modeling of focused devices using acoustic or neutron methods to locate channels
3. Prototype model based on theoretical result
4. Laboratory validation of tool's capability for channel detection
5. Report on project
6. Formulate agreement with logging service company to develop tool for commercial use

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## APPENDIX 1

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APPENDIX 2

USGS Reports from Public Information Files

NOTICE No. 2
DECEMBER 13, 1972

GEOLOGICAL SURVEY
GULF OF MEXICO AREA
OFFICE OF THE OIL AND GAS SUPERVISOR

# OCS OPERATIONS SAFETY ALERT
# SHALLOW DRILLING HAZARDS

The recent blowouts in wells drilling at shallow depth in the South Pass Area off the Louisiana coast suggest that additional measures should be taken while drilling to assure the early detection of shallow hydrocarbons. The use of gas detection equipment for continuous monitoring of the hydrocarbon content of the returning mud stream on all exploratory wells drilling on OCS leases in the Gulf of Mexico Area is recommended from the time conductor pipe is set until total depth is reached.

It is recommended that all operators review 30 CFR 250.41 and OCS Order No. 2 and caution drilling personnel as to proper procedures to be followed in case of threatened loss of well control at shallow depths.

J B Lowenhaupt
for Robert F. Evans
Oil and Gas Supervisor

NOTICE NO. 24
June 2, 1975

GEOLOGICAL SURVEY
GULF OF MEXICO AREA
OFFICE OF THE OIL AND GAS SUPERVISOR
FIELD OPERATIONS

# OCS OPERATIONS SAFETY ALERT

## SHALLOW GAS BLOWOUTS - ONE RIG LOST

Two offshore drilling rigs recently experienced blowouts after drilling into shallow gas zones.

A well on a jack-up mobile platform was coming out of the hole after drilling to 1150 feet RKB when a gas kick occurred. The gas flow was being diverted through two 6-inch divert lines, but also broke out around the outside of the drive pipe. Efforts to control the well flow were unsuccessful. All personnel were safely evacuated from the rig, which subsequently capsized. There was no pollution.

A semi-submersible drilling rig was drilling at 2500 feet RKB with conductor casing set at 1200 feet RKB when a gas kick occurred. The blowout preventer on top of the riser was closed and the diverter lines simultaneously opened. Pressure buildup in the riser forced the riser slip joint up and pushed the upper part of the riser and preventer-diverter assembly into the rotary table, preventing the utility of the divert system. The riser and associated equipment were damaged to the extent that the

riser could not be released from its Gulf bottom assembly. The mudline blowout preventer was closed and kill operations were commenced. Gas began to surface around the rig, which began to lose buoyancy and it had to be moved off location. There were no injuries to personnel and no pollution occurred.

To prevent recurrence of these types of blowouts, the operator plans to take the following action:

1. Use additional casing strings and/or liners in the shallow portion of the hole in order to obtain more formation competency at the casing seats.

2. Plan casing and liner points based on the location of possible shallow gas zones indicated by geophysical data.

3. Use higher mud weights when drilling into suspected shallow gas zones.

4. Redesign bottom-hole drill assembly to minimize the possibility of swabbing.

5. Use closer control of drilling rate and surveillance of drilling operations.

6. Work on elimination of mechanical problems concerning riser-diverter assembly.

D.W. Solanas

D. W. Solanas
Oil and Gas Supervisor
Field Operations
Gulf of Mexico Area

NOTICE NO. 43
June 21, 1976

GEOLOGICAL SURVEY
GULF OF MEXICO AREA
OFFICE OF THE OIL AND GAS SUPERVISOR
FIELD OPERATIONS

# OCS OPERATIONS SAFETY ALERT

## SHALLOW GAS BLOWOUT

A shallow gas blowout recently occurred on an offshore platform drilling rig.

A string of 10 3/4" casing had been run and cemented at 2716'. After 5 1/2 hours was allowed for the cement to set, the blowout preventer was removed. During subsequent operations to rig down the riser the well started flowing dry gas through the 10 3/4" x 16" annulus. Attempts to control the flow were unsuccessful and the platform was abandoned. The well was brought under control sixteen days later with no injury to personnel and no fire or pollution.

The operator believes the primary cause of this gas flow was a change which occurred to the cement resulting in a loss of hydrostatic head pressure against the gas zone. It is believed that an excessive water loss into a porous zone resulted in bridging of the cement which caused the loss of hydrostatic pressure and permitted the gas to enter the well and channel its way to the surface. The operator states this phenomenon is described in the technical paper: William H. Stone and William W. Christian, The Inability of Unset Cement to Control Formation Pressure, SPE 4783, Society of Petroleum Engineers.

In order to prevent a recurrence of this type accident the operator is taking the following actions:

1. Use low water loss, quick setting, fast strength cement.
2. Reciprocate casing during cementing operation.

D.W. Solanas

D. W. Solanas
Oil and Gas Supervisor
Field Operations
Gulf of Mexico Area

NOTICE NO. 66
September 26, 1977

GEOLOGICAL SURVEY
GULF OF MEXICO AREA
OFFICE OF THE OIL AND GAS SUPERVISOR
FIELD OPERATIONS

# OCS OPERATIONS SAFETY ALERT

## BLOWOUTS FROM SURFACE CASING-CONDUCTOR CASING ANNULUS

Recently, several operators have encountered a significant shallow gas flow from the annulus between conductor and surface casing. This flow has occurred several hours subsequent to cementing surface casing while nippling down the B.O.P. stack. In some cases, drilling personnel have had to abandon the drilling facility, or move the drilling vessel off location.

This delayed flow of gas is believed to develop because of a loss of hydrostatic head of the cement column, caused by the cement slurry either dehydrating across permeable zones, or entering a weak or thief zone. This leads to migration of gas upward through small channels in the cement-in-place, or through channels outside the cement-in-place, once the hydrostatic head becomes less than the pressure of any gas bearing zones that have been drilled through. Once this migration up the cement column starts, it results in an additional lowering of the hydrostatic head, which further increases the rate of channeling, until at some point in time there is sufficient loss of hydrostatic head so that a blowout occurs.

If an operator has a well in which there are possible permeable zones in the shallower portion of the open hole, precautions must be taken to prevent the occurrence of this type blowout. The first precaution would be to examine an electrical log of the hole to determine the existence and location of these potential problem zones. If gas sands are exposed, then procedures such as the following are used in order to prevent or minimize the delayed gas flow occurrence:

1. Run the casing using centralizers.
2. After the surface casing is run the casing annulus is thoroughly circulated to remove any gas cut mud and to condition the hole prior to cementing.
3. Use of a low weight cement slurry followed by class H neat tail-in.
4. Use of a fluid loss additive or gel cement to control excessive cement water loss to permeable zones and minimize undesirable dehydration.
5. Reciprocate or rotate casing or both, if feasible.
6. Consideration should be given to using a two stage cementing tool, if necessary.
7. Monitor returns constantly while cementing to detect partial or lost returns or other undesirable occurrences, in order to determine the necessity of running a cement bond log or temperature log and performing remedial cementing prior to removing the B.O.P. stack.
8. Observe annulus flow or pressure after cementing for 6-8 hours or until a cement compression strength of 500-700 psi is reached to determine whether or not to remove the B.O.P. stack entirely. The B.O.P. stack might be partially nippled down, but only to the extent that it can still be used for safely controlling and bleeding off a delayed gas flow.

The above could help prevent this type blowout where potential delayed gas flow conditions exist. The applicability of this safety alert should be determined by each OCS Operator after a thorough review of his particular drilling procedures.

D. W. Solanas

D. W. Solanas
Oil and Gas Supervisor
Field Operations
Gulf of Mexico Area

EXP. 7/74 (A)

GENERAL

# OCS ACCIDENT INVESTIGATION AND ANALYSIS REPORT

Operator Marathon Oil Co. Facility Name Dixilyn 80 (Letourneau)
Facility Supervisor Wesley Williams (MARATHON) Richard Wadley (Dixilyn)
Complex/Rig I.D. Dixilyn Rig 80 Structure/P.L. Segment
Area W.D. Block 86 Lease OCS-G 2934 Field Wildcat

Type Accident Blowout
Personnel Casualties None Injuries None Fatalities
Date 6/1/79
Month Day Year Time 0610
0-2400

Basic Accident Category:

Unsafe Act
Unsafe Procedure
Mechanical Failure
Ship Collision
Improper Design
Jury-rigged System
Act of God
(Other)

Briefly describe what happened. 13-3/8" surface casing cemented at 4:30 a.m. and held pressure on pumpdown plug 15+ minutes. The rig then picked up 1" pipe and started washing out 20" x 13-3/8" annulus. Washed from 4:50 a.m. till 6:00 a.m. Laid down 3 joints 1" pipe when well blew out through the 1" pipe, 20" annular BOP and 20" x 13-3/8" annulus. All personnel evacuated rig by 7:15 a.m. Well blew until 11:20 a.m.

Type of operations conducted at site. Drilling

Specific task in progress at time of accident. Laying down 1" wash pipe after washing out 20" x 13-3/8" annulus.

Is this a routine task? Yes. If yes, what factors were present which caused the accident that were not present when past operations were carried out safely? None known.

W. E. Kramer Jr. John Gazzo
Investigated by: Bill Kramer, Joseph Chong, John Gazzo
Date 6/5/79

Joseph Chong
Warren L. Ledeuck (acting)

Public Information cy
(OMS-2-5)

General Cont.

Equipment involved? 20" annular BOP and diverter, 1" wash pipe and 20" x 13-3/8" annulus.

*Personnel involved. 43 people, including 2 tool pushers.

*Indicate contractor name and address if other than operator personnel were involved.

What system, equipment, procedure, or training changes could be made in order to help prevent future accidents of this type? Discuss fully.
None known.

What was condition of facility when USGS inspectors arrived? Water completely aerated under rig structure. Gas bubble was 5' to 8' in height at times. Well stopped blowing at 11:20 a.m.

Was facility given a thorough USGS inspection after the accident? Yes
What were the results? Rig cleaned up and no sign of any gas.

Did any deficiency noted on past USGS inspections cause or contribute to the accident? No If yes explain.

WEATHER CONDITIONS

| Wind Direction and Velocity | Visibility | Wave Height |
|---|---|---|
| from 5 MPH 10-12 | Good | 3-4 FT |
| | | Temperature 75 °F |

Comments on weather conditions if weather was a contributing factor to the accident. Not a contributing factor.

PART A

## DRILLING BLOWOUTS

Drilling depth when blowout occurred. T.D. 4035'. 13-3/8" casing set at 4000'.

Provide information on the following:

Casing set prior to blowout.

Depth 4000' Hole size 26"

Size, weight, grade 13-3/8", 68 and 72#, N80 and K55

Quantity of cement used 1600 sxs. class H, 12.8#/gal. 500 sxs. Class H, 16.2#/gal.

Briefly describe any indication of improper cementing during casing setting operations. No cementing problem. Had 30 barrels cement returned.

Drill string.

Drillpipe size(s) 5" - 19.5# Grade E

Bottom-Hole assembly Bit; Bit sub, (1) 8" Drill Collar, (1) 17-1/2" stabilizer, (1) 8" Drill Collar, (1) 17-1/2" stabilizer, (4) 8" Drill Collars, (1) 12-1/4" stabilizer crossover sub. Total length: 199.49'.

Drilling fluid properties prior to blowout.

Mud weight 9.6 to 9.7# Temperature None.

Plastic Viscosity None. Yield Point None.

Solids _____ Chloride Content None.

PH _____ %Oil None.

Native mud with salt water gel.

Particular hole problems experienced prior to blowout.

Loss Circulation Drilling Break

Gas Cut Mud Sticking

at 3770' mud had 640 units of gas with prior 30 units background gas.

BOP stack arrangement with choke manifold/diverter system hook-up (Indicate types, sizes and pressure rating). Utilize sketch if necessary.

One 20" Hydril annular preventer--2000# working pressure with two 6" hydraulic remote-controlled diverter valves connected to two 8" diverter lines routed port and starboard for overboard diversion.

PART A CONT.

Mud monitoring system.(component, function, make, model) Exploration logging unit monitors gas, pit levels, rate of flow and rate of bit penetration, with a televised instant read remote in tool pusher's office. In addition to this the rig has its own Warren automatic flow rate indicator, pit level indicator and a Temco gas detector.

Were all of these components operative at time of blowout? Yes

Describe any other drilling monitoring equipment in use prior to blowout. None, except drill crew monitors mud system visually for increase or decrease of volume.

Mud circulating system. (component, make specifications). Two National 1600 duplex mud pumps with 16" x 6-1/2" stroke with .185 BBL per stroke capacity.

Was well flowed through choke manifold? No.
Was well shut-in when kick occurred? No, blew out through 20" x 13-3/8" annulus.
If so, give drillpipe and annulus pressures after shut-in. None recorded.

Was formation at last casing depth pressure tested to leak off after drilling out shoe? Had not yet drilled out shoe.
If so, what was equivalent mud weight at leak off? N/A

Was swabbing effect calculated before each trip to determine desirable drillpipe withdrawal rate? Hole was filled after pulling every 5 stands of drill pipe and any fluid loss recorded.

Which kill procedure was used?(Driller's method,etc.) Unable to use due to severity of blowout.

Relate the chronological order of operations prior to, during, and following blowout. Had just finished cementing 13-3/8" surface casing and washing out 20" x 13-3/8" with 1" pipe, then laid down 3 joints of 1" pipe when well blew out at 6:10 a.m.

Gulf Coast Offshore District
Houston Offshore Division
Production Operations, U S & Canada

Marathon Oil Company

P O Box 53266 OCS
Lafayette, Louisiana 70505
Telephone 318 233 8240

June 14, 1979

U. S. Geological Survey
New Orleans District
P. O. Box 7966
Metairie, Louisiana 70010

Attention: Mr. C. B. Mullin

Re: OCS-G-2934, Well No. 2
West Delta Block 86

Gentlemen:

This letter is to serve as a written report subsequent to the verbal reports to Mr. Warren Frederick of your office on June 1, 1979. The subject of these reports concerns a well control problem experienced following the cementing of the surface casing on OCS-G-2934, Well No. 2, located in West Delta Block 86 on that date.

This well was spudded with the mobile jackup "Dixilyn Rig 370" on May 22, 1979, after drive pipe was driven to 570' (339' of penetration) and the installation of an annular type blowout preventer and diverter system. The 20" conductor casing was set and cemented with 900 sacks of light weight cement followed with 300 sacks of neat Class H at a depth of 979' with cement returns to the surface. The annular space was washed out to a depth of 260' with seawater. After installation of the wellhead on the conductor casing, the previously described blowout prevention equipment was installed. A pilot surface hole was drilled to 4035' with a maximum mud weight of 9.3 lbs. per gallon. During evaluation of this hole, a wireline formation test was recovered from a depth of 3676'. The maximum pressure recorded from this test was 1592 psig or equivalent to 8.33 lbs. per gallon pore pressure. The pilot surface hole was opened. Throughout drilling and opening operations, the mud returns were continuously monitored and no abnormal amounts of drill gas were experienced. The 13 3/8" surface casing was landed in a mud line hanger at 254' with the casing shoe at 4000'. Prior to cementing this casing string, the hole was circulated with sufficient mud volume to displace the annular volume. No evidence of excessive gas was observed by the monitoring equipment. The casing string was cemented with 1600 sacks of Class H cement with 2 1/2% prehydrated gel mixed at 12.8 lbs. per gallon. This slurry was followed by 500 sacks of neat Class H mixed at 16.2 lbs. per gallon. The cement slurry was displaced with mud to the float collar with full returns recovering approximately 20 barrels of cement slurry at the surface. The mixing and displacement operations were without incident. The cement was in place at 0430 hours, June 1, 1979, and the annulus was static after bumping the wiper plug.



NOTED RAY

NOTED—FREDERICK

Two washout strings of 1" tubing were run in the 20" x 13 3/8" annulus to the depth of the previously mentioned mud hanger. The cement was displaced from this portion of the annulus with seawater. Clear seawater returns were obtained with no indication of gas or fluid flow. This operation was complete at 0600 hours, June 1, 1979. Prior to the initiation of removal of these washout strings, the fluid level in the annulus was observed and found to be static. Three joints from one of the 1" washout strings had been removed when a sudden flow from the 20" x 13 3/8" annulus was experienced. The annular preventer was functioned closed which automatically opened the two 6" diverter outlets below this preventer which sealed off the flow from the annulus to the rig floor, diverting the flow of gas outboard from the rig. There was very little evidence of cement in the flow which consisted of gas and salt water.

This well control problem was experienced at 0610 hours or one hour and forty minutes after the cement was in place. The annulus continued to flow gas and salt water out of the diverter outlets for one hour and 20 minutes when a boiling action commenced at the surface of the water around the drive pipe. The activity on the surface of the water and the flow from the open diverter system continued for approximately four more hours when the flow and surface activity began decreasing and stopped completely. This latter stage of flow decreasing developed over a period of thirty to forty minutes.

A sea floor inspection was performed by a diving team and found no evidence of errosion or soil disturbance around the leg penetrations of the drilling rig. The divers found that a conical crater approximately 20' deep existed around the drive pipe. Near the bottom of this crater holes were found erroded in the drive, conductor, and surface casing strings. It is believed these holes were caused by errosion of the casing by flow through the 13 3/8" mud line hanger. Once errosion through all strings was complete, this allowed the flow to escape at the mud line causing the activity previously noted on the surface of the water.

The cause of this well control problem which was experienced is difficult to understand. Pressures within the wellbore as evidenced by the formation tests do not exceed a normal gradient. During all of the operations prior to the incident, the hydrostatic pressure of the fluids in the wellbore was by design sufficient to contain any exposed formation pressure. The sudden occurrence of the problem one hour and forty minutes after the cement was in place leads this writer to conclude that the problem originated during the initial setting stage of the cement column which, as it became self-supporting, caused a decrease in hydrostatic pressure allowing gas to migrate upward in the annulus. It is believed that the migration and accumulation of gas progressed in stages upward in the annulus until overcoming the final strength resistance of the cement column. This phenomenon is plausible; however, it is difficult to understand what caused the decrease in hydrostatic pressure

below that of a normal gradient. The cement slurry by design was essentially "no free water" slurry and there are numerous salt water bearing sands exposed in the wellbore.

To minimize the potential for the reoccurrence of this type of event, the surface casing on subsequent wells in this area will be set prior to penetrating the sand tested at 3676'. Additionally, the surface blowout prevention equipment installed will allow for the well to be shut-in and controlled by conventional methods.

If any additional information is required, please advise.

Yours very truly,

J. F. Strong
District Operations Manager

bd

APPENDIX 3

Typical Industry Responses

DOWELL DIVISION OF DOW CHEMICAL U.S.A.

P. O. BOX 21
TULSA, OKLAHOMA 74102
AREA CODE 918 560-2600

January 2, 1980

Mr. John Martinez
Production Associates
2916 West T.C. Jester
Houston, Texas 77018

Dear Mr. Martinez:

Your concern with gas flow in wells after cementing is very timely, as evidenced by the papers presented on this subject at the recent SPE Meeting in Las Vegas.

Some very significant contributions have been made toward understanding this problem and dealing with it. However, it appears that there are still some missing pieces to the puzzle. This is why Dowell is currently conducting research in this area.

While Dowell is always interested in working with groups such as Production Associates, DOE Bartlesville Energy Technology Center, and U.S. Geological Survey, this particular project presents problems since we are already conducting research in the same area. It would be difficult for us to reveal our future plans without revealing the results of our past research which have not been published.

Perhaps the attached list of references will be of some value to you as you determine the status of the art for controlling gas flow.

Please keep us in mind on future projects that may be of mutual interest.

Sincerely,

B. B. Bradford
Senior Development Specialist

BBB/vlh

Enclosure



AN OPERATING UNIT OF THE DOW CHEMICAL COMPANY

LIFE IS FRAGILE · HANDLE WITH CARE

References:

1) Garcia, J. A. and Clark, C. R.: "An Investigation of Annular Gas Flow Following Cementing Operations", SPE Paper 4701 presented at AIME Symposium on Formation Damage Control, Houston, Texas. (Jan 29-30, 1976).

2) Carter, L. G. and Sagle, K. A. : "A Study of Completion Practices to Minimize Gas Communication", SPE Paper 3164 presented at Central Plains Regional Meeting, Amarillo, Texas. (Nov. 16-17, 1970).

3) Stone, William H. and Christian, W. W. : "The Inability of Unset Cement to Control Formation Pressure", presented at Formation Damage Symposium, New Orleans, Louisiana. (Feb. 6-7, 1974).

4) Carter, L. Greg, Cook, Clyde and Snelson, Lawrence: "Cementing Research in Directional Gas Well Completions" SPE Paper4313 presented at SPE-AIME European Meeting, London, England. (April 2-3, 1973).

5) Christian, W. W., Chatterji, Jiten, and Ostroot, G. Warren: "Gas Leakage in Primary Cementing - A Field Study and Laboratory Investigation", SPE Paper 5517, presented at SPE Meeting, Dallas, Texas. (Sept. 28-Oct. 1, 1975).

6) Thomas, E. W. and Levine, D. C., Exxon Company, U.S.A., SPE Paper 8255, "Annular Gas Flow After Cementing: A Look at Practical Solutions".

7) Tinsley, J. M., Halliburton Services, and Miller, E., Pennzoil, and Sabins, F. L., Halliburton Services, "Study of Factors Causing Annular Gas Flow Following Primary Cementing", SPE Paper No. 8257.

8) Rutledge, J., BJ Hughes, Inc. and Webster, W., Mobil Field Research Laboratory, "Flow After Cementing - A Field Study and Laboratory Model", SPE Paper 8259.

**Shell Development Company**
A Division of Shell Oil Company

Bellaire Research Center
P. O. Box 481
Houston, Texas 77001

3737 Bellaire Boulevard
Houston, Texas 77025

November 30, 1979

Mr. John Martinez
Production Associates
10301 NW Freeway, Suite 202
Houston, TX 77092

Dear Mr. Martinez:

We have considered your request of November 7, 1979, for comments on the study of cementing practices as related to annular gas migration in offshore wells. We offer the following specific responses to the four question areas you addressed:

A. Halliburton appears to have made some significant progress in the understanding of how annular cement columns transmit hydrostatic pressures during the time between placement and final set. They presented their findings at the 54th Annual SPE Fall Technical Conference, September 23-26, 1979, held in Las Vegas, Nevada (Paper No. 8257). We believe it would be valuable to have some independent verification of their findings, particularly for the higher temperatures and pressures found in deep geopressured gas wells. These are the types of wells where annular gas migration is frequently encountered with severe consequences. We believe the test apparatus used by Halliburton could be improved by extending the temperature and pressure modeling capabilities. We would also be interested in development of methods, other than Halliburton's, for sustaining cement compressibility up to final set.

B. Our participation in a project dealing with solution of the annular gas migration problem would depend on the specific objectives and design of the project. We cannot say at this time whether we would participate without having a specific proposal to consider.

C. We could provide a participant for an industry steering committee. We can offer no further technical involvement at this time due to other commitments. We feel such a steering committee is critical to the success of joint programs.

D. We have no laboratory or experimental equipment that would be suitable for this project.

We agree that annular gas migration is a serious problem and is prevalent in many areas besides the offshore. We are interested in reviewing any proposal for a joint industry program to attack this and look forward to hearing from you further.

Very truly yours,

C. L. Wickizer

C. L. Wickizer, Manager
Production Operations
Research Department

HALLIBURTON SERVICES

DRAWER 1431, DUNCAN, OKLAHOMA 73533

CHEMICAL RESEARCH AND
DEVELOPMENT DEPT.

W.T. MALONE, Manager
KNOX A. SLAGLE, Ass't. Manager
REGINALD M. LASATER, Ass't. Manager

November 26, 1979

Mr. John Martinez
Production Associates
10301 N. W. Freeway, Suite 202
Houston, TX 77092

Dear John,

I routed your letter of November 6, 1979 to the managers of the various facets of Halliburton's research organization. The general consensus was that Halliburton Services would be happy to furnish consultation for any D.O.E. research program. We would not be interested in participating in a partially funded project on annular gas flow and would be somewhat reluctant to get involved in a totally funded project.

We at Halliburton Services feel that the key to controlling annular gas flow is our new compressible cement, GAS-CHEK$^{tm}$ cement. As I mentioned in my presentation to your SPE group meeting, the theory behind GAS-CHEK cement is confirmed by the very high success ratio. All our recommendations at this time would revolve around this theory, and all our research in the area is aimed at process refinement.

Halliburton Services has been conducting research concerning the prevention of annular gas flow for over 15 years. During this time we have acquired a great deal of expertise in the area such as modeling conditions under which gas will penetrate cement and cement behavior prior to initial set. Halliburton also has expertise in controlling and measuring slurry parameters such as fluid loss or thickening time which can play a significant role in annular gas flow. We have a very extensive research program in the area of drilling fluid displacement which is an important factor in any cementing operation.

I hope my comments will be of use to you in the initial phase of your project. Please let me know if you need further information. I would also appreciate being informed from time to time of the progress of the project.

Sincerely,

Larry T. Watters

L. T. Watters
Group Leader
Cement Section

LTW:lm

cc: Mr. K. A. Slagle
Mr. D. K. Smith
Mr. J. M. Tinsley



A Halliburton Company

**EXXON** COMPANY, U.S.A.
POST OFFICE BOX 2180 - HOUSTON, TEXAS 77001

PRODUCTION DEPARTMENT

November 21, 1979

Mr. John Martinez
Production Associates
10301 NW Freeway Suite 202
Houston, Texas 77092

Dear Mr. Martinez:

In reply to your survey dated November 6, 1979, Exxon Company, U.S.A. is actively conducting development work to solve the problems related to annular gas flow following cementing. A status report is contained in the SPE paper, "Annular Gas Flow After Cementing: A Look at Practical Solutions," which was presented at Las Vegas, Nevada, this fall.

Our Exxon-funded project at Texas A&M Research Foundation is continuing to investigate commercially available cementing products and techniques to determine if any can prevent the "loss-in-hydrostatic-head" phenomenon common to oil field cements. To date, none of the products tested prevents this phenomenon.

Several of the major cementing companies also have active research projects on this subject. We are working closely with them in an attempt to jointly test their products. Exxon is currently utilizing its predictive technique (described in the SPE paper) to eliminate over 90 percent of the potential annular gas flow problems. This technique has been utilized successfully on over 200 cementing jobs inland and offshore in 1979. Exxon is concentrating its engineering efforts to better understand the "annular gas flow phenomenon" and to develop solutions to prevent the remaining 10 percent potential problems.

Exxon would consider a joint-industry project related to this project, subject to a review of the objectives, industry support, and required funding. Should the DOE be interested in Exxon's ongoing program, we welcome a visit at the Texas A&M laboratory facilities during one of our weekly tests.

Very truly yours,

W P Beyner

GDT:cf
Attachment

c - w/attachment:
Mr. H. J. Flatt



A DIVISION OF EXXON CORPORATION

## APPENDIX 4

API Committee 10
Committee on Standardization of Oilwell Cements

### OFFICERS

| | |
|---|---|
| Chairman | H. J. Beach<br>GULF RESEARCH & DEVELOPMENT CO.<br>Box 36506<br>Houston, TX 77036 |
| Vice Chairman | R. C. Smith<br>AMOCO PRODUCTION CO.<br>Box 591<br>Tulsa, OK 74102 |
| Secretary | S. Maravilla<br>UNIVERSAL ATLAS CEMENT<br>Division U. S. Steel<br>Buffington Station<br>Gary, IN 46401 |
| API Representative | W. S. Wimberley<br>API<br>211 N. Ervay, Suite 1700<br>Dallas, TX 75201 |

### SUBCOMMITTEES

| | |
|---|---|
| User Subcommittee Chairman | D. K. Smith<br>HALLIBURTON SERVICES<br>Box 1431<br>Duncan, OK 73533 |

| | |
|---|---|
| Task Group on Cooperative Testing Chairman | D. G. Calvert<br>MOBIL RESEARCH AND DEVELOPMENT CORP.<br>Field Research Lab<br>Box 900<br>Dallas, TX 75221 |
| Task Group on Oilwell Cement Additives Chairman | R. C. Smith<br>AMOCO PRODUCTION CO.<br>Box 591<br>Tulsa, OK 74102 |
| Task Group on Cement Rheology Chairman | R. M. Beirute<br>WESTERN COMPANY<br>Box 186<br>Fort Worth, TX 76101 |
| Task Group on Cement Slurry Filtration and Free Water Chairman | J. Rutledge<br>MAGCOBAR - DRESSER<br>Box 6504, Suite 3292<br>Houston, TX 77002 |
| Task Group on Cement Bond Logs Chairman | H. G. Kozik<br>MITCHELL ENERGY CORPORATION<br>3900 One Shell Plaza<br>Houston, TX 77002 |

## APPENDIX 5

### Offshore Operators Committee

Offshore Operators Committee
Box 50751
New Orleans, LA 70150

| | |
|---|---|
| Chairman | F. E. Syfan<br>AMOCO PRODUCTION CO.<br>Box 50879<br>New Orleans, LA 70150 |
| Secretary/Treasurer | J. R. MacGregor<br>ODECO<br>Box 61780<br>New Orleans, LA 70161 |
| Drilling Committee Chairman | J. G. Gonders<br>CITIES SERVICE CO.<br>Box 27570<br>Houston, TX 77027 |
| Technical Subcommittee Chairman | F. E. Garrot<br>EXXON CO. U.S.A.<br>Box 60626<br>New Orleans, LA 70160 |



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