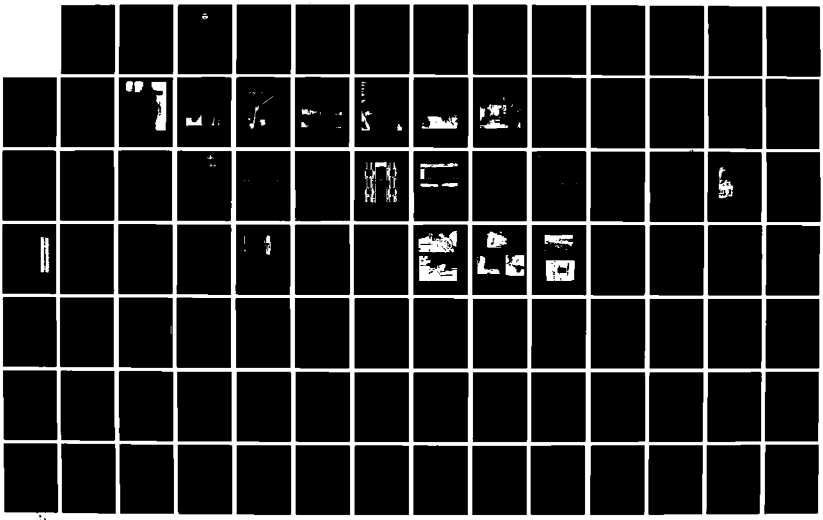
ADA129953

NAVAL OCEAN SYSTEMS CENTER, SAN DIEGO, CA
ASSESSMENT OF THE TECHNOLOGY AND PRACTICE FOR DETERMINING CASING DEGRADATION DURING OFF-SHORE DRILLING OPERATIONS

1 OF 2
NOSC CR 163
UNCLASSIFIED
SEP 1982



6″

MICROCOPY RESOLUTION TEST CHART

(Based on NBS 1963A Target Design)

NOSC CR 163

NOSC CR 163

Contractor Report 163

ASSESSMENT OF THE TECHNOLOGY AND PRACTICE FOR DETERMINING CASING DEGRADATION DURING OFFSHORE DRILLING OPERATIONS

Prepared by
JR Mastandrea
KR Nippear
NDE Technology, Inc.
Torrance, CA 90503

September 1982

Final Report

Prepared for
Naval Ocean Systems Center
Code 9411

NOSC

NAVAL OCEAN SYSTEMS CENTER
San Diego, California 92152

NAVAL OCEAN SYSTEMS CENTER, SAN DIEGO, CA 92152

AN ACTIVITY OF THE NAVAL MATERIAL COMMAND

JM PATTON, CAPT, USN
Commander

HL BLOOD
Technical Director

ADMINISTRATIVE INFORMATION

This work and report was completed by NDE Technology, Inc., under contract N66001-82-C-0029 for Naval Ocean Systems Center. The contract was sponsored by US Department of Interior, Minerals Management Service, Research and Development Program.

Released by
IP LeMaire, Head
Advanced Systems Division

Under authority of
HR Talkington, Head
Ocean Engineering Department

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: NOSC Contractor Report 163 (CR 163) / 2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER: Final
4. TITLE (and Subtitle): ASSESSMENT OF THE TECHNOLOGY AND PRACTICE FOR DETERMINING CASING DEGRADATION DURING OFFSHORE DRILLING OPERATIONS	5. TYPE OF REPORT & PERIOD COVERED: Final 3/28/82 to 6/10/82 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s): J. R. Mastandrea, K. R. Nippear	8. CONTRACT OR GRANT NUMBER(s): NOSC-N66001-82-C-0029
9. PERFORMING ORGANIZATION NAME AND ADDRESS: NDE Technology, Inc., 2909 Oregon Court, Suite C-8, Torrance, CA 90503	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS: Naval Ocean Systems Center, 271 Catalina Boulevard, San Diego, CA 92152	12. REPORT DATE: September, 1982 13. NUMBER OF PAGES: 114
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)	15. SECURITY CLASS. (of this report): Unclassified 15a. DECLASSIFICATION DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Casing
Casing Degradation
Drill Rigs
Blowouts
Casing Loggers
Acoustic Emission
Nondestructive Inspection

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This study provides an assessment of the technology and practice for determining casing degradation during offshore drilling operations. A survey and assessment of the state-of-the-art technology including commercially available casing logging equipment, current research and development and new and novel concepts is carried out. Recommendations are made for certain improvements in casing inspection equipment and practices and the development of a new inspection concept.

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

PREFACE

The effort to provide an assessment of the technology and practice for determining casing degradation during drilling operations was completed by NDE Technology, Inc. under contract (N66001-82-C-0029) to the Naval Ocean Systems Center. The contract was sponsored by the U.S. Department of Interior, Minerals Management Service, Research and Development Program (Mr. John Gregory) and is part of a total research and development program designed to supply technology required for pollution prevention in the outer continental shelf oil and gas operations.

We wish to acknowledge the support and contributions from the following individuals:

Mr. John Gregory for his initiation of the project and for his technical support and contribution on the entire project. Mr. Paul Heckman, the technical coordinator for the Naval Ocean Systems Center, for his guidance and valuable suggestions throughout the project. Mr. Doug Steinmuller and Mr. Rufus Perk of the U. S. Geological Survey for valuable discussions on the project. Mr. Bill Peck and Mr. Jim Carlson of THUMS Long Beach Drilling Company for their support and contributions and their permission to use photographs contained in this report. We wish to thank the offshore service companies, equipment manufacturers and other companies who have provided important suggestions to this report.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF ILLUSTRATIONS

1. INTRODUCTION AND SUMMARY

Increases in the number, size, depth and extreme environment locations of offshore drilling structures have caused a growing need to help insure safe drilling operations for the safety of personnel, protection of the marine environment and the structure. This need is evidenced by the 55 blowouts that have occurred on the Outer Continental Shelf (OCS)during the last ten years.

One important area of concern is the problem of casing degradation during offshore drilling operations. Excessive casing degradation has resulted in casing failures which has led to blowouts. Wall thinning, gouges and cracks are examples of casing degradation that occur during drilling operations. Casing degradation is caused by drill pipe rubbing and other source and can be a serious problem in some applications, for example n deep wells during directional drilling.

This study provides an assessment of the technolog and practice for determining casing degradation during dri operations. A review of casing degradation is presente Section 2. An approach for solution of the problem of casing degradation is developed in Section 3. State-of-the-art technology and practice and current research for determining casing degradation is summarized in Section 4. An assessment of state-of-the-art technology and practice is presented in Section 5 while development requirements are outlined in Section 6. Conclusions and recommendations are presented in Section 7.

Study results indicate that the originating two major causes of casing failure are human error and equipment failure; inadequate casing inspection is found to be a lesser cause of failure. However, the study identifies problems in the use (practice) of casing inspection. For example, casing inspection is not generally used to determine if excessive casing degradation has occurred due to human error or equipment failure. This inadequacy has resulted in blowouts.

The study indicates that the availability and utilization of casing inspection equipment for casing degradation is in reasonably good order. However, new and improved casing inspection equipment are needed. The need exists despite excellent efforts by offshore exploration and service companies who have developed equipment for downhole logging that permits inspection of casing degradation such as excess wall thinning and other defects. The need for improved technology stems from limitations in available nondestructive inspection equipment, the limited in-service time available to inspect casing and practical cost considerations.

The study concludes that problems exist in providing adequate casing inspection. The study also concludes that gains can be made for in-service casing inspection during drilling operations by continuing to improve current technology and practices.

Frequent use of casing inspection, as a diagnostic tool, for detecting unsuspected degradation during normal drilling operations is recommended to help minimize serious casing failure that can result in blowouts. This recommendation is made to encourage a change in the current practice of using casing inspection mainly when serious casing degradation is suspected. Continued development of improved casing inspection logging devices by private companies is encouraged. Development of an acoustic emission/hydrostatic inspection technique is recommended as a low cost, practical means for near-term improvements in periodic inspection of casing during drilling operations.

2. PROBLEM

Casing degradation problems in offshore drilling operations are reviewed in this section. A discussion of casing degradation is provided in Section 2.1. Examples of casing degradation during actual drilling operations are presented in Section 2.2 while typical locations are identified in Section 2.3. The problem of corrosion in downhole casing is discussed in Section 2.4. In order to demonstrate the seriousness of the problem, two recent blowouts involving casing degradation are presented in Section 2.5.

2.1 Discussion of Casing Degradation

Casing degradation is defined in this study to include any deterioration or deficiencies in the casing (pipe wall, threads, etc.) that occur during drilling operations that may result in failure (rupture, hole through cracks, leaks). In general, casing degradation involves excessive wear and corrosion. Specific defects include wall thinning (long lengths or short length localized areas), critical cracks, deep gouges, pits, localized pitting, dents, buckling, etc.

There are a variety of direct causes of casing degradation during drilling operations. The major cause is drill pipe rubbing. Other causes include external impacts during casing installation, tools or other items dropped in the well or damage caused by tools or equipment run through the casing.

Excessive casing degradation (critical defects such as short length and large depth wall thinning or long length and medium wall thinning, critical cracks, dents, deep gouges or pits, etc.) can and has resulted in casing failure which ultimately has led to blowouts. Blowouts can stem from casing failure in areas (see Section 2.2) that are subject to external, subsurface, high pressure gas pockets (7,000 psi to 12,000 psi or greater). The high pressure combined with the failed casing results in an escape of the high pressure gas through the casing to a potentially explosive environment on the offshore drilling structure.

Serious casing degradation generally occurs because of the following three main problems:

- Undetected excessive internal casing degradation (wall thinning, gouges, etc.) during drilling operations.

- <u>Undetected excessive external or internal casing damage (dents or gouges from impacts, etc.) during drilling</u> operations.

- <u>Undetected casing corrosion</u> (internal and/or external). This original corrosion may eventually lead to failure after long term operation of the production well. Also prior casing damage, external impacts, etc. during the original drilling operations may cause acceleration of casing corrosion during long-term operation of the production well.

The original but indirect sources of these problems primarily start with human error and/or equipment failures during drilling operations. A third and direct source but a much lesser contributor to these problems, involves the inability to adequately inspect casing during normal operations.

2.2 Examples of Casing Degradation During Drilling Operations

Casing degradation during drilling operations is due primarily to drill pipe rubbing. Examples of typical casing degradation during drilling are shown in Figures 1 through 3 for the THUMS drilling rigs located at Long Beach and Chaffee Island, California. Photographs of representative drilling operations for the drilling rig at Chaffee Island are shown in Figures 4 through 7.

It should be noted that state-of-the-art operations and inspection practices are used at THUMS drilling operations in an effort to detect casing degradation and avoid failure. For example, the leaks from damaged casings shown in Figures 1 through 3 were detected during hydrostatic tests and specific damaged areas located with downhole loggers.

2.3 Typical Locations of Casing Degradation

For most casing failures, the area of casing degradation is usually located in the intermediate casing string. This string location, for example, is a frequent source of problems in deep wells during directional drilling.

For deep wells, excessive casing degradation such as wall thinning or cracks often occurs in the intermediate casing string when the hole angle changes abruptly. Also, excessive degradation such as buckling can occur because of hole conditions (mud weight, temperature, pressure, etc.). Figure 8 presents a schematic that illustrates a typical area (at the angle point of the hole) of excessive wear that occurs during directional drilling.

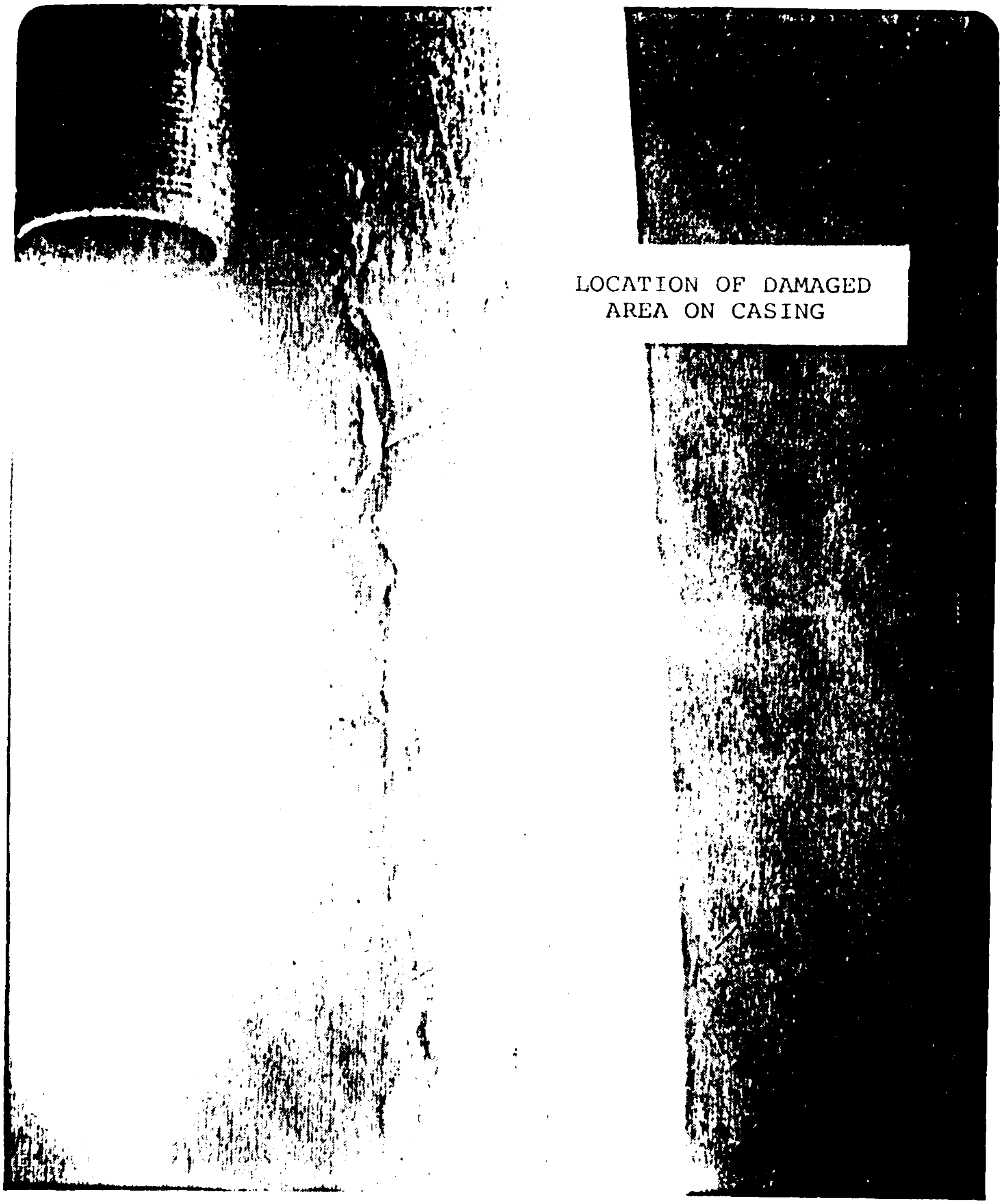


Figure 1. Casing (8-5/8 inch) pulled from THUMS drilling rig, T-8 location on Chaffee Island. (Casing was located at the angle point of the directional hole.)

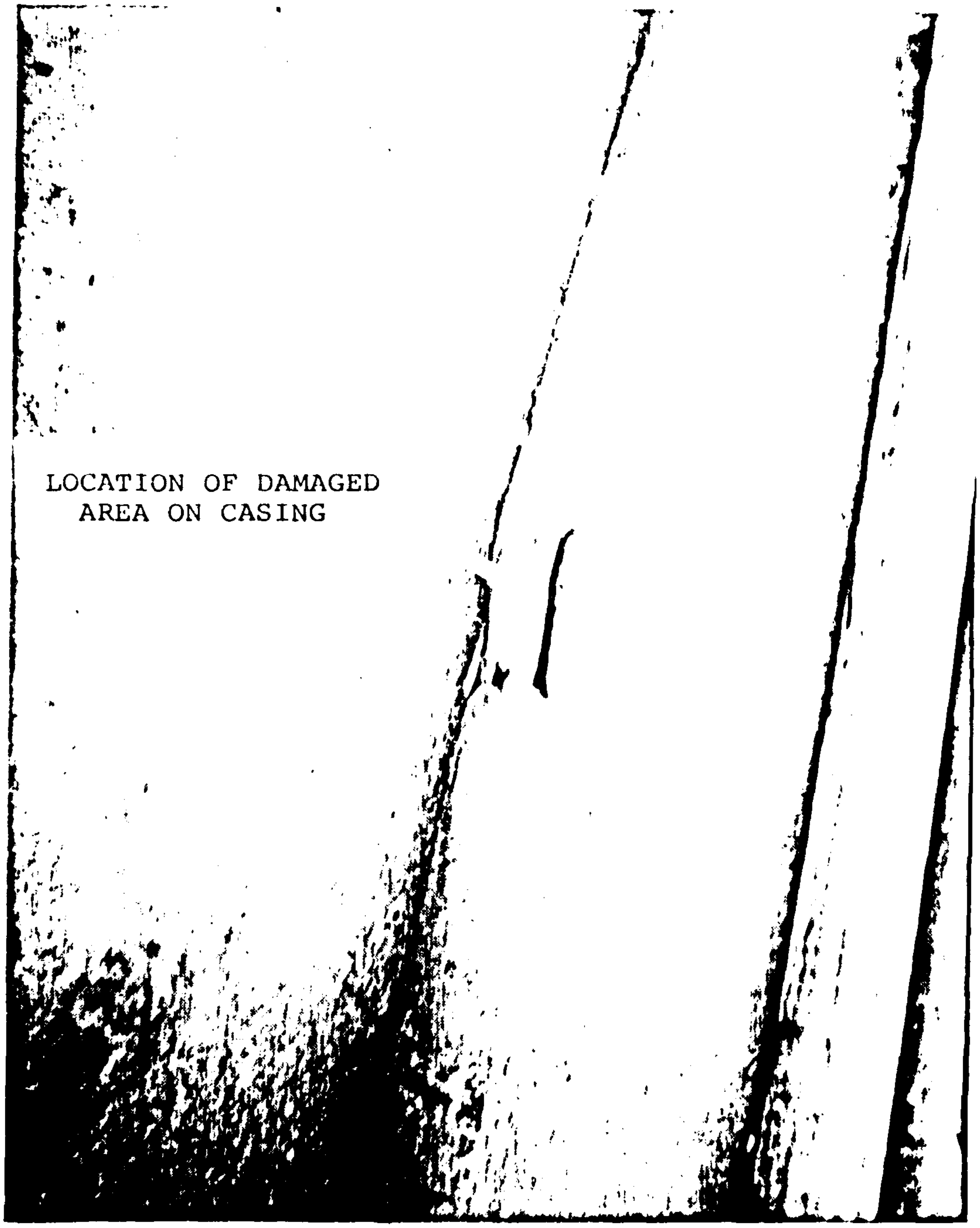


Figure 2. This 8-5/8 inch casing was damaged from gas pressures limiting to 8000 feet. (Casing was removed from a well off the coast of California that did not blow out severely but damage to the casing was relevant.)

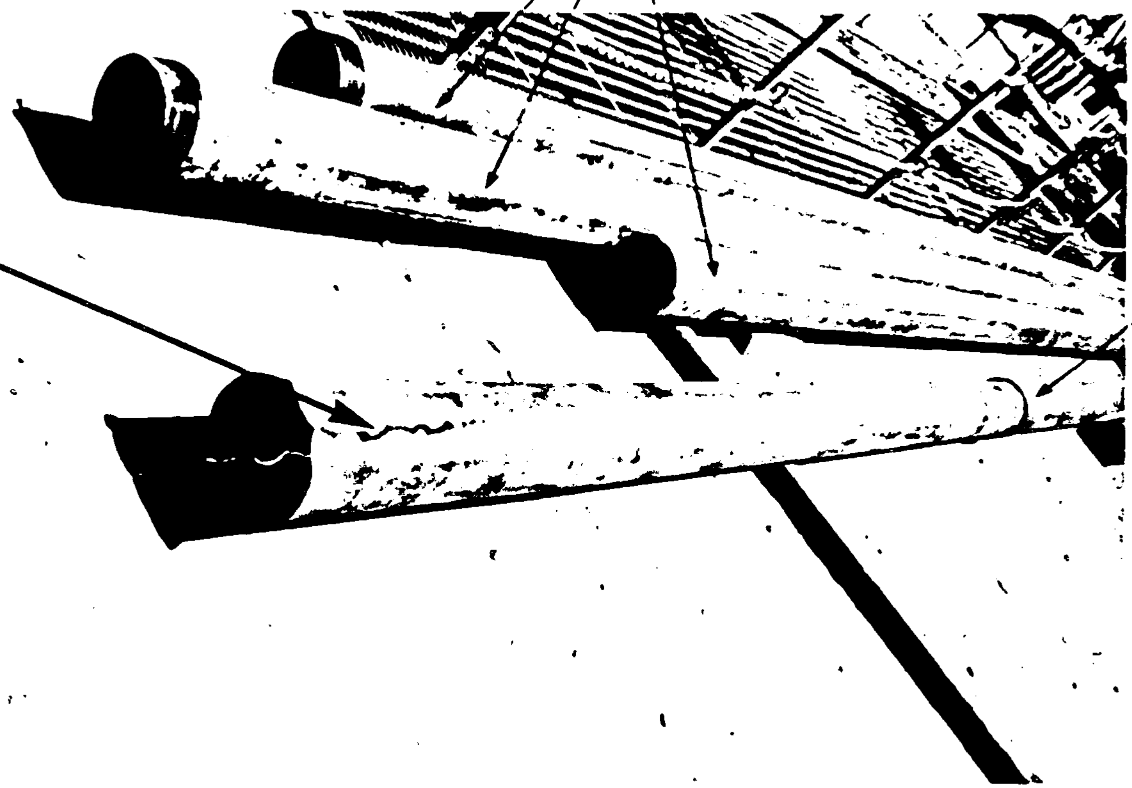


Figure 3. Casing damage of THUMS rig T-7.

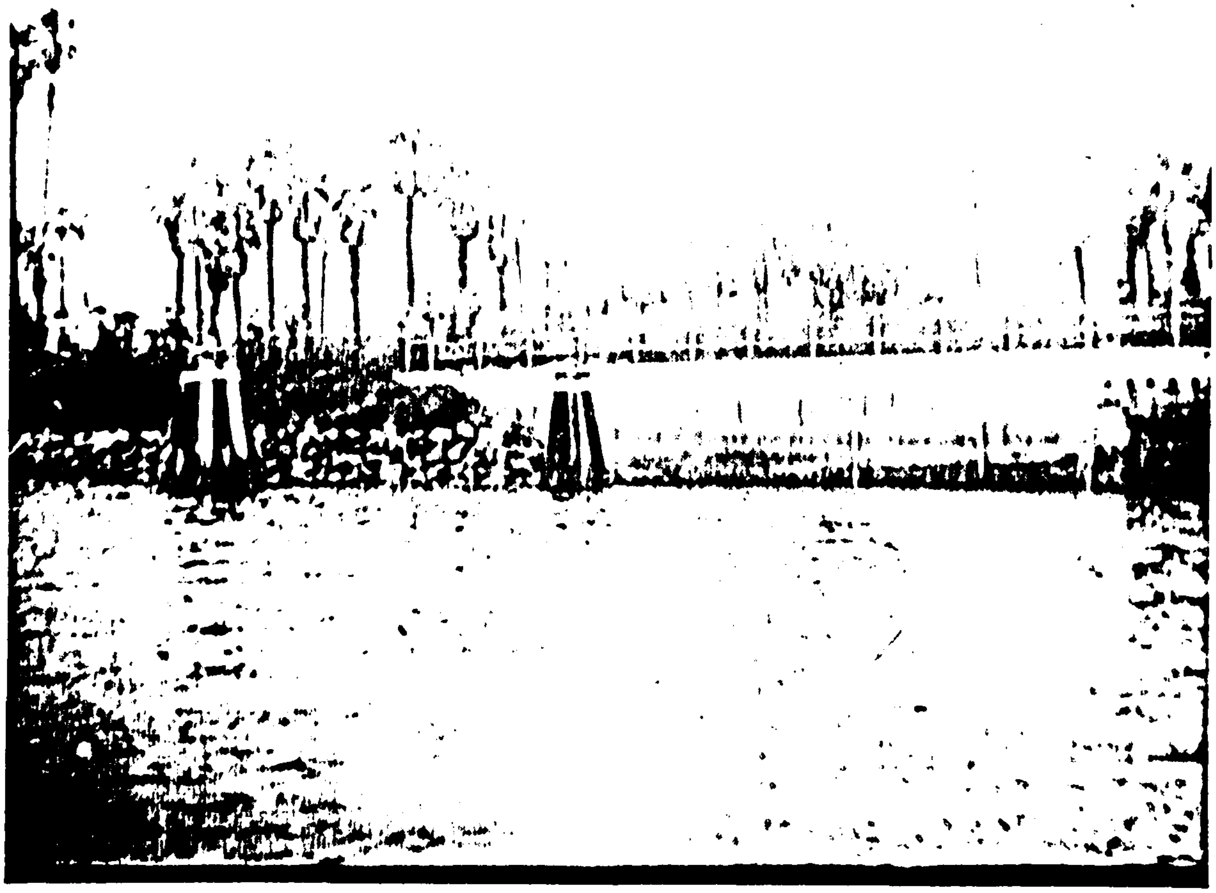


Figure 4. THUMS rig T-8 as it looks from the crew boat approaching Chaffee Island off the coast of Long Beach, California.

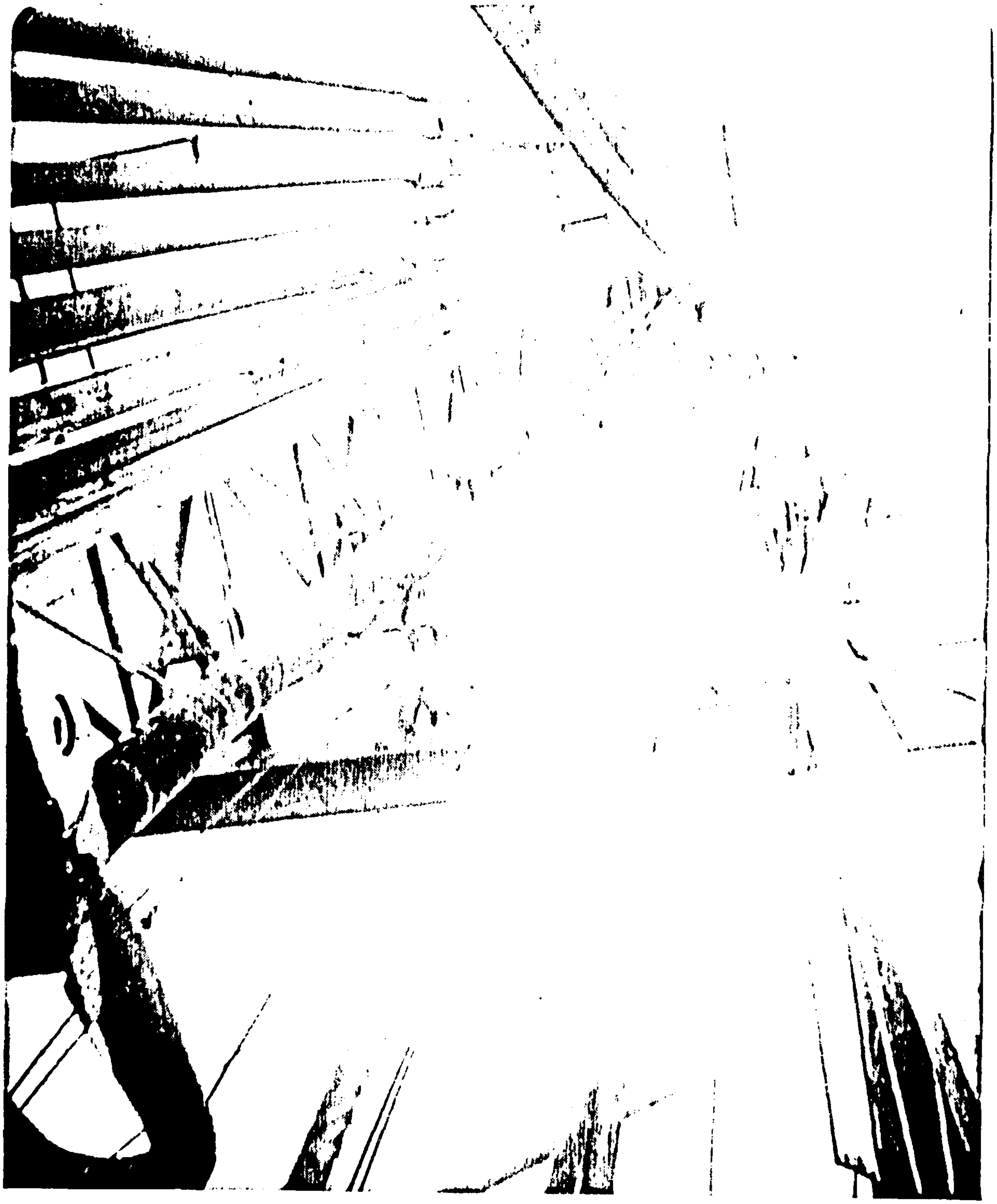


Figure 5. Procedure for salvaging bad casing out of the hole for THUMS rig T-8 at Chaffee Island, California. (Extensive drilling procedures have caused this casing to become worn in vital areas.)

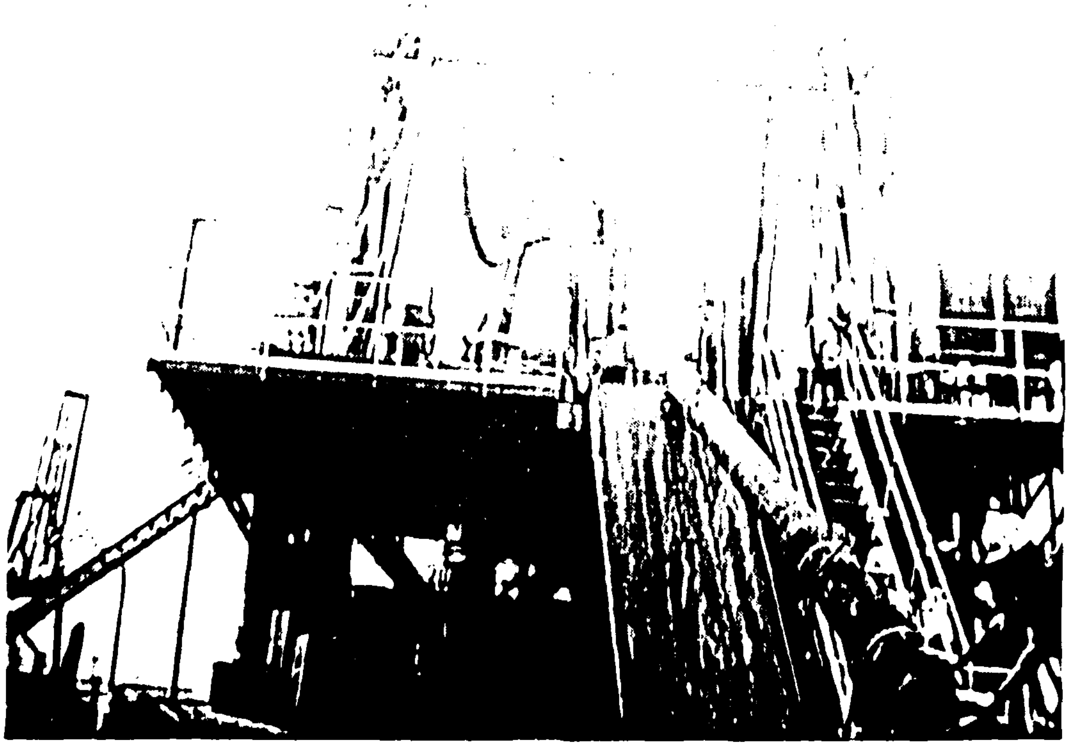


Figure 6. Installation of new casing into the well to continue drilling procedures. (Bad casing was previously removed from the well; the well was then logged for an evaluation of the condition of the formation.)

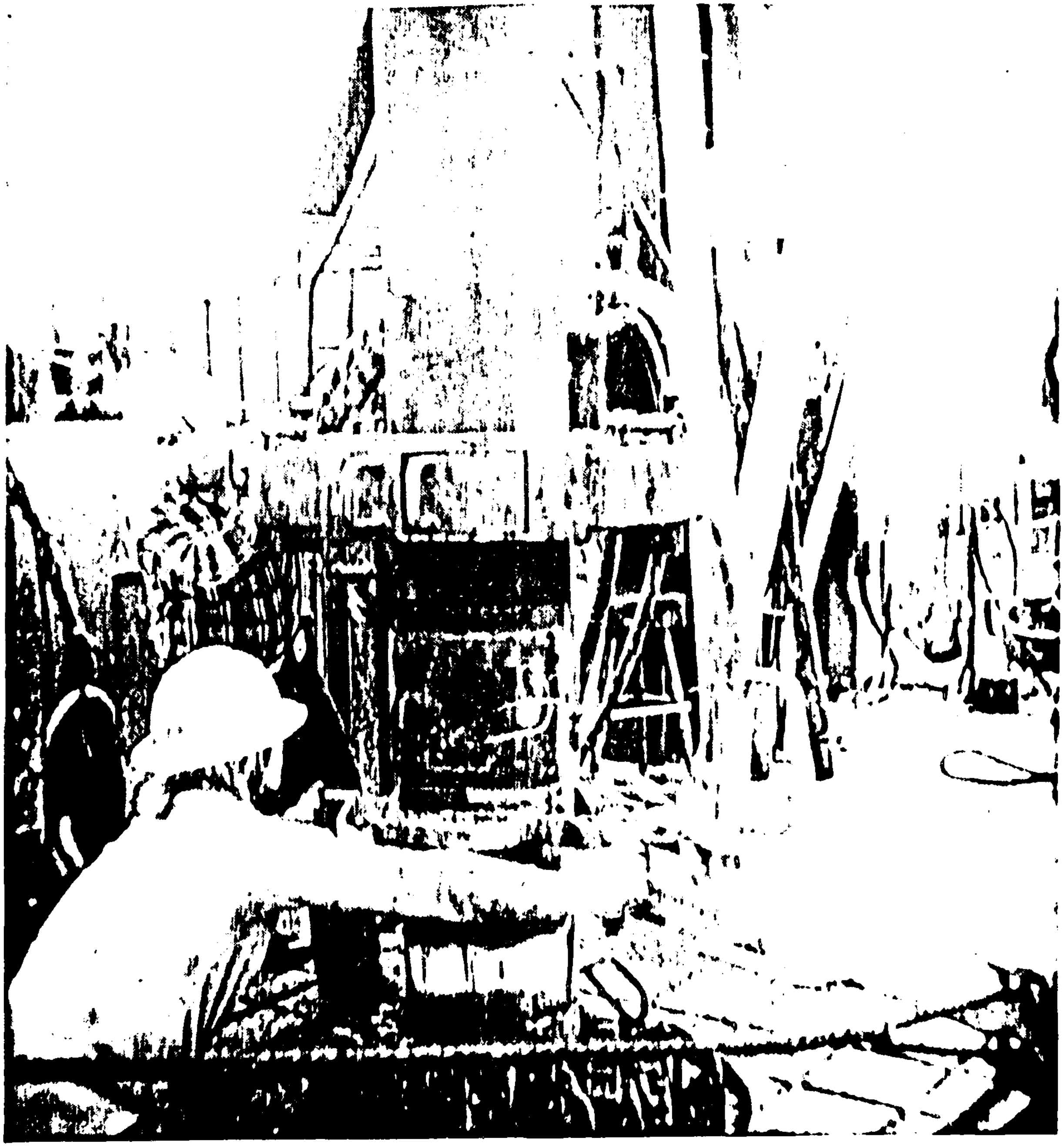


Figure 7. Installation of last casing section into the well. (The man on the bottom left is holding manual backup tongs to keep the casing in the well from turning; the man on the top left is using power tongs to enable him to screw the top section of casing into the bottom section.)

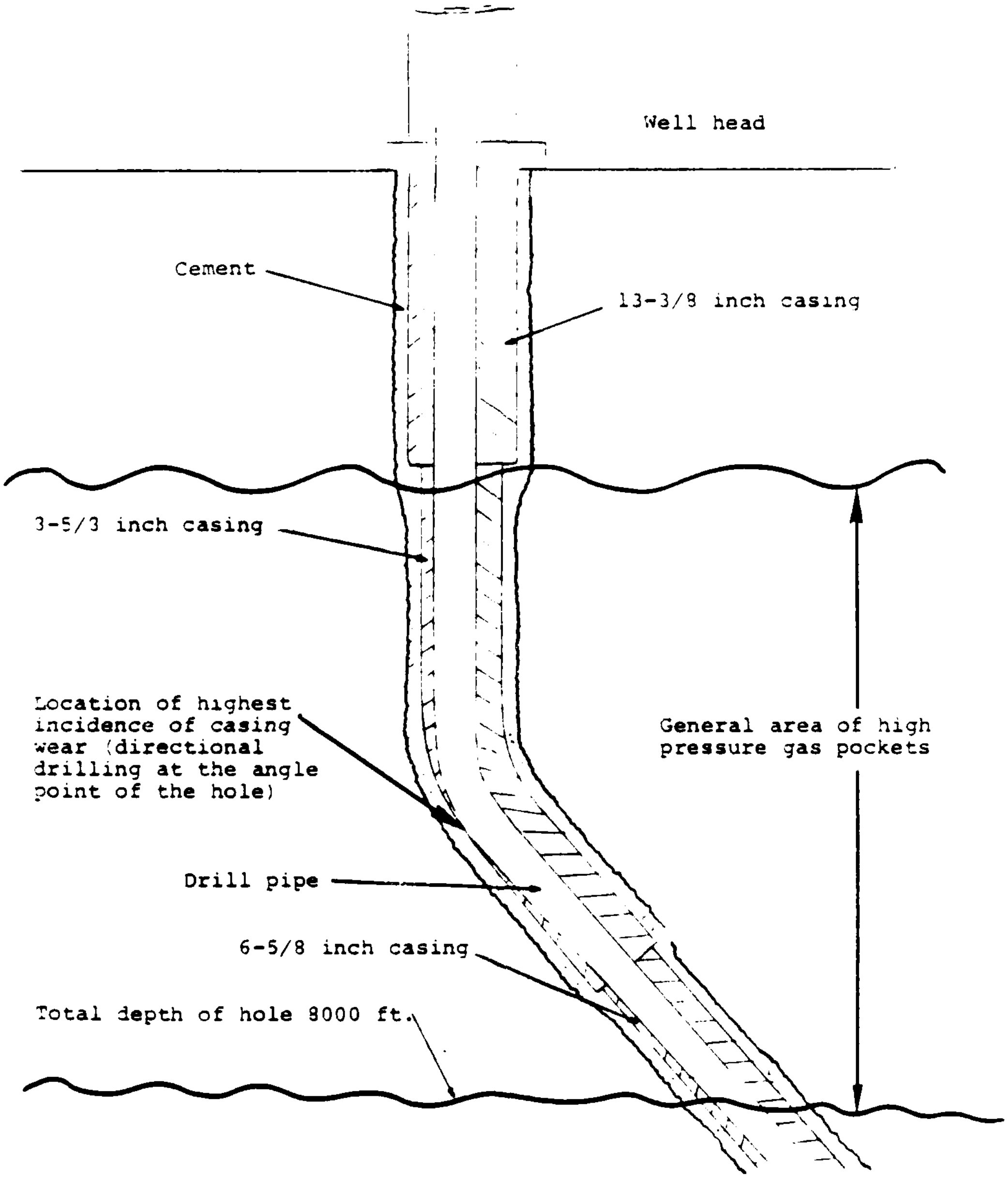


Figure 8. Sketch showing typical area (at the angle point of the hole) of excessive wear that occurs during directional drilling.

One of the main reasons most casing failures occur in the intermediate casing strings is because the strings are often exposed to extended drill pipe movements relative to the other strings. For example, drill pipe movement on directional holes may last for up to three months. During this time severe casing degradation could go undetected and result in a blowout.

2.4 Corrosion in Downhole Casing

Casing degradation resulting from corrosion (internal or external) during drilling operation is not a significant problem because of the limited exposure time of the downhole casing to corrosive environments. However, the casing degradation occurring during drilling operations can be a direct cause of excessive corrosion that may show up later, i.e., 5 years or more after the casing has been in use in the producing well.

Casing degradation of less than critical severity (small localized areas of wall thinning, gouges, pits or longitudinal cracks) occurring during drilling operation may not be detected during normal casing inspection. For example, a degradation (pit) of very short lengthbut of significant depth may satisfy the strength requirements as specified in Code ANSI/ASME B31.4b - 1981 (Reference 11) and pass any in-service casing inspections (hydrostatic test, casing loggers) that may be done.

Some undetected degradation, i.e. short length and large depth degradations (pits, cracks, etc.) may eventually leak due to a corrosive environment of the producing well. Such leaks would not have occurred if the casing degradation were detected.

2.5 Discussion of Actual Cases of Blowouts Involving Casing Failure

Human error, involving the error of not inspecting the casing, generally causes conditions or situations such that abnormal or excessive casing degradation occurs and eventually results in a blowout. Two examples of recent blowouts will be discussed briefly in Sections 2.5.1 and 2.5.2.

2.5.1 City Service - Getty Blowout - Matagorda Island Block 669, Gulf of Mexico

A blowout occurred in Matagorda Island Block 669 in the Gulf of Mexico on August 30, 1980. A United States Geological Survey panel (Reference 1) reported that directional drilling operations had been conducted for 41 days prior to this blowout. During that time the casing became worn and suffered a reduction in strength. When high pressures from a gas zone were encountered; no particular consideration was given to determining a lesser yield internal pressure as a result of probable wear. Apparently, the operators discussed but vetoed the option of venting the gas into the atmosphere. Also, the workmen failed to investigate the possible communication of gas between the 9-5/8 inch and 13-3/8 inch casing strings when pressure on the 9-5/8 inch casing dropped to 4,900 psi from 7,300 psi only five hours before the explosion and fire.

If inspection, such as periodic logging during drilling operations had been used, the worn casing may have been detected and the blowout may never have occurred. Although drilling continued for 41 days straight without casing inspection and the actual blowout resulted from weakened casing, human error was identified as the primary cause of the blowout.

2.5.2 Pennzoil Blowout - High Island Block A-563, Gulf of Mexico

A blowout occurred in Pennzoil High Island Block A-563 in the Gulf of Mexico on November 6, 1976 (Reference 2). On October 8, 1976 a loss of circulation was noted after drilling out cement previously placed in the drive pipe. The operator, however, continued making the hole without circulation from 290 feet to 1350 feet using sea water. To regain circulation, a cement plug was placed below 680 feet using 300 sacks of cement. The drill bit would not re-enter the old hole at 680 feet, so a new hole was begun. A slight dog-leg could have resulted at the level where the bit moved over. At 4493 feet, with 11.7 lb./gal mud in the hole, a second major problem occurred when the direct current control panel shortcircuited due to heat buildup and the rig suffered a power loss to the drawworks and mud pumps for about 12 hours. After about an hour without power, the cementing pumps were connected to the well and circulation began; but, later, when the power was restored, casing pressure was 500 psi and the tubing pressure was 175 psi. After building the mud pits 12.7 lb./gal, the casing pressure was 900 psi.

The investigation team (Refernece 2) identified major trouble signs prior to the actual blowout. These were:

- Drilling with no circulation from 690 feet to 1350 feet.

- Cementing the surface pipe with no circulation after pumping the first 20 barrels of cement.

- Tripping and fishing in the open hole below the surface casing for 12 days without testing the casing or the casing shoe for a leak.

- Drilling into the 6600 feet salt water sand without sufficient mud weights with the pumps off.

The referenced report states that "Pennzoil, in their decision process, did not recognize the possibility of casing damage from the earlier fishing operations and therefore took no precautionary action to assure casing integrity." The report further states that "Although the blowout began with salt water flow at 6634 feet, the basic control lay with the integrity of the surface pipe and a good cement job and with the blowout preventors, mud pumps and the mud supply. The integrity of the surface pipe was lost through the development of a leak."

One of the main recommendations resulting from this investigation was the following:

> Research to detect casing and wear by a device(s) run on drill pipe or wireline which would give up-dated casing condition quickly and simply.

3. SOLUTION TO PROBLEM

The approach used for solution to the problem of casing degradation was: (1) assess the technology and practice for determining casing degradation during drilling operations; and (2) present recommendations or development requirements that would provide solutions for any holes in the technology and/or practice of inspecting casing. This approach is intended to help minimize (acceptable risk) the problem of casing degradation since it will be impossible to completely eliminate casing degradation.

The general requirement is to provide adequate casing inspection to prevent blowouts and other serious problems during drilling operations. The recommendation that resulted from the review of the Pennzoil blowout (Section 2.5) provides a specific requirement, i.e., to detect casing degradation by a device(s) run on drill pipe, wire-line or by other means which would give updated casing condition information quickly, simply and at a practical cost.

The technical approach used is as follows:

- <u>Survey</u>

  Conduct a survey of

  - Offshore exploration and service companies that have developed equipment for downhole logging including those which inspect for casing degradation such as pipe wall thinning, cracks and pits.
  - Current research by companies developing advanced instruments for casing inspection.
  - State-of-the-art technology that can be applied to casing inspection.
  - Industry practices for casing inspection during drilling operations.

- <u>Assessment</u>

  Compare survey information with project requirements,

  Identify holes in technology where further development is required.

- <u>Development Requirements</u>

  Systematic, long-term development plan to obtain useful equipment.

4. STATE-OF-THE-ART TECHNOLOGY AND PRACTICE

This section investigates the state-of-the-art technology and practice for determining casing degradation. Section 4.1 summarizes the survey work carried out. Results of the survey for casing logging devices are presented in Section 4.2. Hydrostatic inspection and acoustic emission inspection are discussed in Section 4.3 and 4.4 respectively. Current research for casing loggers is presented in Section 4.5. Industry practices for casing degradation are discussed in Section 4.6.

4.1 Summary of Survey Work

A survey was conducted to determine the state-of-the-art technology and practice for determining casing degradation. The effort included a survey of the following: (1) literature; (2) offshore exploration and service companies that have developed equipment for downhole logging; (3) R&D companies developing advanced instruments for casing and inspection; (4) other equipment manufacturers and R&D companies involved in products or services that potentially could be used and (5) offshore equipment users and operators. The survey included information on equipment and techniques that were commercially available, in the developmental stage, or potentially feasible.

Information was obtained from the following main sources:

- Government regulatory agencies (both U.S. and foreign) involved in offshore activities.
- Over twenty exploration and service companies have developed equipment and services for downhole logging including those which inspect for casing or pipe wall thickness and structural defects.
- Governmental agencies (both U.S. and foreign) and firms involved in development of advanced instruments for inspection of casing and pipe.
- Over five hundred companies involved in nondestructive evaluation and testing that may be applicable to this project.

- Surveys from information services including

  - National Technical Information Service (NTIS)
  - System Development Corporation (SDC)
  - NASA Industrial Application Center (NIAC)
  - Other

- NDE Technology, Inc. and appropriate Federal and local libraries.

- Technical journals and periodicals in the areas of off-shore and nondestructive evaluation and testing.

A list of exploration and service companies, areas searched using the indicated information services and nondestructive inspection companies surveyed are included in Appendix A. Abstracts of pertinent reports on casing inspection tools and related research obtained from the literature search are given in Appendix B

4.2 Downhole Logging Equipment

Three main types of downhole logging equipment for inspection of casing and corrosion are currently available. They are:

- Caliper Inspection Tool
- Electromagnetic Thickness Tool
- Electromagnetic/Eddy Current Inspection Tool.

These three devices are summarized in Table 1. Pertinent manufacturer information is included in the subsections that follow. Each type of logging device will be described briefly in Section 4.2.1 through 4.2.3.

4.2.1 Caliper inspection tool

Caliper inspection tools are electro-mechanical devices that have spring-loaded caliper finger mechanisms continuously in contact with the casing wall. The finger penetrating the greatest depth into any irregularity in the wall generates an electrical signal which is amplified and recorded at the surface on a precision recorder. The fingers are usually positioned at the top and bottom of the tool for two separate readings. The calipers have multiple fingers typically spaced about 0.5 inches apart to assure thorough investigation of the internal wall. The device continuously measures the minimum and maximum diameter of the internal pipe. The typical inspection speed of these devices is about 3000-4000 feet per hour. Information from two manufacturers, Dia-Log and Gearhart-Owen, are provided in Figures 9 through 11.

TABLE 1. SUMMARY OF STATE-OF-THE-ART CASING INSPECTION TOOLS

TECHNIQUE	DEVICE MANUFACTURER	PRINCIPLE OF OPERATION	DEFECT MEASUREMENT	SENSITIVITY/ INSPECTION TIME	ADVANTAGES	DISADVANTAGES
Caliper Wireline Electro- Mechanical	Multi-arm Inspection Caliper, Manufacturers: Gearhart-Owen, Inc., Dia-Log Co., other.	Electromechanical Spring loaded caliper finger mechanisms continuously in contact with casing wall. Any feeler gage is capable of moving the minimum or maximum diameter of the actuator. Movement of each actuatior is converted to an electrical signal. Outputs of each channed is transmitted to the surface by a wireline.	Internal surface defects such as corrosion, perforations holes, separations splits, flats, tubing abnormalities, etc. Worn areas, severe corrosion	About 150 feet per minute 0.5" resoultion of the inner pipe circumference	Commercially available Simple Low cost Good for large defects	Does not work well when internal wall is covered with oil, grease, paint Does not evaluate wall thickness Detects only large defects
Magnetic Wireline Caliper Electro- Magnetic	Magnelog Manufacturers: Dresser Atlas Industries, Inc., Electromanetic Thickness Tool (ETT) Manufacturer: Johnston Schlumberger. Electronic Casing Caliper Log Manufacturer: NL McCullough	Electromagnetic Wall thickness is determined by a comparison of the amount of phase shift in the magnetic field, the phase shift being proportional to the magnetic field. Measurement is also made of the magnetic permeability of the void between the tool and the inner wall. This results in an electronic caliper. Electrical outputs are transmit- to the surface by a wireline.	Changes in casing wall thickness Identifies external or internal corrosion Pits of holes in casing Parted seams Severe defects on the outer string of a double string of casing	About 150 feet per minute About 1 inch	Commercially available Low cost Good for defect loc- location Detects verticai split splits such as parted seams Detects severe defects on the outer string of a double string of casing	Detects only large defects Gradual changes in wall thickness are difficult to detect Does not work in nonmetals
Electromagnetic Wireline	Pipe Analysis Tool (PAT) Manufacturer: Johnston Schlumberger. Vertilog Tool Manufacturer: Dresser Atlas, Inc.	Electromagnetic/Eddy Current Tool provides a combination of magnetic flux leakage and high-frequency-eddy current tests. Magnetic-flux-leakage testing relies upon the detection of perturbation in the magnetic field caused by defects or irregularities in the casing. Differences in the induced current is a measure of the magnitude of the defect Differences in the high frequency eddy currents is a measure of surface defects Electrical outputs transmitted by wireline.	Casing wall thickness Identies internal of external Small defects such as voids, pits, cracks, tubing abnormalities, etc. Detects corrosion, wear, wall thinning etc.	About 175 feet per minute Resolution to about 1/8" in diameter with 20% penetration of body wall	Commercily available Reasonable cost Good for defect location Detects small defects High resolution Detects defect on inside or outside the casing	Does not work in nonmetals Gradual changes in wall thickness Casing should be scraped prior to the survey Ineffective in detecting vertical splits such as parted seams

DESCRIPTION

Gearhart-Owen Tubing and Casing Inspection Calipers accurately determine the internal size and condition of oil well casing and tubing. To do this, the tools are equipped with multiple caliper legs. These legs continuously measure the minimum and maximum diameter of the internal wall of the pipe. By having multiple measurement legs arranged so that the feeler tips are only 0.5" apart, under the worst case condition, a thorough inspection of the complete internal wall is assured. This feature makes these tools excellent devices for detecting internal surface defects such as corrosion, perforations, holes, separations, splits, flats and build-ups as well as the physical extent of such casing and tubing abnormalities. Tubing pump rod wear and erosion from sand production is easily detected, as well as internal casing wear from drilling or milling operations especially in deviated holes.

OPERATION

The tools are equipped with 30, 40, or 60 individual feeler legs to give a minimum resolution of 0.5" of the internal pipe circumference.

Any one feeler leg is capable of moving either the minimum or maximum diameter actuator. The movement of each of the two actuators is converted to an equivalent frequency change in the corresponding oscillator channel. The outputs of both channels are transmitted simultaneously to the surface

As shown on the back cover, standard NIMS surface equipment is used to record the downhole information. The minimum internal diameter is recorded on Tracks 2 and 3 at a scale of 0.1" per chart division and the maximum detected internal diameter is represented as remaining wall on Track 1 with 0.05" per chart division.

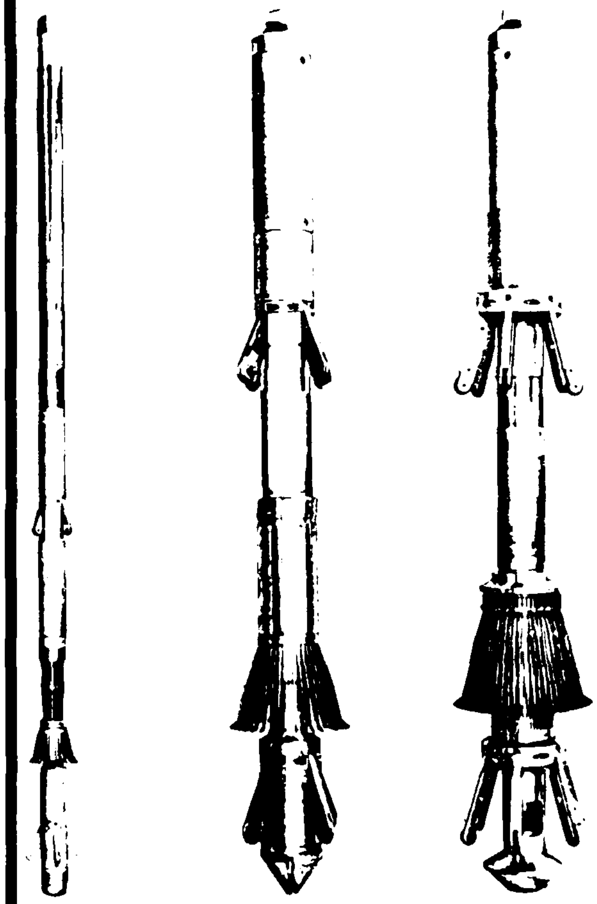


Figure 9. Commercially available caliper inspection tool (Gearhart-Owen)

MEASUREMENT

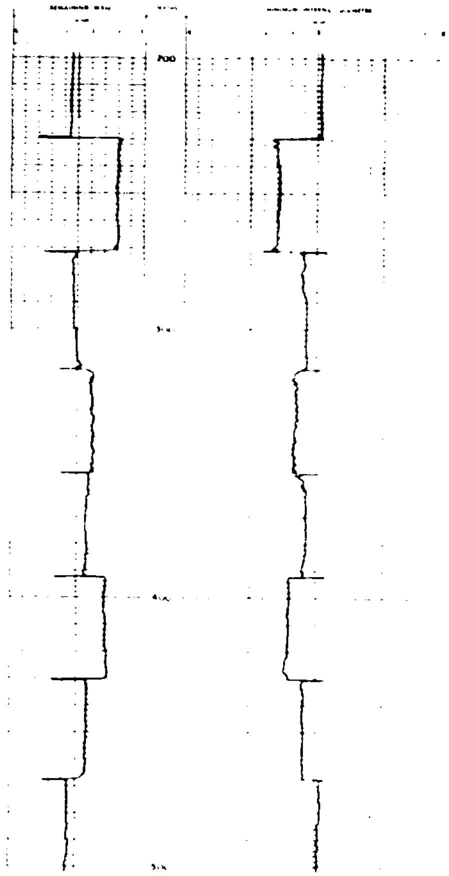
Measurement resolution and accuracy depend to a great extent on accurate and repeatable centralization of the tool. Two sets of powerful roller tipped centralizer arms assure accurate centralization. Both the feeler arms and the centralizer legs are in their closed position while *running the tool in the hole. At the bottom of the* survey depth, feeler legs and centralizer arms are brought to their open position by a motor driven mechanism. The tool can be closed and reopened under surface control for any number of log repeats. This multipass feature allows the detection of pipe defects that are even smaller than the distance between the feeler arm tips.

The profile of the individual feeler legs was chosen to allow maximum penetration of the legs into holes and corrosion pitting.

The curve on Track 1 accurately represents the position of the feeler tip that has moved *furthest from the pipe center and the curve on* Tracks 2 and 3 is the position of the feeler tip that is closest to the center of the pipe. The latter will show build-up and partially collapsed pipe. The maximum I.D. (Remaining Wall) curve will show holes and internal metal loss due to corrosion.

Generally, if an anomaly shows on both curves, it exists all around the internal wall. If it shows only on one curve then this anomaly exists only partially around.

A specially developed high-speed servo amplifier assures accurate representation of the feeler arm movements on the strip chart recorder at logging speeds of up to eighty feet per minute.



STANDARD CASING AND CASING ANOMALIES

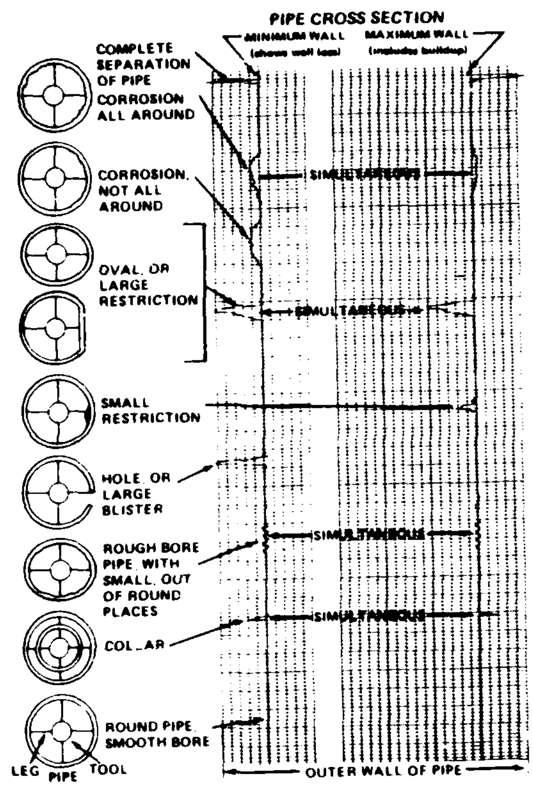
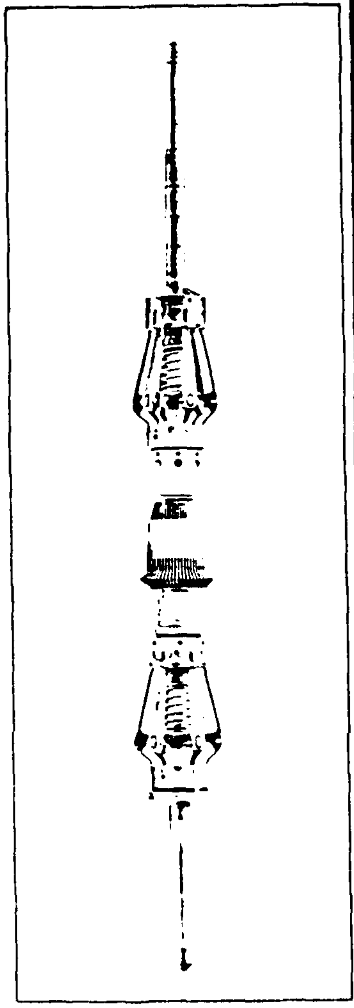


Figure 9. Commercially available caliper inspection tool (Gearhart-Owen) (Continued)

Casing Profile Caliper Service



Applications

Dia-Log Casing Profile Calipers show when casing is in serviceable condition or indicate the need for remedial action by locating any worn and corroded areas or holes in the casing

The Casing Profile Caliper is of particular value when drilling operations have been carried on for an extended period of time through the casing string It is invaluable in determining whether a *liner can be safely hung or if a full* production string is required By showing the original condition of new casing, a *Profile Caliper* Base Log provides a basis of comparison for any future casing work It also verifies that the proper weight of casing has been set by indentifying the thickness of each joint

In producing wells, the Casing Profile Caliper can locate holes and worn and corroded areas which may require remedial work By running the log during normal workovers the progress of corrosion and wear can be closely monitored Perforations can be located in relation to casing collars, and perforations and slotted liners can be checked The profile caliper log is also helpful in determining a suitable place in the casing for relocating a packer It can grade casing to be salvaged before it is pulled

Size of Casing Profile Calipers

O D of Casing	Number of Feelers	Tool Diameter
4½"–6"	40	3⅝"
6⅝"–7⅝"	64	5⅜"
8⅝"–9"	64	7¼"
9⅝"	64	7¾"
10¾"	64	8¼"
11¾"	64	9 9/16"
13⅜"	64	11 5/16"

Operation

The Dia-Log Casing Profile Caliper has a number of 085' wide tungsten carbide tipped feelers which are in continuous spring-loaded contact with the inner circumference of the casing Each feeler is free to move independently to conform to the condition of the casing wall The remaining wall thickness is determined by the feeler that extends the furthest from the axis of the caliper Unique centralizers maintain the caliper in positive axial alignment in the casing to ensure the accuracy of the measurement The accuracy of the measured remaining wall thickness is a function of the API specifications for new casing which allow the nominal O D to vary by ± 75%

Figure 10. Commercially available caliper inspection tool (Dia-Log)

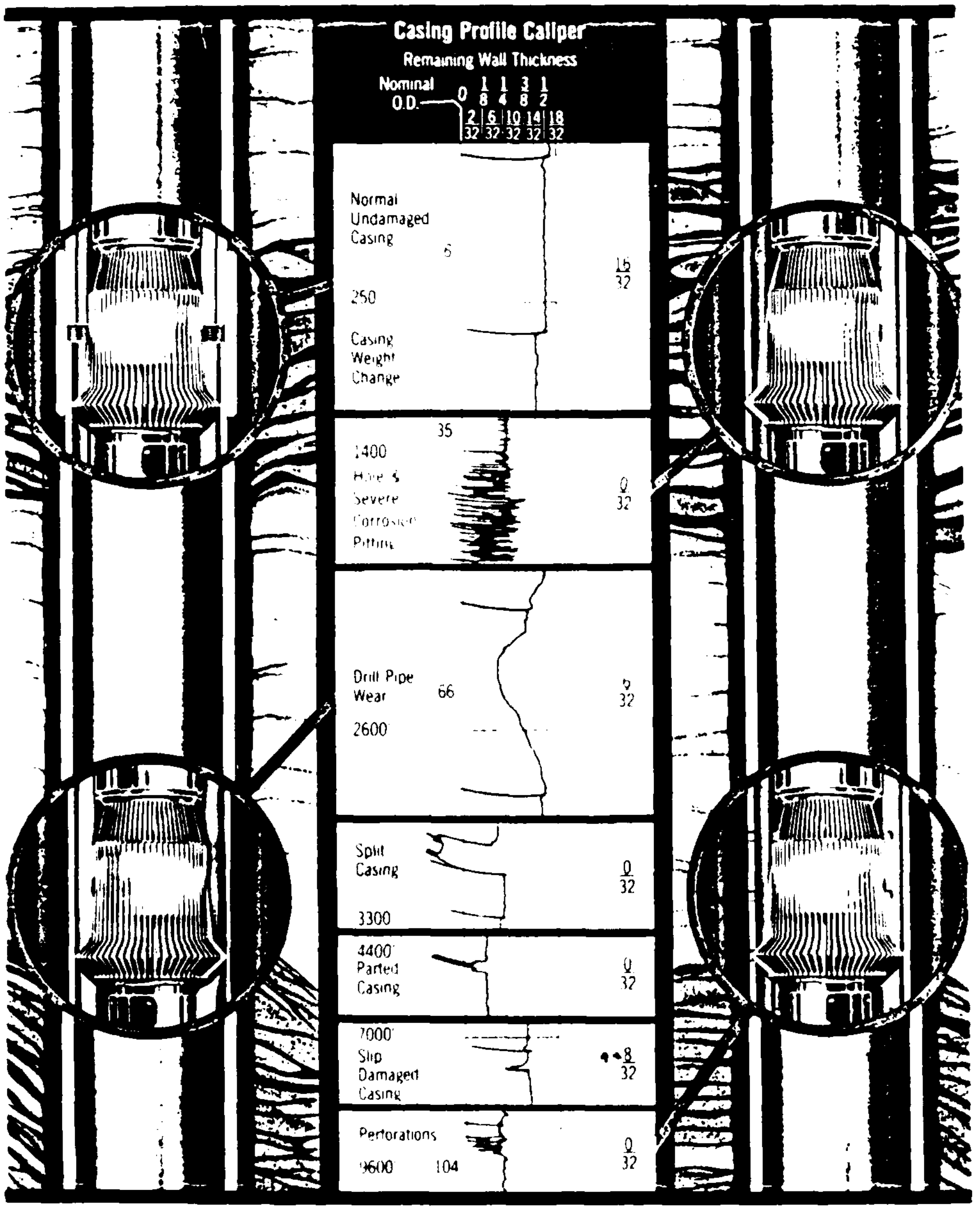
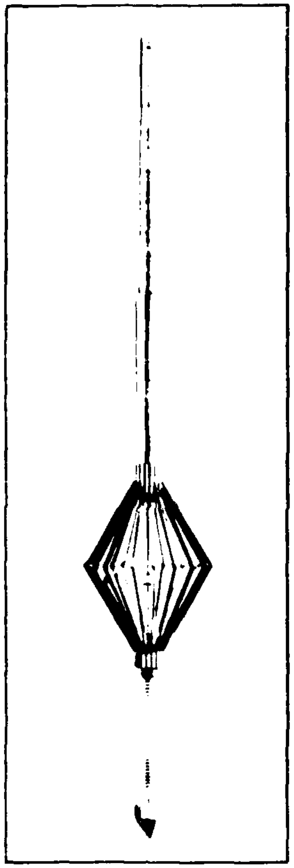


Figure 10. Commercially available caliper inspection tool (Dia-Log) (Continued)

Casing Minimum I.D. Caliper Service



Applications

The minimum I.D. Caliper log is of particular value when planning redrill or workover operations in collapsed or deformed casing. It helps in planning remedial programs by indicating the actual condition of the casing or liner. It determines the maximum size tools such as bits, scrapers, submersible pumps, packers, etc., that can be run safely into the well. It identifies casing weight change intervals and detects casing that has parted and pulled apart.

Description

The minimum I.D. Caliper is 3" O.D. and can pass through and accurately measure restrictions as small as 3¼" in casing with a nominal inside diameter up to 13⅜". It continuously measures the smallest diameter throughout the entire casing string, with the information recorded at the surface as an easily understood log.

Operation

The Dia-Log Casing Minimum I.D. Caliper has eighteen equally spaced arms arranged radially in a single cage. They are mechanically linked together so that the deflection of one arm results in the deflection of all arms an equal amount. No attempt is made to centralize the caliper in the casing. It is allowed to freely orient itself and pass through all types of casing deformities. The arms constantly seek the smallest inside diameter of the casing. This continuous measurement of the arm cage diameter is then an accurate measuring of the casing minimum I.D.

Prior to the logging operation, the tool and the surface electronic systems are calibrated by mechanically setting the caliper to indicate deformities within a predetermined measuring range. Generally, some information is known regarding the expected deformity, and the Dia-Log operator calibrates the tool in the measuring range best suited to expected conditions.

If a deformity is encountered in excess of the preset limits, it also will be detected, and a subsequent recalibrated run will be made to accurately measure the deformed interval.

Only one or two runs with the caliper will provide much more information than many runs with gauge rings or impression blocks.

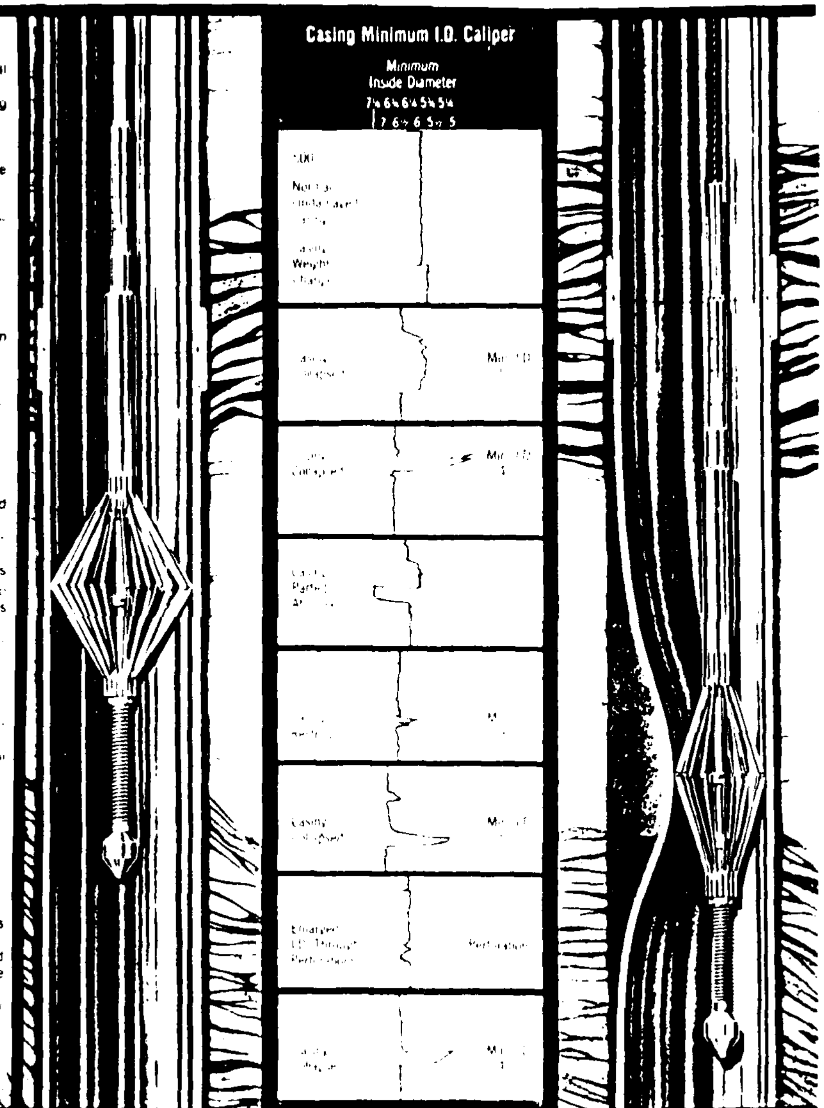


Figure 11. Commercially available minimum I.D. caliper casing inspection tool (Dia-Log)

The caliper inspection tools are capable of detecting internal defects such as corrosion, holes, perforations, separations, splits, flats, buildups and the physical extent of these casing abnormalities. Typical accuracies of internal wall measurements are about ± 7.5%.

Limitations of these devices include the inability to determine defects such as corrosion on the outside of the casing and defect resolution.

4.2.2 Electromagnetic Thickness Tool

The electromagnetic thickness tool is an electro-mechanical device in which wall thickness is determined by a comparison of the amount of phase shift in the magnetic field, the phase shift being proportional to casing thickness. An increase in the phase shift indicates a thicker wall while a decrease in the phase shift indicates a thinner wall. The device also provides a measurement of the magnetic permeability of the void between the tool and the inner pipe of the casing so that the device becomes an electronic caliper. Information on a device supplied by Dresser Atlas is provided in Figure 12.

The device is used to monitor changes in casing wall thickness and includes the ability to distinguish between internal and external casing loss. External corrosion, external pits, holes and other abnormalities on the casing wall are also detectable. The device is particularly useful for detecting severe corrosion or defects in the outer string of a double string of casing.

A major limitation of the device is its inability to resolve hole sizes of better than 1 inch. Another important limitation of the device is that gradual changes in casing wall thickness and permeability of the casing material are adequate to cause phase shift changes along the length of the joint. This limitation causes a poor resolution of the electromagnetic thickness tool.

Magnelog

The Magnelog is a production log in the casing inspection category. All data presented in the Magnelog are obtained by subsurface instrumentation principles similar to those used in open hole induction logging.

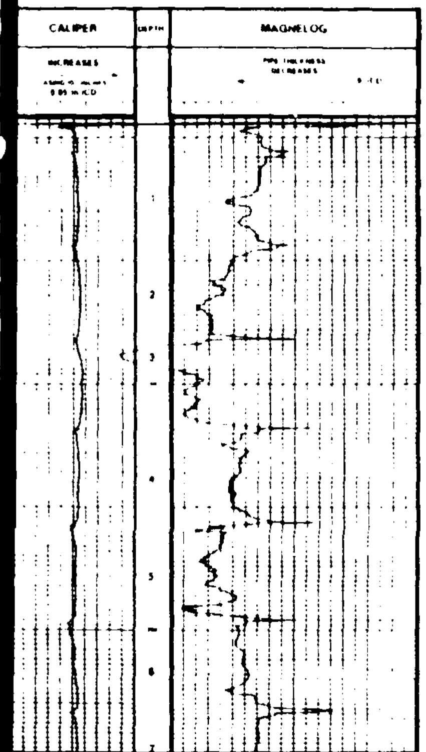
The casing wall thickness is determined by a comparison of the amount of phase shift in the magnetic field, the phase shift being proportional to casing thickness. A measurement is also made of the magnetic permeability of the void between the tol and the inner wall of the casing. The result is an electronic caliper

The simultaneous recording of these two measurements allows for distinguishing between internal and external loss of metal from the casing. External pits, as well as holes, will be shown on the wall thickness curve. The electronic caliper curve will show the internal pits and holes in the casing.

INSTRUMENT SPECIFICATIONS

LENGTH	8 ft	2 44 m
DIAMETER	3-5/8 in	92 1 mm
WEIGHT (W/O CENTRALIZERS)	114 lb	51 7 kg
MAX TEMPERATURE	270 °F (1 hr)	132 °C (1 hr)
MAX PRESSURE	20,000 psi	137 9 MPa
MIN BOREHOLE DIAMETER	4 in	101 6 mm
SIGNALS		
CALIPER	20 kHz	
PIPE WEIGHT	16 Hz	

Magnelog



APPLICATIONS

- Determine casing joints with different weight or wall thickness
- Locate casing collars and other casing string hardware
- Locate evidence of casing corrosion and identify as external or internal
- Locate pits or holes in casing

AUXILIARY PRODUCTION LOGS

- C.A.T. Log™
- Gamma Ray · Neutron Logs for stratigraphy at different levels of corrosion
- Continuous Spinner Flowmeter and Nuclear Flolog for confirmation of holes
- Through-Tubing Logs
- *Casing Potential Profile*
- Acoustic Cement Bond Log

Figure 12. Commercially available electromagnetic casing thickness tool (Dresser Atlas)

4.2.3 Electromagnetic/Eddy Current Inspection Tool

The electromagnetic/eddy current inspection tool provides a combination of magnetic flux leakage and high-frequency-eddy-current tests and results in the best available means of in-place inspection of casing. A discussion of the principle of operation of the magnetic flux and eddy current, obtained from pages 4 and 5 of Reference 3, is provided in the next two paragraphs.

In the magnetic flux leakage test the magnetic flux path, which is distorted in the vicinity of a defect, has a small component normal to the casing wall both above and below the defect. As the flux leakage coils pass over the defect as shown in Figure 13, this component grows from zero to a maximum and then back to zero, thereby inducing a current in each of the flux leakage coils. Since the coils are at different points in the field, the current induced in each is different. The difference in the induced currents in the upper and lower flux leakage is a measure of the rate of change of the flux vector into the well bore and hence of the magnitude of the defect.

In the eddy current test a high-frequency current in the eddy current coil generates a magnetic field, Bc, which induces a circulating current: ii, in the casing, as shown in Figure 14. This induced current generates a countervailing field Bi. The resulting field intensity is detected by the flux leakage coils and separated from the flux leakage signal by a frequency filter. Flaws in the casing surface impede the formation of circulation currents and hence have a substantial effect on the distribution of the induced field, Bi. Changes in the difference in the induced currents in the sensing coils, i1 - i2, are a measure of surface quality. The effect of good and bad casing on this test is shown in Figure 14. The depth of inspection with this technique is only about 1 mm of casing.

Overall, the magnetic flux leakage test inspects for the casing wall thickness and the eddy current test detects flaws on the inner surface. This inspection tool provides the most effective and accurate means that is currently available for in-place inspection of casing.

Two companies, Johnston/Schlumberger and Dresser Atlas, are the major companies that provide this in-place inspection equipment. The PAT and a supplementary electromagnetic thickness tool (ETT) are generally used together by Johnston/Schlumberger while a Vertilog tool is supplied by Dresser Atlas. These inspection tools are described in Figures 15 through 17.

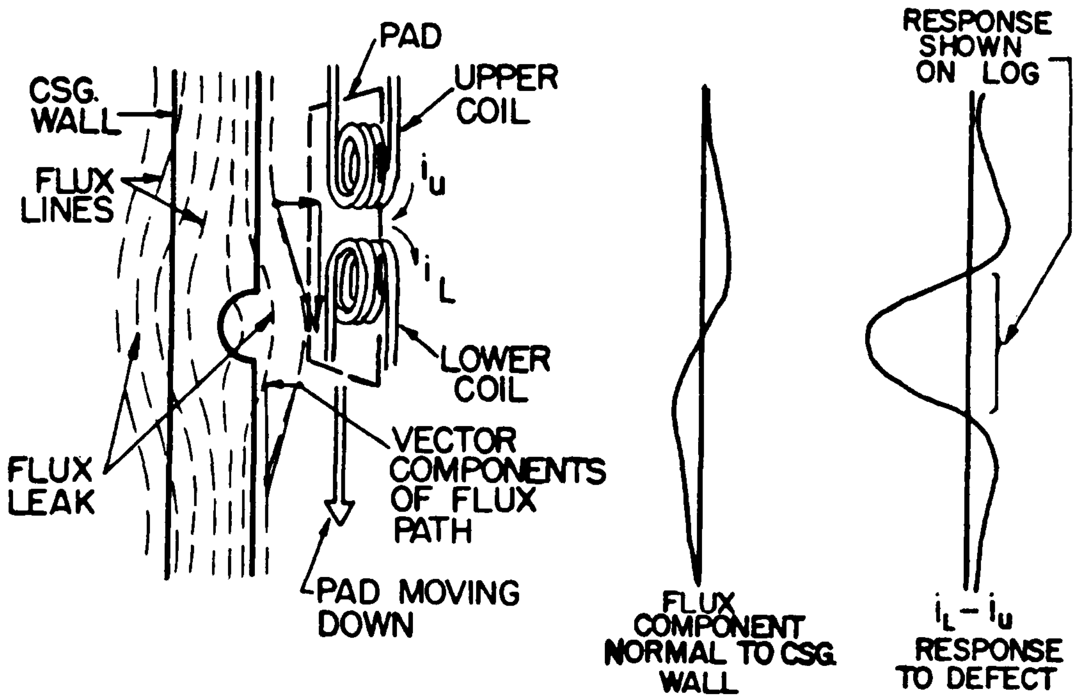


Figure 13. Flux leakage test. (Source: Reference 3)

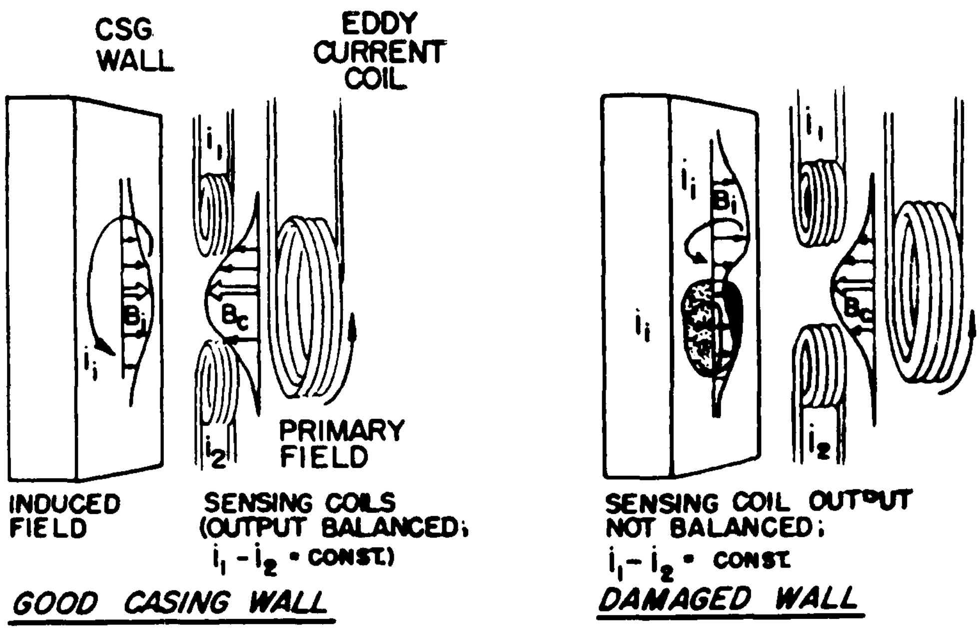


Figure 14. Eddy current test. (Source: Reference 3)

THE TECHNIQUE

Evaluation of various nondestructive testing techniques has indicated that a combination of magnetic flux-leakage and high-frequency eddy-current tests provides the best approach for in-place inspection of well casings, to detect small, isolated defects or corroded areas and to determine whether they are located on the inner or outer casing wall. Sonic techniques were ruled out for two reasons. First, in gas-filled wells it is difficult to couple sonic energy into and out of the casing. Second, the surface of the well casing is generally rough or scaly, whereas acoustic-thickness measurements work best when the pipe surfaces are smooth, so as to serve as good internal sound reflectors.

Magnetic-flux-leakage testing relies upon the detection of perturbations in the magnetic field caused by defects or irregularities in the casing. Implementation of this technique requires a source of magnetic flux from an electromagnet, which is part of the Pipe Analysis sonde, and pickup coils that ride the inner surface of the casing on an array of 12 pads at the center of the sonde. A defect anywhere in the casing wall causes fringing of flux. (At the defect there is less iron in the pipe to conduct magnetic flux, causing some of the flux to fringe around the defect inside the pipe.) The fringing flux extending into the hole is detected by pickup coils. (Similarly, external metallic hardware in contact with the casing will produce a change in the flux in the hole, which will also be detected by the tool. Information concerning placement of scratchers or similar hardware is essential here for correct interpretation.) *Printed-circuit coils in each pad serve as pickup coils* for the magnetic-flux leakage detection and also as receiver coils for the high frequency eddy-current test made on the inner surface of the casing.

For the eddy current test a transmitter coil is mounted above the pickup coils in each pad. Frequency for the eddy-current test is chosen so that the depth of investigation is only about 1 millimeter into the inner casing wall; as a result, this test is insensitive to defects on the outer surface of the casing. Thus, simultaneous defect signals from both the eddy-current and magnetic-flux-leakage tests indicate that the defect is on the inner surface of the pipe. On the other hand, an indication from the magnetic flux-leakage *test with no indication from the eddy current measurement* indicates the defect to be on the outer surface of the casing.

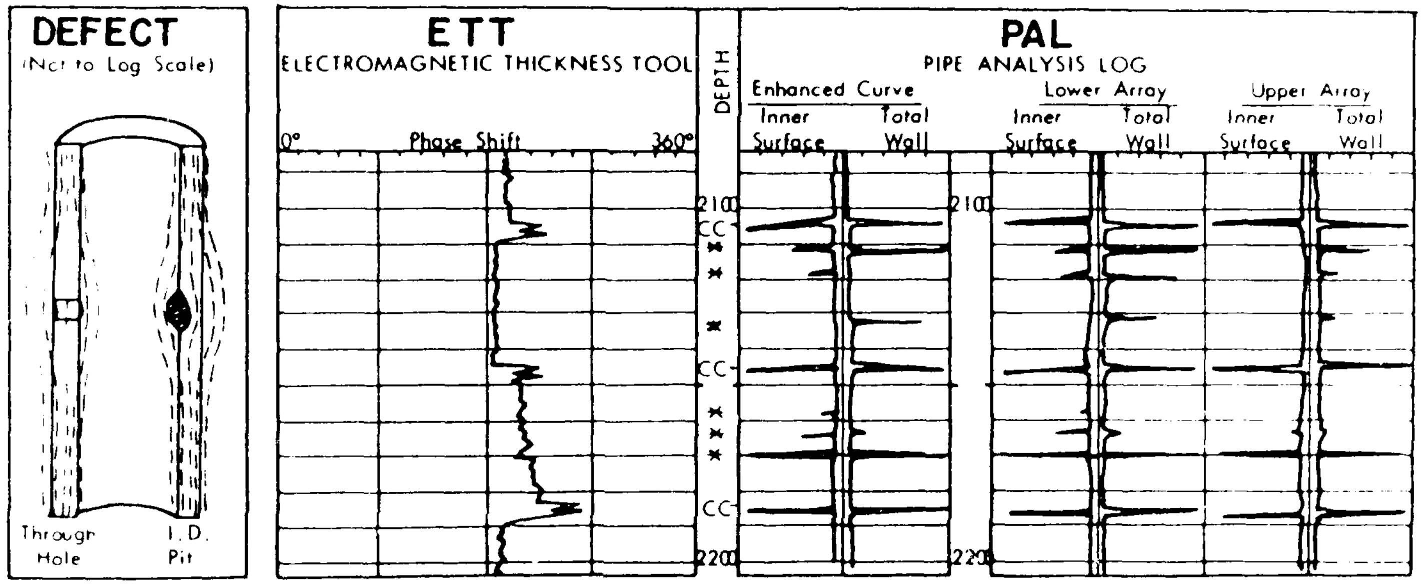
THE TOOL

The Pipe Analysis Tool, shown partially in Fig. , consists of a sonde, an upper and a lower cartridge and two centralizers. There is also an uphole signal processing panel. In addition to an electromagnet, the sonde has two arrays of six pads, each of which provides full circumferential inspection of the casing. The two arrays are staggered with respect to each other to provide overlapping coverage of the wall surface. The pads are spring loaded and adjust *for casing-inspection sizes from 5-in. to 7⅝-in. casing.* The device has the capability of operating in a large number of casing sizes, i.e., 5 in. (11 pound or lighter), 5½-in., 6⅝-in., 7 in., and 7⅝-in. OD casing.

*Trademark of [illegible]nberger

Figure 15. Commercially available electromagnetic/eddy current casing inspection tool (Johnston/Schlumberger)

* POINT DEFECTS ON I.D. - 2112', 2119', 2132', 2158', 2164' & 2170'
I.D. PITS, THROUGH HOLES



COMMENTS

- IF IN NEW CASING, DEFECTS, IF THRU HOLES, CORRESPOND AS FOLLOWS:
- 2112' - 3/4" THRU HOLE (DRILLED)
  2119' - 1/2" THRU HOLE (DRILLED)
  2132' - 3/8" THRU HOLE (DRILLED)
  2170' - 1" THRU HOLE (DRILLED)

  SEE: NEW CASING INSPECTION LOG, J.F. CUTHBERT & W.M. JOHNSON, JR., INCLUDED AS APPENDIX TO THESE GUIDELINES

- INNER SURFACE EDDY CURRENT MEASUREMENT IS NOT CAPABLE OF LESS THAN 1/2" DIA RESOLUTION
- FLUX LEAKAGE RESPONSE LARGER FOR DEEP BUT SMALL DIAMETER DEFECTS.
- PAD OVERLAP EFFECTS APPARENT ON BOTH EDDY CURRENT & FLUX LEAKAGE TESTS
- DEFECT AT 2158' DOES NOT SHOW ON FLUX LEAKAGE (TOTAL WALL) TEST & THEREFORE IS MINOR, < 1 MM DEEP
  DEFECT AT 2164' SHOWS LARGER ON EDDY CURRENT THAN FLUX LEAKAGE TEST, THEREFORE SHALLOW I.D. PIT
  [illegible] SAMPLE PAL LOG, FIGURE 6, & 7.

Figure 15. Commercially available electromagnetic/eddy current casing inspection tool (Johnston/Schlumberger) (Continued)

NL McCullough's Casing Inspection Electronic Casing Caliper log accurately detects and records the extent of casing damage caused by corrosion. It locates pits, holes, vertical splits, parted or broken collars, and reveals the extent of damage caused by the wearing action of sucker rods, tubing, or drill pipe.

The Casing Inspection Tool measures the wall thickness of the pipe by recording the total metal loss on the inside and outside of the pipe. A calibrated curve of average wall thickness is presented on the log.

The Electronic Casing Caliper Tool measures and records the inside diameter of the pipe. It is so sensitive that even small variations of inside diameter are detected. A curve indicating average inside diameter appears on the log.

Both logs are recorded simultaneously, and collar locations are clearly shown. A comparison of the two curves reveals the extent of metal loss or pipe damage and tells whether the damage is external, internal or both. Tools may be run individually when required. The table on page 3 lists sizes of Casing Inspection and Electronic Caliper tools available.

Casing Inspection Log

Principle of Operation. The Casing Inspection log relates the effects of eddy currents on a magnetic field to casing wall thickness. The tool consists of two radial coils, an exciter and a pickup coil. The exciter coil is fed from an AC voltage source at the surface, in turn producing a magnetic field downhole. This field sets up eddy currents in the casing wall. These currents cause the magnetic field to be attenuated and shifted in phase. The resulting magnetic field is detected by the pickup coil and transmitted to the surface. The magnetic field as detected by the pickup coil is then *compared with the original field generated by the exciter coil, and the resulting phase* shift in the magnetic field is recorded on a strip-chart recorder.

The theory of eddy currents indicates that a change in magnetic field is the result of four factors: casing wall thickness, frequency, mangetic permeability and resistivity of the metal.

The magnetic permeability and resistivity are unknown for any given joint of casing, and vary considerably among types of casing and casing manufacturers. Also, stresses placed upon casing when it is set causes additional variation in magnetic permeability. However, these variations are minimized by using a reference joint to arrive at a metal thickness scale, and by using that reference joint for all subsequent logs recorded in the same well.

Electronic Casing Caliper Log

Principle of Operation. The Casing Caliper log uses a method of relating surface currents induced on the inner diameter of casing or tubing to the actual inner diameter. The tool consists of a non-contacting coil system generating an electromagnetic field which sets up surface currents on the inner surface of the pipe. These currents are detected by the coil system. *The reading obtained is a measure of the average inner diameter of the* pipe over a length of one to two inches, depending on tool size. Successful logs can be recorded through scale, paraffin or cement adhering to the inner surface of the pipe. The log is particularly sensitive in locating vertical splits because of the interruption of surface currents along the inner surface of the pipe.

The Casing Caliper tool is calibrated with casing sleeves precision bored to exact inside diameters. A two-point calibration insures accurate and repeatable logs. The [illegible] itself is linear and is presented with a scale of 0.025 inches [illegible] inch division.

Equipment

The combination downhole tool is illustrated in Figure 1. Centralizing springs are used at the top and bottom of the tool to minimize wear on the tool housing. Both tools may be run individually or in tandem as shown in Figure 1.

The combination tool is temperature rated to 400°F, and pressure rated to 20,000 psi. Satisfactory results can be obtained in any type of well fluid.

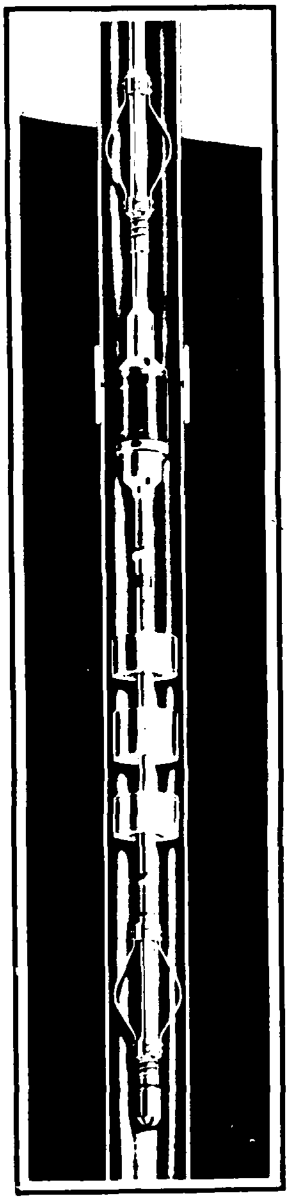


Figure 1

Figure 16. Commercially available electromagnetic/ eddy current inspection tool (NL McCullough)

Figure [illegible]. A typical simultaneous Electronic Casing Inspection of 7 in. 23 lb casing. *The wall* thickness as measured by the Casing Inspection Tool is shown on the right. Casing collars are indicated at 3525 and 3570 ft. The double response is due to the two-coil measuring system and the deflection to the right is caused by the additional mass of the casing collar. *The Electronic Casing Caliper Log* is shown on the left side of the depth column. The single sharp deflection to the right at each collar is caused by *the natural separation* occurring between joints. Three anomalies are present at 3533, 3566 and 3597 ft. The Casing Inspection Log indicates thinning, and the Casing Caliper Log shows an increase in inside diameter. From the regular spacing of these responses it can be concluded that tubing collar wear in the casing string during pumping action has taken place.

Tolerance on the inside diameter of casing and tubing can be approximated from API tables. Outside diameter tolerance for 7 in. casing is + 0.75 per cent. Wall thickness tolerance is listed as 12.5 per cent. By combining these two figures the inside diameter tolerance for 7 in. 23 lb casing can be calculated. With a nominal ID of 6.366 the tolerance allows variation from 6.314 to 6.498. Limits have been shown on Figure 2 to illustrate the magnitude.

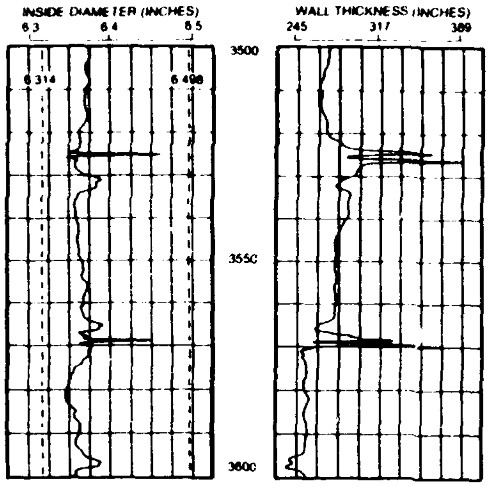
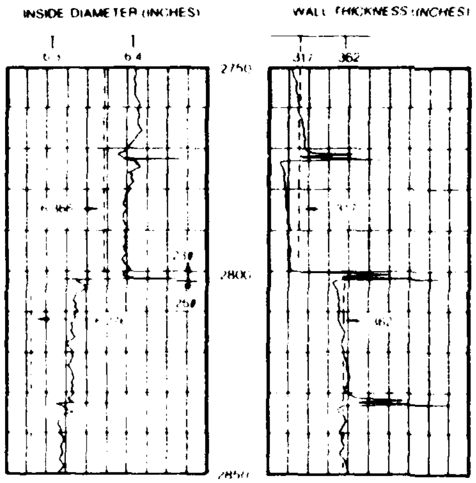


Figure [illegible]. A log run in 7 in. casing showing the response to a change in weight from [illegible] lb to 26 lb casing. The 26 lb casing [illegible] a smaller inside diameter and a thicker wall.



NL McCullough's Casing Inspection/Electronic Casing Caliper log accurately detects and records the extent of casing damage caused by corrosion. It locates pits, holes, vertical splits, parted or broken collars, and reveals the extent of damage caused by the wearing action of sucker rods, tubing, or drill pipe.

The Casing Inspection Tool measures the wall thickness of the pipe by recording the total metal loss on the inside and outside of the pipe. A calibrated curve of average wall thickness is presented on the log.

The Electronic Casing Caliper Tool measures and records the inside diameter of the pipe. It is so sensitive that even small variations of inside diameter are detected. A curve indicating average inside diameter appears on the log.

Both logs are recorded simultaneously, and collar locations are clearly shown. A comparison of the two curves reveals the extent of metal loss or pipe damage and tells whether the damage is external, internal or both. Tools may be run individually when required. The table on page 3 lists sizes of Casing Inspection and Electronic Caliper tools available.

Casing Inspection Log

Principle of Operation. The Casing Inspection log relates the effects of eddy currents on a magnetic field to casing wall thickness. The tool consists of two radial coils, an exciter and a pickup coil. The exciter coil is fed from an AC voltage source at the surface, in turn producing a magnetic field downhole. This field sets up *eddy currents in the casing wall. These currents cause* the magnetic field to be attenuated and shifted in phase. The resulting magnetic field is detected by the pickup coil and transmitted to the surface. The magnetic field as detected by the pickup coil is then compared with the original field generated by the exciter coil, and the resulting phase shift in the magnetic field is recorded on a strip-chart recorder.

The theory of eddy currents indicates that a change in magnetic field is the result of four factors: casing wall thickness, frequency, mangetic permeability and resistivity of the metal.

The magnetic permeability and resistivity are unknown for any given joint of casing, and vary considerably among types of casing and casing manufacturers. Also, stresses placed upon casing when it is set causes additional variation in magnetic permeability. However, these variations are minimized by using a reference joint to arrive at a metal thickness scale, and by using that reference joint for all subsequent logs recorded in the same well.

Figure 16. Commercially available electromagnetic/eddy current inspection tool (NL McCullough) (Continued)

DESCRIPTION

The Vertilog is a downhole casing inspection service. The recordings produced allow identification of damaged intervals and severity of corrosion. Measurements taken determine if corrosion or damage is internal or external and if it is isolated or circumferential.

Due to instrument design, casing inspection covers the full circumference and minor elongation does not affect the reliability of the measurements. Anomalies as small as 1/8" in diameter with as little as 20% penetration of the nominal bodywall of the casing can be detected.

All casing sizes, weights, and grades from 4-1/2" O.D. through 8-5/8" O.D., except 6-5/8"O.D., can be inspected at the present time.

The tools are temperature-rated at 250°F and pressure-rated at 10,000 psi.

The logging speed is 125 feet per minute and no special borehole fluids are required for the survey. It is recommended that the casing be scraped just prior to the survey for the most definitive measurements.

The data is presented in a standard log format; however, the usual depth scale is 10" per 100 feet of borehole for improved definition. The measurements are presented on a four track log grid.

Track one and two are designated as Flux Leakage-1 (FL-1) and Flux Leakage-2 (FL-2) and correspond to the two rings of shoes on the Vertilog instrument. Recorder deflections in these tracks indicate the severity of corrosion that has taken place and also the location of the collars.

The third track is designated the Discriminator Track with recorder deflections allowing interpretation of whether the damage is internal or external.

The fourth track is referred to as the Average Track. he ratio of the height of the signal recorded by a casing collar (360°) to one within a joint determines if the damage is isolated or circumferential.

Figure 17. Commercially available electromagnetic/eddy current casing inspectio- tool (Dresser Atlas)

THEORY OF OPERATION

The Vertilog instrument is designed for maximum resolution for each size of casing. Because of this a different tool is required for each size of casing. Figure 17A gives tool specifications for the available sizes. The instrument designed to survey 8-5/8" O.D. casing is shown in Figure 17B.

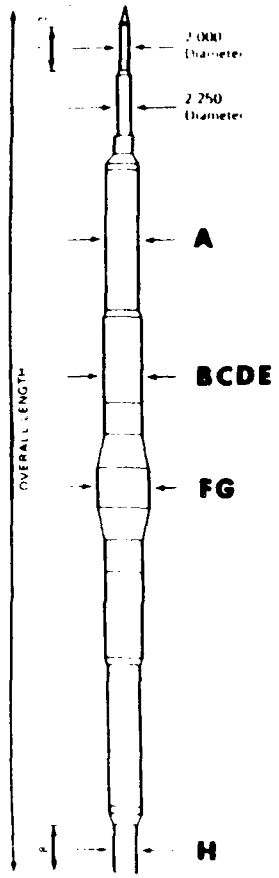
A basic block diagram of the Vertilog system incorporating the shoes, electronics, wireline, and recorder is shown in Figure 17C.

The downhole instrument consists of six or twelve shoes (depending on size casing being surveyed), an electromagnet and two electronic packages. Figure 17D illustrates the shoe section of the tool. Each shoe has four transducers, two connected to each electronic package. The Flux Leakage (FL) electronic package processes the signal relating to the severity of the corrosion. The Eddy Current (EC) electronic package discriminates between internal and external corrosion.

The two electronic packages relate directly to the two principles used in the Vertilog system.

The magnetic flux leakage detection theory is used in the FL package and eddy current sensing is used in the EC package.

The recorded log, the magnetic principles, and electronic packages are all inter-related.



Dresser Atlas
VERTILOG DOWNHOLE CASING INSPECTION

Tool Specifications

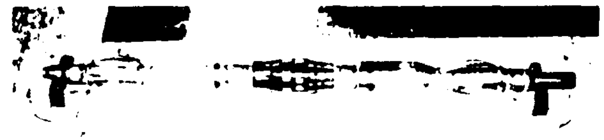
	Specifications	4½" Tool	4½" Tool 5" Transducers	5½" Tool	5½" Tool 5" Transducers	7" Tool	8 5/8" Tool
A	Diameter	3 437	3 437	3 437	3 437	4 875	4 875
B	Diameter	3 625	3 625	4 250	4 250	5 500	[illegible]
C	#1 Sleeve Diameter	3 875	3 875	4 625	4 625	5 875	[illegible]
D	#2 Sleeve Diameter						[illegible]
E	#3 Sleeve Diameter						[illegible]
F	Minimum Diameter	3 743	3 882	4 447	4 325	5 923	[illegible]
G	Maximum Diameter	4 954	4 954	5 579	5 579	[illegible]	[illegible]
H	Diameter	3 438	3 438	3 438	3 438	3 438	3 438
	Approx Weight lbs	225	225	260	260	440	650

Overall Length of Tool

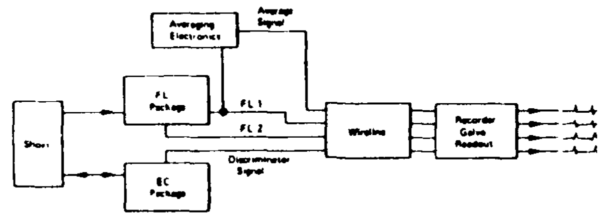
Specifications	4½" Tool	4½" Tool with 5" Transducers	5½" Tool	5½" Tool with 5" Transducers	7" Tool	8 5/8" Tool
No Sinker Bar	10 10 7/32	10 10 7/32	10 10 7/32	10 10 7/32	11 11 32	11 9 32
1 Sinker Bar	13 10 7/32	13 10 7/32	13 10 7/32	13 10 7/32	14 11 32	14 9 32
2 Sinker Bar	16 10 7/32	16 0 7/32	16 10 7/32	16 10 7/32	17 11 32	[illegible] 9 32
3 Sinker Bar	19 10 7/32	19 10 7/32	19 10 7/32	19 10 7/32	20 [illegible] 32	20 9 32

* Sinker Bar weighs approximately 140 lbs

A Tool Specifications



B 8 5/8 O D Vertilog Tool



C Block Diagram of the Vertilog System

D Shoe Section

Figure 17. Commercially available electromagnetic/eddy current casing inspection tool (Dresser Atlas)

These inspection tools allow the identification of damaged intervals and severity of corrosion. Anomalies as small as 1/8-inch in diameter with as little as 20% penetration of the nominal bodywall of the casing can be detected. Defects on the inside and outside can also be determined using this tool.

The electromagnetic/eddy current inspection tool is ineffective in detecting vertical splits such as a parted casing seam because it is not capable of picking gradients circumferentially in the casing wall. Since the electromagnetic thickness tool is capable of measuring wall thickness and indicates vertical splits, it can be used to supplement the electromagnetic/eddy current inspection tool.

4.3 Hydrostatic Test

Hydrostatic testing is a standard method for inspecting casing during offshore operations. Typically, hydrostatic tests are carried out two or three times during a complete drilling operation (well program). The technique basically involves the following typical procedure:

1. Close the pipe rams with the drill pipe in the well.

2. Prepare the pressurization medium - drilling fluid.

3. Pressurize the casing (using mud pumps) to a maximum test pressure (usually 1.1 to 1.25 times the maximum operating pressure).

4. Hold the test pressure for a prescribed period of time (typically less than 30 minutes).

5. Monitor pressure drop to check the cement bond and the casing for leaks.

Testing procedures are prescribed by the drilling operator, the recommended practices of the Minerals Management Service and such general procedures as API RP-1100 (see Reference 12). Section 6.1.1 provides additional details of the hydrostatic testing procedure.

Hydrostatic tests are normally used to check for proper cement bonds and leakage in the cement bonds and casing. The intent is to detect degradation that has developed into a detectable leak at test pressure.

Hydrostatic tests, in general, do not detect casing degradation that will eventually cause failure (impending failure) because of limitations in the technique itself and the infrequent use of the test. For example, additional new degradation of the intermediate string due to later drilling operations after the hydrostatic tests, such as during and after drilling the production hole, is not detectable.

The merits of hydrostatic testing have been studied in detail. References 12 through 18 provide recent work and the current understanding of the benefits and limitations. In general, hydrostatic tests are a good means of testing casing, pipeline and tank for leaks.

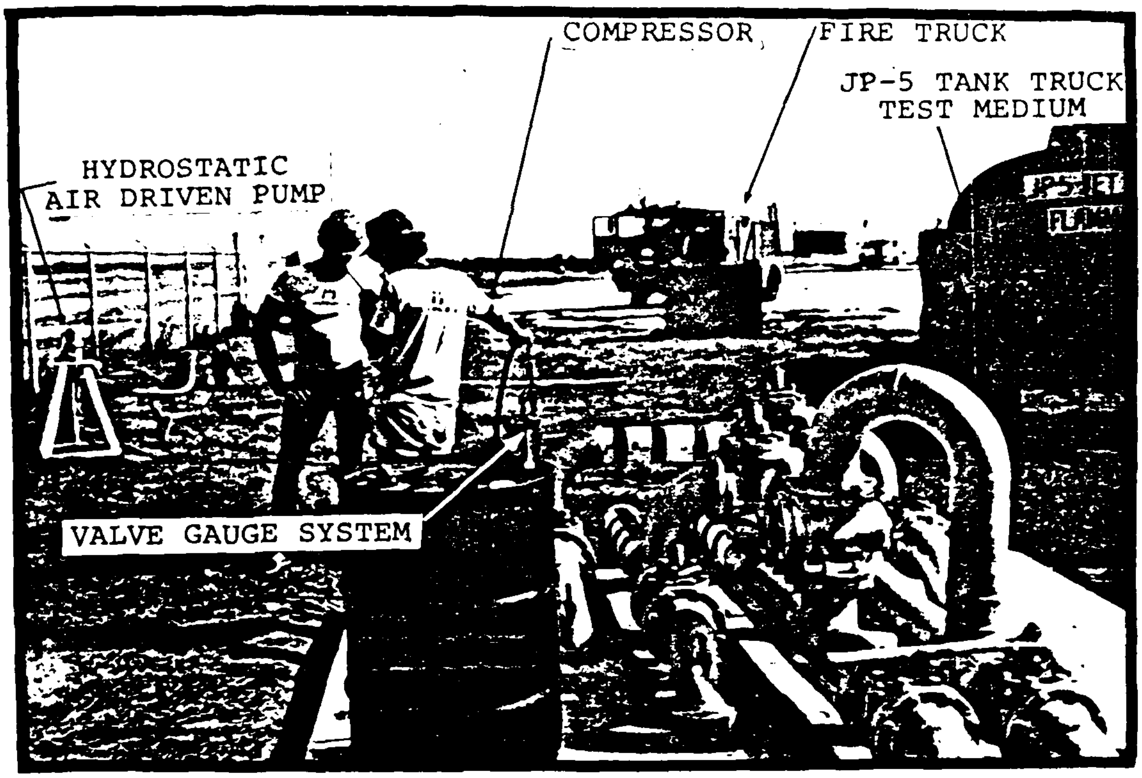
The hydrostatic test normally is just one of a number of inspections for insuring the integrity of casing. In most applications, a combination of inspection measures with varying inspection schedules (see Reference 6) are necessary to insure the integrity of the components. This definitely holds true for casing inspection where hydrostatic testing and casing loggers are currently used. Here, casing loggers are needed to detect and locate casing deficiencies that are not detectable with hydrostatic testing.

4.4 Acoustic Emission Inspection

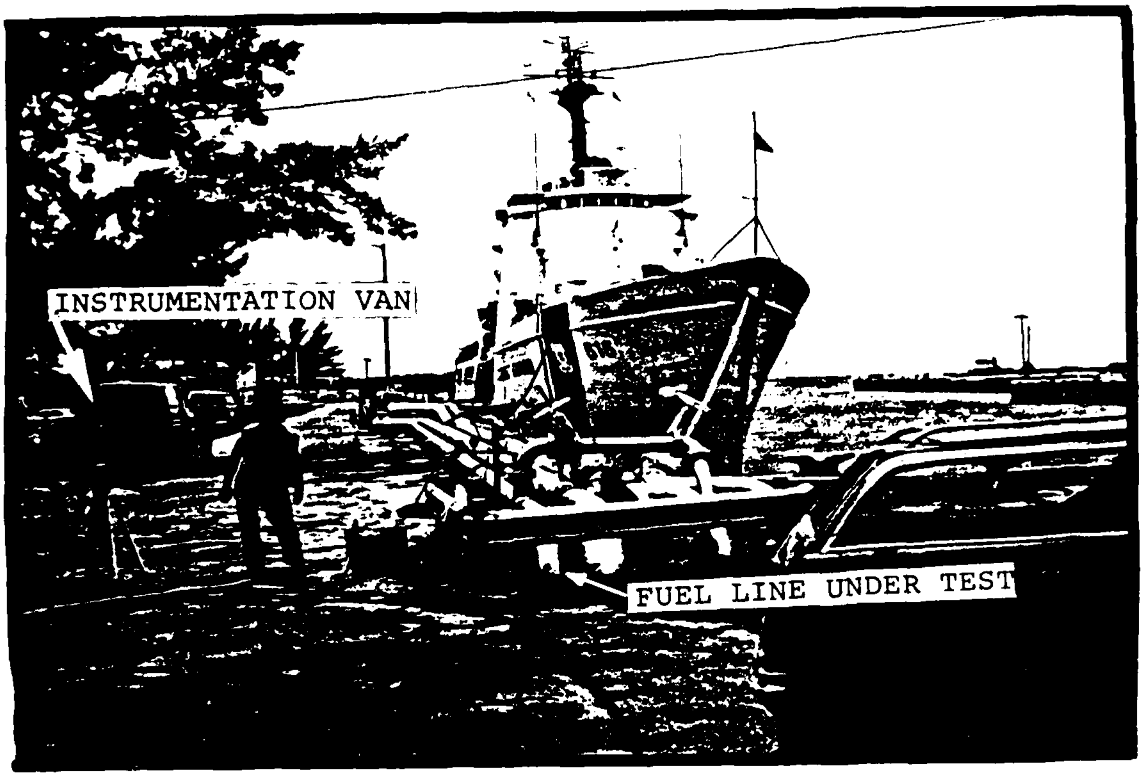
Acoustic emission inspection for detection of both leakage and impending failures of storage tanks, nuclear reactors, line pipe, etc. is a relatively new technique that is rapidly gaining acceptance particularly in nuclear reactor safety. References 19 through 25 give evidence of the various applications of acoustic emission monitoring. Figures 18 through 21 show photographs of typical acoustic emission monitoring applications on buried lines at an aircraft and ship fuel depot, for the Alaskan oil pipeline, and for an Air Force F-105 fighter. Acoustic emission inspection normally is used along with other inspection methods but it is frequently used as a stand-alone method.

Numerous inspection studies, research and on-going inspection program results have conclusively shown that acoustic systems can be used to detect and locate leaks and impending failures. An example of the corrosion detection using acoustic emission is shown in Figure 21. Examples of detection and location of other impending failures such as flaws and small leaks are shown for two pipeline systems in Figures 18 through 21. Acoustic emission inspection is considered (by many industry experts) to be a modern and practical approach to solving many inspection problems that have gone unsolved because of a void in the nondestructive inspection technology.

Acoustic emission apparently has not been used for casing inspection. It has the potential, however, to detect minute leaks that cannot be detected by hydrostatic test or to locate leaks in the event that hydrostatic tests indicate a leak but no other inspection means is successful in locating the leak. A second and equally important application of the acoustic emission inspection is to detect and locate casing degradation that reaches a critical stage (impending failure) and may lead to a leak or rupture of the casing.



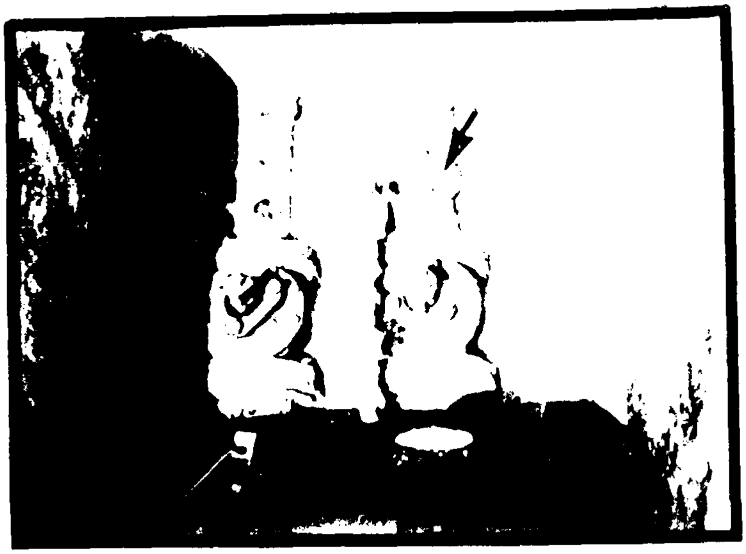
(A) TEST SETUP AT TANK FARM



(B) TEST SETUP AT FUEL PIER

Figure 18. NDE Technology, Inc. team carrying out acoustic emission/hydrostatic test of a pipeline system at an aircraft and ship fueling facility.

(A) LEAKING SECTION OF PIPING SYSTEM DETECTED VISUALLY WITH NDE TECHNOLOGY, INC. VAN - BASED ACOUSTIC SYSTEM



ACOUSTIC SENSOR ON PIPE ON VALVE PIT

ACOUSTIC SENSOR ON PIPING AT PIER

(B) ACOUSTIC EMISSION INSTRUMENTATION SYSTEM AT VARIOUS LOCATIONS ON THE PIPELINE SYSTEM

Figure 19. Typical leaks and instrumentation used during acoustic emission/hydrostatic test at an aircraft and ship fueling facility.

Figure 20. On a section of Alaskan oil pipeline, a van-based system performs acoustic emission source-location test for flaws.

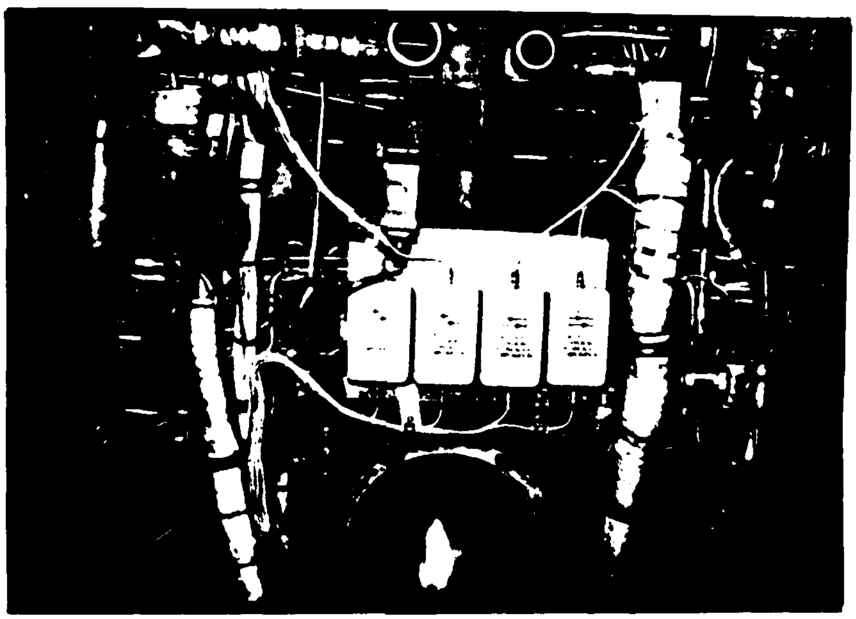


Figure 21. In a corrosion monitoring test on an Air Force F-105, four acoustic emission sensors listen to the corrosion process as minute bubbles of hydrogen form in the materials undergoing corrosion. This monitoring system maps out the areas where corrosion is occurring.

The acoustic emission systems use acoustic sensors to detect the acoustic signal generated at the defect or leak of the component tested. External impacts, excessive internal stresses from material defects and damage, precursor internal stresses just before a leak or material failure are all different; each event produces a characteristic signal that can be differentiated from each other.

Acoustic emission signals are complex, dependent upon structure and fault type and the frequency typically dependent upon structure and fault type and the frequency typically extends to the megahertz range. These acoustic signals are commonly called "acoustic emissions" and are excellent indicators of defects or leaks.

Generally, impending failure type acoustic emissions, except for impacts, are repetitive. Repitition rate usually increases to a peak value, then drops off slightly, and then increases dramatically just before a critical material failure or leak occurs. The acoustic emissions for impending failure can only occur when the component is stressed - externally loaded or pressurized. In addition to detecting impending failures, acoustic systems detect the continuous waves generated at a leak source and which propagate along the component (casing, pipeline, etc.) to the acoustic sensor.

Acoustic systems with suitable signal processors and sensors can be used to detect and process the acoustic signals for detection and location of defects and failures. Using known wave attenuation characteristics of the pipeline, and also using suitable signal enhancement, counting ag and processing technique, the location and condition of the flawed or leaking area may be determined.

4.5 Current Research by Companies Developing Advanced Instruments for Inspection of Casing and Pipe

A variety of NDE equipment and techniques are available for inspecting casing and pipe. A list of potential and actual equipment for in-place casing inspection and piping is given in Table 2. Table 3 lists currently available logging type equipment for pipeline that potentially could be used for casing inspection.

In general, most companies currently providing casing inspection loggers are improving their existing devices. Survey results indicate that three new casing logging devices are currently under extensive development and test. They are:

- Ultrasonic (test market)
- Nuclear (test market)
- Electrosonic.

These devices are being developed by Gearhart-Owen (nuclear, ultrasonic) and Johnston/Schlumberger (electrosonic). Unfortunately, detailed information for the evaluation of these devices was not available.

TABLE 2. POTENTIALLY APPLICABLE NDE DOWNHOLE EQUIPMENT

DOWNHOLE LOGGERS - PERIODIC INSPECTION

- Magnetic flux
- Caliper
- Active ultrasonics
- Passive ultrasonics
- Ultrasonic Imaging
- Nuclear
- TV Camera
- Stereo Pairs
- Eddy Current
- EMATT
- Other

DOWNHOLE LOGGERS - CONTINUOUS/PERIODIC MONITORING

- Acoustic
- Acoustic emission
- Hydrostatic
- Other

TABLE 3. LOGGING DEVICES FOR PIPING

Equipment	Defects Measured	Sensitivity	Advantages	Disadvantages
PROPELLED THROUGH PIPELINE BY FLUID FLOW				
(a) Magnetic Flux (Electromagnetic: (Changes in wall thickness affects magnetic field. Induced magnetic field and detection accomplished with electromagnetic or permanent magnets.)	1. Corrosion 2. Hardspots, mtd. flaws 3. Girth welds, pits 4. Cathodic protection 5. Improper bends of pipeline 6. Gouges 7. Dents, buckles 8. Hydrogen blisters 9. Bends	1. Severity of corrosion in three ranges - 15-30% of wall 30-50% of wall 50% of wall 2. Approximately 1/8 inch defect 3. Severity of pitting	1. High reliability 2. Locates defects 3. Permanent record 4. Monitors integrity of line 5. Locates potential failures before they become catastrophic 6. Help evaluate effectiveness of cathodic protection coating 7. Commercially available for 6-36 inch diameter lines	1. High cost 2. Difficult to interpret magnetic anomalies 3. Requires human interpretation 4. Electromagnetic type cannot determine if defect is inside or outside of pipe 5. Permanent magnet type can get stuck in pipeline and difficult to remove 6. Anomalies around girth weld difficult to detect 7. Does not detect thin cracks very well
[illegible] ... mechanism ... transmits ... in pipe ... meters to a ... device ... housing.)	1. Measures changes in inside pipeline diameter 2. Detects dents, buckles 3. Detects obstructions 4. Changes in wall thickness 5. Flat spots, bends 6. Partially closed valves	1. Abrupt changes in wall thickness of 1/8" or more 2. High degree of accuracy of measuring length of heavy wall pipe	1. Extremely useful in new pipeline construction 2. Medium cost 3. Location size and location of significant changes in pipeline	1. Much lower sensitivity than magnetic flux inspection pig
Active Ultrasonics (Ultrasonically scans pipeline in transverse direction using active ultrasonic scanning tool.)	1. Detection of fluid escaping through hairline cracks or small holes	1. Indicates dimension of defect	1. Location of defect 2. Permanent record 3. New units are currently under development for pipelines that are of medium cost and require minimum interpretation.	1. High Cost 2. Difficult to interpret 3. Requires human interpretation 4. Not widely used

(CONTINUED)

TABLE 3. LOGGING DEVICES FOR PIPING (CONTINUED)

(d) Passive Ultrasonics (An escaping fluid from a pipeline leak emits sounds. A passive ultrasonic detector, mounted in an oil-tight container, detects the leak.)	1. Detection of fluid escaping through hairline cracks or small corrosion holes.	1. 3 to 5 gallons per hour leaks	1. Locates leak within a few feet 2. Should work well if a leak detector pig is built and dedicated for a specific pipeline.	1. High cost 2. Not commercially in use in the U.S. because of difficulty in applying device to a variety of pipelines. 3. Requires some development for reliable results. 4. Background noise stage currently limits leak resolution.
(e) TV Camera (TV inspection camera with low light TV camera and video tape or TV monitor.)	1. Visually inspects inside of pipeline for cracks, pits, etc.	1. Slightly better than visual inspection 2. 360° viewing	1. Simple 2. Permanent record 3. Medium cost	1. In feasibility stage only because TV signals currently cannot be transmitted without a cable attached to camera.
(f) Nuclear (Nuclear source installed in inspection pig. Minute radioactive quantities transmitted through a leak is sensed by external detectors.)	1. Small hole through cracks	1. Sensitivity uncertain	1. Simple	1. Feasibility stage only 2. Radiation safety requirement 3. High signal attenuation from source caused by water 4. High cost
(g) Ultrasonic Holographic Imaging (3-dimensional view of inside of pipeline wall - includes scanning head, recording module, electronic holographic computer signal processor and power supply.)	1. Detects inside the material 2. Corrosion and/or erosion 3. Pits 4. Loss of material on inside or outside of wall 5. Wall thickness	1. Flaw area of about 0.01 in a 0.01 in. 2. Instrument can be set to meet any API specification 3. Thickness resolution of about 0.02 in. 4. Provides 3-dimensional image showing length, width, geometry and depth	1. Excellent picture of inside pipe 2. Covers 5 to 10 miles per hour 3. Excellent incipient failure detection 4. Simple interpretation of data	1. High cost[d] 2. Product not commercially available 3. Requires high developmental cost 4. Reliability and performance specifications are uncertain

[d] Development costs of this type of inspection pig to be propelled through the water fluid flow may range from [illegible] million dollars for a [illegible] reliable version.

(CONTINUED)

TABLE 3. LOGGING DEVICES FOR PIPING (CONTINUED)

Equipment	Defects Measured	Sensitivity[d]	Advantages[c]	Disadvantages
(h) Electromagnetic Noncontact Transducer EMATT (Electromagnetic noncontact transducers in inspection pig focus a beam of energy directed around the pipe circumference. A longitudinal stress corrosion crack or region or corrosion reflects energy back to the detector transducer. Device is blown through pipe by a gas stream.)	1. Longitudinal stress corrosion cracks 2. Generalized pipe wall thinning	1. Unknown	1. Well suited when there is difficulty coupling sound to pipeline through a liquid or grease 2. May work well at high speeds - 20 mph	1. Experimental/ feasibility stage
(i) Super Atmospheric A fluid is flowed through a pipeline at superatmospheric pressure. A floatable leak sensor, which is responsive to pressure and velocity differentials caused by a leak, is moved through the pipeline along with a fluid. Sensor stops movement through conduit at location of a leak.	1. Leaks	1. Unknown	1. Potentially more sensitive than acoustic inspection pig	1. Requires out of service operations 2. Requires elevated pressures
(j) Flow Meter (Unit comprises a steel cylindrical pig sliding inside pipe on flexible drawing bonds. Inside is a flow meter electronics package. When leak is detected by a drop in test pressure unit is introduced into line and positioned by pumping. At point of leakage a sharp change in flow rate and direction occurs and is detected by flowmeter.)	1. Leaks	1. Accurate leak location	1. Single 2. Particularly useful for undersea lines	1. Leak location only 2. [illegible] inspection

(CONTINUED)

TABLE 3. LOGGING DEVICES FOR PIPING (CONTINUED)

INSPECTION PIGS PUSHED OR PULLED THROUGH PIPELINE OR HOSE STRING VIA CABLES, ETC.				
(a) Camera (Low-light type camera and video tape or TV monitor)	1. Visually inspect inside of pipeline for cracks, [illegible] sion pits, [illegible] condition, etc.	1. Slightly better than visual sensitivity 2. 360° viewing	1. Medium cost 2. Can be used to inspect inside of hoses particularly in evacuated condition 3. Some incipient failure detection 4. High reliability 5. Commercially available 6. Can be stopped for viewing of questionable areas of pipe or hose	1. Requires out-of-service operation 2. Currently limited from 1000 to 3000 ft. 3. Requires winch to pull camera 4. Requires clean, clear water 5. Works best with fresh water
[illegible]	1. Same as above	1. Slightly more sensitive and better pictures than camera	1. Medium cost 2. Can be used to inspect inside of pipeline or hoses 3. Some incipient failure detection 4. High reliability 5. Commercially available	1. Requires a conductive coaxial cable 2. Currently limited to about 3000 ft. 3. Requires clean, clear water

(CONTINUED)

TABLE 3. LOGGING DEVICES FOR PIPING (CONTINUED)

Equipment	Defects Measured	Sensitivity	Advantages	Disadvantages
(m) Eddy Current (Eddy current changes in non-magnetic tubing caused by defects are detected by a recording impedance bridge.)	1. Wall thickness 2. Pits 3. Cracks 4. Holes 5. Corrosion 6. Surface or near surface defects	1. Longitudinal cracks .004 in deep by .4 in in length can be detected 2. Changes in wall thickness of 1% in a 0.4 in length can be detected	1. Medium cost 2. Good incipient failure detection 3. Widely used 4. Commercially available 5. Locates defects near surface	1. Insensitive to circumferential cracks, short cracks and shallow cracks 2. Requires out-of-service operation 3. Non-magnetic materials only 4. Limited to a few 30 foot lengths of pipe
INSPECTION PIGS WITH MANNED INSPECTORS (PUSHED OR INTERNALLY POWERED THROUGH LARGE PIPE LINES)				
(n) Inspection methods Available (See Table	1. All internal defects and pipeline corrosion	1. Best overall sensitivity of any inspect method for pipeline	1. Best overall incipient inspection technique for internal examination of pipeline 2. Operational under limited use	1. Very high cost 2. Slow 3. Requires out-of-service operation 4. Feasibility stage for powered type vehicle
(O) Ultrasonic (Holographic Imaging) (See discussion (g) Method was applied to ALYESKA pipeline using manned inspectors and a powered vehicle)	1. Some as (g)	1. Same as (g)	1. Excellent hard copy pictures of internal flaw in pipeline 2. Excellent incipient failure detection 3. Simple data interpretations 4. Commercially available	1. High cost 2. Device must be designed and engineered for specific pipeline 3. Reliability and specifications are uncertain at this time 4. Requires out-of-service operation
(p) Ultrasonic Riser Unit removed inside riser while the ultrasonic transducer rotates to data in helican scan.	1. Riser thinning, cracks, etc.	1. Better then 20% of thickness	1. Small enough to pass around pipe elbows without jamming 2. Lightweight 3. Commercially available.	1. Not self-propelled. 2. Out-of-service inspection
INSPECTION PIG TRACKING				
(q) Tracking (Inspection pigs are located in pipeline by monitoring signal from nuclear, acoustic pinger or nuclear source inside inspection pig. Also clearing pigs or an acoustic pinger inside a polyurethane sphere are often used.)	1. Locates stuck inspection or cleaning pig caused by pipeline defects--improper bending or medium or major leaks	1. Sensitive only to large defects in pipeline	1. Simple locating methods 2. Low cost for polyurethane spheres 3. Commercially available	1. Insensitive to most pipeline defects

4.6 Casing Inspection Practices

The availability and utilization of casing inspection is in good order because of offshore industry attempts to minimize casing degradation. ..owever, there appear to be certain problems. These problems have been discussed previously and will be summarized in the following paragraphs.

In general, a common practice during drilling operations is to use state-of-the-art casing inspection only after a serious problem is suspected. This practice may not prevent some blowouts because inspection may be used too late. This practice also fails to prevent blowouts from unsuspected problems because routine diagnostic inspections are not generally carried out. The two examples of recent blowouts described in Section 2.5 demonstrate typical problems with this practice. In these two blowouts, personnel errors or equipment failure resulted in unsuspected critical casing degradation that went undetected and casing failure occurred. The main reason for the hesitancy to use state-of-the-art casing inspection equipment more frequently is the huge cost due primarily to down-time. In many cases, the apparent cost/benefit of diagnostic (preventive) inspections cannot be justified by the operator.

In order to inspect (using casing loggers, etc.) for casing degradation, i.e., such as excessive corrosion, etc. in the producing well it is necessary to shut down the well and stop production. In many instances, such inspections are very costly. Thus the cost/benefit of casing inspection is often difficult to justify particularly because of the low incidence of failures. Unfortunately, the casing degradation problem does result in such problems as oil seepage into the water and large leaks may result in major environmental problems and safety hazards.

5. ASSESSMENT

In this section, the problem (see Section 2), survey information (see Section 4) and major requirements (see Section 5) are considered in an assessment to identify any holes in the technology where further development is required. A comparative analysis summary is provided in Section 5.1. Holes in the technology are discussed in Section 5.2.

5.1 Comparative Analysis

Each of the three types of state-of-the-art casing logging devices have certain limitationsthat produce significant uncertainty in the measurement. These limitations are discussed in Sections 4.2.1 through 4.2.3 and are summarized in Table 1. Significant limitations are listed below:

- Caliper
  - Difficulty in detecting small defects
  - Does not detect defects on the outside of the casing
- Electromagnetic
  - Gradual changes in wall thickness must be interpreted with caution
  - Poor resolution of wall defects
- Electromagnetic/Eddy Current
  - Cannot detect vertical splits such as parted casing
  - Not good at detecting gradual changes in wall thickness.

The other types of devices in the developmental or test phase have significant limitations also. Some of these include:

- Ultrasonic
  - Costly
  - Rough, scaly inner and outer wall seriously affect resolution of defect

- Nuclear

  - Must run logger through the casing very slowly (about a few feet per minute) to provide the high defect resolution that would give it an advantage over other casing inspection devices.

Hydrostatic tests of casing are limited to detecting casing degradation that actually leaks or ruptures at the test pressure. The test does not detect excessive casing degradation (eventual leak or rupture) that may occur after drilling operations resume.

5.2 Holes in the Technology and Practice

At this time, hydrostatic leak test and casing inspection loggers are used for casing inspections. Holes in the technology and practice for casing inspection will be summarized in the paragraphs that follow.

No casing logging device can be used alone with adequate certainty that all critical defects have been detected. At this time, various logging devices must be run in an attempt to provide a reasonable assurance of acceptable casing integrity.

Unfortunately, the down-time associated with casing logging and other costs tends to limit their use. In general, casing loggers are used in instances when a defect or failure is suspected rather than for use as a preventative maintenance tool for early warning of impending failure.

Only hydrostatic tests are carried out routinely to inspect for casing failure. Generally the tests are limited to a maximum of three tests during normal drilling operations. Although this method is a good way to find large leaks, small leaks are difficult to detect. Also, the hydrostatic test is insensitive to many internal defects that may eventually lead to a leak or rupture.

More sensitive, low cost, practical and short test-time casing inspection equipment that provides a good indication of impending failure is needed. Additionally, inspection equipment that does not interfere with normal operations and can be used as a good diagnostic tool to check for serious degradation of the casing is needed. Ideally, both needs should be solved by a single device.

6. DEVELOPMENT REQUIREMENTS

At this time, development of a downhole casing logging inspection device is not recommended for the following reasons:

- Industry use of these tools generally occurs only when a possible failure is suspected.
- Research and development is now being conducted by a few highly qualified exploration and service companies for new and improved logging tools.
- The high cost, in excess of a million dollars, to develop an advanced casing inspection tool with only marginal advances expected in the technology.
- Limited market for a new inspection tool.

Participation with private industry, however, on a cost sharing or other joint basis for a feasible and practical device would have merit. At this time, however, no concept appears to warrant such an expenditure.

Development of acoustic emission hydrostatic test equipment that can be used during normal down periods is recommended. Such equipment is simple, practical and low cost. If successful, the inspection equipment and technique would gain industry-wide acceptance and would be a significant advance in the inspection of casing. The acoustic emission/hydrostatic test equipment potentially would provide detection of minute leaks and degradation (critical defects) that may lead to casing failure. The concept will be described briefly in the subsections that follow.

6.1 Acoustic Emission/Hydrostatic Test Equipment

This section describes the acoustic emission/hydrostatic test technique. Details of typical hydrostatic testing during drilling operation will be described in Section 6.1.1. This will provide background information on the hydrostatic test portion of the new technique. Section 6.1.2 will describe the acoustic emission/hydrostatic concept.

6.1.1 Hydrostatic testing

The following standard procedure is used for drilling operations when casing is inserted into the well.

After each section of casing string has been landed to its determined depth, cement is pumped into the casing and through the float collar and shoe located at the bottom of the casing string (see Figure 22). The pressurized float collar and shoe allow the cement to pass through the casing and up the sides of the well hole between the casing and earth, thus cementing the casing into the earth without filling the hole with cement. This procedure is carried out just before hydrostatically testing the casing.

After the cement has hardened and the casing is secure in its place, the blind rams are opened and the pipe rams are closed around the drill pipe. Then the casing is hydrostatically pressurized (generally to 500 psi to 3,400 psi depending on the location specification and casing sizes) with drilling fluids using the mud pumps.

6.1.2 Acoustic Emission Inspection Technique

Acoustic emission testing techniques can be applied simultaneously with hydrostatic testing for improvement in leak sensitivity and for detection and location of casing degradation, i.e., critical cracks, flaws, gouges, etc. and minute leaks. Although the acoustic emission inspection technique is not expected to detect certain types of wall thinning degradations, i.e., long length (few feet or more) and short depth (approximately 10%) wall thinning, it may detect short length and large depth wall thinning. The fact that the technique is expected to detect critical defects not detectable by hydrostatic tests and some casing loggers it is sufficient to justify a test of its feasibility.

Details of two typical applications of the acoustic emission technique for casing degradation inspection and cement bond checking are described in the subsections that follow.

6.1.2.1 Acoustic emission technique for casing degradation

One application of acoustic emission/hydrostatic testing is to test the intermediate casing string for degradations. The test for casing degradation for this specific application is carried out just prior to setting the production liner string. The paragraphs below will describe briefly a specific application and general test procedure* to follow.

To satisfy U.S. drilling regulations, the 8-5/8 inch intermediate casing string is set and cemented in before continuing to drill for the production string (7-5/8 inch hole for the 6-5/8 inch production string). Once the 8-5/8 inch casing is set, the

---

* This information is for demonstration of the concept. Specific and exact details of the technique may be varied depending upon drilling operations, U.S. regulations and other considerations. Exact details would require a more in-depth analysis of the technology and applications and is beyond the scope of this project.

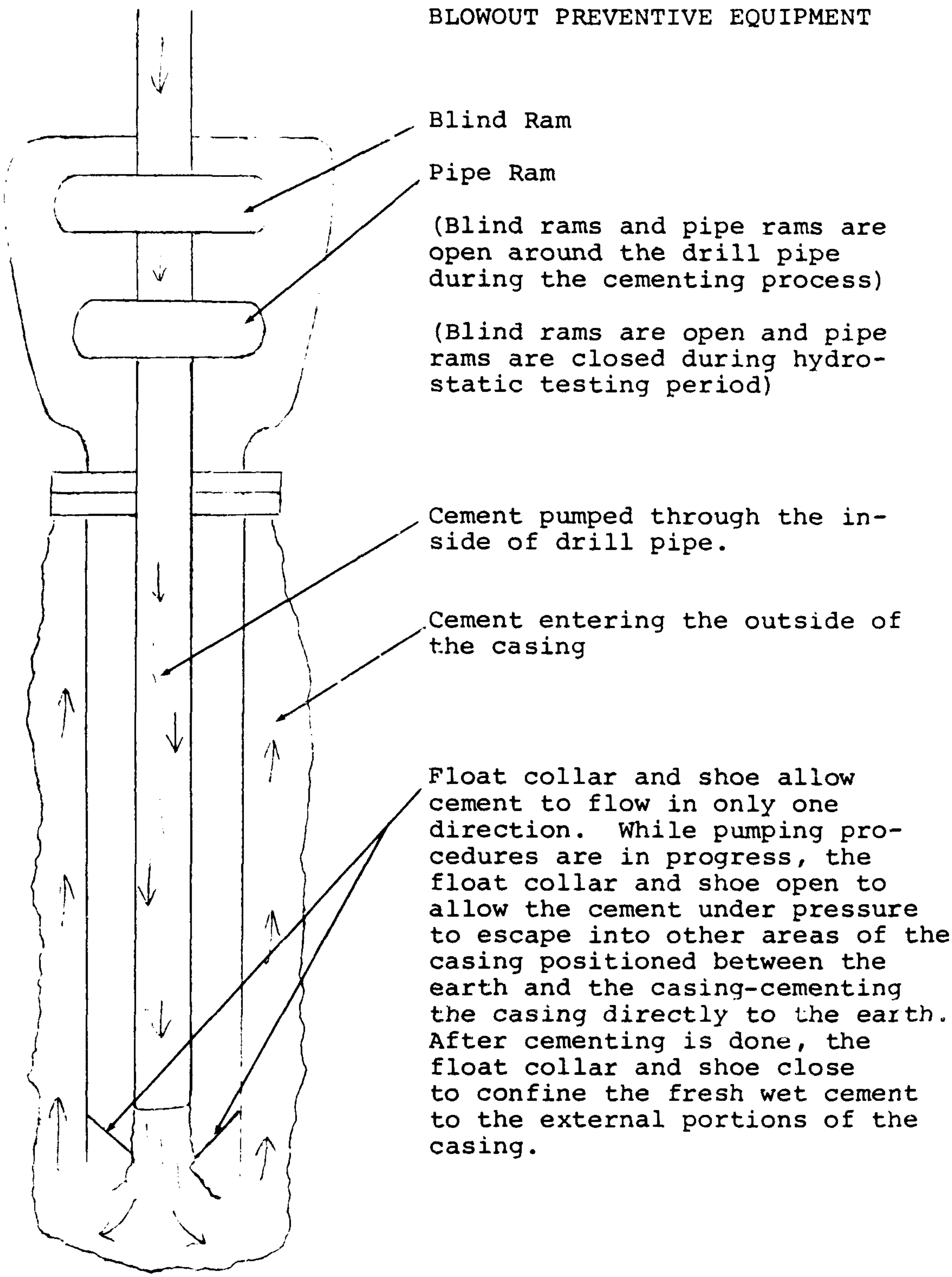


Figure 22. Standard cementing process for casing.

drilling contractor in most circumstances must drill (if the well program calls for it) a 7-5/8 inch hole from the bottom of the 8-5/8 inch casing to total depth of the well. In order to complete this procedure, the contractor must drill through the inside of the 8-5/8 inch casing string. After drilling the 8-5/8 inch casing string with a 7-5/8 inch bit for the production string (6-5/8 inch casing) there is always casing wear on any severely deviated hole (30° to 75°). In offshore wells, the production string alone can go as deep as 3000 feet from the bottom of the 8-5/8 inch casing to total depth. The combination of the long length production string and the angle of the hole can result in severe casing wear from the drill pipe. The acoustic emission inspection can be applied at this stage of the drilling operation.

Before setting the production string casing, a standard model "G" lok-set retrievable bridge plug (manufactured by Baker Service Tools) can be run to the bottom of the 8-5/8 inch casing string. Next the bridge plug can be set by the drill pipe while simultaneously lowering acoustic transducers into the hole. With both the bridge plug and the acoustic transducers set in place, the 8-5/8 inch casing can be pressurized to any appropriate allowable pressure. During the pressure test (pressurization, holding the pressure, reducing the pressure) the casing can be monitored by an acoustic emission system for detection of leaks and impending failures (significant degradations).

The general procedure for monitoring casing degradation in this particular application using an acoustic eimssion system is as follows:

- Complete drilling of production string to total depth,
- Pull out the drilling string,
- Set the acoustic emission transducers into the hole,
- Set bridge plug in place using the drill pipe,
- Pressurize the 8-5/8 inch casing, and
- Monitor for leaks and degradations using an acoustic emission system.

6.1.2.2 Acoustic emission inspection technique for checking the cement bond

Another application of the acoustic emission/hydrostatic testing technique is to test the integrity of the cement bond and the casing in the first casing string (typically 13-5/8 inch diameter casing). The paragraphs that follow will describe briefly a specific application and a general procedure.

The acoustic emission inspection can be implemented by first utilizing the down-time in the setting of the cement (just) prior to hydrostatic testing) to install the acoustic sensors. Then the acoustic emission system located on the drill rig can be used to monitor the casing degradation and possibly the integrity of the cement bond during the standard hydrostatic test for checking the cement bond.

Implementation of the acoustic emissions technique can be described by the following example. After the cement has been pumped, there is a period (24 to 48 hours) when the cement must not be disturbed. During this period, acoustic transducers can be descended into the casing while not disturbing normal operations. During the pressure test (pressurization, holding the pressure and then reducing the pressure) the casing can be monitored for cement bond integrity, casing leaks and degradations.

The general procedure for monitoring the first string is as follows:

- Install new pipe in the hole,
- Close the pipe rams,
- Leave the blind rams open,
- Install acoustic sensors from approximately 200 to 1000 feet (covering the first and second string),
- Wait for the mud to harden (24 to 48 hours),
- Pressurize with mud pumps,
- Monitor for a secure cement bond, casing leakage and impending failures using an acoustic emission system.

6 .2 ROM Cost and Schedule

It is expected that the feasibility of the acoustic emission/hydrostatic inspection technique for casing could be completed within a year. Feasibility costs would be less than \$100K. Developmental costs for a prototype demonstration system, including a computer and microprocessor, would be approximately \$200K and require about 18 months.

7. CONCLUSIONS AND RECOMMENDATIONS

Nondestructive inspection techniques for determining casing degradation during offshore drilling operations are examined because of the potential for blowouts and other serious problems from casing failure. Study results indicate that the originating two major causes of casing failure are human error and equipment failure; inadequate casing inspection is found to be a lesser cause of failure. However, the study identifies problems in the use (practice) of casing inspection that help to contribute to blowouts.

It is concluded that the availability and utilization of casing inspection equipment for casing degradation is in reasonably good order. However, certain technical and practical problems exist in providing adequate casing inspection. The study also concludes that gains can be made for in-service casing inspection during drilling operations by continuing to improve current technology and practices.

Frequent use of casing inspection , as a diagnostic tool, for detecting unsuspected degradation during normal drilling operations is recommended to help minimize serious casing failure that can result in blowouts. This recommendation is made to encourage a change in the current practice of using casing inspection mainly when serious casing degradation is suspected.

Continued development of improved casing inspection logging devices by private companies is encouraged. At this time, a major U.S. government research and development for a new casing inspection tool is not recommended because of the high cost and of the low potential for significant advances expected in the technology.

Development of an acoustic emission/hydrostatic inspection technique is recommended as a low cost, practical means for near-term improvements in periodic inspection of casing during drilling operations.

8. REFERENCES

1. Blowout-Matagorda Island Block 669 in the Gulf of Mexico-City Service, Getty. Oil & Gas Journal, pp 58-59, October 5, 1981.

2. An Investigation of Pennzoil's Blowout and Loss of Platform. High Island Block A-563 Gulf of Mexico. By Investigation Team of the U.S. Geological Survey, Department of Interior, May 1977.

3. Smolen, J.J. PAT Provisionary Interpretation Guidelines. Schlumberger Well Services, July 1976.

4. Underwater Inspection/Testing/Monitoring of Offshore Structures. Conducted by R. Frank Busby Associated. Sponsored by DOT, DOE and DOI, Contract 7-35336, February 1978.

5. Mastandrea, J.R., J.A. Simmons, P.B. Kimbal, and K.J. Gilbert. Deepwater Port Inspection Methods and Procedures. Report No. CG -D-31-78, United States Coast Guard, Department of Transportation, March 1978.

6. Mastandrea, J.R., Petroleum Pipeline Leak Detection Study. Sponsored by the Environmental Protection Agency. Report No. EPA 68-03-2352, February 1981.

7. Funge, F.J., K.S. Chang, D.I. Juran, et. al. Offshore Pipeline Safety Practices, Volume II - Main Text. Report DOT/MTB/OPSO 77/14, 1977.

8. Safety and Offshore Oil. Committee on Assessment of Safety of OCS Activities, Marine Board, Assembly of Engineering Council and National Research Council. Supported by Contract 14-309-0001-18602 between the U.S. Geological Survey and the National Academy of Sciences, 1981.

9. Rules for the Design, Construction and Inspection of Offshore Structure - Appendix I, Inservice Inspection. Det Norske Veritas, 1980.

10. Rules for Submarine Pipeline Systems. Det Norske Veritas, 1981.

11. ANSI B31.4.b Liquid Petroleum Transportation Piping Systems. American Society of Mechanical Engineers. 1981.

12. Duffy, A.R., et. al. Study of Feasibility of Basing Natural Gas Pipeline Operating Pressure on Hydrostatic Test Pressure. Project N6-18. American Gas Association, Inc. Battelle Columbus Laboratories, 1968.

13. Kiefner, J.R., Maxey, W.A., and Eifer, R.V. A Study of the Causes of Failures of Defects That Have Survived A Prior Hydrostatic Test. N6-18 Report No. 111. AGA Catalog No. L51398. Battelle Columbus Laboratories, November, 1980.

14. API RP 1110. Recommended Practice for Pressure Testing of Liquid Petroleum Pipelines. American Petroleum Institute, November, 1981.

15. API RP 1111. Recommended Practice for Design, Construction, Operation and Maintenance of Offshore Hydrocarbon Pipelines, March 1976.

16. Kiefner, J.R., and Maxey, W.A., Judging Defect Severity on Offshore Pipelines. Presented at the Interpipe Conference, Houston, Texas, February 23-25, 1982.

17. Kiefner, J.F. and Duffy, A.R. Summary of Research to Determine the Strength of Corroded Areas in Line Pipe. Presented at a public hearing held by the Office of Pipeline Safety, Department of Transportation. July, 1971.

18. Kiefner, J.R., and Duffy, A.R. Criteria for Determining the Strength of Corroded Areas of Gas Transmission Lines. American Gas Association, Operating Section Proceedings. 1973.

19. Webb, M.J.M. Acoustic Emission Tracks Platform Cracks. Offshore Journal, pp. 78, 79 Arpil, 1982,

20. McElroy, J.W. Acoustic Emission Application in Fossil Plant On-Line Monitoring, EPRI Workshop on Incipient Failure Detection of Fossil Power, Palo Alto, California, 1982.

21. Possa, 6. New Acoustic Techniques for Leak Detection in Fossil Fuel Power Plant Components. EPRI Workshop on Incipient Failure Detection for Fossil Power. Palo Alto, California, 1982.

22. Hagen, E.W. A Progress Report on the Use of Acoustic Emission to Detect Incipient Failure in Nuclear Pressure Vessels, Nuclear Safety Vol 15 No. 5. Sept., 1974.

23. McElroy, J.W. *Development of Acoustic Emission* Testing for the Inspection of Gas Distribution Pipelines, Mon. Struct. Integrity by Acoustic Emission. ASTM-STP-571, ASTM, 1975 pp. 59-79.

24. Dunegan, H.L. and Hartman, W.F. Advances in Acoustic Emission. Proceeding of International Conference in Acoustic Emission. Sept. 1979

APPENDIX A

LIST OF SURVEYED SERVICE AND CONTRACTING COMPANIES, MANUFACTURERS, SEARCH AREAS

TABLE A.1. SURVEYED CONTRACTING AND OTHER FIRMS INVOLVED IN DOWNHOLE CASING INSPECTION

A.M.F. Tuboscope Oklahoma City, OK	Scientific Drilling Controls Irvine, CA
Dia-Log Whittier, CA	Vetco Services, Inc. Ventura, CA
Drilco, Div. of Smith Int. Inc. Houston, TX	Well-Ex Logging Co. Norwalk, CA
Flopetrol Venezuela	Lamb Ultraonic Tubular Inspection Services Lafayette, LA
Gearhart/Owen Long Beach, CA	World Wide Oil Tools, Inc. Houston, TX
Johnston/Schlumberger Signal Hill, CA	Hughs Tool Co. Houston, TX
NDT Systems, Inc. Odessa, TX	P.A. Inc. Los Angeles, CA
N.L. McCullough Long Beach, CA	Hydrotech Houston, TX
Peabody, Inc. Chicago, IL	Halliburton Houston, TX
Pengo Industries, Inc. Ventura, CA	U.S. Engineering, Inc. Odessa, TX

TABLE A.2. PARTIAL LIST OF SURVEYED MANUFACTURERS AND R&D COMPANIES INVOLVED IN OFFSHORE NDE

Aanderaa Instruments Lt.
560 Alpha Street
Victoria, B.C. Canada V8Z1B2

A.B. Plumbing, Heating and Cooling
205-22nd Street
Sacramento, CA 95816

Acco, Bristor Div.
40 Bristor St.
Waterbury, Conn. 06720

Ace Pipe Cleaning, Inc.
4000 Truman Rd.
Kansas City, MO 64127

Accusonic Division
Ocean Research Equipment
P. O. Box 709
Falmouth, Mass. 02541

ADEC Corporation
Irvine, CA 92707

Aero Vac Products
Industrial Products Division-
High Voltage Engineering Corp.
P. O. Box 416
South Bedford St.
Burlington, Mass 01803

Air Monitor Corporation
P. O. Box 6358
Santa Rosa, CA 95406

Air Products
Box 538
Allentown, PA 18105

Airco Industrial Gases
575 Mountain Ave.
Murray Hill, NJ 07974

Allison Control
New Jersey

Alphs Metrics
Winnepeg, Canada

Alphine Geophysical Assocs.
Oak Street
Norwoor, New Jersey

American Instrument Co.
8030 Georgia Ave.
Silver Spring, MD 20910

American Standards Testing Bureau, Inc.
40 Walter St.
New York, NY 10004

Ametek
Straza Division
790 Greenfield Drive
P. O. Box 666
El Cajon, CA 92022

Amtek, Inc. (Pa)
Station Square Two,
Paoli, PA 19301

AMF Sea-Link
Herdon, VA

AMF Tuboscope Inc.
P. O. Box 808
Houston, TX 77001

Amiproducts, Inc.
1504 W. 28th St.
New York, NY 10001

Analog Technology
3410 E. Foothill
Pasadena, CA 91107

Androx Limited
P. O. Box 814
St. Catherine, Ontario

Andrex Radiation Products
Copenhage, Denmark

Applied Instruments Corp.
1681 West Broadway
Anaheim, CA 92802

Applied Research Labs.
P. O. Drawer 1,
Homestead, Fla. 33030

Aquatech, Inc.
10620 Cedar Ave.
Cleveland, Ohio 44106

AstroNautical Research, Inc.
Dunham Road
P. O. Box 495
Beverly, Mass. 01915

Atomics International
8400 DeSoto Ave.
Canoga Park, CA

Automation Industries
Sperry Division
Downey, CA

Automation Products, Inc.
3030 Max Roy
Houston, TX 77008

TABLE A.2. PARTIAL LIST OF SURVEYED MANUFACTURERS AND R&D COMPANIES INVOLVED IN OFFSHORE NDE (CONTINUED)

B & K Instruments, Inc.
5111 West 164th St.
Cleveland, Ohio 44142

Bacharach Instrument Co.
West Coast Operations
2300 Leghorn St.
Mt. View, CA 94043

Badger Meter, Inc.
Environmental & Electronic
Products Division
150 E. Standard Ave.
Richmond, CA 94804

Bailey Meter Company,
Sub Babcock & Wilcox Co.
29801 Euclid Ave.
Wicklittle, Ohio 44092

Baird-Atomic, Inc.
125 Middlesex Turnpike
Bedford, Massachusetts 01730

Barnes Engineering
Stanford, CT

Barry Research Corporation
1530 Page Mill Road
Palo Alto, CA 94304

Barton
Monterey Park, CA

Beck Instruments
2500 Harbor Blvd
Fullerton, CA

BBN Instrument Corp.
Cambridge, Mass

Belco Pollution Control
Corporation
570 W. Mt. Pleasant Ave.
Livingston, NH 07039

Belfort Instrument
1605 S. Clinton
Baltimore, Maryland

Bendix
Environmental Science Div.
1400 Taylor Avenue
Baltimore, Maryland 21204

Bendix Corporation
New York, NY

Benthos, Inc.
North Falmouth, Mass 02556

Bethany International, Inc.
6161 Savoy Drive
Suite 940
Houston, TX 77036

The Bethlehem Corporation
25th and Lennox Streest
P. O. Box 348
Easton, PA 18042

The Bethlehem Corporation
225 W. 2nd St.
Bethlehem, PA 18016

Block Engineering
Cambridge, Mass

Blue White Industries
14931 Chestnut St.
Westminster, CA 92683

Brantner and Assoc., Inc.
P. O. Box 2224
Newport Beach, CA 92663

Bridgestone Tire Company, Ltd.
Yokohama, Japan

British Hovercraft Corp.
East Cowes
Isle of wright, England

Branson Probolog

Brooks Instrument,
Div. of Emerson Electric
407 W. Vine St.
Harfield, PA 19440

Bunker Ramo
Electronic System Div.
Westlake, CA 91354

BVS. Inc.
Water Pollution Samplers
P. O. Box 243
Hone Brook, PA 19344

B/W Controls, Inc.
2200 East Maple Road
Birmingham, Michigan 48102

TABLE A.2. PARTIAL LIST OF SURVEYED MANUFACTURERS AND R&D COMPANIES INVOLVED IN OFFSHORE NDE (CONTINUED)

Cambridge Filter Corp.
7645 Henry Clay Blvd.
Syracuse, NY 13201

Cameron Ironworks
Houston, TX

Can-Tex Industries,
Div. of Harsco Corp
P. O. Box 340
Mineral Wells, TX 76067

Capital Controls Company
Division of Dart Industries
Advance Lane
Colmar, PA 18915

Capital Controls Company
Division of Dart Industries
P. O. Box 211
Colmar, PA 18915

The Carborundum Company
Process Equipment Plant
Aurora Road
Solon, Ohio 44139

The Carborundum Company
Graphite Products Div.
P. O. Box 577
Niagra Falls, N.Y. 14302

C-E INVALCO,
Div. of Combustion Engineering
P. O. Box 556
Tulsa, OK 74101

Central States Underwater
Contracting, Inc.
3077 Merriam Lane
Kansas City, KS 66102

Century Systems Corp.
P. O. Box 133
Arkansas City, KS 67005

Cherne Industrial, Inc.
5701 South Country Road 18
Edina, Minnesota 55436

Chemtrix
Hillsboro, OR

Circle Chemical Co.
P. O. Box 221
Hinckley, IL 60520

Circle Seal Corporation
P. O. Box 3666
Anaheim, CA 92803

Cleveland Controls, Inc.
1111 Brookpark Rd.
Cleveland, Ohio 44109

Columbia Research Lab
Woodlyn, PA

Commercial Diving Division
3323 W. Warner Ave.
Santa Ana, CA

Consolidated Controls Corp.
15 Durant Ave.
Bethel, Conn 06801

Consolidated Technology
P. O. Box 261
Mt. Kisco, NY 10549

Controlotron Corp
111 Bell St.
W. Babylon, NY 11704

Corning Glass Works,
Houghton Pk
Corning, NY 14830

Cox Instrument.
15300 Fullerton,
Detroit, Mich. 48227

CUES, Inc.
3501 Vineland Rd.
P. O. Box 5516
Orlando, FL 32805

C. W. Stevens, Inc.
429 S. Walnut St.
Kennett Square, PA 19348

TABLE A.2. PARTIAL LIST OF SURVEYED MANUFACTURERS AND R&D COMPANIES INVOLVED IN OFFSHORE NDE (CONTINUED)

Daniel Industries
P. O. Box 19097
Houston, TX 77024

Data Courier, Inc.
620 So. Fifth St.
Louisville, Kentucky 40202

Datemetrics, Inc.
340 Fordham Rd.
Wilmington, Mass. 01887

Dayton X-ray Co.
1150 W. Second St.
Dayton, Ohio

Del Norte Technology, Inc.
P. O. Box 696
Euless, Texas 76039

Det Norske Veritas
Gren Seveien 92
Oslo 6, Norway

Detroit Testing Lab., Inc.
8720 Northend Avenue
Oak Park, Michigan 48237

Device Engineering, Inc.
36 Pier La., W.
Fairfield, NJ 07006

Dieterich Standard Corp.
Subsidiary of Doover Corp.
Box 9000
Boulder, Colorado 80302

Dow Chemical
Pasadena, Calif

Dranetz Engineering Labs
2385 S. Clinton Ave.
South Plainfield, NJ 07080

Dresser Industries, Inc.
10201 Westheimer Road
P. O. Box 2928
Houston, TX 77001

Duriron Company, Inc.
Dayton, Ohio 45401

DuPont Co.
Instrument Products
Scientific and Process Div.
Wilmington, Del. 19898

D. W. Harmon Company
5353 Topanga Cyn Blvd Ste 3
Woodlands Hills, CA 91364

Dwyer Instruments, Inc.
P. O. Box 373
Junction Ind. 212 and U.S. 12
Michigan City, Indiana 46360

Dynamold, Inc.
P. O. Box 9616
2905 Shamrock Ave.
Fort Worth, TX 76107

TABLE A.2. PARTIAL LIST OF SURVEYED MANUFACTURERS AND R&D COMPANIES INVOLVED IN OFFSHORE NDE (CONTINUED)

Echo Laboratories
Titusville, PA 16354

Ecologic Instruments
Bohemia NY

Ecosystem Research and
Technology Corp.
P. O. Box 35712
Dallas, EX 75235

E. D. Bullard Co.
2680 Bridgeway
Sausalito, CA 94965

Edo Western Corp.
2645 South 300 West
Salt Lake City, Utah 84115

E.I. du Pont de Nemours & Co,
Market St.
Wilmington DEL 19898

Electro
15146 Downey Ave.
Paramount, CA 90723

Electro Optics
Santa Barbara, CA

Electric System Design
317 W. University Dr.
Arlington Heights, Ill.

Ellis & Ford Mfg. Co., Inc.
P. O. Box 308
Birmingham, Mich 38012

Endevco
Rancho Viejo Rd
San Juan Capistrano, CA

Engelhard Minerals &
Chemicals Corp.
Engelhard Industries Div.
430 Mountain Ave.
Murray Hill, NH 07974

Enraf

Environmental Devices Corp.
Tower Building
Marion, Mass. 02738

Environmental Tectronics Corp.
County Line Industrial Park
Southhampton, PA 18966

Envirotech
12881 Knott Ave. Ste 106
Garden Grove, CA 92645

Envirotech Corp.
3000 Sand Hill Rd.
Menlo Park, CA 94025

Eocom
19722 Jamboree Blvd.
Irvine, CA 92715

Epic, Inc.
Instruments for Science and
Industry
150 Nassau St.
New York, NY 10038

Erdco Engineering Corp.
136 Official Rd.
Addison, IL 60101

ERM/Marathon
West Germany
Rep. Proprietary Rights
Service Corp.
180 East End Ave.
New York, NY 10028

Esterline Angus Inst. Corp.
Box 24000
Indianapolis, IN 46224

Exon Nuclear Company, Inc.
Research and Technology Center
2955 George Washington Way
Richland, Washington 99352

Extranuclear Labs, Inc.
250 Alphs Dr.
P. O. Box 11512
Pittsburgh, PA 15238

Exotech, Inc.
Garthersburg, Md

TABLE A.2. PARTIAL LIST OF SURVEYED MANUFACTURERS AND R&D COMPANIES INVOLVED IN OFFSHORE NDE (CONTINUED)

Fisher and Porter
County Line Rd.
Warminster, Pennsylvania 18974

FluiDynamic Devices Limited
3216 Lenworth Dr.
Mississauga Ontario
Canada L4X2G1

Flow Technology, Inc.
4250 East Broadway Road
Post Office Box 21346
Phoenix Arizona 85040

Formulabs, Inc.,
Flourescent Dye Tracing Systems Div.
529 W. 4th Ave
P. O. Box 1056
Escondido, Calif 92025
(714) 741-2345

The Foxboro Co.,
Neponset Ave.
Foxboro, Mass 02035
(617) 543-8750

Foxboro/Trans-Sonics, Inc.
P. O. Box 435
Burling, Mass 01803

GARD, Inc.
7449 North Natchez Ave
Niles, IL 60648

Garret-Callahan Co
111 Rollins Rd
Millbrae, CA 94030

General Dynamics
Electronics Division
San Diego, CA

General Electric Company
Ocean Systems Programs Dept.
3198 Chestnut St.
Philadelphia, PA 19101

General Metal Works, Inc.
8368 Bridgetown Road
Cleves, Ohio 45002

General Monitors, Inc.
3019 Enterprise St.
Costa Mesa, CA 92626

General Oceanics, Inc.
5535 N.W. 7th Ave
Miami, Fla. 33127

GI
Box 3356
Cherry Hill, NJ 08034

G&H Laboratories
1001 W. Arbor Vitae
Inglewood, CA 90301

Gianni Institute
Indio, CA

Girard Polly-Pig Inc.
P. O. Box 27208
Houston, TX 77027

Glass Innovations, Inc.
P. O. Box B
Addison, NY 14801

Gould, Inc. Control and
System Division
340 Fordham Rd
Wilmington, Mass. 01887

Gow-Mac Instrument Co.
100 Kings Road
Madison, NJ 07940

G.M. Mfg & Instrument Corp.
P. O. Box 947
El Cajon, CA 92022

Gulton Industries, Inc.
Servonic/Instrumentation Div.
1644 Whittier Ave.
Costa Mesa, CA 92627

Gulion Industries
Fullerton, CA 92651

TABLE A.2. PARTIAL LIST OF SURVEYED MANUFACTURERS AND R&D COMPANIES INVOLVED IN OFFSHORE NDE (CONTINUED)

Halliburton Services
A Division of Halliburton Co.
Duncan, Oklahoma 73533

Harris Calorific Division
Emerson Electric Co.
5501 Cass Avenue
Cleveland, Ohio 44102

Hastings
Hampton, VA

The H.C. Nutting Co
4120 Airport Road
Cincinnati, Ohio 45226

Healy Scott Int.
San Diego, CA

Heath Consultants, Inc.
100 Tosca Drive
Stroughton, Mass. 02072

Helle Engineering, Inc.
7198 Convoy Court
San Diego, CA 92120

Hershey Products, Inc.
Niagara, NY

Hershey Products, Inc.
Industrial Measurement Div.
Old Valley Falls Rd
Spartanburg, SC 29303

Hewlett Packard
Delcon Division

H. C. Nutting Co.
Cincinatti, Ohio

High Voltage Engineering Corp.
S. Bedford Rd.
Burlington, Mass 01803

Holiday
Carporinta, Calif

Holosonics, Inc.
2400 Stevens Drive
Richland, Wash. 99352

Honeywell, Inc.
1100 Virginia Drive
Fort Washington, PA 19034

Honeywell, Inc.
Lexington, MA

Honeywell, Inc.
Marine Systems Division
5303 Shilshole Ave. N.W.
Seattle, Washington 98107

HRB Singer
State College, PA

Humphrey, Inc.

Hydro Products
A. Tetra Tech Company
11777 Sorrento Valley Road
San Diego, CA 92121

TABLE A.2. PARTIAL LIST OF SURVEYED MANUFACTURERS AND R&D COMPANIES INVOLVED IN OFFSHORE NDE (CONTINUED)

IMODCO International, Ltd.
Los Angeles, CA

Impulsphysics
Hamburg, Germany

Innerspace Technology, Inc.
27 Frederick Street
Waldwick, NJ 07463

Inertia Switch, Ltd. Banchory
Works Hardings Lane
Hartley Wintney
Hants, United Kingdom
Hartley Wintney-2951

Institute for Research, Inc.
8330 Westglen Dr.
Houston, TX 77063

Instron Corp.
Los Alamitos, CA

Internation Imaging Systems
Commack, NY

Internation Sensor Technology
3201 South Halladay Street
Santa Ana, CA 92705

International Transducer Corp.
Subsidiary of Channel Ind., Inc.
640 McCloskey Pl.
Goleta, CA 93017

InterOcean Systems, Inc.
3540 Aero Ct.
San Diego, CA 92123

InterOcean Systems, Inc.
3510 Kurtz Ave
San Diego, CA

Intersea Research Corp.
P. O. Box 2389
La Jolla, CA 92038

Ionics, Inc.
65 Grove Street
Watertown, Mass 02172

IRD Mechanalysis, Inc.
Columbus, Ohio

ISCO
P. O. Box 5347
4700 Superior Ave
Lincoln, Neb. 68505

ITT Barton
580 Monterey Pass Rd.
Monterey Park, CA 91754

James Dean Divers, Inc.
New Orleans, LA

John Chance Company
LaFayette, LA

J. Ray M'Dermott

SBM, Inc.
New Orleans, LA

Kahl Scientific Instrument Corp
P. O. Box 1166
El Cajon, CA 92002

Kawaski Intl.
P. O. Box 1082
Cupertino, CA 95014

KB Heroteck
P. O. Box 350
Lewistown, PA 17044

K.J. Law
23660 Research Drive
Farmington Hill, Mich.

Klein Associates
Undersea Search and Survey
Salem, New Hampshire 03709

Konel Grp. Corporation
Subsidiary Narco Scientific
271 Harbor Way, S.
San Francisco, CA 94080

Kontes,
Spruce St.
Vineland, NJ 08360

Kratos
403 S. Raymond,
Pasadena, CA

Kurz Instruments, Inc.
P. O. Box 849
20 Village Square
Carmel, CA 93924

KZF Environmental Design
Cons., Inc.
2830 Victory Pkwy
Cincinnati, Ohio 45206

TABLE A.2. PARTIAL LIST OF SURVEYED MANUFACTURERS AND R&D COMPANIES INVOLVED IN OFFSHORE NDE (CONTINUED)

Land and Offshore Services
Banchory Grampian, Scotland

Lear Siegler, Inc.
Environmental Technology Div
74 Inverness Drive East
Englewood, Colo. 80110

Leeds & Northrup Co.
Sumneytown Pike
North Wales, PA 19454

Lenox Instrument
An Esterline Company
111 East Luray Street
Philadelphia, PA 19120

Leopold Company
Division of Sybron Corp.
227 S. Division Street
Zelienople, PA 16063

Lester Laboratories, Inc.
2370 Lawrence St.
Atlanta, GA 30344

Leupold & Stevens, Inc.
600 N.W. Meadow Dr.
P. O. Box 688
Beaverton, Ore. 97005

Lion Precision Corp.
60 Bridge St.
Newton, Mass. 02195

Lordkinematics
Paramous, NH

Lumenite Electronic Corp.
2331 N. 17th Ave.
Franklin Park, IL 60131

Mackallor Bros.
Chino, CA

Magnaflux Corporation
7300 West Lawrence Avenue
Chicago, IL 60656

Magnavox
Govt. and Indust.
Electronics Co.
2829 Maricopa Street
Torrance, CA 90503

Menning Environmental Corp.
120 DuBois
Santa Cruz, CA 95061

Mancstat Corporation
519 Eigth Ave
New York, NY 10018

The Marconi International
Marine, Ltd.
Oil Industry Division
Elettra House, Westway
Chelmsford, Esses, England

Marine Moisture Control Co.
449 Sheridan Blvd.
Inwood, L.I., NY 11696

Martek Instruments
Newport Beach, CA

Matheson
P. O. Box 85
East Rutherford, NJ 07073

McDonnell Douglas Corp.
Huntington Beach, CA

Mead Instruments Corp.
One Dey La
Riverdale, NJ 07457

Measurement Control Systems
Division of United Spring
1495 E. Warner Ave.
Santa Ana, CA 92707

Meriam Instrument
10920 Madison Ave.
Cleveland, Ohio 44102

Metrotek, Inc.
P. O. Box 101
Richland, WA 99352

MG Scientific Gases
210 Cougar Ct
Hillsborough, NJ 08876

Micro Motion, Inc.
2700 29th St
Boulder, Colo

Milton-Roy Co.
Hays-Republic Div
742 E. Eight St.
Michigan City, Ind. 46360

Mine Safety Appliances Co.
400 Penn Center Blvd.
Pittsburgh, PA 15235

Moniter Technology, Inc.
630 Price Avenue
Redwood City, CA 94063

Montedoro-Whitney Corp
2740 McMillan Rd.
P. O. Box 1401
San Luis Obispo, CA 93406

TABLE A.2. PARTIAL LIST OF SURVEYED MANUFACTURERS AND R&D COMPANIES INVOLVED IN OFFSHORE NDE (CONTINUED)

Nebraska Testing Labs
4453 S. 67th St.
Omaha, Neb 68106

New York Testing Labs, Inc.
81 Urban Ave.
Westbury, LI, NY 11590

Nippon Kokan
Japan

Nupro Co.
4800 E. 345th St.
Willoughby, Ohio 44094

Nu Sonics Inc.
Tulsa Oklahoma
Phone (203) 623-8800

National Environmental
Instruments, Inc.
P. O. Box 590
Pilgrim Station
Warwick, RI 02888

National Instrument Labs, Inc.
910 Princess Ann St.
Fredricksburg VA 22401

National Power Rodding Corp.
1000 S. Western Ave.
Chicago, IL 60612

NB Products, Inc.
935 Horsham Rd.
Horsham, PA 19044

N-CON Systems Co., Inc.
308 Main St.
New Rochelle, NY 10801

Ocean Research Equipment, Inc.
P. O. Box 709
Falmouth, Mass. 02541

Ocean Systems
Houston, TX

Oceaneering, International
Houston, TX

Ocean Technical Services Ltd
43/44 Albermarle St.
London W/X 3Fe
England

Offshore Navigation, Inc.
5723 Jefferson Hwy.
Harahan, LA 70183

Olympus Corp. of America/
Industrial Fiberoptics Dept.
2 Nevada Drive
New Hyde Park, NY 11040

Optronics Labs
Silver Springs, MD

O.R.E., Inc.
P. O. Box 709
Falmouth Heights Rd.
Falmouth, Mass. 02541

TABLE A.2. PARTIAL LIST OF SURVEYED MANUFACTURERS AND R&D COMPANIES INVOLVED IN OFFSHORE NDE (CONTINUED)

Panometrics
221 Crescent St.
Waltham, Mass. 02154

Peabody Testing
Magnaflux Corp.

Pennwalt
Wallace and Tiernan Division
25 Main St.
Belleville, NJ 07109

The Permutit Co., Inc. of
Sybron Corp.
E. 49 Midland Ave.
Paramus, NJ 07652

Perry Oceanographics, Inc.
P. O. Box 10297
Riviera Beach, Florida 33404

Plessey, Inc.
Tellurometer USA
89 Marcus Blvd.
Hauppage, NY 11787

Joseph G. Pollard Co., Inc.
New Hyde Park, NY 11040

Power Engineering & Equip. Co.
1826 W. 213 St.
Torrance, CA 90501

Precision Gas Products, Inc.
Sub. of Burdox, Inc.
681 Mill Street
Rahway, NJ 07065

Preformed Line Products
P. O. Box 91129
Cleveland, Ohio 44101

Princeton Applied Research Corp.
P. O. Box 2565
Princeton, NJ 08540

Pro-Tech, Inc.
Liquid Samplers and Flow
Monitors
1510 Russel Rd.
Paoli, PA 19301

Radiation Dynamics, Inc.
Melville, NY

RAMCO
Dallas, TX

Ramapo Instrument Co., Inc.
2 Mars Court
P. O. Box 429
Montville, NJ 07045

Rambie, Inc.
P. O. Box 3214
Irving, TX 75061

Raytheon Company
Submarine Signal Div.
Ocean Systems Center
1847 W. Main Road
Portsmouth, RI 02871

Reliance Instrument Mfg. Corp.
164 Garibaldi Ave.
Lodi, NJ 07644

Reynolds French Co.

Robertshaw Controls Co.,
Industrial Instrumentation Div.
1809 Staples Mill Rd.
Richmond, VA 23230

Robinson Pipe Cleaning Co.
606 W. Pike St.
Canonsburg, PA 15317

Roma Sales, Inc.
407A North Central Avenue
Glendale, CA 91203

R. P. Cargille Labs, Inc.
55 Commerce Rd
Cedar Grove, NJ 07009

Earl Ruble & Associates, Inc.
217 S. Lake Ave.
Duluth, Minn 55802

TABLE A.2. PARTIAL LIST OF SURVEYED MANUFACTURERS AND R&D COMPANIES INVOLVED IN OFFSHORE NDE (CONTINUED)

SBM of America
Houston, TX

Schaevitz Engineering
P. O. Box 505
Camden, NJ 08101

Science Pump Corp.
1431 Ferry Avenue
Camden, NJ 08104

Science Applications, Inc.
201 West Dyer Rd.
Unit 6
Santa Ans, CA

Scientific Gas Products, Inc.
2230 Hamilton Blvd.
S. Plainfield, NJ 07080

Scientific Glass & Inst., Inc.
P. O. Box 6
Houston, TX 77001

Scott Ato
225 Erie Street
Lancaster, NJ 14086

Seatech Corp.
Ocean Engineering
985 N.W. 95th St.
Miami, Fla. 33150

SEDCO
Houston, TX

Sensotec
1400 Holly Avenue
Columbus, Ohio 43212

Siemens Aktiegesellschaft
Bereich Mebund Prozebtechnik
P. O. Box 211080
Federal Republic of Germany

Sierra Instruments, Inc.
P. O. Box 909
Carmel Valley, CA 93924

Sigma Instruments Ltd.
55 Six Point Road
Toronto, Ontario M8Z 2X3

Sigmamotor, Inc.
14 Elizabeth St.
Middleport, NY 14105

Singer-American Meter Div.
13500 Philmont Ave.
Philadelphis, PA 19116

Sirco Controls Co.
401 Second Ave. W.
Seattle, Washington 98119

Sirco Products Limited
8815 Selkirk Street
Vancouver, BC V6P 4J7

Sofec, Inc.
2000 W. Loop
Houston, TX

Soltraplex, Inc.
Lehavre, France

Sona Tech, Inc.
Goleta, CA 93017

Sonic Inc
Trenton, NJ

Sound Wave Systems, Inc.
3001 Red Hill Bldg. 1 Ste 102
Costa Mesa, CA 92626

Spectrogram
North Hampton, Conn

Sperry
Marine Systems
Greak Neck, NY 11020

Stoner Associates

Sub Sea International
New Orleans, LA

Sunshine Chemical Corp.
P. O. Box 17041
West Hartford, Conn 06117

Supelco, Inc.
Supelco Park
Bellefonte, PA 16823

Sylvester Underseas Inspection
900 Hingham Street
Rockland, Mass. 02370

TABLE A.2. PARTIAL LIST OF SURVEYED MANUFACTURERS AND R&D COMPANIES INVOLVED IN OFFSHORE NDE (CONTINUED)

TDW Pipeline Surveys
P. O. Box 1286
Tulsa, OK 74101

T.D. Williams, Inc.
P. O. Box 3404
Tulsa, OK

TechEcology, Inc.
645 N. Mary
Sunnyvale, CA 94086

Teledyne Analytical Instruments
P. O. Box 70
333 W. Mission Dr
San Gabriel, CA

Teledyne Hastings-Raydist
P. O. Box 1275
Hampton, VA 23661

Teledyne Gurley
514 Fulton St.
Troy, NY 12181

Terriss-Consolidated Ind.
126-128 Hope Street
Brooklyn, NY 11211

Texas Instr.
Dallas, TX

Thermal Instrument Co.
217 Sterner Mill Rd
Trevose, PA 19047

Thermal Systems, Inc.
2500 Cleveland Ave.
N. St. Paul, Minn 55113

Top Flight, Inc.
Oklahoma City, OK

Tom Ponton Industries, Inc.
13923 Artesia Blvd
Cerritos, CA 90701

Transworld Inspection Corp.

Turner Designs
2247 A Old Middlefield Way
Mountain View, CA 94043

Tylan Corporation
19220 So. Normandie
Torrance, CA 90502

Tuthill Pump Co.
12500 S. Crawford Ave.
Chicago, IL 60658

Uniloc
Irving, CA

Union Carbide Corporation
120 South Riverside Plaza
Chicago, IL 60606

Unit Process Assemblies, Inc.

UOP
Johnson Division
P. O. Box 3118
St. Paul, Minn. 55165

Vanode Company
Torrance, CA

Varec

Varian
611 Hansen Way
Palo Alto, CA 94303

Varian/Vacuum division
9901 Paramount Blvd.
Downey, CA 90240

Vetco Pipeline Service
1600 Brittmoore road
Houston, Texas 77043

Vidimar
Tulsa, OK

TABLE A.2. PARTIAL LIST OF SURVEYED MANUFACTURERS AND R&D COMPANIES INVOLVED IN OFFSHORE NDE (CONTINUED)

Wallace-Fisher Instrument Co.
P. O. Box 51
Ocean Grove Station
Swansea, Mass 02777

Waukesha Foundry Division
Abex Corporation
1300 Lincoln Ave.
Waukesha, Wisc. 53186

Weather Measure Corporation
P. O. Box 41257
Sacramento, CA 95841

WECO, Division SMC
Brea, CA

Wesmar
Seattle, Washington

Westinghouse Elec. Corp.
Oceanic Division (Ultrasonic
P. O. Box 1488
Annapolis, Md

Wild Hurburugg Instr. Inc.
Famingdale, NY

Whesssue Fielden

World Wide Oil Too, Inc.
4041 Hollister
Houston, TX 77080

Wright and Wright, Inc.
80 Winchester St.
Newton, Mass. 02161

Waugh Control Corp.
9001 Full Bright Ave
Chatsword, CA 91311

Xarway Corporation
Blue Bell, PA 19422

XMAS, Inc.
8186 East 44th Street
Tulsa, OK 74145

Zimmite Corporation
810 Sharon Drive
Cleveland, Ohio 44145

Zurn Industries, Inc.
Hays Fluid Controls Div.
12 & Plum Sts.
Erie, PA 16512

Zanderlans and Sons, Inc.
1320 South Socramento St.
Lodi, Calif.

TABLE A.3. DETAILS ON SDC AND NIAC DATA BASE SEARCHES

SDC COMPUTER DATA BASE SEARCH

- Tulsa
- NASA
- NIAC
- APLIT
- Dia-Log
- API

NIAC DATA BASE SEARCH

- Tulsa
- NASA
- Dia-Log
- TRIS
- Standards and specifications
- API

TABLE A.3. DETAILS ON SDC AND NIAC DATA BASE SEARCHES (Cont'd.)

P7154754

THIS IS AN OFF-LINE CITATION LIST GENERATED BY

ORBIT IV

S.D.C.'S INTERNATIONAL SEARCH SERVICE

CASING INSPECTION

NUMBER OF CITATIONS PRINTED = 62 APRIL 27, 1982

THIS SEARCH WAS PERFORMED ON TULSA

TABLE A.3. DETAILS ON SDC AND NIAC DATA BASE SEARCHES (Cont'd.)

P7155834

THIS IS AN OFF-LINE CITATION LIST GENERATED BY

ORBIT IV

S.D.C.'S INTERNATIONAL SEARCH SERVICE

CASING INSPECTION

NUMBER OF CITATIONS PRINTED = 89 APRIL 27, 1982

THIS SEARCH WAS PERFORMED ON APILIT

TABLE A.3. DETAILS ON SDC AND NIAC DATA BASE SEARCHES (Cont'd.)

User 1599 Date:27apr82 Time:16:58:51 File: 6

Set	Items	Description
1	0	CASING(W)INSPECTION?
2	101	WELL CASINGS?
3	0	WELL CASINGS(S)INSPECTION
4	1800	NONDESTRUCTIVE(W)TESTING
5	142	NONDESTRUCTIVE(W)EVALUAT?
6	8626	INSPECTION
7	7830	INSPECTION/DE,ID
8	233	LEAK(W)DETECT?
9	194	LEAK DETECT?
10	280	LEAK TEST?
11	2020	PIPELINE?
12	5871	PIPE? ?
13	7902	UNDERGROUND
14	7803	UNDERWATER
15	1475	OFFSHORE
16	48	ONSHORE
17	16951	13-16/+
18	539	STORAGE(W)TANK?
19	160	OFFSHORE(W)PLATFORM?
20	98	RISER? ?
21	1	19*20
22	2	MARINE RISER?
23	1312	2+18+19+22+21+((11+12)*17)
24	23	23*(4+5+7+8+9+10)
25	1	(23*6)-24
26	1	20*(4+5+7+8+9+10)
27	24	24+26
28	24	27/1-24/DT,D
29	1	MAINTENANCE(W)CODE?
30	34	MAINTENANCE(W)STANDARD?
31	0	30*2
32	0	30*18
33	0	30*19
34	0	33*11
35	0	30*11

Print 28/7/1-24

Search Time: 0.132 Prints: 24 Descs.: [illegible]1

APPENDIX B

ABSTRACTS OF PERTINENT EFFORTS IN CASING INSPECTION OBTAINED DURING THE LITERATURE SEARCH

TABLE B.1 PERTINENT CASING INSPECTION REPORTS

	51965
	METHOD AND APPARATUS FOR TESTING WELL PIPE SUCH AS CASING OR FLOW TUBING
AUTHORS	LOOMIS G L
SOURCE	US 3,165,919, C 1/19/65, F 2/8/62
ENTRY YEAR	1965
INDEX TERMS	*CASING LEAK; *CASING (WELL); CONTRACT; DEFECT; DETECTOR; ECONOMIC FACTOR; ENGLISH; FLUID FLOW; FLUID LOSS; HYDRAULIC PRESSURE; INSTRUMENT; LEAK; LEAK DETECTOR; LEGAL CONSIDERATION; PACKER; PATENT; PRESSURE; *PROCEDURE; RUSSIAN; *TESTING; TUBE; TUBING (WELL); TUBULAR GOODS; WELL COMPL SERV + WORKOVER; WELL COMPLETION; WELL SERVICING; WELL WORKOVER; (P) USA

	101058
	METHOD FOR LOCATING TENSION FAILURES IN OIL WELL CASINGS
AUTHORS	MURPHEY C E JR; PATTERSON M M; SHEFFIELD B C
SOURCE	US 3,393,732, C 7/23/68, F 5/21/65 SHELL OIL CO
ENTRY YEAR	1968
INDEX TERMS	*CASING FAILURE; CASING LEAK; CASING (WELL); CONTRACT; DETECTION; ECONOMIC FACTOR; ENGLISH; FAILURE; *FLAW DETECTION; FLUID LOSS; FORCE; INSPECTING; LEAK; LEGAL CONSIDERATION; LOCATION; *MAGNETIC EQUIPMENT; MAGNETIC INDUCTION; MAGNETIC PROPERTY; PATENT; PHYSICAL PROPERTY; *PIPE INSPECTION; RECOVERY; SHELL OIL CO; STRESS; SURVEYING; TENSION; TESTING; THERMAL EXPANSION; THERMAL PROPERTY; THERMAL RECOVERY; TUBULAR GOODS; WELL LOGGING; WELL LOGGING EQUIPMENT; WELL LOGGING + SURVEYING; *WELL SURVEYING; (P) USA

	147864
TITLE	HOW TO FIND CASING LEAKS
SOURCE	PETROL ENG V 43, NO 6, PP 76, 78, JUNE 1971
ENTRY YEAR	1971
INDEX TERMS	CASING FAILURE; *CASING LEAK; CASING (WELL); DETECTION; DETECTOR; ENGLISH; FAILURE; FLAW DETECTION; FLUID LOSS; GAS STORAGE WELL; GAS WELL; INFLATABLE PACKER; INSTRUMENT; LEAK; *LEAK DETECTOR; PACKER; SURVEYING; TUBULAR GOODS; WELL; WELL LOGGING + SURVEYING; *WELL SURVEY EQUIPMENT; WELL SURVEYING; WIRE LINE OPERATION; *WIRE LINE TOOL

TABLE B.1 PERTINENT CASING INSPECTION REPORTS (CONTINUED)

	197454
TITLE	NEW CASING INSPECTION LOG
AUTHORS	CUTHBERT J F; JOHNSON W M JR
SOURCE	49TH ANNU SPE OF AIME FALL MTG PREPRINT NO SPE-5090, 12 PP, 1974
ENTRY YEAR	1974
INDEX TERMS	*CALIPER LOGGING; CASING LEAK; *CASING (WELL); DATA; DETECTION; DETECTOR; ENGLISH; EXAMPLE; FLAW DETECTION; FLUID LOSS; *INSPECTING; INSTRUMENT; LEAK; LEAK DETECTOR; *NONDESTRUCTIVE TESTING; *PIPE INSPECTION; PIPE TESTING; *SURVEYING; *TESTING; THICKNESS; *TUBULAR GOODS; WELL LOGGING + SURVEYING; WELL SURVEY EQUIPMENT; *WELL SURVEYING; WELL TOOL

	128526
TITLE	NEW PORTABLE TOOL TESTS GAS-WELL CASING FOR LEAKS QUICKLY, CHEAPLY
SOURCE	OIL GAS J V 68, NO 18, PP 132-134, 5/4/70
ENTRY YEAR	1970
INDEX TERMS	*CASING LEAK; *CASING (WELL); CITIES SERVICE GAS CO; DETECTION; DETECTOR; DRILLING RIG; ENGLISH; FIELD TESTING; *FLAW DETECTION; FLUID LOSS; GAS WELL; INSTRUMENT; LEAK; *LEAK DETECTOR; LUBRICATOR (WELL); MAST; *PIPE TESTING; PORTABILITY; PORTABLE RIG; PRESSURE; PUMP; SEAL; TESTING; TUBULAR GOODS; WELL; WELL COMPL SERV + WORKOVER; WIRE LINE OPERATION

	64655
TITLE	METHOD OF LOCATING CASING LEAKS
AUTHORS	AGISHEV A P; KRIVOSHEEVA V I; BARANINKO S E; BALABANOV V F
SOURCE	USSR 176,218, F 4/27/64
ENTRY YEAR	1966
INDEX TERMS	AMMONIA; ANNULUS; *CASING LEAK; *CASING (WELL); COMPRESSED GAS; CONTRACT; COPPER CHLORIDE, CUCL; DEFECT; *DETECTION; ECONOMIC FACTOR; FLAW DETECTION; FLUID LOSS; INDICATOR; INJECTION; *INSTRUMENT; *LEAK; LEGAL CONSIDERATION; OXYGEN; PATENT; RUSSIAN; TUBULAR GOODS; WELL COMPL SERV + WORKOVER; WELL SERVICING; (P) USSR

	118773
TITLE	DETERMINING THE LOCATION OF A DEFECT IN CASING
AUTHORS	ALIEV E SH; ISHKHANOVA G L; KYAZIMOV D KH; NURIEV S D; VINOGRADOV K V
SOURCE	NEFT KHOZ NO 5, PP 40-42, MAY 1969 (IN RUSSIAN)
ENTRY YEAR	1969
INDEX TERMS	ANNULUS; BUBBLE POINT; *CASING FAILURE; *CASING LEAK; CASING (WELL); DEFECT; DETECTION; DETERMINING; DISTRIBUTION; EQUATION; FAILURE; *FLAW DETECTION; FLOWING WELL; FLUID FLOW EQUATION; FLUID LOSS; LAPLACE EQUATION; LEAK; LIQUID LEVEL; LOCATION; MATHEMATICS; PHASE BEHAVIOR; PHYSICAL PROPERTY; PRESSURE; PRESSURE DISTRIBUTION; PRODUCING WELL; RUSSIAN; TRANSITION TEMPERATURE; TUBULAR GOODS; WELL; WELL COMPL SERV + WORKOVER; WELL PRESSURE

	53331
TITLE	THREAD LEAKS IN TUBING AND CASING STRINGS
AUTHORS	KERR H P
SOURCE	API PROD DIV SOUTHERN DIST MTG (SHREVEPORT, LA, 2/25- 26/65) PREPRINT NO 926-10-K, 13 PP
ENTRY YEAR	1965
INDEX TERMS	*CASING LEAK; *CASING (WELL); DATA; DEFECT; DETECTION; FLAW DETECTION; FLUID FLOW; FLUID LOSS; HIGH PRESSURE; *HYDRAULIC PRESSURE; *LEAK; PRESSURE; TABLE (DATA); TESTING; *THREAD (MECHANICAL); TUBE; *TUBING (WELL); TUBULAR GOODS; WELL COMPL SERV + WORKOVER

TITLE	FLEXIBLE SONDE INTENDED FOR THE NONDESTRUCTIVE TESTING OF PIPES OF GREAT LENGTH (SONDE SOUPLE DESTINEE AU CONTROLE NON DESTRUCTIF DE TUBES DE GRANDE LONGUEUR)
AUTHORS	AMEDRO A; AUDENARD B; DE MOL R
SOURCE	FR 2,461,950, P 2/6/81, F 7/24/79 (APPL 7,919,080) (CIE GENERALE RADIOLOGIE); ABSTR., BULL OFFIC PROPRIETE IND (FR) V 22, NO 11, PT
ENTRY YEAR	1981
INDEX TERMS	(P) FRANCE; CIE GENERALE RADIOLOGIE; COMPRESSION; CONDUCTOR PIPE; DEFORMATION; DESIGN CRITERIA; *DETECTOR; EDDY CURRENT; ELECTRIC CURRENT; ELECTRICITY; FLEXIBILITY; FRENCH; *INSPECTING; *INSTRUMENT; *MATERIALS TESTING; MECHANICAL PROPERTY; *NONDESTRUCTIVE TESTING; PATENT (A); PHYSICAL PROPERTY; PIPE; *PIPE INSPECTION; *PIPE TESTING; PIPELINE; SONDE; SPECIFICATION; SUPPLEMENTAL TECHNOLOGY; *TEST PROBE; *TESTING; TUBULAR GOODS; WELL LOGGING EQUIPMENT

UCRL-15032 NTIS Prices: PC A10/MF A01

Assessment of Non-Destructive Testing of Well Casing,, Cement and Cement Bond in High Temperature Wells

GeoEnergy Corp., Las Vegas, NV.*Department of Energy. 9506248)

AUTHOR: Knutson, , C. K.; Boardman, C. R.
GO305L2 Fld: 8I, 97P, 48A GRAI8004
215p
Contract: W-7405-ENG-48
Monitor: 18

Abstract: Because of the difficulty in bringing geothermal well blowouts under control, any indication of a casing/cement problem should be expeditiously evaluated and solved. There are currently no high temperature cement bond and casing integrity logging systems for geothermal wells with maximum temperatures in excess of 500 exp O F. The market is currently insufficient to warrannt the private investment necessary to develop tools and cables capable of withstanding high temperatures. It is concluded that a DOE-funded development program is required to assure that diagnostic tools are available in the interim until geothermal resource development activities are of sufficient magnitude to support developmental work on high temperature casing/cement logging capabilities by industry. This program should be similar to and complement the current DOE program for development of reservoir evaluation logging capabilities for hot wells. The appendices contain annotated bibliographies on the following: high temperature logging in general, cement integrity testing, casing integrity testing, casing and cement failures, and special and protective treatment techniques. Also included are composite listing of references in alphabetical order by senior author. (ERA citation 04:051361)

879393 EDB-82:054235
Principles and applications of a new in-situ method for inspection of well casing
Smith, G.S.
Schlumberger Well Serv. Oklahoma City, Okla
Soc. Pet. Eng. AIME, Pap. (United States) 545-551 p. 1981 Coden: SEAPA
Middle East technical conference Manama, Bahrain 9 Mar 1981
Journal Announcement: EDB8201
Document Type: Journal Article; Conference literature
Languages: English
Subfile: EI .(COMPENDEX)
Report No.: CONF-8103116-
Work Location: United States
The ETT-C is a recent y developed corrosion tool for the in-situ inspection of well casing. Electromagnetic techniques are used to measure casing wall thickness, apparent magnetic permeability, and inside diameter. The ETT-C system monitors magnetic permeability to obtain an independent wall thickness measurement. A sensitive, non-contact internal diameter measurement has also been added. A system description explains the ETT-C measurement principles, significance, and processing interaction. Tool applications and interpretation are also discussed. The utility of the additional information provided by the ETT-C is demonstrated with log examples. 4 refs..

TABLE B.2 PERTINENT REPORTS APPLICABLE TO CASING INSPECTION

	MAGNETIC INSTRUMENTATION PIG HELPS NGPL ((NATURAL GAS PIPELINE CO. OF AMERICA)) INSPECT PIPELINES FOR POTENTIAL LEAKS
AUTHORS	HOLM W K; NATURAL GAS PIPELINE CO OF AMERICA
ORGANIZATIONAL SOURCE	NAT. GAS PIPELINE CO. AM.
SOURCE	16TH ANNU. PIPELINE OPERATION MAINT. INST. (LIBERAL, KANS. 11/18-19/80) OIL GAS J. V79 N.22 123-24,126,128 (6/1/81) IN ENGLISH
CATEGORY CODE NAME	PIPELINE MAINTENANCE
INDEX TERMS	AXIAL; COMPATIBILITY; CORROSION; DEFECT; DISTRICT 3; FAILURE; GULF COAST; HYDROSTATIC TESTING; INSPECTING*; LEAK; LOCATION; MAGNET*; MAGNETIC FIELD; MAGNETISM; MATERIAL DEPLETION; MEETING PAPER; MOBILITY; MODEL; NORTH AMERICA; OPERATING CONDITION; PATH; PIPELINE; PIPELINE CROSSING; PIPELINE PIG*; PRESSURE; PROTOTYPE; PUMP STATION; SPIRAL; SPLITTING; STREAM; TEXAS; THICKNESS; TRUNK PIPELINE; USA; VELOCITY; WALL; WELDING
SUPPLEMENTARY TERMS	WHARTON, TEXAS; BRAZOS RIVER, TEXAS; PRESSURE-HOLDING CAPABILITY; SELF-PROPELLED; DUMMY-PIG
LINKED TERMS	AXIAL; DEFECT; LOCATION
LINKED TERMS	COMPATIBILITY; HYDROSTATIC TESTING; INSPECTING
LINKED TERMS	MAGNET; SPIRAL
LINKED TERMS	MOBILITY; MODEL; PIPELINE PIG; PROTOTYPE
LINKED TERMS	PATH; PIPELINE; TRUNK PIPELINE
LINKED TERMS	THICKNESS; WALL
ABSTRACT	Magnetic Instrumentation Pig Helps NGPL [(Natural Gas Pipeline Co. of America)] Inspect Pipelines for Potential Leaks.

TITLE	ULTRASONIC RISER INSPECTION TOOL SUCCESSFUL
AUTHORS	DANISH WELDING INSTITUTE
SOURCE	OCEAN IND. V13 N.8 65-66 (AUG. 1978) IN ENGLISH
CATEGORY CODE NAME	PIPELINE MAINTENANCE
INDEX TERMS	ASSOCIATION; BUSINESS OPERATION; CABLE; CLOGGING; CORROSION; CRUDE OIL; CRUDE OIL (WELL); DEFORMATION; DENMARK; ECONOMIC FACTOR; EQUIPMENT, EQUIPMENT TESTING*; INSPECTING; LEASE; LEGAL CONSIDERATION; NONDESTRUCTIVE TESTING*; NORTH SEA; OFFSHORE STRUCTURE*; PIPE; RISER*; SALINE WATER, SCANDINAVIA; SEA; SPINNING; TECHNICAL SERVICE; TRANSDUCER; ULTRASONIC TESTING*;

New pipeline leak detection p
Pipes Pipelines Int. (United States) 21 26-28 p. Aug 1976 Coden: PPIIA
Journal Announcement: EDB7810
Document Type: Journal Article
Languages: English
Subfile: GSA (Gas Abstracts)
Work Location: United States

The Pressure Spy, a new pipeline pig developed by West Germany's Dr. Hans Goedecke KG, reliably and quickly locates leaks occurring during hydrostatic pressure tests in long-distance underground pipelines. Pumped by means of liquid or gas pressure to a predetermined position in the line, the pig seals the pipeline with respect to small pressure differentials and sends signals to the outside, which aid in locating the pig and determining in which direction from the pig the leak is to be found. An assessment of the technique points out that all possible sizes of leaks can be located with the same tool in all pressure fluids without additional cutting or welding on the pipe or damage to the insulation

447533 ERA-04:011445, INS-79:002224, EDB-79:021631
Report on Boeing pipeline leak detection system
Aichele, W.T.
Atomics International Div., Richland, WA (USA). Rockwell Hanford Operations
69 p. Aug 1978
Country of Publication: United States
Journal Announcement: EDB7901
Availability: Dep. NTIS, PC A04/MF A01.
Document Type: Report
Languages: English
Subfile: INS .(US Atomindex input); ERA .(Energy Research Abstracts); TIC .(Technical Information Center)
Report No.: RHO-LD-61
Work Location: United States
Contract No.: EY-77-C-06-1030
Testing was performed on both simulated (test) and existing (water) pipelines to evaluate the Boeing leak detection technique. This technique uses a transformer mounted around the pipe to induce a voltage level onto the pipeline. The induced ground potential is measured from a distant ground probe, inserted into the surrounding soil, with respect to the excited pipeline. The induced voltage level will depend on the soil characteristics, the distance from the excited pipeline, and the probe types. If liquid should leak from the excited pipeline, the escaping liquid will modify the induced potential of the soil surrounding the excited pipeline. This will change the response of the quiescent soil characteristics and cause the voltage level on the detecting probes in the area of the leak to increase. This voltage increase will indicate a soil anomaly. However, the liquid does not have to reach the detection probe to reveal an anomalous soil condition. Several different detection probes were used and evaluated for sensitivity and response time. Although not evaluated during this test, results indicate that a wire laid parallel to the pipe axis may be the best probe configuration. A general sensitivity figure for any of the probes cannot be made from these tests; however, the technique used will reliably detect a pipeline leak of ten gallons. An additional test was performed using the Boeing pipeline leak detection technique to locate the position and depth of an underground pipeline. This test showed that the location and depth of an excited pipeline could be determined from above the ground where other methods for pipeline location had previously failed

360242 EDB-78:048870
Active acoustic detection of leaks in underground natural gas distribution lines
Jette, A.N.; Morris, M.S.; Murphy, J.C.; Parker, J.G.
Johns Hopkins Univ, Baltimore, Md
Mater. Eval. (United States) 35:10 90-96, 99 p. Oct 1977 Coden: MAEVA
Journal Announcement: EDB7804
Document Type: Journal Article
Languages: English
Subfile: EI .(COMPENDEX)
Work Location: United States
Detection of leaks in residential natural gas distribution lines is a matter of concern to both industry and federal regulatory agencies. A research effort directed toward an understanding of the fundamentals of active acoustic detection of leaks is described. This program encompasses three main areas: experimental pipeline field measurements; theoretical investigation of elastic waves radiated from underground piping generated by coupling of the pipe walls to the internal acoustic pressure variations; and development of an optical earth vibration sensor based on laser interferometry. 10 refs

ADA 129953

NAVAL OCEAN SYSTEMS CENTER, SAN DIEGO, CA
ASSESSMENT OF THE TECHNOLOGY AND PRACTICE FOR DETERMINING CASING DEGRADATION DURING OFF-SHORE DRILLING OPERATIONS

NOSC CR 163
UNCLASSIFIED
SEP 1982

END
DATE
FILMED

447533 ERA-04:011445, INS-79:002224, EDB-79:021631
Report on Boeing pipeline leak detection system
Aichele, W.T.
Atomics International Div., Richland, WA (USA). Rockwell Hanford Operations
69 p. Aug 1978
Country of Publication: United States
Journal Announcement: EDB7901
Availability: Dep. NTIS, PC A04/MF A01.
Document Type: Report
Languages: English
Subfile: INS .(US Atomindex input); ERA .(Energy Research Abstracts); TIC .(Technical Information Center)
Report No.: RHO-LD-61
Work Location: United States
Contract No.: EY-77-C-06-1030
Testing was performed on both simulated (test) and existing (water) pipelines to evaluate the Boeing leak detection technique. This technique uses a transformer mounted around the pipe to induce a voltage level onto the pipeline. The induced ground potential is measured from a distant ground probe, inserted into the surrounding soil, with respect to the excited pipeline. The induced voltage level will depend on the soil characteristics, the distance from the excited pipeline, and the probe types. If liquid should leak from the excited pipeline, the escaping liquid will modify the induced potential of the soil surrounding the excited pipeline. This will change the response of the quiescent soil characteristics and cause the voltage level on the detecting probes in the area of the leak to increase. This voltage increase will indicate a soil anomaly. However, the liquid does not have to reach the detection probe to reveal an anomalous soil condition. Several different detection probes were used and evaluated for sensitivity and response time. Although not evaluated during this test, results indicate that a wire laid parallel to the pipe axis may be the best probe configuration. A general sensitivity figure for any of the probes cannot be made from these tests; however, the technique used will reliably detect a pipeline leak of ten gallons. An additional test was performed using the Boeing pipeline leak detection technique to locate the position and depth of an underground pipeline. This test showed that the location and depth of an excited pipeline could be determined from above the ground where other methods for pipeline location had previously failed.

360242 EDB-78:048870
Active acoustic detection of leaks in underground natural gas distribution lines
Jette, A.N.; Morris, M.S.; Murphy, J.C.; Parker, J.G.
Johns Hopkins Univ, Baltimore, Md
Mater. Eval. (United States) 35:10 90-96, 99 p. Oct 1977 Coden: MAEVA
Journal Announcement: EDB7804
Document Type: Journal Article
Languages: English
Subfile: EI .(COMPENDEX)
Work Location: United States
Detection of leaks in residential natural gas distribution lines is a matter of concern to both industry and federal regulatory agencies. A research effort directed toward an understanding of the fundamentals of active acoustic detection of leaks is described. This program encompasses three main areas: experimental pipeline field measurements; theoretical investigation of elastic waves radiated from underground piping generated by coupling of the pipe walls to the internal acoustic pressure variations; and development of an optical earth vibration sensor based on laser interferometry. 10 refs

225012 ERA-02:030514, EDB-77:062859

Surveying in-place pipelines for dents, buckles and other diameter reductions

Nondestructive testing for pipe systems. Symposium papers and related information (Natural gas)

Jordan, S.

TDW Pipeline Surveys, Tulsa, OK

Institute of Gas Technology, Chicago, IL (USA)

195-216 p. Aug 1976

Symposium on nondestructive testing for pipe systems Chicago, IL, USA 7 Jun 1976

Country of Publication: United States

Journal Announcement: EDB7705

Document Type: Analytic of a Report: Conference literature

Languages: English

Subfile: ERA .(Energy Research Abstracts); TIC .(Technical Information Center)

Report No.: CONF-760689-

Work Location: United States

The use of large diameter, thin wall, high strength pipe for onshore pipeline construction in recent years has necessitated the development of sophisticated inspection tools for dents, buckles and other diameter reductions. The Kaliper Pig is a self-contained measuring and recording instrument which is used to survey newly constructed pipelines and also operating lines. The pig produces a graphical recording of pipeline inside diameter. Location of diameter reductions is made possible by the length of recording chart which is proportional to pipeline length. Offshore pipelines are now being laid in depths considered impossible a few years ago. Severe weather conditions in many offshore petroleum areas further complicate construction of the lines. Under such conditions, buckling of the pipeline between the stern of the lay barge and the touchdown point is not uncommon. Repairs to an offshore pipeline after construction are more expensive (by a factor of ten) than those made while the lay barge is on-station. For these reasons a buckle detection system operating on the barge during pipe laying is necessary. The K-Troll system uses a roller supported measuring tool pulled inside the pipeline on an electromechanical tow cable. The cable length allows inspection of the pipe after it has contacted the ocean floor. Diameter readings are displayed and recorded on a data console in the lay barge control tower..

331708 AIX-08:332716, NTS-78:001441, EDB-78:020335

Application of radioisotopes in oil, gas and petrochemical industries. Transport of hydrocarbons

Castagnet, A.C.G.

Instituto de Energia Atomica, Sao Paulo (Brazil). Divisao de Aplicacao de Radioisotopos na Engenharia e na Industria

38 p. Aug 1976

Country of Publication: Brazil

Journal Announcement: EDB7712

Availability: Dep. NTIS (US Sales Only), PC A03/MF A01.

Document Type: Report

Languages: Portuguese

Subfile: NTS .(NTIS); AIX .(non-US Atomindex input)

Report No.: IEA-TI-51

Work Location: Brazil

The fundamentals and the methodology of the principal radioisotope techniques used in the construction and operation of oil-pipes are described. These techniques deal with gamma radiography of weilds, scraper tracking, leak localization in underground pipes and interface detection. The practical use of the mathematical formulas deduced during the theoretical treatment of each method is illustrated through several examples. A procedure for the design of an interface detector based on gamma ray attenuation is presented..

TABLE B.2 PERTINENT REPORTS APPLICABLE TO CASING INSPECTION (CONTINUED)

-13-

ACCESSION NUMBER	2880789
TITLE	NEW ELECTRONIC DEVICE FOR DETECTING A PIPELINE RUPTURE.
AUTHORS	MONDEIL L
ORGANIZATIONAL SOURCE	SOCIETE NATIONALE ELF-AQUITAINE PRODUCTION FRANCE
SOURCE	97TH CONGRESS OF THE ASSOCIATION TECHNIQUE DE L'INDUSTRIE DU GAZ EN FRANCE, PARIS, SEPT. 23/26, 1980 15-22 IN FRENCH GAS ABSTR. ABSTR.NO. 80-1507 V36 N.12 (DEC. 80)
CATEGORY CODE NAME	PIPELINE OPERATING PROBLEMS
INDEX TERMS	ABSTRACT; ALARM; BATTERY; BURSTING; CASING; DETECTOR*; ELECTRIC CIRCUIT*; ELECTRIC POWER SOURCE; ELF AQUITAINE; ENERGY SOURCE; FAILURE; FIREPROOFING; INSTRUMENT*; INSULATING MATERIAL; LEAK; LEAK DETECTOR*; MEETING PAPER; OPERATING CONDITION; PIPELINE*; PRESSURE; SAFETY EQUIPMENT; SOLAR ENERGY; THERMAL INSULATION; TUBE; VALVE

Leaks in gas grids. Localisation and criteria of judgement
Discussion meeting of gas engineers, Augsburg 1979. Reports
Gasfachliche Aussprachetagung, Augsburg 1979. Berichte
DVGW-Schriftenreihe Gas
Pucknat, D.
172-188 p. 1979
Country of Publication: Germany, Federal Republic of
Publ: ZfGW-Verl.,Frankfurt am Main, Germany, F.R.,
Journal Announcement: EDB8202
Document Type: Analytic of a Book
Languages: German
Subfile: DE .(Federal Republic of Germany (sent to DOE from))
Work Location: Germany, Federal Republic of

Underground gas pipelines are effected by mechanical, physical and chemical influences which might cause leaks. Therefore, a systematical surveillance of the pipelines is necessary. Tha gas measuring and gas detecting equipment used are only suitable to localize leaks, but not to measure the gas quantity. In order to determine the danger arising from the leak, a practical system of classification is introduced using which the sequence of eliminating the leaks detected can be determined.

Leak Detection in Underwater Oil Pipelines

National Maritime Research Center-Galveston, Tex. Cargo Handling and Terminals Program.

AUTHOR: Jackson, Patricia A.
C1972K2 Fld: 14B, 21D, 85E*, 86L, 68D, 73D GRAI7401
Sep 73 41p*
Rept No: NMRC-272-23100-R2
Project: NMRC-272-23100
Monitor: 18

Abstract: The findings of a brief state-of-the-art review of leak detection devices suitable for underwater oil pipelines is discussed. The review includes consideration of leak or crack detection by flow measurement, pressure, ultrasonics, acoustic emission, magnetic flux, visual examination, eddy current, radioactive slugs, electromechanical and electrochemical tapes, doublewalled pipes, coaxial cable lasers, permeable membranes, and remote sensing.

TABLE B.2 PERTINENT REPORTS APPLICABLE TO CASING INSPECTION (CONTINUED)

	210529 PROCESS AND APPARATUS FOR THE NONDESTRUCTIVE TESTING OF TUBULAR OR CYLINDRICAL OBJECTS
SOURCE	FR 2.241.224. C 3/14/75. F 8/14/73; BRITISH STEEL CORP
ENTRY YEAR	1975
INDEX TERMS	ACOUSTICS; ALLOY; BRITISH STEEL CORP; *CONSTRUCTION; DATA ANALYSIS; DATA PROCESSING; DATA RECORDING; *DETECTION; ELASTIC WAVE; FERROUS ALLOY; *FLAW DETECTION; FRENCH; INSPECTING; LINE PIPE; MAINTENANCE; MECHANICAL WAVE; *NONDESTRUCTIVE TESTING; PATENT (A); PIGGING; PIPE; PIPE INSPECTION; *PIPE TESTING; PIPELINE; *PIPELINE CONSTRUCTION; PIPELINE PIG; PIPELINING, SHIP + STORAGE; RECORDING; REPAIR; SOUND WAVE; SOUND WAVE PROPAGATION; STEEL; *TESTING; TUBULAR GOODS; *ULTRASONIC TESTING; ULTRASONICS; WAVE; WAVE PHENOMENON; WAVE PROPAGATION; (P) FRANCE

409847 ERA-03:053013, EDB-78:109027
Energy and thermography: partners of tomorrow
Proceedings of the third biennial infrared information exchange
Pontello, A.P.; Warren, C. (ed.)
Federal Energy Administration, Philadelphia
41-52 p. 1977
3. biennial infrared information exchange meeting St. Louis, MO, USA 24 Aug 1976
Country of Publication: United States
Publ: AGA Corp.,Secaucus, NJ.
Journal Announcement: EDB7809
Note: See CONF-760886--
Document Type: Analytic of a Book; Conference literature
Languages: English
Subfile: ERA .(Energy Research Abstracts); TIC .(Technical Information Center)
Work Location: United States

Thermography has been successfully applied in the area of energy conservation where suspected heat losses have been detected from homes and buildings. In demonstrated tests conducted in a large metropolitan city, located in the northeastern section of the United States, aerial and ground level thermograms revealed substantial heat loss from buildings and homes by conduction and infiltration. Sources of heat loss were attributed to inefficient and/or lack of weather-stripping, caulking, insulated windows, chimneys, attic doors, and insulation materials. Thermography further demonstrated its capability to monitor our energy resources by detecting potential fire hazards at oil refinery sites. Scanning of refinery complexes by both infrared aerial and ground level thermography methods indicated fuel storage tank levels and ''hot'' spots in sections of pipelines, distillation facilities, storage tanks, and other refinery operations where, while normal, should be closely observed during any crisis created by fires. In the event of a fire, observation of a refinery site, by thermography, could indicate the neighboring areas where ''hot'' spots are present posing additional fire hazards..

735230 EDB-81:043486

Application of acoustic emission analysis to the integrity monitoring of offshore steel production platforms

Rogers, L.M.; Hansen, J.P.; Webborn, C.

Unit Ispec Co, UK

Mater. Eval. (United States) 38:8 39-49 p. Aug 1980

Coden: MAEVA

Journal Announcement: EDB8104

Document Type: Journal Article

Languages: English

Subfile: EI .(COMPENDEX)

Work Location: United Kingdom

Acoustic emission from a propagating fatigue crack was studied during the fatigue testing of a large scale double-T tubular welded joint with 1.8m dia., 75mm thick chord members and 0.9m dia., 36mm interconnecting branch. At commencement of testing strong emissions were detected from a 110mm long subsurface defect. The emissions decayed to an insignificant level after 250,000 cycles, suggesting that the defect had attained a stable state. The first sign of fatigue cracking occurred after 627,000 cycles and strong regular acoustic emission was detected after 1,344,000 cycles when the fatigue crack was 400mm long and 10mm deep. Good correlation was obtained between the acoustic emission from the propagating fatigue crack and crack extension as measured by the ac potential drop method. After the development of the through-thickness-crack (at 3,210,000 cycles), it was possible to resolve for the first time crack closure emissions which were generally less prolific and of lower amplitude than the crack growth emissions. 10 refs..

422242 ERA-03:057437, EDB-78:121423

Nondestructive examination of subsea structures using acoustic emission technology

Ninth annual offshore technology conference. Proceedings. Volume II

Parry, D.L.

Exxon Nuclear Co., Inc., Richland, WA

467-474 p. 1977

Offshore technology conference Houston, TX, USA 2 May 1977

Country of Publication: United States

Publ: Offshore Technology Conference,Dallas, TX,

Journal Announcement: EDB7811

Document Type: Analytic of a Book; Conference literature

Languages: English

Subfile: ERA .(Energy Research Abstracts); TIC .(Technical Information Center)

Report No.: CONF-7705120-P2

Work Location: United States

In October of 1976, Exxon Nuclear Company, Inc. conducted the first offshore, undersea nondestructive examination using their NDT-ACOUSTICS technology. For a period of over six years, Exxon Nuclear has been applying their technology for the integrity of large industrial structures. The October test was, however, the first application of acoustic emission analysis technology in an undersea environment on an offshore platform. The technology was demonstrated to be a sensitive new tool for the fast, accurate detection and location of discontinuities in subsea structures..

TABLE B.3 PERTINENT REPORTS ON ACOUSTIC EMISSION INSPECTION

792008 EDB-81:100273
Acoustic emission monitoring techniques applied to offshore structure--subsea and topside applications
European offshore petroleum conference and exhibition
Webborn, T.J.C.; Rogers, L.M.; Hansen, J.P.; McWade, S.
Unit Insp Co
415-421 p. Oct 1980
1. European offshore petroleum conference exhibition London, UK 21 Oct 1980
Country of Publication: United Kingdom
Publ: European Offshore Petroleum Conference,London, England
.
Journal Announcement: EDB8107
Document Type: Analytic of a Book; Conference literature
Languages: English
Subfile: EI .(COMPENDEX)
Report No.: CONF-8010200-
Work Location: United Kingdom
The introduction of continuous monitoring techniques to establish structural integrity is reviewed and the promising acoustic emission analysis method is described in some detail. The use of acoustic emission analysis to monitor fatigue cracking or repaired cracks in the submerged part of offshore structures has been researched and applied to a number of platforms in the North Sea, together with laboratory and offshore exercises to assess the feasibility of the technique. The extension of the method to topside applications, for which land based experience can be paralleled, is shown to offer a number of benefits when applied to pressurized components and systems, critical areas of the superstructure, slew ring cranes and general leak detection. 9 refs..

422233 ERA-03:057428, EDB-78:121414
Acoustic emission: new inspection technique
Ninth annual offshore technology conference. Proceedings. Volume II
Dunegan, H.L.
349-356 p. 1977
Offshore technology conference Houston, TX, USA 2 May 1977
Country of Publication: United States
Publ. Offshore Technology Conference,Dallas, TX, •
Journal Announcement: EDB7811
Document Type: Analytic of a Book; Conference literature
Languages: English
Subfile: ERA .(Energy Research Abstracts); TIC (Technical Information Center)
Report No.: CONF-7705120-P2
Work Location: United States
It is shown that high amplitude acoustic emission signals are present from corrosion products accumulated on crack surfaces of a steel similar to that used for offshore platforms. It is postulated that these signals, as well as those present during crack extension due to fatigue can be utilized to locate and evaluate fatigue cracks growing on an offshore platform. Critical issues for successful continuous monitoring such as signal amplitude, separating valid signals from noise and operator involvement are given. Solutions of the critical issues involve the use of (1) frequency filtering, (2) spatial filtering, (3) parametric filtering, and (4) amplitude distribution analysis. An example of a new method of data logging using a computer-interfaced acoustic emission system which gives an operator a quick survey of the relative activity of all nodes on a typical platform is presented. It is shown that acoustic emission techniques can provide practical alternatives to present methods being used for inspection of deep water offshore structures undergoing structural degradation due to fatigue crack growth.

TABLE B.4 PERTINENT REPORTS FOR NDE FOR OFFSHORE STRUCTURES

697582 EDB-81:005831

Strategy for monitoring, inspection and repair for fixed offshore structures

Proceedings of the international conference on the behavior of offshore structures, 2nd (BOSS '79), 1979. Vol. 2 (Oil wells, natural gas wells)

Marshall, P.W.; Stephens, H.S.; Knight, S.M. (eds.)

Shell Oil Co, USA

369-390 p. 1979

2. International conference on the behaviour of offshore structures London, UK 28 Aug 1979

Country of Publication: United Kingdom

Publ: British Hydromechanics Research Association,Cranfield, England,

Journal Announcement: EDB8012

Document Type: Analytic of a Book; Conference literature

Languages: English

Subfile: EI .(COMPENDEX)

Report No.: CONF-7908134-

Work Location: United States

The philosophy of making trade-offs between cost and risk permits rational allocation resources in offshore energy development projects, provided the technical and economic considerations are formulated so as to include indirect human and social consequences. 15 refs..

AD-A100 676/6 NTIS Prices: PC A06/MF A01

The Laboratory Application of a Nondestructive Evaluation Technique for Detecting Incipient Crack Formation in Model Offshore Structures

Daedalean Associates, Inc., Woodbine, MD. (051740000 390758)

AUTHOR: Jachowski, Bruce; Fresch, David C.; Brasfield, Ray G.; Thiruvengadam, A. P.

Technical rept.

G4911B1 Fld: 13B, 50B GRAI8122

May 80 102p

Rept No: DAI-LLY-7763-003-TR

Contract: N00014-77-C-0567

Abstract: This report discusses the technical feasibility of applying an internal Friction Damping - Nondestructive Evaluation technique for offshore structures. The theory of internal friction damping is presented as it has been historically applied to various materials. The report then discusses the methodology for the application of internal friction damping. The experimental apparatus and specific laboratory technique as applied to a 1/14 scale model offshore structure is next discussed in detail. The experimental test results are related to the feasibility of employing the test technique as a device for detecting incipient cracking in offshore structures. The report includes discussion of specific conclusions and recommendations for further investigation of in-service offshore structures. (Author)

TABLE B.4 PERTINENT REPORTS FOR NDE FOR OFFSHORE STRUCTURES (CONTINUED)

	2702467
	MAINTENANCE/PREDICT PUMP PROBLEMS WITH (ACOUSTIC) IFD ((INCIPIENT FAILURE DETECTION) SURVEILLANCE)
AUTHORS	BLOCH H P; EXXON CHEMICAL CO
ORGANIZATIONAL SOURCE	EXXON CHEM. CO.
SOURCE	HYDROCARBON PROCESS. V60 N.1 87-94 (JAN. 1980) IN ENGLISH
CATEGORY CODE NAME	EQUIPMENT-MATERIALS-UTILITIES
INDEX TERMS	ACOUSTICS*; ALIGNMENT; ANTIFRICTION BEARING; BEARING; CASING; CAVITATION; CENTRIFUGAL PUMP*; COMPUTER CONTROL; COMPUTING; ELECTRIC MOTOR; ESSO; FAILURE; FLUID FLOW; FORCE; LEAK; MAINTENANCE*; MONITORING*; OPERATIONAL PROBLEM; PIPING SYSTEM*; PUMP*; RESONANCE; REVIEW; SEAL; STRESS; TRANSDUCER; VIBRATION
SUPPLEMENTARY TERMS	ACOUSTIC INCIPIENT FAILURE DETECTION
LINKED TERMS	ALIGNMENT; ELECTRIC MOTOR; PUMP
ABSTRACT	Maintenance/Predict Pump Problems with [Acoustic] IFD [(Incipient Failure Detection) Surveillance]. A discussion of acoustic IFD covers differences from conventional vibration monitoring [Abstract No. 24-8427] the effectiveness of high-frequency IFD transducers in detecting defective bearings, as determined by resonant frequency and location; economic justification for basic

218829 EDB-77:056636

Permanently installed ultrasonic testing system for offshore platforms

Second annual offshore technology conference. Vol. II

Ostrofsky, B.

251-256 p. 1970

Offshore technology conference Houston, TX, USA 22 Apr 1970

Country of Publication: United States

Publ: Offshore Technology Conference,Dallas,

Journal Announcement: EDB7705

Note: See CONF-700464--P2

Document Type: Analytic of a Book; Conference literature

Languages: English

Subfile: TIC .(Technical Information Center)

Work Location: United States

An ultrasonic pulse-echo system has been designed and tested for monitoring structural welds on offshore drilling rigs in severe climates. The design includes 144 permanently installed shear-wave transducers for the inspection of 80 areas at interior and exterior surfaces of a rig, both above and below water level. Protective metal capsules have been designed to enclose the transducers, which are expected to operate reliably for at least five years without servicing, even when located 125 feet under water. The transducer terminals can be connected to a single instrument on the platform of a rig, where the ultrasonic pulses can be received and read through a suitable switching mechanism. Although originally designed to monitor two types of weld geometries, the system can be adapted for other configurations as well as for thickness measurements..

TABLE B.4 PERTINENT REPORTS FOR NDE FOR OFFSHORE STRUCTURES (CONTINUED)

AERE-R-8067 NTIS Prices: PC A04/MF A01

Underwater Inspection of Fixed Offshore Platforms. A Review and Assessment of Techniques

UKAEA Research Group, Harwell. Atomic Energy Research Establishment. (6408000)

AUTHOR: Bainton, K. F.; Silk, M. G.; Williams, N. R.; Davies, D. M.; Lyon, I. R.
C6602G2 Fld: 08I, 48A ERA0105
Jul 75 62p
Monitor: 18
U.S. Sales Only.

Abstract: The techniques applicable to both present gas production platforms and planned oil production platforms in water to at least 600 ft are reviewed. The limitations of these techniques are discussed and possible means of reducing them are indicated. The minimization of the problems encountered in underwater inspection is considered. The options explored are providing the diver with better equipment, introducing equipment not requiring operation by a diver skilled in nondestructive testing, replacing divers with fixed detectors or scanner on the rig or with detectors fixed to submersibles, and setting realistic inspection standards.

PB-300 381/1ST NTIS Prices: PC A04/MF A01

Inspection of Offshore Oil and Gas Platforms and Risers

Assembly of *Engineering Marine Board*, Washington, DC •Geological Survey, Reston, VA. Conservation Div.•Office of Naval Research, Arlington, VA. (046951000)
Final rept. 1977-79.
F2314E3 Fld: 13M, 14B, 13B, 50B•, 47• GRAI7925
Jul 79 58p•
Contract: N00014-76-C-0309
Monitor: USGS/CD-79/001

Abstract: Various aspects of offshore platform mandated responsibility are discussed. Particular emphasis is placed on the structural inspection of offshore oil and gas platforms; and recommendations for an inspection program of offshore platforms are presented. Inspection considerations for the identification of structural flaws, degradation, or changes that would require remedial measures to safeguard human life, conserve natural resources, and protect the environment are addressed. Criteria for inspections address such issues as safety of personnel, adequacy of monitoring techniques, cost-benefit relationships, adequacy and credibility of inspections, priorities, and available technology. Recommended inspections have been placed in four categories relating to the merits of the inspections and the available Nondestructive Examination (NDE) techniques. Corresponding and potential Research and Development areas are identified. A bibliography of current documents, papers, and reports is included.

755491 EDB-81:063750
''Vibro-detection'' applied to offshore platforms
Lepert, P.; Chay, M.; Heas, J.Y.; Narzul, P.
Syminex
Offshore Technol. Conf. (United States) 4 627-634 p.
1980 Coden: OSTCB
12. annual offshore technology conference Houston, TX, USA
5 May 1980
Journal Announcement: EDB8104
Document Type: Journal Article; Conference literature
Languages: English
Subfile: EI .(COMPENDEX)
Report No.: CONF-8005152-
Work Location: United States
This paper concerns the main features of a joint research project about the techniques using the dynamic properties of an offshore steel structure to detect a structural damage. A relation is established between the occurrence of a failure and the modification of the dynamic properties of the structure. Finally, vibro-detection is presented as a powerful tool for future offshore surveys, and an efficient complement to the conventional nondestructive testing methods. 5 refs..

AD-A055 727/2ST NTIS Prices: PC A25/MF A01

Deepwater Port Inspection Methods and Procedures

Science Applications Inc Mclean Va (408404)

AUTHOR: Mastandrea, J. R.; Gilbert, K. J.; Simmons, J. A.; Kimball, P. B.
Final rept.
E2045C1 Fld: 13B, 13J, 68D, 47 GRAI7820
Mar 78 591p
Contract: DOT-CG-60670-A
Monitor: USCG-D-31-78
Prepared in cooperation with Science Applications, Inc., Santa
Abstract: The Deepwater Ports Act of 1974 gives the Secretary of the Department of Transportation and, by delegation, the U.S. Coast Guard, specific authority to regulate the design, construction and operation of Deep Water Ports (DWPs) off the coast of the United States. Some of the regulations deal with safety and prevention of oil pollution. This study is one of several providing information for future regulations dealing with pollution. It identifies and assesses inspection methods and procedures for the Oil Transfer System (OTS) of DWPs. Recommendations are made for inspection methods and procedures that would provide an effective means of minimizing accidental oil spills from the OTS of DWPs in U.S. waters. The recommendations were based primarily on a cost-effectiveness analysis for both commonly used and technologically advanced inspection methods and procedures that were considered to provide the best available technology for DWPs in U.S. waters. Inspection methods considered apply primarily to the components of the OTS, onsite, during normal operations and also to components of other systems whose failure could affect the integrity of the OTS. Failure of components and subsystems of the OTS, which contributed most significantly to the risk of oil spills, were identified in a system safety analysis. (Author)

761412 AIX-12:592769, EDB-81:069672
Improvements in or relating to the inspection of underwater structures (Patent)
Caldecourt, L.R.; Evans, G.V.; Parsons, T.V.
Patent No.: GB 2,041,,200/A/ Assignees: UKAEA Headquarters, London
6 p. 3 Sep 1980
Country of Publication: United Kingdom
Journal Announcement: EDB8103
Document Type: Patent
Languages: English
Subfile: AIX .(non-US Atomindex input)
Work Location: United Kingdom
A radiation detector is described, for use in the inspection of underwater structures, which is capable of withstanding high pressures and arduous marine conditions. The ingress of water into the body of the radiation detector tube is prevented by the use of a resilient waterproof compound. Marine structures incorporating such radiation detectors are described, whereby the presence or density of flowing cement grout in the legs of an offshore platform may be determined..

843730 EDB-82:018568
Inspecting pipeline clusters, wellheads, fixed platform/sub O/ pollution control
Furse, L.D.; Shiller, G.I.; Slater, R.A.; Vernon, J.W.
Hydrospace (London) (United Kingdom) 5:2 53-56 p. Aug 1972 Coden: HYSPA
Journal Announcement: EDB8008
Document Type: Journal Article
Languages: English
Subfile: TUL .(University of Tulsa)
Work Location: United Kingdom
The capabilities and work of the Nekton fleet of 3 submersibles is described with particular reference to services to the offshore oil industry. The types of projects in which Nekton submersibles are presently finding work as classified under 5 general categories: inspection; monitoring; geological mapping and sampling; biological ivestigation and inventory; and search and recovery. A typical operation is described which involved inspections on pipeline cluster, a production platform, 3 underwater wellheads, and a pollution control structure. (Abstract only - original article not available from T.U.).

755458 EDB-81:063717
Inspection of concrete platforms: crack detection by current density measurements
Bournat, J.P.; Stankoff, A.; Auboiroux, M.
Intersub Dev
Offshore Technol. Conf. (United States) 2 247-254 p. 1980 Coden: OSTCB
12. annual offshore technology conference Houston, TX, USA 5 May 1980
Journal Announcement: EDB8104
Document Type: Journal Article; Conference literature
Languages: English
Subfile: EI .(COMPENDEX)
Report No.: CONF-8005152-
Work Location: United States
Evaluation of concrete wall condition is one of the major inspection tasks that has to be performed on concrete production platforms. A new survey is proposed allowing crack detection over large concrete areas through a measurement of the dc currents due to corrosion or cathodic protection when contact occurs between seawater and the reinforcement bars 3 refs..

TABLE B.4 PERTINENT REPORTS FOR NDE FOR OFFSHORE STRUCTURES (CONTINUED)

755482 EDB-81:063741
Evaluation of internal corrosion on marine risers by divers using acoustical holography techniques
Stankoff, A.; Guenon, Y.; Thomas, G.
Intersub-Dev
Offshore Technol. Conf. (United States) 4 383-393 p. 1980 Coden: OSTCB
12. annual offshore technology conference Houston, TX, USA 5 May 1980
Journal Announcement: EDB8104
Document Type: Journal Article; Conference literature
Languages: English
Subfile: EI .(COMPENDEX)
Report No.: CONF-8005152-
Work Location: United States
Monitoring and maintenance of marine risers is suggested as essential for operators of offshore oil and gas production platforms, as any damage to the risers can result in a partial or total shut down of production. This paper describes a method producing a three-dimensional acoustical image of the internal face of a marine riser. Inspection is carried out by a diver operating from a lock-out submersible. 6 refs..

409933 GAP-78:011254, EDB-78:109113
Thermal imaging techniques applied for preventive maintenance and energy savings
Ind. Heat. (Pittsburgh) (United States) 46:6 34-36 p. Jun 1978 Coden: INHTA
Journal Announcement: EDB7809
Document Type: Journal Article
Languages: English
Subfile: GAP .(General and Practical); TIC .(Technical Information Center)
Work Location: United States
The use of infrared thermography to detect heat losses in industrial equipment, and thereby to identify defects in the condition or operation of such equipment is discussed. Thermographs of combustion equipment, recuperators, process heat pipelines, storage tanks, steam traps, and power substation insulators are shown. Eliminating the defects results in energy conservation. (LCL).

395402 EDB-78:094582
New ultrasonic tool checks offshore pipeline, welds
Jackson, H.
MatEval NDT Co, Merseyside, Engl
Oil Gas J. (United States) 76:11 78, 80 p. 13 Mar 1978
Coden: OIGJA
Journal Announcement: EDB7808
Document Type: Journal Article
Languages: English
Subfile: EI .(COMPENDEX)
Work Location: United Kingdom
Continued worldwide construction of offshore oil and gas pipelines requires better methods for inspecting welds and determining corrosion damage. Several new ultrasonic methods for evaluating weld integrity and pinpointing area of possible corrosion have been developed, and are highghlighted here. These automated ultrasonic instruments are being used for nondestructive internal and external inspection of oil and gas risers at production platforms, tubulars or cans in the rig fabricating yard, and pipeline field welds..

TABLE B.4 PERTINENT REPORTS FOR NDE FOR OFFSHORE STRUCTURES (CONTINUED)

856816 EDB-82:031655

Underwater magnetic particle inspection aids platform repairs

Ocean Ind. (United States) 14 53-54 p. May 1979

Coden: OCIDA

Journal Announcement: EDB8202

Document Type: Journal Article

Languages: English

Subfile: GSA .(Gas Abstracts)

Work Location: United States

Owing to their present accuracy and cost-effective procedures, nondestructive testing techniques offer an immediate answer to the pressing need for routine inspection and preventive maintenance of offshore structures. With magnetic-particle inspection, a diver releases a premixed solution of magnetic particles onto a structure's metal surface between the poles of an applied magnetic field, usually in areas adjacent to welds. The magnetic field gathers the fluorescent particles into surface cracks, which then become visible. Putty strips applied to cracks make a casting of the fissure that can be brought to the surface for examination. Where greater penetration of the metal surface is necessary, ultrasonic testing offers a complimentary approach to the magnetic-particle procedure. This method detects subsurface voids and stress fissures but is of limited use for detecting surface defects..

END
DATE
FILMED

JUNE 14, 1983