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PIPELINE TRANSPORTATION SAFETY

VOLUME II - AN ANNOTATED BIBLIOGRAPHY (PART I)

Prepared for

U.S. DEPARTMENT OF TRANSPORTATION
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Washington DC 20590

DRAFT

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16. Abstract

This annotated bibliography (Part I) provides reference information and background material to assist in the strategic planning of future pipeline transportation safety research and development priorities for the Transportation Programs Bureau of the U.S. Department of Transportation. The period covered is from 1970 through 1979 and includes research and development sponsored by both government agencies and industry. Part II of this bibliography will be published within a year.

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PREFACE

A literature search is being conducted by the Transportation Systems Center for reports, books, papers, and journal articles which are relevent to pipeline transportation safety research and development. This bibliography will give information on much of the literature which has been published on such subjects as pipeline corrosion, protection, fracture analysis, manufacturing, testing, welding, safety procedures, etc.

The references and abstracts have been selected from information obtained during literature searches of organizations such as: U.S. Department of Transportation Headquarters Library, Research and Special Programs Administration, National Bureau of Standards, Department of Energy, Department of Defense, National Bureau of Standards, National Transportation Safety Board, American Gas Association, Gas Research Institute, American Petroleum Institute, Pipeline Industry journals, and special libraries.

The references in this bibliography have been grouped into three major categories:

1. Reports,
2. Journal Articles,
3. Books, proceedings, conference papers, brochures, and monographs.

The references in the first category are arranged alphabetically by corporate source and the other two categories are arranged alphabetically by author.

Each reference is preceded by an accession letter and a four-digit number (ex. R0150). The letter R is used for the report series, the letter J is used for the journal series, and the letter B is for books, proceedings, papers, or monographs. As far as possible, references are supplied with a corresponding abstract.

In some references there is an accession number listed for retrieval from the National Technical Information Service (NTIS) or other organizations.

An index by corporate source, personal author, and subject is also provided after the references. Each index contains the accession letter and number and page number (ex. R0330 R-13).

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R0010
AMF, Inc., Goleta, Calif. Advanced Systems Lab. (Sponsored by U.S. DOT, Washington, DC. Office of Pipeline Safety Operations).
STUDY ON CURRENT PRACTICES, TECHNOLOGIES, PROBLEMS, AND RECOMMENDATIONS RELATING TO THE OVERALL SAFETY OF GAS PIPELINE DISTRIBUTION SYSTEMS.
Bartol J.A. and Nichols, R.
Final Report, Nov. 28, 1975, 113 p.

This study provides an overall assessment of the safety of natural gas distribution systems and the measures being promoted or in use to increase safety. The report summerizes data collected by the Office of Pipeline Safety Operations (OPSO) and the results of OPSO sponsored studies and other research intended to improve the safety of specific gas distribution problems. The report also focuses on several problem areas identified as important from a safety standpoint and formulates conclusions and recommendations based on previous work and research currently underway. Techniques employed included a wide literature survey, review of leakage data, and fault tree analysis. The main topics in the report relate to gas distribution pipeline system inspection and assessment, corrosion, outside force damage, odorization, plastic pipe ueage, emergency plans, valving and rapid shutdown, and master metering. This assessment include findings, conclusions, and recommendations for increasing gas system safety for each topic.

PB-251 996/5ST

R0020
Army Biological Labs, Frederick, Md.
GRAPHITIZATION OF CAST IRON AS AN ELECTROBIOCHEMICAL PROCESS IN ANAEROBIC SOILS.
Von Wolzogen Kurh, C.A.H. and van derVlugt, L.S.
Report No. trans-1021, March 1964, 2 p.

The topics in this report include: review of the literature; description of the phenomenon of corrosion of cast iron in the ground; sulfate reduction and its occurrance in nature; consideration of the possibility that hydrogen sulfide from sulfate reduction is the cause of iron graphitization; significance of sulfate reduction in the process of iron corrosion in the ground; chemistry of the anaerobic iron-corrosion process with sulfate reduction; process of iron corrosion with sulfate reduction; iron corrosion processes encountered in waterline practice, considered from the electrochemical point of view; the concept of 'aggressiveness' of soils; and a discussion of pipe material and its protection in connection with soil aggressiveness.

AD-617 552

R0030
Army Foreign Science and Technology Center, Charlottesville, Va.
POLYMER AND POLYMER-BITUMAN MATERIALS FOR PROTECTING PIPELINES FROM CORROSION.
Kozlovskaya, A.A.
Report No. FSTC-HT-23-1063-72, Mar. 29, 1972. 100 p. (Translation.)

The VNIIST has developed an epoxy-coal-tar composition which has the properties necessary for coating large-diameter gas pipelines: ability to be hardened by hot or cold methods, mechanical stability, chemical stability, reasonable cost, good adhesion, long service life, stability over a wide temperature range. The book discusses: raw materials for polymer and polymer-bitumen coatings; rubber-bitumen and polymer-bitumen insulating materials (brizol wrapping, bitudiene, bitulene, bitumen-polydiene-polypropylene enamel); coatings based on synthetic resins; techniques for preparing and applying coatings under factory and field conditions. (Author)

AD-745 549

R0040
Army Foreign Science and Technology Center, Charlottesville, Va.
LAMINATED PLASTICS IN CHEMICAL EQUIPMENT AND PIPELINES.
Shevchenko, A.A. and Vlasov, P.V.
Report No. FSTC-HT-23-75-73, June 21, 1973, 234 p. (Translation.)

This Russian report gives a classification and nonmeclature of laminated materials, their physiocomechanical characteristics, and their stability in corrosive media. Basic information on the failure mechanism of laminated plastics is presented. Methods of testing laminated plastics for corrosive stability, longevity, and creep are set forth. Methods of calculating and designing chemical equipment and pipelines made of laminated plastics are given. The book is written for designers of chemical equipment and engineering technicians in the chemical industry. Since there is a lack of data on the variation of the strength characteristics of laminated plastics in contact with chemically corrosive media in typical chemical processing conditions, the systematized calculation materials given in the book as well as methods for obtaining required data on strength and other characteristics of laminated plastics are intended to partially fill this gap. (Modified author abstract)

AD-764 433

R0050
Army Mobility Equipment Research and Development Command, Fort Belvoir, VA.
MILITARY PETROLEUM PIPELINE SYSTEMS.
Studebaker, W.E.
MERADCOM-2249, June 1978, 252 p.

The present Army capability to install, operate, and maintain petroleum produce pipelines is examined in light of current commercial pipeline technology and projections of fuel consumption for combat units in the event of future hostilities. The objective of this investigation is to provide a measure of effectiveness for and determine the technical feasibility of alternative pipeline systems operating as subsystems in a large logistical system for distribution of fuels in a theater of operations during wartime conditions. A broad array of pipe materials, pipe joining techniques, pumping equipment, ancillary pipeline components, and system designs are evaluated. The findings indicate that substantive improvement in the operational effectiveness of military pipeline can be achieved using aluminum pipe and self-latching mechanical couplings in lieu of the existing military standard lightweight steel pipe joined by grooved-end, split-ring mechanical couplings. High-speed, medium-duty, diesel-engine-driven pump units are recommended for all pipeline pump station applications. Flexible hoselines are not an efficient or cost effective means for transporting large volumes of fuel over long distances. (Author)

AD-A061 492/5WT

R0051
Arthur D. Little, Inc., Cambridge, Mass.
TECHNOLOGY AND CURRENT PRACTICES FOR PROCESSING, TRANSFERRING AND STORING LIQUEFIED NATURAL GAS.
Allan, D., Atallah, S., et al.
Report No. DOT/OPS-75/01, December 1974, 205 p.

Current state-of-the-art safety information related to the design, location, construction, operation and maintenance of facilities required for liquefaction, transfer, storage, and revaporization of natural gas is assembled and summarized. A detailed review of codes, standards and practices pertaining to LNG installations is presented along with an evaluation of present trends in LNG safety requirements. LNG safety research programs completed or in progress are described and key research results summarized. Finally, a methodology for quantitative assessment of risks associated with LNG facilities is outlined. The report provides a compendium of background information from which the Office of Pipeline Safety may select and build in carrying out its regulatory responsibilities relating to LNG facilities.

PB-241 048/8GA

R0052
Arthur D. Little, Inc., Cambridge, Mass.
SUPPLEMENT TASK III - SUMMARY OF LNG SAFETY RESEARCH.
Atallah, S., Drake, E., et al.
Report No. DOT/MTB/OPSO-77/11, December 1974, 208 p. (see also PB-241 048.)

Results from major published research programs related to assessment and alleviation of potential LNG hazards are described. Topics covered include: vaporization and dispersion from LNG spills, boiling heat transfer rates for LNG on water, superheat 'explosions,' tank stratification and rollover, thermal radiation from LNG pool fires, detonation conditions, pool spread and thermal radiation from ignited LNG releases on water, deflagration of natural gas - air vapor clouds, and LNG fire control and suppression research. In addition to descriptive material, an extensive bibliography is included and future research needs are suggested.

PB-273 378/AS

R0053
AMF, Inc., Advanced Systems Laboratory, Goleta, CA 33017.
ENVIRONMENTALLY INDUCED CRACKING OF NATURAL GAS AND LIQUID PIPELINES - VOLUME 1.
Bartol, J.A., Wells, C.H., et al.
Report No. DOT/MTB/OPSO-78/01, December 1977, 146 p.

The purpose of this study was to provide the Office of Pipeline Safety Operations with an appraisal of the seriousness of certain types of environmentally induced cracking problems in natural gas and liquid petroleum pipelines. Measures for locating and identifying such cracks or for identifying conditions leading to their occurrence are identified. Predictions of future incidence probability are formulated and recommendations made for needed research and action.

PB-282 923/AS

R0054
AMF, Inc., Advanced Systems Laboratory, Goleta, CA 33017.
ENVIRONMENTALLY INDUCED CRACKING OF NATURAL GAS AND LIQUID PIPELINES - VOLUME 2.
Bartol, J.A., Wells, C.H., et al.
Report No. DOT/MTB/OPSO-78/02, December 1977, 150 p.

The purpose of this study was to provide the Office of Pipeline Safety operations with an appraisal fo the seriousness of certain types of environmentally induced cracking problems in natural gas and liquid or for identifying conditions leading to their occurrence are identified. Predictions of future incidence probability are formulated and recommendations made for needed research and action.

PB-282 924/AS

R0055
AMF, inc., Advanced Systems Laboratory, Goleta, CA 33017.
STUDY TO EVALUATE THE TOOLS AND PROCEDURES FOR ASSESSING THE SAFETY OF EXISTING GAS DISTRIBUTION SYSTEMS.
Bartol J.A., and Nichols, R.W.
Report No. DOT/OPS-75-04, January 1975, 199 p.

This study aimed at finding how the safety of natural gas distribution systems is related to their physical condition. The physical methods and equipment presently being used by gas distribution system companies for this purpose were reviewed and evaluated, as well as statistical data on leaks and failures. A review was made of (a) nondestructive testing techniques that appear applicable to the problem, and (b) current research and development directed to distribution system evaluation. As assessment was made of relative cost effectiveness of the various techniques.

PB-241 845

R0060
Battelle Memorial Inst., Columbus, Ohio, Defense Metals Information Center.
EXPLOSIVE BONDING.
Linse, V.D. and Wittman, F.H., et al.
Report No. DMIC-Memo-225, Sept. 15, 1967, 32 p.

The report describes in some detail the practical aspects of the explosive-bonding process, including basic mechanics of the process, practices of those in the field, metal combinations that have been bonded, and applications of explosively bonded products. Methods of testing points produced by explosive bonding are described. An exhaustive list of metal combinations which have been explosively-bonded is included in the report. (Author)

AF-820 736

R0070
Battelle Columbus Labs., Ohio. (Sponsored by U.S. DOT, Washington, D.C., Office of Pipeline Safety Operations)
TRANSPORTATION OF HIGHLY VOLATILE, TOXIC, OR CORROSIVE LIQUIDS BY PIPELINE.
Bearint, D.C. and Berry, W.E., et al.
Report No. DOT/OPS-75-06, Feb. 9, 1976, 320 p.

The purpose of this study was to identify and catalogue the specific esign, construction, operation, and maintenance practices of operators of ipeline systems transporting highly volatile, toxic, or corrosive liquids. he primary method of information gathering was a questionnaire mailed to elected liquid pipeline companies. A literature survey was also conducted. everal liquid pipeline companies that responded to the questionnaire were ubsequently contacted for additional information. Response to the question-aire was good; 19 pipelines completed questionnaires describing 25 systems ransporting liquefied petroleum gases (LPG) and 4 systems transporting anydrous

ammonia (NH3). It is concluded that the above situation is not necessarily unsatisfactory. While improvements are possible, the liquid pipeline companies appear to strive for a high level of integrity and reliability in all their pipelines, regardless of the commodity being transported.

PB-253 218/2ST

R0080
Bureau of Reclamation, Denver, Colo. Chemical Engineering Branch.
PRELIMINARY INVESTIGATION OF ELECTRODEPOSITED ASPHALT COATINGS.
Morrison, W.B.
Report No. ChE-55, Feb. 1966, 43 p.

A preliminary laboratory study was conducted to determine the feasibility of using electrodeposited asphalt coatings for controlling irrigation well casing corrosion. Black iron pipe sections (2 in. inside dia by 4 in. in length) corroded by nitric acid were used to simulate well casings. Investigation included tests to determine the best asphalt-emulsion material, dilution, and electrical potential requirement for depositing an asphalt coating on iron pipel. Durability of the deposited coatings was not evaluated. Test results indicated: (1) A satisfactory asphalt coating was electrodeposited on black iron pipe using a hard-base proprietary cationic asphalt emulsion diluted to 20% by volume concentration and subjected to a rectifier output voltage of 50 v; (2) For asphalt emulsion in concentrations of 5, 10, and 20% by volume, the 20% asphalt emulsion produced the best coating. (3) A potential drop across the electrodes ranging from 5 to 20 v, and an average current density of about 5 ma/in. squared provided the best condition for electrodeposition; (4) Tests conducted at higher voltages resulted in some breakout of asphalt on the surface and an increased amount of gas products formed at the pipe face. Also, the efficiency was lower. (5) The rate at which asphaltic materials are deposited is important for obtaining a uniform coating. (Author)

PB-170 813

R0090
Calgary Univ., Alberta (Canada).
DENSE PHASE TRANSMISSION OF NATURAL GAS.
Katz, D.L. and King, D.
Report No. CONF-731033-10, 1973, 32 p.

The advantages of transporting dense phase natural gas arise from its high density. Because a given amount of gas in a dense phase pipeline occupies a much smaller volume than in a conventional pipeline, a considerable reduction in the size of pipe and in the size of pumping installations can be achieved. Its disadvantages are caused by the low operating temperatures which require the use of refrigeration and more exotic metallurgy. The economic trade-off between the reduction in size and the increase in complexity is investigated.

R0100
California Univ. Berkeley, Coll. of Engineering
MARINE PIPELINES: AN ANNOTATED BIBLIOGRAPHY.
Bowie, G.I. and Wiegel, R.L.
Miscellaneous Report, March 1977, 61 p.

This annotated bibliography presents a compilation of literature describing the design, construction, operation, and maintenance of pipelines in the ocean and rivers. These pipelines may range in diameter from a few inches to more than 15 feet and may be short or more than 100 miles long. The problems encountered in installing and repairing pipelines are discussed. (Author)

AD-A038 747/2ST

R0110
Centre de Recherches Scientifiques et Techniques de l'Industrie des Fabrications Metalliques, Brussels, Belgium.
STRESSES IN PIPE BENDS OF OVAL OR ELLIPTICAL CROSS SECTION SUBJECTED TO INTERNAL PRESSURE.
Sys, A.
Report No. CRIF-MT-110, December 1975, 36 p.

A review is given of the different theoretical stresses which occur in a pipe bend. The results of stress measurements on three pipe bends with an out-of-roundness varying from 0 to 5.5% and with the following nominal dimensions are described: external diameter 274 mm; wall thickness 9.4 mm; inside radius of bending 1000 mm. After a brief discussion of the results, a comparison is made between the experimental and theoretical stresses from which it was found that a close relation exists between the formula of Dvorak and the experimental results. A proposal which is based on the ASME code is finally given, to determine the admissibility for out-of-roundness in pipe bends. (Author)

N76-24398/9ST

R0120
Cold Regions Research and Engineering Lab, Hanover N.H.
HAINES-FAIRBANKS PIPELINE: DESIGN, CONSTRUCTION AND OPERATION.
Garfield, D. and Ashline, C., et al.
Report No. CRREL-SP-77-4, Feb. 1977, 24 p.

This report, one of a series, is intended to provide a background for the analysis and evaluation of new pipelines being built in cold regions. Topics discussed include the initial design, construction, testing, operation and maintenance of, and modifications to, the 8-in. pipeline from the deep water port of Haines to military installations at Fairbanks, Alaska. The 626-mile multi-product pipeline began operation in 1956. The results of a corrosion survey completed in 1970 indicated that extensive renovation would be required to continue operations, and the section from Haines to Eielson Air Force Base was closed in 1973. (Author).

AD-A038 445/3ST

R0130
Department of Transportation, Washington, DC.
NATURAL GAS PIPELINE SAFETY ACT
Materials Transportation Bureau
Report No. DOT/RSPA/MTB-79-1, 1977, 96 p.

This report is a summary of DOT activity associated with the administration of the Natural Gas Pipeline Safety Act of 1968 for calendar year 1977. The report includes the year's highlights, and detailed coverage of gas pipeline failures and casualties, regulatory activity, compliance activity, federal/state cooperation and the grant-in-aid program, research and pipeline safety studies, dissemination of pipeline safety information, cooperation with other federal agencies, a summary of outstanding problems, a listing of waivers granted under the act, recommendations for additional legislation, and a report of activity related to the Alaska pipelines.

PB-294 717/4WT

R0131
Department of Transportation, Office of Pipeline Safety Operations, Washington, DC.
(FIRST) ANNUAL REPORT ON THE ADMINISTRATION OF THE NATURAL GAS PIPELINE SAFETY ACT OF 1968.
Report No. DOT/MTB/OPSO-77/03.

This report summarizes the pipeline safety activities of the Department of Transportation from the approval of the Natural Gas Pipeline Safety Act of 1968 to the end of 1968. Topics covered include creation of the Office of Pipeline Safety, publication of interim minimum Federal Safety Standards, appointment of the Technical Pipeline Safety Standards Committee, and meetings with representatives of State and Federal governmental agencies, the gas pipeline and related industries, industry associations, the trade press, and the general public.

PB-273 595/9ST

R0132
Department of Transportation, Office of Pipeline Safety Operations, Washington, DC.
SECOND ANNUAL REPORT OF THE SECRETARY OF TRANSPORTATION ON THE ADMINISTRATION OF THE NATURAL GAS PIPELINE SAFETY ACT OF 1968.
Report No. DOT/MTB/OPSO-77/04.

This report summarizes the major activities of the Office of Pipeline Safety for calendar year 1969, its first full year of operation. Topics covered include organizational developments; gas pipeline failures and casualties; Federal pipeline safety standards; and State participation in the Federal gas pipeline safety program.

PB-273 596/7ST

R0133
Department of Transportation, Office of Pipeline Safety Operations, Washington, DC.
THIRD ANNUAL REPORT OF THE SECRETARY OF TRANSPORTATION ON THE ADMINISTRATION OF NATURAL GAS PIPELINE SAFETY ACT OF 1968.
Report No. DOT/MTB/OPSO-77/05.

This report summarizes the major activities of the Office of Pipeline Safety for the calendar year 1970. Topics covered include organizational developments; gas pipeline failures and casualties; Federal pipeline safety standards; State participation in the Federal gas pipeline safety program; and educational and research activities.

PB-273 597/5ST

R0134
Department of Transportation, Office of Pipeline Safety Operations, Washington, DC.
FOURTH ANNUAL REPORT OF THE SECRETARY OF TRANSPORTATION ON THE ADMINISTRATION OF THE NATURAL GAS PIPELINE SAFETY ACT OF 1968.
Report No. DOT/MTB/OPSO-77/06.

This report summarizes the major activities of the Office of Pipeline Safety for the calendar year 1971. Topics covered include organizational developments; gas pipeline failures and casualties; Federal pipeline safety standards; State participation in the Federal gas pipeline safety program; and educational and research activities.

PB-273 598/3ST

R0135
Department of Transportation, Office of Pipeline Safety Operations, Washington, DC.
FIFTH ANNUAL REPORT OF THE SECRETARY OF TRANSPORTATION ON THE ADMINISTRATION OF THE NATURAL GAS PIPELINE SAFETY ACT OF 1968.
Report No. DOT/MTB/OPSO-77/07.

This report summarizes the major activities of the Office of Pipeline Safety for the calendar year 1972. Topics covered include organizational developments; gas pipeline failures and casualties; Federal pipeline safety standards; State participation in the Federal gas pipeline safety program; compliance and enforcement activities; and educational and research activities.

PB-273 599/1ST

R0136
Department of Transportation, Office of Pipeline Safety Operations, Washington, DC.
SIXTH ANNUAL REPORT OF THE SECRETARY OF TRANSPORTATION ON THE ADMINISTRATION OF THE NATURAL GAS PIPELINE SAFETY ACT OF 1968.
Report No. DOT/MTB/OPSO-77/08.

This report summarizes the major activities of the Office of Pipeline Safety for the calendar year 1973. Topics covered include gas pipeline failures and casualties; Federal pipeline safety standards; State participation in the Federal gas pipeline safety program; compliance and enforcement activities; and educational and research activities.

PB-273 600/7ST

R0137
Department of Transportation, Office of Pipeline Safety Operations, Washington, DC.
SEVENTH ANNUAL REPORT ON THE ADMINISTRATION OF THE NATURAL GAS PIPELINE SAFETY ACT OF 1968.
Report No. DOT/MTB/OPSO-77/9.

This report summarizes the major activities of the Office of Pipeline Safety for the calendar year 1974. Topics covered include gas pipeline failures and casualties; Federal pipeline safety standards; State participation in the Federal gas pipeline safety program; compliance and enforcement activities; and educational and research activities.

PB-273 601/5ST

R0138
Department of Transportation, Office of Pipeline Safety Operations, Washington, DC.
EIGHTH ANNUAL REPORT ON THE ADMINISTRATION OF THE NATURAL GAS PIPELINE SAFETY ACT OF 1968.
Report No. DOT/MTB/OPSO-77/10, April 19, 1976, 79 p.

This report describes the pipeline safety responsibilities of the newly established Materials Transportation Bureau, of which the Office of Pipeline Safety Operations (OPSO) is a part, and summarizes OPSO's major activities for the calendar year 1975. Topics covered include gas pipeline failures and casualties; Federal pipeline safety standards; State participation in the Federal gas pipeline safety program; compliance and enforcement activities; and educational and research activities.

PB-273 602/3ST

R0139
Department of Transportation, Office of Pipeline Safety Operations, Washington, DC.
NINTH ANNUAL REPORT ON THE ADMINISTRATION OF THE NATURAL GAS PIPELINE SAFETY ACT.
Report No. DOT/MTB/OPSO-77/02, June 8, 1977, 93 p.

This report summarizes the major activities of the Office of Pipeline Safety Operations (OPSO) for the calendar year 1976. Topics covered include gas pipeline failures and casualties; Federal pipeline safety standards; State participation in the Federal gas pipeline safety program; OPSO's compliance and enforcement activities; and the Trans-Alaska crude oil pipeline system.

PB-272 488/8ST

R0140
Department of Transportation, Office of Pipeline Safety Operations, Washington, DC.
ANALYSIS AND MANAGEMENT OF A PIPELINE SAFETY INFORMATION SYSTEM.
Devine, M.D., Morrison, J.I., et al.
Report No. DOT/TST-75/47, October 1974, 159 p.

This report is concerned primarily with the statistical analysis of data collected by the Office of Pipeline Safety for the calender years 1970-73. The data processing and data system management activities performed for the period of April 1973 - November 1974 are also described. The statistical analysis of data provides information on the effects of many parameters on pipeline leaks and/or safety. These parameters include type of material used for pipeline construction, age of pipeline, diameter of pipeline, method of protecting pipeline from corrosion, failure of pipeline produced by digging equipment, and other similar parameters. The conclusions which can be drawn concerning the effects of each parameter of pipeline leaks and/or safety are presented. In addition, recommendations for changes which should be made in

future data reporting and the methods of analysis to be employed by OPS personnel are presented.

PB-238 828/8GA

R0145
Dravo Van Houten, Inc., New York (sponsored by U.S. DOT, Washington, D.C., Office of Pipeline Safety Operations).
OFFSHORE PIPELINE FACILITY SAFETY PRACTICES. VOLUME I. EXECUTIVE SUMMARY.
Funge, W.J. and Chang, Kai S., et al.
Report No. DOT/MTB/OPSO-77/13, December 1977, 68 p.

This report presents an evaluation of the state-of-the-art of the design, construction, operation and maintenance of offshore pipeline facilities, an identification of potential hazards to operation, and a review of selected pipeline safety regulations. The report include an appraisal of existing domestic and foreign practices, their adequacy for assuring safe operation, and an analysis of the need for additional R&D and of the need for regulatory changes or other action by Federal agencies an/or industry to quarantee safe operation of offshore pipeline facilities.

PB-281 865/6ST

R0150
Dravo Van Houten, Inc., New York (Sponsored by U.S. DOT, Washington, D.C., Office of Pipeline Safety Operations).
OFFSHORE PIPELINE FACILITY SAFETY PRACTICES. VOLUME II. MAIN TEXT.
Funge, W.J. and Chang, Kai S., et al.
Report No. DOT/MTB/OPSO-77/14, December 1977, 563 p.

This report presents an evaluation of the state-of-the-art of the design, construction, operation and maintenance of offshore pipeline facilities, an identification of potential hazards to operation, and a review of selected pipeline safety regulations. The report includes an appraisal of existing domestic and foreign practices, their adequacy for assuring safe operation, and an analysis of the need for additional R&D and of the need for regulatory changes or other action by Federal agencies and/or industry to quarantee safe operation of offshore pipeline facilities.

PB-281 867/2ST

R0160
Environmental Protection Agency.
EVALUATION OF A BISTATIC AREAL SCANNING OIL SENSOR.
Rambie, G and Morgan, R.
EPA Report 68-01-3270

A detailed report describing the first phase in the evaluation of a scanning oil sensor, which will be used by the EPA to detect hydrocargon spills on water. The report recommends a second phase hardware construction and test effort.

R0170
GARD, Inc. (sponsored by the U.S. Nuclear Regulatory Commission).
INSPECTION OF NUCLEAR REACTOR WELDING BY ACOUSTIC EMISSION
Prine, D.W. and Matheison, T.A.
Progress Report, Nov. 1977-Nov. 1978, March 1979

The first phase of work, of a two phase program aimed at expanding the capabilities of in-process acoustic monitoring of nuclear fabrication welds from flaw detection and location to flaw characterization in terms of type and size, is discussed in this report. The data base for this research was provided by previously collected AE data from laboratory and shop nuclear fabrication welds. This data was analyzed and computer subroutines were developed that would automatically determine flaw type and size.

R0180
Hawaii Univ., Honolulu, Dept. of Civil Engineering (sponsored by the National Oceanic and Atmospheric Administration, Rockville, Md., Office of Sea Grant).
NEAR-BOTTOM WATER MOTION UNDER OCEAN WAVES
Grace, R.A.
Report No. UNIHI-SEAGRANT-CP-77-03, July 1976, 11 p. (Conference Proceedings reprint)

A 2-year ocean experiment involving wave-induced forces on a test pipe mounted on the sea floor involved in measurement of various quantities other than the pipe forces per se. A pair of these involved surface wave characteristics and wave-induced water motion at the level of the pipe center-line but off to one end of the pipe. These wave-kinematics data have been combined, and the results of this work make up this paper in which the emphasis is on the deterministic approach to data interpretation. Presented are comparisons of the velocity and acceleration data with the predictions of Airy and stream function theories plus discussion of the dispersion of the field data. The purpose of the paper is to suggest to designers of bottom-laid structures, such as pipes, how values of the peak velocity and maximum acceleration of the water motion associated with a non-breaking design wave of specified characteristics can be chosen.

PB-277 924/7ST

R0190
IIT Research Inst., Chicago, IL.
MUTUAL DESIGN CONSIDERATIONS FOR OVERHEAD AC TRANSMISSION LINES AND GAS TRANSMISSION PIPELINES. VOLUME 1, ENGINEERING ANALYSIS. FINAL REPORT
Dabkowski, J. and Taflove, A.
Report No. EPRI-EL-904 (V.1), Sept. 1978, 502 p.

As a result of a program jointly funded by the Electric Power Research Institute (EPRI) and the Pipeline Research Committee (PRC) of the American Gas Association (A.G.A) known data has been consolidated and a systematic investigation has been made into the mutual effects of ac electric power transmission lines (power lines) and natural gas transmission pipelines (pipelines) jointly sharing rights-of-way. The results presented are of use to both the electric power and natural gas transmission industries for addressing problems arising

from a mutual coexistence. Program objectives were to consolidate known data concerning mutual effects arising from power lines and pipelines sharing a common right-of-way, develop a unified and systematic method for predicting electromagnetically induced voltages and currents on pipelines, and investigate mitigation techniques to minimize interference effects upon pipeline and component reliability and personnel safety. In the fulfillment of these objectives, new techniques for coupling prediction and pipeline mitigation have been developed and other available data has been collected and summarized. The overall objective of the program was to develop a reference book which concisely presented the coupling prediction and mitigation information derived in a manner useful to both power and pipeline industry users in the design, construction and operation of their respective systems.

EPRI-EL-904 (VII)

R0200
IIT Research Inst., Chicago, IL.
MUTUAL DESIGN CONSIDERATIONS FOR OVERHEAD AC TRANSMISSION LINES AND GAS TRANSMISSION PIPELINES. VOLUME 2. PREDICTION AND MITIGATION PROCEDURES. FINAL REPORT.
Dabkowski, J., and Taflove, A.
Report No. EPRI-EL-904(V.2), Sept. 1978, pp. 179.

As a result of a program jointly funded by the Electric Power Research Institute (EPRI) and the Pipeline Research Committee (PRC) of the American Gas Association (A.G.A.), known data have been consolidated and a systematic investigation has been made into the mutual effects of ac electric power transmission lines (power lines) and natural gas transmission pipelines (pipelines) jointly sharing rights-of-way. The results presented are of use to both the electric power and natural gas transmission industries for addressing problems arising from a mutual coexistence.

EPRI-EL-904(V.2)

R0210
IIT Research Inst., Chicago, IL.
EFFECTIVENESS OF PROGRAMS FOR PREVENTION OF DAMAGE TO PIPELINES BY OUTSIDE FORCES.
Courtney, W.J., Yie, G., et al.
Report No. DOT/MTB/OPSO-77/12, Nov. 1977, 311 p.

This investigation was conducted to determine the status of programs for prevention of damage to underground facilities of utilities, pipelines and other underground line systems. The study was centered on outside force/outside party damage during excavation near the underground facilities. Data concerning underground damage were analyzed; these data were obtained from OPSO, utilities, other line operators, one-call systems, and State agencies. The data analysis shows that there are wide variations in the effectiveness of damage prevention programs across the country. Many laws or regulations reviewed encourage the formation of one-call systems. In some one-call systems all of the utilities, private and municipal, are members, in others only private utilities are members. All organizations responsible for underground facilities need to work together on mutual damage prevention efforts to be effective. The one-call systems are a logical outgrowth of individual utility

efforts to reduce outside party damage. When many utilities join together and advertise a single phone number to receive excavator calls, a one-call system exists. A number of conclusions and recommendations for improvement of underground damage prevention programs are presented.

PB-281 866/4WT

R0220
Institute of Gas Technology, Chicago, IL.
STUDY OF THE BEHAVIOR OF GAS DISTRIBUTION EQUIPMENT IN HYDROGEN SERVICE UPDATE 1978.
Johnson, D.G., Jasionowski, W.J., et al.
Report No. CONF-781142-5, 1978, 12 p.

If the operating pressures and piping are unchanged, conclusions reached are: Existing in-place components and piping with the possible exception of meters should be adequate for hydrogen delivery. Due to the required flow increase of hydrogen, mechanical limitations of in-place meters will probably necessitate replacement with similar but larger capacity meters. In isolated situations, the difference in pipe flow characteristics of natural gas and hydrogen may necessitate a small increase either in delivery pressure or pipeline volume to provide equivalent energy delivery rates. The hydrogen-to-natural gas volumetric leak ratio for individual components will range from 2.5 to 5 and possibly greater, depending on the permeation characteristics of the material of construction and the joining methods. Although the overall hydrogen-to-natural gas volumetric leak ratio for a given distribution system could range from about 2.9 to 3.5, the increase in energy loss from leakage will be minimal and may in fact be less. Short term (6 mo.) exposure to hydrogen will not affect the mechanical or physical properties of metallic materials of system components. Plastic products and adhesives may be affected by the exposure. Due to hydrogen's wider flammability range and low ignition energy, large leaks from pipeline breakage (or other modes of failure) may be significant safety hazards. Special pipeline repair, replacement and addition procedures will need to be devised. Added monitoring and control devices may be necessary at high pressure or high volume distribution locations. Joule Thompson effects, when encountered, will be minute and will not affect operations. Hydrogen leaks (to the atmosphere) will not ignite spontaneously without an ignition source: hydrogen escaping from a leak expands somewhat adiabatically and cools.

R0230
Institute of Gas Technology, Chicago, IL. (Sponsored by U.S. DOT, Washington, DC, Office of Pipeline Safety Operations).
STUDY OF THE PROPERTIES OF NUMEROUS ODORANTS AND ASSESSMENT OF THEIR EFFECTIVENESS IN VARIOUS ENVIRONMENTAL CONDITIONS TO ALERT PEOPLE TO THE PRESENCE OF NATURAL GAS.
Chisholm, J., Kniebes, V., et al.
Final Report, Oct. 1975, 112 p.

A study was conducted to provide present state-of-the-art information on the odorization of natural gas. The input data for the study came from three sources: A literature survey of past and present gas industry odorization practices, a questionnaire (Appendix A) submitted to those responsible for the gas industry's odorization programs, and a series of personal interviews with pertinent employees of individual gas companies and odorant suppliers.

Tertiary butyl mercaptan blends are preferred over other commercial odorants. Nearly all companies check odor levels with odorometers. Titrators are most often used for continuous monitoring of odorant concentrations. Industry has indicated a general acceptance of present Federal regulations and recommends that further regulation be considered carefully in terms of its real contribution to safety.

PB-249 528/1ST

R0240
Mechanics Research, Inc., Los Angeles, CA.
FERROUS PIPELINE CORROSION PROCESSES, DETECTION, AND MITIGATION.
Report No. DOT/MTB/OPSO-77/01, October 1971, 256 p.

The purpose of this program was to determine the current state-of-the-art of corrosion of ferrous pipelines. This included corrosion mechanisms, frequency and causes of corrosion failure, corrosion mitigation, corrosion detection, and inspection of standards. Emphasis was placed on corrosion literature published between 1945 and July 1970. Only exceptional publications outside of this period were utilized. The program goal was achieved by three separate but interacting paths: (1) a literature survey, (2) a questionnaire, and (3) personal contacts.

PB-269 056/8WT

R0241
Mechanics Research, Inc., Los Angeles, CA.
RAPID SHUTDOWN OF FAILED FACILITIES AND PRESSURE LIMITING TO PREVENT FAILURES, PART I, FINAL REPORT.
Platus, D.L., MacKenzie, D.W., et al.
Report No. DOT-OPS-75-02, April 30, 1973 - October 31, 1974, 225 p.

The state-of-the-art was determined for (1) rapid shutdown of failed pipeline systems, and (2) limiting of pressure to prevent failure. Liquid pipelines, gas transmission lines and gas distribution systems were studied. Information was obtained from a comprehensive questionnaire survey of the industry, a literature search, and other sources. The effectiveness of rapid shutdown in reducing accident effects was determined from analysis of historical accident data and analysis of the sequence of events between failure and shutdown. Costs of implementing rapid shutdown and resulting benefits were estimated. Feasibility of a liquid spillage limitation, and relative risks in rapid shutdown vs. continued operation of a failed gas distribution facility were investigated. For systems studied, results indicate that rapid shutdown does reduce accident effects. Rapid shutdown equipment which is technically and economically feasible is identified.

PB-241 325/OGA

R0242
Mechanics Research, Inc., Los Angeles, CA
RAPID SHUTDOWN OF FAILED FACILITIES AND PRESSURE LIMITING TO PREVENT FAILURES, PART II, INDUSTRY SURVEY REPORT.
Platus, D.L., Morse, C.P., et al.
Report No. DOT/OPSO-75-03, October 1974, 410 p.

The report covers the industry survey portion of a study to determine the state-of-the-art for (1) rapid shutdown of failed pipeline systems, and (2) limiting of pressure to prevent failure due to overpressure. Technical summaries of shutdown and pressure limiting systems and components were prepared. These cover current shutdown and pressure limiting practices by the industry (frequency of use of various methods and equipment), and technical descriptions and analyses of typical systems and components. Promising rapid shutdown equipment was identified and detailed summaries and analyses were prepared, including operator and carrier experience, performance and reliability data, advantages, disadvantages, manufacturers, and costs.

PB-241 326/8GA, PB-241 324 (for both reports)

R0243
Mitre Corporation, Mclean, Virginia. Metrek Division
ACCIDENTS AND UNSCHEDULED EVENTS ASSOCIATED WITH NON-NUCLEAR ENERGY RESOURCES AND TECHNOLOGY.
Bliss, C., et al.
Report No. M-76-68, February 1977, p. 293.

This report covers accidents and unscheduled events associated with non-nuclear energy resources and technology that are identified for each step in the energy cycle. Both natural and anthropogenic causes of accidents or unscheduled events are considered. Data concerning these accidents are summarized. Estimates of frequency and severity are presented for all accidents. The energy systems discussed are oil, natural gas, LNG, oil shale, etc.

R0250
National Bureau of Standards, Washington, DC.
UNDERGROUND CORROSION.
Romanoff, M.
Report No. 579, April 1, 1957, 232 p.

This is a final report on the studies of underground corrosion conducted by the National Bureau of Standards from 1910 to 1955. Up to 1922, the studies were confined to corrosion due to stray-current electrolysis and its mitigation. After it became apparent that serious corrosion occurred in soils under conditions that precluded stray-currents as an explanation, a field burial program was initiated in order to obtain information pertaining to the effect of soil properties on the corrosion of metals. More than 36,500 specimens, representing 333 varieties of ferrous, nonferrous, and protective coating materials, were exposed in 128 test locations throughout the U.S. During this time the electrical and electrochemical aspects of underground corrosion have been continuously studied in the laboratory. Results from both field and laboratory investigations are presented. (Author).

PB-168 350

R0260
National Bureau of Standards, Washington, DC.
CONSIDERATION OF FRACTURE MECHANICS ANALYSIS AND DEFECT DIMENSION MEASUREMENT ASSESSMENT FOR THE TRANS-ALASKA OIL PIPELINE GIRTH WELDS, VOLUME I.
Berger, H., and Smith , J.H.
Report No. NBSIR-76-1154- Vol. 1, DOT/MTB/OPSO-76/02, Oct. 18, 1976, 184 p.

In anticipation of a request for waivers on defective girth welds in the Trans-Alaska oil pipeline, DOT requested assistance from the National Bureau of Standards (NBS) in evaluating the fracture mechanics analysis and the nondestructive evaluation (NDE) methods used to detect and determine dimensions of weld defects. NBS measured the required mechanical properties of the weld metal, developed and evaluated fracture mechanics methods to determine the allowable defect sizes, and evaluated various methods of measuring the size of defects present in the welds from existing field radiographs. Results of this investigation show that the fracture mechanics analysis can be used to determine the allowable defect sizes concerning the integrity of the pipeline, but that these analyses have not been experimentally verified at this time. Defect dimensions can be determined with sufficient accuracy to be useful in the fracture mechanics analyses if the radiographs are made under carefully controlled conditions. If the radiographs are not made with close control, the accuracy of the defect sizes may not be sufficient to permit their use in establishing allowable defect sizes.

PB-260 400/7WT

R0261
National Bureau of Standards, Washington DC.
CONSIDERATION OF FRACTURE MECHANICS ANALYSIS AND DEFECTS DIMENSION MEASUREMENT ASSESSMENT FOR THE TRANS-ALASKA OIL PIPELINE GIRTH WELDS, VOLUME II.
Berger, H., and Smith, J.H.
Report No. DOT/MTB/OPSO-76-03, October 18, 1976, 139 p.

The volume contains the appendices to the above report. These appendices contain several technical reports from consultants and NBS staff. In some cases, the terminology, units, and symbols chosen are not consistent with the main body of the report (Volume I). However, within a given appendix report, notation and symbols are consistent. (Portions of this document are not fully legible.)

PB-260 401/5GA

R0270
National Bureau of Standard, Washington, DC.
CONSIDERATION OF FRACTURE MECHANICS ANALYSIS AND DEFECTS DIMENSION MEASUREMENT ASSESSMENT FOR THE TRANS-ALASKA OIL PIPELINE GIRTH WELDS, VOLUME II.
Berger, H., and Smith, J.H.
Report No. NBSIR-76-1154-Vol. 2, DOT/MTB/OPSO-76/03, Oct. 18, 1976, 139 p.

The volume contains the appendices to the above report. These appendices contain several technical reports from consultants and NBS staff. In some cases, the terminology, units, and symbols chosen are not consistent with the main body of the report (Volume I). However, within a given appendix report, notation and symbols are consistent. (Portions of this document are not fully legible.)

PB-260 401/5WT

R0271
National Bureau of Standards, Washington, DC.
EXAMINATION OF FAILED CAST IRON PIPE LINE, BALTIMORE GAS AND ELECTRIC CO., BALTIMORE, MARYLAND.
Picklesimer, M.L.
Report No. DOT/OPS-71/01, July 1971, 42 p.

A 7-inch long section of 4-inch diameter grey cast iron pipe that fractured in low pressure natural gas service for the Baltimore Gas and Electric Company, Baltimore, Maryland was submitted by the Office of Pipeline Safety to the Engineering Metallurgy Section, Metallurgy Division, NBS, for examination. The failure occurred during sub-freezing weather in a distribution line in a residential area. The section contained one of the fracture faces of the failed pipe. The corrosion proceeded by penetration of the interface between the pearlitic matrix and the graphite flakes present in the microstructure, consuming the ferrite of the pearlitic matrix. Eventually, even the cementite of the pearlite, the particles of massive cementite present in some grain boundaries, and the iron phosphide particles occurring in some regions were consumed by the corrosion.

PB-243 530/3GA

R0272
National Bureau of Standards, Washington, DC.
EXAMINATION OF FAILED CAST IRON GAS PIPE LINC, PUBLIC SERVICE ELECTRIC AND GAS CO., WEST ORANGE, NEW JERSEY.
Picklesimer, M.L.
Report No. DOT/OPS-71/02, July 1971, 42 p.

A 12-inch long section of 6-inch diameter cast iron pipe that fractured in low pressure natural gas service was submitted by the Office of Pipeline Safety for examination. The failure occurred during sub-freezing weather in a distribution line in a residential area. The section contained one of the fracture faces of the failed pipe. Examination of the section of the pipe showed that the specimen had lost by corrosion approximately 10 percent of its cross-sectional area for supporting applied loads. The corrosion proceeded by penetration of the interface between the pearlitic matrix and the graphite flakes present in the microstructure, consuming the ferrite of the pearlitic matrix. Eventually, even the iron phosphide particles occurring in some regions were consumed by the corrosion.

PB-243 531/1GA

R0273
National Bureau of Standards, Washington, DC.
EXAMINATION OF FRACTURED WELD IN 16-INCH STEEL PIPE GAS MAIN, PHILADELPHIA ELECTRIC CO., WEST CONSHOHOCKEN, PENNSYLVANIA.
Picklesimer, M.L.
Report No. DOT/OPS-71/03, August 1971, 28 p.

A 16-inch diameter steel pipeline carrying natural gas at 60 psi fractured at a weld joint while in service in a residential area. A circumferential section was submitted by the Office of Pipeline Safety for examination and, if possible, a determination of the cause of failure. It was concluded that the weld had been made by manual gas torch welding (probably oxy-acetylene); that there was a significant lack of penetration and fusion of the weld metal into the joint; that an oxidizing flame had been used during the welding, 'burning' the weld metal, removing carbon, and embrittling it by causing too much oxygen to be dissolved in the molten weld metal; and that a poor welding technique had been used by the welder.

PB-243 532/9GA

R0274
National Bureau of Standards, Washington, DC.
EXAMINATION OF FAILED FOUR INCH CAST IRON PIPE GAS MAIN. UGI CORP., LEHIGH DIVISION, BETHLEHEM, PENNSYLVANIA.
Picklesimer, M.L.
Report No. DOT/ODS-72/01, July 1972, 33 p.

The cracked section of a 4-inch diameter cast iron gas main which caused an explosion in a residential area of Allentown, PA was examined by NBS to determine the cause of the failure. The uniform appearance and lack of specific markings on the surface of the crack indicated that the crack probably formed quickly, and in a single event. It was concluded that the crack probably initiated at a local spot of corrosion ('graphitization') on the bottom of the pipe because of the loss of cross-section there (1/4 of the wall thickness lost). The load required was produced by an external force. This force was probably caused by the settling of a bridge wall located within 27 inches of the pipe, and the loss of supporting soil due to a leak in a steel water pipe within 4 inches of the break in the gas main.

PB-243 533/7GA

R0275
National Bureau of Standards, Washington, DC.
EXAMINATION OF SEVERAL COMPONENTS REMOVED FROM SITE OF NATURAL GAS EXPLOSIVE, McKEESPORT HOSP., McKEESPORT, PA., EQUITABLE GAS CO., PITTSBURGH, PENNSYLVANIA.
Picklesimer, M.L.
Report No. DOT/OPS-72/02, October 1972, 114 p.

Several operating components removed from the regulator station and the boiler room of the McKeesport Hospital after a natural gas explosion have been examined by NBS. These components included, among others, the main-line pressure regulator and the pressure relief valve from the regulator station, the low-pressure regulator for the boiler being started up at the time of the explosion, and a Weld-O-Let Tee fitting from the gas distribution system near the feed line take-off for the boiler concerned. All fractured regulator flanges appeared to have been broken-off in simple tensile fracture. The high 'lock-up' pressure was probably caused by the valves not being spaced on the stem rod such that thet both met their respective seats at exactly the same position of the stem rod in the regulator body. No evidence could be positively determined as to whether or not the fracture of the joint between the Weld-O-Let Tee fitting from the 6-inch diameter main supply line to the 8-inch diameter line were completed by a single loading event. Definite cause of failure was not determined.

R0276
National Bureau of Standards, Washington, DC.
EXAMINATION OF FAILED TEN INCH CAST IRON PIPE GAS MAIN. PENNSYLVANIA GAS AND WATER CO., SCRANTON, PENNSYLVANIA.
Picklesimer, M.L. and Shives, T.R.
Report No. DOT/OPS-72/03, December 1972, 27 p.

The Office of Pipeline Safety submitted a length of the pipe containing the crack which caused a gas explosion which essentially destroyed a building in Scranton, PA, to NBS for examination in order to determine the cause of failure. Cross sections taken through the pipe revealed extensive graphitization (corrosion). The graphitization started at the outside wall surface of the pipe and progressed inward. In addition, relatively large amounts of free ferrite were observed surrounding the graphite flakes, accounting for the apparent 'ductility' in this material. It was concluded that the load carrying capacity of the pipe had been reduced significantly because of the graphitization and the porosity, and that this reduced load carrying capacity coupled with an apparent bending stress applied externally caused the pipe to crack.

PB-243 535/2GA

R0277
National Bureau of Standards, Washington, DC.
EXAMINATION OF FAILED SIX INCH CAST IRON PIPE GAS MAIN, PROVIDENCE GAS CO., EAST PROVIDENCE, RHODE ISLAND.
Feinberg, I.J. and Picklesimer, M.L.
Report No. DOT/OPS-72/04, December 1972, 25 p.

Analysis revealed that the subject pipe material had an inferior composition and microstructure. Graphitization contributed to crack initiation and crack propagation resulted largely from overload, such as that which could have been caused by ground settlement or the movement of heavy equipment over the ground in the region of the fracture. The oxidized surface of the crack and the presence of the wax-like deposit in the crack lead to the conclusion that the crack was not fresh and had been in existence for some time.

PB-243 536/0GA

R0278
National Bureau of Standards, Washington, DC.
EXAMINATION OF FAILED GALVANIZED STEEL PIPE NATURAL GAS DISTRIBUTION LINE, NORTH RICHLAND HILLS, LONE STAR GAS CO., FORT WORTH, TEXAS.
Picklesimer, M.L.
Report No. DOT/OPS-73/01, January 1973, 36 p.

A section of fractured 1 1/4 inch diameter galvanized steel pipe natural gas distribution line was examined to characterize the principal features of the fracture surface and to attempt to determine the mode and cause of the fracture. Scanning Electron Microscope (SEM) examination of the fracture surface showed that the fracture had occurred brittlely by cleavage, with very little or no ductility present. It was concluded that the galvanized steel pipe failed brittlely in service due to the probable application of a bending load (not axial) with very little movement being required. It was concluded that the pipe was probably charged with hydrogen at the root of the cut threads at the junction with the 90 degree elbow by a galvanic current produced by corrosion of the galvanized steel pipe in soil.

PB-243 537/8GA

R0279
National Bureau of Standards, Washington, DC.
EXAMINATION OF FAILED FOUR INCH CAST PIPE GAS MAIN: ELIZABETHTOWN GAS CO., ISELIN, NEW JERSEY,
Feinberg, I.J. and Picklesimer, M.L.
Report No. DOT/OPS-73/02, February 1973, 20 p.

Examination revealed that the subject pipe material had a microstructure not usually specified for the application. Graphitization probably contributed directly to crack initiation and crack propagation and fracture probably resulted from an externally applied load. From the freshness of the fracture surface, it is concluded that the fracture was of recent origin when its presence was detected.

PB-243 538/6GA

R0280
National Bureau of Standards, Washington, DC.
EXAMINATION OF A FAILED 2-INCH DIAMETER GALVANIZED STEEL PIPE: VALLEY GAS CO., WOONSOCKET, RHODE ISLAND.
Interrante, C.G., Hicho, G.E., et al.
Report No. DOT/OPS-73/03, February 1973, 49 p.

The sections of a fractured 2-inch diameter galvanized steel pipe used in natural gas residential distribution service in Woonsocket, Rhode Island were examined to determine the mode of fracture. Notched tensile and impact specimens made from the pipe were tested in the uncharged and hydrogen-charged conditions. The fractures in the uncharged tensile specimens were ductile, occurring by dimpled rupture. Those in the impact specimens, the hydrogen-charged tensile specimens, and the original pipe were 'brittle',

occurring with very little to no ductility by transgranular quasicleavage. Since the fracture features of the original pipe fracture were duplicated by the hydrogen-charged notched tensile specimens. It was concluded that the galvanized pipe failed in service due to (1) an external force, (2) stress concentration by the junction of the root of the pipe thread and the face of the 90 degree pipe elbow, and (3) a low ductility at the root of the pipe thread probably as a result of charging with hydrogen produced by the galvanic current from the corrosion protection of the galvanized coating.

PB-243 539/4GA

R0281
National Bureau of Standards, Washington, DC.
EXAMINATION OF A FAILED SIX INCH CAST IRON PIPE NATURAL GAS MAIN, ATLANTA GAS LIGHT CO., ATLANTA, GEORGIA.
Shives, T.R.
Report No. DOT/OPS-73/04, April 1973, 29 p.

A 5-foot length of 6-inch grey cast iron pipe from a natural gas main in Atlanta, Georgia, was submitted for examination. The pipe had fractured at the approximate center of the submitted length. The fracture appeared to have initiated at the top of the pipe and occurred in at least two stages, with the region at the bottom of the pipe being the last part to fail. Graphitization (corrosion), penetrating up to 30 percent of the wall thickness in one area adjacent to the fracture, was found in all cross sections examined, although most of the material examined was free of graphitization. The likely cause of failure was the application of an external load to produce a bending stress in an area weakened by graphitization.

PB-243 540/2GA

R0282
National Bureau of Standards, Washington, DC.
EXAMINATION OF FAILED ONE INCH BLACK IRON PIPE NATURAL GAS SERVICE LINE, IOWA PUBLIC SERVICE CO., EAGLE GROVE, IOWA.
Shives, T.R.
Report No. DOT/OPS-73/05, August 1973, 25 p.

A fractured 1-inch black iron pipe natural gas service line which connected to a building involved in an explosion and fire in Eagle Grove, Iowa, on February 2, 1973, was examined by the NBS Mechanical Properties Section. The fracture was ductile in nature. There was no evidence found to indicate the presence of a pre-existing crack. The fracture appeared to have been due to bending stresses caused by loading from an external source.

PB-243 541/0GA

R0283
National Bureau of Standards, Washington, DC.
EXAMINATION OF FAILED SIX INCH CAST IRON PIPE NATURAL GAS MAIN: ILLINOIS POWER CO., EAST SAINT LOUIS, ILLINOIS.
Feinberg, I.J. and Picklesimer, M.L.
Report No. DOT/OPS-73/06, September 1973, 23 p.

Examination revealed that the subject pipe had a micro-structure not normally present in material meeting the usual specifications for the application. Graphitization probably aided crack initiation and crack propagation and fracture probably resulted from an externally applied load. From the freshness of the fracture surface, it was concluded that the fracture was of recent origin.

PB-243 542/8GA

R0284
National Bureau of Standards, Washington, D.C.
EXAMINATION OF FAILED 8-INCH WELDED STEEL PIPE NATURAL GAS MAIN, UGI CORP., COOPERSBURG, PENNSYLVANIA.
Picklesimer, M.L. and Shives, T.R.
Report No. DOT/OPS-73/07, November 1973, 36 p.

The Office of Pipeline Safety submitted a 4-foot length of 8-inch diameter welded steel pipe natural gas main containing a crack in the weld to the NBS Mechanical Properties Section for examination. The apparent crack origin was located at about the 4:30 o'clock position, assuming the top of the pipe to be at twelve o'clock and the outside of the bend of the pipe as installed was at three o'clock. The crack had propagated about two-thirds of the way around the pipe circumference. Optical and scanning electron microscopy revealed the fracture to have been predominantly brittle in nature. There was lack of weld penetration around a large part of the weld circumference and the weld metal exhibited some porosity. These features are normal for steel pipe welded by the oxy-acetylene practice used at the time the weld was made. While these features of the weld helped to define the path of the fracture, they probably did not contribute to it. Examination of the fracture and comparison of its features with those of fractures produced in the laboratory indicated that failure was probably brought about as a result of a single event, impact loading from an external source.

PB-243 543/6GA

R0285
National Bureau of Standards, Washington, DC.
FAILURE ANALYSIS OF A POLY (VINYL CHLORIDE) NATURAL GAS MAIN PIPE FROM LAS VEGAS, NEW MEXICO.
Toner, S.D.
Report No. DOT/OPS-74/01, May 1974, 15 p.

A natural gas leak from a poly (vinyl chloride) (PVC) gas main was considered to be the attributable cause of a fatal explosion in a private residence in Las vegas, New Mexico. An analysis of the pipe was conducted in an effort to determine the possible cause of failure. The results indicated that failure occurred as a result of weakening of the pipe due to the presence of a stress crack initiated by an occluded particle, which had apparently been molded into the pipe wall during its fabrication.

PB-243 544/4GA

R0286
National Bureau of Standards, Washington, D.C.
FAILURE ANALYSIS OF A POLY (VINYL CHLORIDE) (PVC) PLASTIC NATURAL GAS TRANSMISSION PIPE FROM LAS VEGAS, NEVADA.
Toner, S.D.
Report No. DOT/OPS-74/02, May 1974, 15 p.

A natural gas leak from a poly(vinyl chloride) (PVC) gas distribution line was the reported cause of a fatal explosion in a motel complex in Las Vegas, Navada. An analysis of the pipe was conducted to determine the cause of failure. The results indicated that the pipe compound had not been properly fused during the extrusion process. In connecting the plastic pipe to a metal pipe, a solvent-based primer had been used to activate the adhesive on a pipe wrap tape, applied over the plastic pipe and a compression fitting. The solvent apparently caused gross swelling of the pipe, beneath the tape, negating the effect of a metal insert stiffener. Subsequent creep deformation of an adjacent section of the plastic pipe apparently exerted sufficient tensile stress on the swollen portion of the plastic pipe to induce the formation of a stress crack.

PB-243 545/1GA

R0287
National Bureau of Standards, Washington, DC.
EXAMINATION OF FAILED FOUR INCH CAST IRON PIPE NATURAL GAS MAIN, PHILADELPHIA GAS WORKS, PHILADELPHIA, PENNSYLVANIA.
Toner, S.D.
Report No. DOT/OPS-74/03, May 1974, 15 p.

The Office of Pipeline Safety submitted several pieces of 4-inch diameter cast iron natural gas main pipe to the Mechanical Properties Section for examination. An accumulation of gas that had escaped from a fracture in the pipeline resulted in an explosion in the 1200 block of South Markoe Street in Philadelphia, Pennsylvania on May 3, 1974. The fracture had occurred in a transverse plane that passed through a service tap hole in the top of the pipe. The fracture was brittle in nature and there was no evidence to indicate the existence of a crack prior to the failure. There was extensive graphitic corrosion in some areas of the pipe, although this does not appear to be related to the failure. A chemical analysis indicated that the phosphorus content of the pipe material was higher than desirable. The microstructure contained a considerable amount of iron-iron phosphide eutectic. Failure apparently occured from a single stressing event caused by bending loads from an external source.

PB-243 546/9GA

R0288
National Bureau of Standards, Washington, DC.
EXAMINATION OF FAILED TWO INCH STEEL PIPE NATURAL GAS MAIN, COLUMBIA GAS CO., YORK CO., PENNSYLVANIA.
Shives, T.R.
Report No. DOT/OPS-75/05, January 1975, 42 p.

The Mechanical Properties Section of the NBS examined a length of a cracked 2-inch diameter plain carbon, welded steel natural gas main pipe at the request of the Office of Pipeline Safety. The pipe had a transverse crack extending about 85 percent of the circumference. The pipeline had suffered considerable mechanical damage in the vicinity of the failure, and the crack, which propagated in an essentially brittle manner, appeared to have initiated in a gouged area near the bottom of the pipe. There was a considerable amount of corrosion product on the surface of the pipe in the gouged area. The amount and distribution of corrosion product on the fracture surface indicated that the crack had formed in at least two stages, and that a crack was present prior to the time of failure. The likely mechanism of fracture for the first stage of the crack appears to be stress corrosion cracking. For the second stage of the crack, either stress corrosion cracking or impact appears to be the likely mechanism of failure.

PB-243 547/7GA

R0290
National Bureau of Standards, Washington, DC, Inst. for Applied Technology.
CORROSION OF METALLIC PIPING ON MILITARY BASES - A SURVEY.
Brown, P W. and Clifton, J.F.
Report No. NBSIR-75-923, Nov. 1975, 21 p.

The results of surveys of the extent of corrosion of metallic piping systems at selected military installations have been analyzed. Potable water, fire protection, heat distribution, cooling, and natural gas distribution systems are included in these surveys. The corrosion evaluation techniques used in these surveys and the types of protection applied are discussed. General recommendations regarding continuation and extension of these surveys are given.

PB-250 767/1ST

R0295
National Maritime Research Center-Galveston, TX, Cargo Handling and Terminals Program.
LEAK DETECTION IN UNDERWATER OIL PIPELINES.
Jackson, P.A.
Report No. NMRC-272-23100-R2, Sept. 1973, 41 p.

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. The review was performed to provide appropriate pollution control information prior to the construction of underwater oil pipelines from deep water tanker terminals to shore facilities. It was recommended that a stationary ultrasonic through-the-pipe-wall crack/flow detector be used with a coaxial cable and shroud positioned a short distance above the pipe.

COM-73-11776/4

R0300
National Technical Information Service, Springfield, VA.
CATHODIC PROTECTION (A BIBLIOGRAPHY WITH ABSTRACTS).
Smith, M.F.
Report for 1964-Dec. 74, Jan. 1975, 130 p.

Cathodic protection of ships, moorings, nuclear reactors, underground pipes, underwater equipment, and steel reinforcement are presented in 125 abstracts. The research covers electrochemistry, electrode cleaning, method reliability and electron microscopy.

NTIS/PS-75/241/OST

R0310
National Transportation Safety Board, Washington, DC. Office of Evaluations and Safety Objectives.
SAFETY REPORT ON THE PROGRESS OF IMPROVEMENTS IN PIPELINE TRANSPORTATION OF HIGHLY VOLATILE LIQUIDS.
Report No. NTSB/SR-79/3, Sept. 28, 1979, 19 p.

The most hazardous liquid products transported by pipelines are highly volatile liquids (HVL), such as liquefied petroleum gas and anhydrous ammonia. Since the Safety Board began investigating HVL pipeline accidents in 1970, it has issued a total of 19 recommendations to DOT urging adoption of improved safety requirements for these pipelines. In FY 1979 the Safety Board, concerned that needed improvements either have not been implemented or have not been implemented as rapidly as possible, established a safety objective for improved safeguards for HVL pipelines. The objective was twofold, designed to: (1) Demonstrate the need for improvements, and (2) obtain the

committment of DOT's Materials Transportation Bureau (MTB) to implement standards recommended by the Safety Board. As a result of the Safety Board's accident investigation and safety objective activities, MTB has proposed or adopted new HVL pipeline safety standards which will, when fully implemented, substantially reduce the probability of accidents and the risk of casualties and property losses. However, reduction of the remaining risks to the public safety will require further action by MTB to: (1) Expedite implementation of proposed safeguards; (2) establish safety requirements based upon the population which may be exposed to harm; and (3) establish minimum performance requirements for the prompt detection and rapid isolation of failed sections of HVL pipelines.

PB80-102189

R0320
Naval Civil Engineering Lab., Port Hueneme, CA.
A SURVEY OF PIPE CORROSION AT NAVAL ACTIVITIES.
Stephenson, J.
Report No. N-700, March 26, 1965, 2 p.

To determine the effectivness of methods used in the field to protect pipeline systems from corrosion within a group of government activities, engineers from the Naval Civil Engineering Laboratory made on-site investigations of piping distribution systems in a total of 23 Naval activities located in various places. The data collected from the sites were more commonly from service pipelines such as steam, hot water, potable water, sea water, sewage, air, gas and oil. One hundred and six pipe installations were investigated. Information as to site, soil characteristics, type of coating or covering, date of installation, length of pipe involved, and reports on the success or failure of the systems are recorded in tabular form. The most serious failures reported are in underground hot pipeline systems where, in most cases, the lines are installed below the water table. (Author).

AD-614 259

R0330
Naval Intelligence Support Center, Washington, DC (Translation Div).
THE EFFECT OF PRESSURE OF THE CORRODING LIQUID ON THE STRENGTH OF METALS DURING LOW CYCLE FATIGUE TESTING.
Utkin, V.S., and Moroz, I.S.
Report No. NISC-Trans-3690, Sept. 30, 1975, 10 p.

A negative effect of different corroding media, including water, on the strength of materials subjected to variable stresses has been known for some time. A large number of industrial equipment (pipes, reservoirs, tanks, etc.) are subjected simultaneously to variable stresses and high pressure produced by corroding liquid media. The performance of structural elements under these conditions is lowered, as well as their useful service life. This work was undertaken to study the effect of the water pressure (0-200 atm) on low cycle fatigue of cylindrical specimens (with a circular cut) made of different alloys.

AD-A016 386/5ST

R0340
Notre Dame Univ., IN., Dept. of Aerospace and Mechanical Engineering.
A SHELL MODEL OF A BURIED PIPE IN A SEISMIC ENVIRONMENT
Muleski, G.E., Ariman, T., et al.
Report No. TR-2, NSF/RA-78-686, Oct. 1978, 40 p.

In a number of recent investigations, a buried pipe undergoing seismic excitation was modelled as a beam on a visco-elastic foundation. However, it is known that two of the observed failure modes in the buried piplines under seismic loads are buckling and fracture. Therefore, in this paper, a thin circular cylindrical shell model in a resisting soil medium is used for a buried pipe. The coupled equilibrium equations arising from this model are modified to yield three decoupled equations which somewhat simplify the analysis. Then, an application for a long buried pipe is presented and the results are discussed and compared with those of the beam model.

PB80-116387

R0350
Office of Naval Research, London, England
LIAISON TECHNOLOGIST PROGRAM: OCEAN FACILITIES ENGINEERING.
Cordy, R.N.
Report No. ONRL-R-9-77, Sept. 14, 1977, 21 p.

This report summarizes the findings of a review of ocean facilities engineering technology in Europe. Principal investigation areas include cable/pipeline burial and trenching, undersea work systems, underwater inspection and non-destructive testing, geotechnical properties of seafloor materials, seawater hydraulic power transmission and diver electrical safety. The appendix describes the investigation techniques and concepts on the benefits of the program.

AD-A045 078/3ST

R0360
Office of Oil and Gas, Washington, DC (Sponsored by the Defense Civil Preparedness Agency, Washington, DC).
VULNERABILITY OF NATURAL GAS SYSTEMS.
Stephens, M.M., Golasinski, J.A.
Final Report, June 1974, 127 p.

This report describes the general manner and pattern in which the natural gas industry operates within the U.S. and describes in detail the transmission aspect of the system within the region encompassing all of Louisiana and 13 counties of Mississippi. It brings together a description of all segments of the industry, relates some of the operational problems, projects, and in some instances, future problems as they relate to national security and emergency planning.

AD-A007 583/8ST

R0370
Prevention of Deterioration Center, Nas-Nro, Washington, DC.
BIBLIOGRAPHY ON MICROBIAL CORROSION OF METALS.
Lee, R.
Report No. S63 025, PDI48074, July 11, 1963, 2 p.

Corrosion inhibition, sea water, microbiology, fungusproofing, iron, steel, pipes, underground, documentation, aluminum, biological contamination, copper, lead, and abstracts are the descriptors in this bibliography.

AD-601 247

R0380
Public Service Electric and Gas Co., Newark, NJ.
BLENDING OF HYDROGEN IN NATURAL GAS DISTRIBUTION SYSTEMS. VOLUME III. GAS BLENDS LEAKAGE TESTS OF SELECTED DISTRIBUTION SYSTEM COMPONENTS. FINAL REPORT. June 1, 1976--April 30, 1978.
Report No. CONS-2925-3, May 1978, 66 p.

This report describes tests made using various types of joints and materials commonly installed in gas-distribution systems to determine the gas-leakage behavior when blends of hydrogen and natural gas are distributed. Twenty sample test joints, consisting of eleven cast-iron cement and jute joints, five steel joints, and four plastic joints, were tested using straight natural gas, varying blends of hydrogen with natural gas, and varying humidity levels of the gas mixture. In the case of the steel joints, the pressure level was also vaired but the gas mixture was not humidified. Test results show: (1) cast-iron joints and steel joints that did not leak with natural gas did not leak with blends of up to 40% hydrogen in natural gas; (2) cast-iron joints and steel joints that had small leaks with natural gas did not leak at a higher rate with blends of up to 40% hydrogen in natural gas; (3) cast-iron joints that had large leaks with natural gas showed a detectable increase in leakage as the hydrogen level in the gas blend increased; (4) efforts to determine if the permeability of polyethylene tubing increases with increasing concentrations of hydrogen in natural gas, and with aging of the plastic, were inconclusive; and (5) there was no preferential leakage of hydrogen in any of the joints tested using blends with up to 40% hydrogen in natural gas.

CONS-2925-3

R0390
Sumitomo Metal Industries.
EFFECT OF COPPER ON THE WELDABILITY OF LINE PIPE.
Miyoshi, E., et al.
Report No. I.I.W.-IX-968-76, May 1976, 30 p.

In this report, the effect of copper on weldability is studied from the point of cold cracking and hot cracking. The addition of copper into the pipe steel is effective in reducing the susceptibility of hydrogen induced cracking. However, copper is thought to have a deteriorating effect on a weldability when added to line pipe steel. This report describes three tests

J0010
Anderson, H.J.
LIQUIFIED-METHANE PIPELINE: NEXT GAS-TRANSMISSION STEP?
Oil & Gas Journal, February 8, 1965, pp. 74-80.

The competition with electric power stimulates the search for lower cost natural gas transportation and is the focus of this article. The available technology points to vacuum-jacketed, insulated line as the probable answer.

J0020
Ateya, B.G. and Pickering, H.W.
ON THE NATURE OF ELECTROCHEMICAL REACTIONS AT A CRACK TIP DURING HYDROGEN CHARGING OF A METAL.
Electrochemical Science and Technology, Vol. 122, No. 8, August 1975, pp. 1018-1026.

The electrochemical conditions within cracks in metals undergoing cathodic hydrogen charging in acid solutions are analyzed. The gradients of the electrical potential and concentrations of the various ionic species and the current distribution are calculated for a model crack. The actual potential profiles were measured in slots in Fe, Ni, and Cu samples during hydrogen charging using an electrical potential probe. The measured potential drop in the electrolyte in the slots of all three metals is often very large, e.g., 0.5V. This is about an order of magnitude larger than that calculated, and is in general at odds with the usually implicit assumption that the electrode potential is not an important variable within a growing crack. The reason for this discrepancy is shown to be the large potential variation caused by the presence of trapped hydrogen gas bubbles in the slot.

The measured electrode potentials in the slot during cathodic hydrogen charging are in the region of metal dissolution in the case of the two base metals. Fe and Ni. On the other hand, the outer surface of these metals is under perfect cathodic protection for the typical impressed cathodic currents of 5 or 10 mA cm^{-2}. Subsequent tests of electrolyte samples taken from within slots while the current was flowing, indeed, showed the presence of relatively large amounts of iron and nickel ions indicating that anodic dissolution of iron and nickel occurs within the slots, though not at the outer surface during cathodic hydrogen charging. Analysis of the solution at the outer surface of the slot under conditions of impressed current showed the absence of significant concentrations of metal ions.

J0030
Backhaus, H.W.
OFFSHORE LNG - HANDLING SYSTEM AIMED AT SEVERE CONDITIONS
Oil Gas Journal, Vol. 75, No. 40, September 26, 1977, p. 60-64.

A liquefied natural gas (LNG) handling system has been designed for inclement weather and rough sea conditions so that transfer and maintenance can be done easily. Special consideration was given to such important variables as cryogenic liquid-handling difficulties (boil-off, flash gases, etc.), pipe insulation, weight coatings for buoyancy control, subsea positioning, and installation methods. Significant components of the system are described in detail.

J0040
Barnby, R.T., et al.
THE FRACTURE RESISTANCE OF NICKEL BRONZE TUBES
International Journal of Fracture, Vol. 13, No. 5, October 1977, pp. 681-693.

This article describes an experiment conducted to determine the basic toughness value for an alloy used in the production of sand cast cylinders. This experiment was undertaken in order to accomplish safe, economic design stresses for engineering structures. Cylindrical pressure vessels, by the nature of their geometric form, were found to have reduced resistance to fractures. The tests were run on nickel aluminum bronze tubes. The test results concluded that the alloy has a toughness of 150Mn/m 3/2 at a thickness of 9.53mm.

J0050
Bowman, R., et al.
CO/CO2 CRACKING IN INERT GAS - MISCIBLE FLOODING.
Material Performance, Vol. 16, No. 4, April 1977, pp. 28-32.

A description of an inert gas injection experiment conducted by Shell is given in this short article. This experiment found residual CO plus CO2 in combustion gases was sufficient at high pressures to cause transgrandular stress corrosion cracking of low strength tubular and line pipe in the presence of an aqueous phase. Inhibition is possible, but competive absorption from brine salts, biocides, and former inhibitors complicates inhibitors selection.

J0060
Brown, R.J.
PIPELINE DESIGN TO REDUCE ANCHOR AND FISHING BOAT DAMAGE.
Transportation Engineering Journal, Vol. 99, No. TE2, May 1973, pp. 199-210.

This article describes methods for protecting unburied submarines pipelines from damage by dragging anchors and shipboards. Types of risk, damage, and pipe protection systems are described, along with the factors that must be considered when determining the most feasible form of protection for a given set of conditions. An example is given of a typical pipeline protection system, using different methods of protection on different sections of the pipeline, depending on their need.

J0070
Brown, A., Harrison, J., et al.
TRANS-GRANULAR STRESS CORROSION CRACKING (S.C.C.) OF FERRITE STEELS.
Corrosion Science, 1970, Vol. 10, pp. 547-548.

In a letter to the editor format, this material discusses the cause of severe cracking in ferritic steel components carrying coal gas. Stress corrosion cracking was attributed to the low strength of the steel in which cracking was transgranular, and there was an absence of any causative agent for stress corrosion cracking. Experiments were conducted to explore this new metal environment stress corrosion system. The results of these experiments indicated that

carbon monoxide (CO) must be present in the environment before cracking can be initiated. The greater the concentration of the CO, the shorter the time needed to cause cracking and the lower the stress required.

J0080
Burdekin, F.M., and Stone, D.E.W.
THE CRACK OPENING DISPLACEMENT APPROACH TO FRACTURE MECHANICS IN YIELDING MATERIALS.
Journal of Strain Analysis, Vol. 1, No. 2, 1966, pp. 145-153.

An introduction is given to the fracture mechanics approach employing the concept of crack opening displacement for application to situations in which linear elastic fracture mechanics is invalidated by yielding. The hypothesis of a critical crack opening displacement to fracture has been examined experimentally using mild steel specimens of vastly differing dimensions. Subsidiary experiments have been carried out to define the factors responsible for the apparent effect of absolute size on the results. A theoretical analysis simulates elastic-plastic conditions to give a relationship between applied stresses and strains, crack length, and crack opening displacement.

J0090
Carlson, R.E.
INTERNAL COATING OF WELDS USED ON OFFSHORE LINE.
Pipeline & Gas Journal, Vol. 205, No. 1, Jan 1978, pp. 34-35.

Fusion coating of internal weld surfaces received its first major test recently on a 33-mile, 20- and 24-in. pipeline project for Tennesse Gas Pipeline Co. in the offshore and coastal waters of South Louisiana. Both the internal and external surfaces were coated with a high-build thickness of epoxy fusion coating for corrosion control. The pipe - 10 miles of 24-in. and 23 miles of 20-in - was fusion coated at Surfcote's Houston facility. Remaining to be coated when the pipe arrived on the lay barges were the girth welds and surrounding cutback areas. The coating operations and the lay barge procedures are briefly described.

J0100
Coldren, A.P. and Tither, G.
METALLOGRAPHIC STUDY OF HYDROGEN-INDUCED CRACKING IN LINE PIPE STEELS.
Journal of Metals, Vol. 28, 1976, pp. 5-10.

This article describes a study conducted to ascertain the relative roles of inclusions versus bainite and martensite in promoting hydrogen-induced cracking in two types of X65 line steel pipe, Cb-V steel and Mo-Cb steel.

The study involved exposing steel hot-rolled plates to H2S-saturated synthetic sea water. The test results revealed non-metallic inclusions which were associated with hydrogen-induced cracking. Hydrogen-induced cracking was found to be correlated with the sulfur content of the steel. The evidence also suggested that pre-existing voids created by decohesion of the sulfide/matrix interface during hot rolling provide sites for the formation of molecular hydrogen. As the hydrogen pressure rises in the voids, cracks propagate along the

paths of low fracture resistance. A possible solution to the problem of hydrogen-induced cracking and perhaps sulfide stress corrosion cracking, can be found in the use of small copper additions to low-carbon line pipe steels.

J0110
Congram, G.E.
ALLOY OVERLAY HELPS PROTECT NORTH SEA PIPELINES.
Oil & Gas Journal, Vol. 76, No. 19, May 8 1978, pp. 202,206,209.

Weld overlaying with a new nickel-chromium alloy is preventing subsea pipeline corrosion in high risk areas in the North Sea. Risk areas in Frigg field are those where pipes pass through the walls of concrete platforms used to support a gas treatment plant and other equipment. The new overlay, Inconel 625, is a nickel-chromium alloy which has high resistance to pitting and crevice corrosion cracking. It has high tensile strength, high corrosion fatigue strength, and maximum resistance to stress-corrosion cracking. Post-weld heat treatment is not needed and it can be laid down on a dissimilar metal such as steel without appreciable loss of properties through weld dilution.

J0120
Crowell, D.C.
HYDROSTATIC TESTING, SURVEYS ASSURE PIPELINE EFFICIENCY
Oil & Gas Journal, Vol. 76, No. 23, Jun 5 1978, pp. 129-135.

The author explains how hydrostatic testing, early maintenance, replacement of corroded sections, and electronic pigging can help assure safety and reliability of gas pipelines. A formal hydrostatic test and rehabilitation program established by Natural Gas Pipeline Co. of America (NGPL) is discussed, and its application to Gulf Coast and Amarillo pipelines, as well as in the Chicago district, is described. An electronic survey for detecting and evaluating pipeline corrosion is also covered.

J0130
Cox, G.E., Holland E.H.
HELP ELIMINATE PROTECTION INTERFERENCE: LOCATE PIPE CONTACTS WITH P/S SURVEY.
Pipeline Gas Journal, Vol. 205, No. 3, March 1978, pp. 35-36.

In applying cathodic protection to a large, metropolitan gas distribution system - in a city with wall-to-wall pavement - many problems are encountered. These include uncoated fittings, holidays in the coatings, under ground contacts, and uninsulated meters that must be corrected, one at a time, before the desirable potential shift can be achieved. The authors describe a method for locating contacts with "foreign" lines and underground structures, which consists in taking pipe-to-soil readings at regular intervals and plotting these potentials in order to indicate where depressions in the normal slope of the attenuation curve appear. Advantages of this potential profile method are discussed.

J0140
De Winton, C.
JOINT INTERNE FILLS A GAP.
Gas World Gas Journal, Vol. 182, No. 4709, Dec 1977, pp. 637-638,651.

Leakage control of gas distribution networks has become the art of not digging holes. This article describes the Joint Interne technique, a system for repairing the smaller diameter gas main from within. In this approach, a leaking joint in a small diameter main is repaired by placing a seal over it inside the pipe by well-trained operators working outside it. The use of the Joint Interne system by the British gas industry in a field trial carried out in the Northern Gas regional area is described.

J0150
Dixon, D.A. and Rutledge, D.R.
STIFFENED CATENARY CALCULATIONS IN PIPELINE LAYING PROBLEMS.
Transactions, American Society of Mechanical Engineers, Vol. 90, February 1968, pp. 153-170.

A method for calculating the required tension and pipe angle at the lay barge for the laying of a pipeline in deep water from a lay barge with an inclined derrick without the use of a stinger, is described in this paper. Equations to determine the end conditions of the pipeline required at the lay barge to prevent excessive bending stresses at the point of maximum curvature near the ocean floor are developed using two methods of analyses. The equations are derived by first assuming the pipeline to take the form of a natural catenary, and second assuming the pipeline to take the form of a stiffened catenary. Both methods yield about the same results for the calculation of the required tension at the lay barge, but the stiffened catenary method gives better results for the angle of the pipe at the lay barge, because end effects due to pipeline bending stiffness have been neglected in assuming the pipe to take the form of a natural catenary. A comparison is made between the two methods and examples are given to illustrate their use.

J0160
Edminston, K.
NEW SYSTEM REPAIRS PIPELINE IN 190-FOOT WATER
Ocean Industry, Vol. 6, No. 1, June 1971, pp. 35-38.

A description of a system designed to repair pipelines in deep water. The system is composed of a pipeline-up frame, underwater habitat control console, and umbilical cords. This system can handle the repair of pipelines up to 48 inches in diameter.

J0170
Evans, J.T.
TIME-DEPENDENT PLASTIC RELAXATION AT A CRACK TIP.
Acta Metallurgica, Vol. 25, 1977, pp. 805-808.

A development of the model of Atkinson and Kay is presented, in which time-dependent plastic relaxation at a crack tip is represented by the movement of a single dislocation with a variable Burgers vector. The predictions of the model are compared with observations of crack opening displacement in mild steel. Some implications for fracture by stress corrosion cracking and fatigue are discussed.

J0180
Felker, C.E., Rieffle, Paul F.
NEW BOLTED COUPLINGS END PULLOUT WORRIES ON PLASTIC AND STEEL PIPE
Pipeline Gas Journal, Vol. 205, No. 6, May 1978, pp. 67,68,70,72,73.

A unique coupling design is described that uses pullout stress applied to the coupling to strengthen the grip on the pipe. Developed by Coupling Systems Inc., the Maxi-Hold coupling using this new design can be used to join any combination of metallic or plastic pipe without harnesses or other anchoring means. Performance tests show an unprecedented level of pullout resistance.

J0190
Fessler, R.R. and Barlo, T.J.
MANY CAUSES POSSIBLE FOR STRESS-CORROSION CRACKING
Pipeline and Gas Journal, Vol. 206, March 1979, pp. 25-28.

The Pipeline Research Committee of the American Gas Association sponsored a research program (Project NG-18) to determine the cause of stress-corrosion cracking in buried pipelines. This article gives an account of the findings from this program. Among the various causes reported are: the condition of the steel (it's production technique), defects in the pipe coating, the presence of carbonate-bicarbonate solutions, and the temperature in the pipeline environment. The inter-relationship of the various factors is also explained.

J0200
Gerhold, W.
CORROSION BEHAVIOR OF DUCTILE, CAST-IRON PIPE IN SOIL ENVIRONMENTS.
Journal of American Water Works Association, Vol. 68, No. 12, Dec. 1976, pp. 5506-5510.

Ductile cast-iron pipe was buried for up to fourteen years in a variety of soil environments. This final report, comparing its performance to that of carbon steel buried in the same soils, suggests the two substances corrode at nearly the same rates when encased in some soils. Different soils, however, alter the corrosion rates considerably for both materials.

J0210
Gerus, B.R.D., Cassin, J.N.
CORROSION IN THE BURNT TIMBER WET SOUR GAS GATHERING SYSTEM.
Mater Performance, Vol. 17, No. 3, March 1978, pp. 25-28.

A detailed account covering 4 years operation of a 37 mile (60 km) pipeline transporting natural gas containing condensate, water, and substantial percentages of hydrogen sulfide is given. During the interval 1970-74, at least 5 leaks in various segments of the line, including some in replaced piping, alerted operators to corrosion problems. Use of amine film forming, vapor phase, water dispersable, and other types of inhibitors is reported. Use of hydrogen probes, coupons, electrical resistance probes, ultrasonic test methods, radiography, and linalogs is discussed along with the relative efficiency of the methods in indicating potential corrosion damage. Recommendations include: warnings that sludge removal will not necessarily stop progress of pits; pits are isolated by geometry and resistance properties of the electrolyte and adjacent corrosion product layers; high superficial gas velocities (about 10 ft/s or 305 cm/s) help reduce pitting; radiographic inspection was the sole sure way to locate pits; and Linalog surveys were helpful.

J0220
Ionin, D.A., Yakovlev, E.I., Dobryak, D.S.
STATISTICAL METHOD OF LOCATING GAS LEAKS ALONG A GAS PIPELINE ROUTE.
Izv Vyssh Uchebn Zaved Neft Gaz, No. 3, 1977, pp. 83-87.

The method of detecting gas leaks and determining their location, considered in the article, is based on the evaluation of the difference between the times of arrival of pressure disturbances due to a rupture of the gas pipeline, at the ends of a controlled sector. Algorithms of determination of the location of a leak and of a maximum-probability estimation of its magnitude are proposed. The potential accuracy of the proposed method is evaluated. Calculations that have been made show that this method is highly accurate (In Russian).

J0230
Irwin, G.
FRACTURE.
Handbuch Der Physik, Vol. 6, 1958, pp. 551-590.

This article presents the principal concepts needed for an explanation of experimental observations of fractures. The experiments discussed are limited to those necessary for purposes of illustration.

J0240
Jette, N.A., Morris, M.S., et al.
ACTIVE ACOUSTIC DETECTION OF LEAKS IN UNDERGROUND NATURAL GAS DISTRIBUTION LINES.
Materials Evaluation, Vol. 35, No. 10, Oct 1977, pp. 90-96, 99.

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 prssure variations; and development of an optical earth vibration sensor based on laser interferometry. 10 refs.

J0250
Kanninen, M.F., Broek, et al.
TOWARDS AN ELASTIC-PLASTIC FRACTURE MECHANICS PREDICTIVE CAPABILITY FOR REACTOR PIPING.
Nuclear Engineering and Design, Vol. 48, 1978, 117-134.

Intergranular stress corrosion cracks have been discovered in the recirculation bypass piping and core spray lines of several boiling water reactor (BWR) plants. These cracks initiate in heat-affected zones of girth welds and grow circumferentially by combined stress corrosion and fatigue. Reactor piping is mainly type 304 stainless steel, a material which exhibits high ductility and toughness. A test program described in this paper demonstrates that catastrophic crack growth in these materials is preceded by considerable amounts of stable crack growth accompanied by large plastic deformation. Thus, conventional linear elastic fracture mechanics, which only applies to the initiation of crack growth in materials behaving in a predominantly linear elastic fashion, is inadequate for a failure analysis of reactor piping.

This paper is based upon research initiated by a need to develop a realistic failure prediction and a way to delineate leak-before-break conditions for reactor piping. An effective engineering solution for the type of cracks that have been discovered in BWR plants was first developed. This was based upon a simple net section flow stress criterion. Subsequent work to develop an elastic-plastic fracture mechanics methodology has also been pursued. A survey of progress being made is described in this paper. This work is based on the use of finite element models together with experimental results to identify criteria appropriate for the onset of crack extension and for stable crack growth. A number of criteria have been evaluated. However, the optimum fracture criterion has not yet been determined, even for conditions which do not include all of the complications involved in reactor piping.

J0260
Kiefner, J.F.
CRITERIA SET FOR PIPELINE REPAIR.
Oil & Gas Journal, August 7, 1978, pp. 104-118.

Criteria formulated for safe and effective repairs on defective areas in in-service pipelines are discussed in this article. Two repair methods have been found to be the most efficient; these are full-encirclement sleeves and deposited weld metal. The applications of these methods are explained in full. A list of pipeline repair terms definitions is also included in this article.

J0270
Kiefner, J., Duffy, A., et al.
FEASIBILITY AND METHODS OF REPAIRING CORRODED LINE PIPE.
Materials Protection and Performance, Vol. 11, No. 10, Oct. 1972, pp. 16-25.

Permanent repairs for corrosion defects are made possible by: internal on-stream inspection devices and/or monitoring cathodic protection currents that detect severe corrosion damage; reliable methods for predicting the remaining strength of corroded pipe; and the nature of corroded pipe which often allows the removal of coating and oxide to reveal sound metal beneath making patching of the damage area feasible. This eight page article explains various methods used to repair corroded line pipes, along with giving an account of experiments conducted using these methods. Among the techniques discussed are full encirclement split sleeves, patches, and deposited weld metal.

J0280
Koshiga, F., Kurita, Y., et al.
SHEAR FRACTURE PROPAGATION BY DCB TESTING.
Journal of Pressure Vessel Technology, Vol. 100, Fall 1978, pp. 18-23.

Spring-loaded DCB testing was developed as a laboratory simulation test of shear fracture propagation in pressurized gas pipelines. This article investigates shear fracture propagation in steel using DCB testing. The DCB testing system consists of a spring, a dully grooved double cantilever beam specimen, and a device for measuring crack velocity, load, opening displacement at loading point and strain distribution ahead of propagating crack. The particulars of this technique are explained along with the experimental results derived from tests conducted on steel.

J0290
Kottmann, A.
CARRYING CAPACITY OF PIPES MADE OF DIFFERENT MATERIALS UNDER VERY UNFAVORABLE CONDITIONS.
Gas Wasserfach Gas, Erdgas, Vol. 119, No. 6, June 1978, pp. 225-233.

On the basis of a study of transverse fractures and longitudinal cracks in very old gray cast iron pipes, an attempt was made to determine under what loads pipes made of different materials can be stressed to failure or beyond the yield point. A calculation shows that only a manufacturer's error can be responsible for damage to properly laid pipes. However, in large-scale pipe laying bending moments can arise which cause considerable deformations in plastically deformable pipes and fractures in other pipes, 5 refs. In German.

J0300
Kowaka, M. and Nagata, N.
TRANSGRANULAR STRESS CORROSION CRACKING OF MILD STEELS AND LOW ALLOY STEELS IN THE H2O-CO-CO2 SYSTEM.
Corrosion, Vol. 24, No. 12, December, 1968, pp. 427-429.

This article examines a new type of stress corrosion cracking, the failure of mild steel and low alloy steel pipes that occurred in an H2O-CO-CO2 system operating at room temperature up to 100°C (212°F). The experimental procedures that generated the cracks and its results are also reported in this brief article.

J0310
Krivian, L.
HOT SPOT CORROSION-HOT SPOT PROTECTION: SOME EXPERIENCES GAINED IN THE APPLICATION OF ELECTRIC DRAINAGE.
EUROCOR '77: Published by Soc. of Chem. Ind., Longdon, Engl. 1977, pp. 373-378.

Old pipelines of cast iron had to be replaced by welded steel pipelines. The pressure in the main distribution lines was increased up to 1-6 atm. In those towns where electrical tramways are being operated the danger of explosion has multiplied. Electric drainage was applied to prevent the corrosive effect of stray currents in three Hungarian towns. Pipe-to-soil potential proved a useful measurement for the location of dangerous spots and for the evaluation of the effectiveness of drainage bonds. The electric drainage is considered a special method of electrochemical corrosion control.

J0320
Mai, Y.W., Atkins, A.G., et al.
DETERMINATION OF VALID R-CURVES FOR MATERIALS WITH LARGE FRACTURE TOUCHNESS TO YIELD STRENGTH RATIOS.
International Journal of Fracture, Vol. 12, No. 3, June 1976, pp. 391-407.

Crack growth resistance curves are derived from a generalized theory of quasi-static crack propagation due to Gurney and Hunt. Both the subcritical and continuous cracking regions are investigated, where the fracture toughness of the material may depend on the cracking rate, the reacting environment at the crack tip and the mode of fracture. Precise conditions for stability of the spreading crack relative to chosen constraints of either a displacement- or load-controlled machine are formulated. Cracking of sheet materials with high fracture toughness and low yield stress, which do not satisfy certain size requirements, is often complicated by generalized yielding at regions remote from the crack tip. Complete R-curves for such materials cannot be established with conventional testpieces in the laboratory. The present paper adopts a new experimental technique (1) where a laboratory size reinforcement rig attached to the testpiece eliminates all irreversibilities caused by generalized yielding. Valid fracture toughness values and crack growth at the crack tip. Successful R-curve experiments are described for fracture in a few

ductile and tough materials such as 7075-T-3 and 1100-0 aluminum alloys, and a low carbon steel. Comparison is made with other published R-curves, and the influence of sheet thickness and ratio on the geometry of R-curves is investigated.

J0330
Masamichi, Furunaga, et al.
THE TEST METHOD OF HYDROGEN INDUCED CRACKING OF ROLLED STEELS UNDER WET HYDROGEN SULFIDE ENVIRONMENT.
The Sumitomo Search, No. 14, November 1975, pp. 43-57.

The test method of hydrogen induced cracking (HIC) of rolled steels under wet hydrogen sulfide (H_2S) environment was developed. The cracking susceptibilities of steels were evaluated in this test and compared with each others. The influence of metallurgical factors on HIC of steels also could be investigated.

In this paper, various testing conditions were investigated and the meaning of standard testing conditions was revealed. Then some interesting applications to HIC of steels given by this test were indicated.

J0340
Mazine and Uhlig
EFFECT OF TEMPERATURE AND SOME INHIBITORS ON STRESS CORROSION CRACKING OF CARBON STEELS IN NITRATE AND ALKALINE SOLUTIONS.
Corrosion, Vol. 28, No. 11, November 1972, pp. 427-433.

The effect of temperature is reported on failure times and critical potentials of mild steel and 0.24% C low alloy steel in a nitrate test solution, and in concentrated NaOH solution. The inhibiting behavior of small additions of acetates or chlorides to the nitrate solution, and Quebracho extract to NaOH solutions are studied. Mechanism of failure appears to depend on adsorption of damaging ions on appropriate defect sites of the plastically deforming metal, followed by weakening of adjacent metal bonds. The various procedures used to undertake this experiment are described in this paper.

J0350
McEowen, L.J. and Elsea, A.R.
BEHAVIOR OF HIGH STRENGTH STEELS UNDER CATHODIC PROTECTION.
Corrosion, Vol. 21, January 1965, pp. 28-37.

The problem of delayed failure or hydrogen-stress cracking in high strength steel has been well known for many years and has been the subject of considerable research.

Samples of line pipe steel were heat treated to yield strengths in the range of 110,000 to 150,000 psi. These steels were subjected to various tensile stresses while being charged with hydrogen in the laboratory under conditions simulating cathodic protection in the field. Hydrogen-stress cracking occurred at stresses in the range of operating stresses that might be used with these high

strength steels. Research is still being conducted to determine whether the laboratory tests would predict the field behavior of these materials if they were to be used at the high strength levels.

J0360
Miyoshi, E., Tanaka, T., et al.
HYDROGEN-INDUCED CRACKING OF STEELS UNDER WET HYDROGEN SULFIDE ENVIRONMENT.
Transactions of ASME, Journal of Engineering for Industry, No. 75-pet-2, June 1976, pp. 58-67.

The hydrogen induced cracking (HIC) of as-rolled steels has been investigated and is discussed in this article. The specimens were immersed into the synthetic sea water saturated with H_2S. Since the cracks initiated at the elongated MnS particles, the HIC susceptibility decreased with decreasing sulfur content. It was, however, often observed that the HIC occurred even in the steels containing extremely low sulfur. These cracks propagated along an anomalous structure, which consisted of low temperature transformation products. Such an anomalous structure arose from the segregation of manganese and phosphorus during the solidification of steels. As to the controlled rolled steels, the effects of texture, residual strain, and the shape of inclusions on the HIC were examined. It was revealed that the rolling at lower temperature did affect the HIC susceptibility with elongating the sulfide inclusions, while little effect of controlled rolling was recognized in the extremely low sulfur steels. It was also demonstrated that the addition of small amount of copper markedly reduced the amount of hydrogen absorbed. This could be due to the interface reaction between steel and wet H_2S environment. As the application of the foregoing results, the steel highly resistant to the HIC under the present experimental environment has been developed.

J0370
Moore, E.M. and Warga, J.J.
FACTORS INFLUENCING THE HYDROGEN CRACKING SENSITIVITY OF PIPELINE STEELS.
Material Performance, Vol. 15, No. 6, June 1976, pp. 17-23.

Tests are described which permit a qualitative assessment of the probable sensitivity of pipeline steels to stress cracking by hydrogen. Investigation of the possible causes of hydrogen stress cracking and the results of test programs indicates that cracking susceptibility is a function of composition and deoxidation practice which produces Mn sulfide inclusions of a geometry leading to cracking. Sulfur content does not appear to be significant, nor do variations in mechanical properties. Authors conclude semi-killed steels are markedly less susceptible, that addition of 0.25 to 3% Cu reduces cracking and blistering in fully killed steels. Use of recommended metallurgical controls should not, however, reduce necessity for inhibitor injection or other operational controls.

J0380
Nichols, R.W.
THE USE OF OVERSTRESSING TECHNIQUES TO REDUCE THE RISK OF SUBSEQUENT BRITTLE FRACTURE - PART 1.
British Welding Journal, January 1968, pp. 21-42.

This paper reviews various aspects of the application of a preload under controlled conditions as a means of reducing the possibility of subsequent fast fracture and is based on numerous replies to open letters as well as on published information. It is important to distinguish between three separate uses of the overstressing techniques, namely:

(a) In structures not given a thermal stress relief, to reduce the level of residual stresses near to welds by producing local yield. By reducing such residual stresses, it is expected that the risk of fracture at a particular level of externally applied stress is also reduced.

(b) To demonstrate that a structure does not contain defects sufficiently large to cause failure on subsequent application under similar conditions of a slightly smaller service load. While such an approach has always been qualitatively implicit in the proof test which is common to many design codes, of recent years various fracture mechanics approaches have made quantitative treatments on this basis.

(c) To remove the damaging effect of any defects which exist, for example, by work hardening the material at the tip of the crack to increase its yield strength, by producing local yield there which leaves a residual stress pattern and so reduces the stress at the tip of a crack under a given external load, by reducing the sharpness of the tip of a crack by the local yield. These effects would be expected to apply even to vessels which have already been thermally stress relieved (unlike (a)), and should have beneficial effects at temperatures lower than those at which the overstressing was done.

J0390
Nichols, R.W.
THE USE OF OVERSTRESSING TECHNIQUES TO REDUCE THE RISK OF SUBSEQUENT BRITTLE FRACTURE - PART 2.
British Welding Journal, February 1968, pp. 75-84.

Part 1 of this paper dealt with theoretical and laboratory evidence of the advantages of overstressing unstressrelieved structures; the benefits accruing other than the reduction of residual stresses, and other possible effects.

Part 2 gives details of some of the techniques of overstressing that have been used in practice.

J0400
Oil and Gas Journal
SPECIAL REPAIR METHOD CUTS COST ON AUSTRALIAN GAS LINE.
Oil & Gas Journal, Vol. 75, No. 41, October 3, 1977, pp. 90-92.

A specially developed repair method is highlighted that helped save millions during construction of a 1300-km gas pipeline in Australia. Once a defective section in the line was isolated, a diesel-powered trolley equipped with arc welders and grinders traveled the line and made the majority of repairs. Various steps involved in the repair procedure are described along with the results of the examination and repair of welds.

J0410
Parkins, R.N. and Fessler, R.R.
STRESS CORROSION CRACKING OF HIGH-PRESSURE GAS TRANSMISSION PIPELINES.
Material In Engineering Applications, Vol. 1, December 1978, pp. 80-95.

Stress corrosion cracks that have been found on the outside surfaces of gas pipelines in the USA have been characterized by a branched, intergranular path and a black Fe_3O_4 deposit on the crack surfaces. An ongoing research programme sponsored by the Pipeline Research Committee of the American Gas Association has revealed much about the causes of the cracking and about possible preventive measures. This research is discussed in depth in this paper.

It is believed that most, if not all, of the cracks have formed in a sodium carbonate-sodium bicarbonate environment in which a critical balance of activity and passivity has been achieved. Laboratory experiments have shown that the narrow range of potentials in which cracking is possible and the rate of crack growth can be correlated with the anodic polarization behavior. Temperature has a strong effect on the rate of crack growth and on the probability of establishing appropriate electrochemical conditions for cracking. The occurrence of cracking has not been related to any unusual or specific composition of steel but modification of steel processing might eventually offer a practical way of preventing the problem. The function of stress is primarily to produce a rate of straining sufficient to continually expose fresh metal at the tip of the crack.

J0420
Popelar, C., Rosenfield, A.R., et al.
STEADY-STATE CRACK PROGATION IN PRESSURIZED PIPELINES.
Transactions of the ASME, February 1977, pp. 112-121.

Previous work at Battelle-Columbus on the development of a theoretical model for unstable crack propagation and crack arrest in a pressurized pipeline is extended in this paper by including the effect of backfill. The approach being developed involves four essential aspects of crack propagation in pipelines. These four components of the problem are: 1) a shell theory characterization of the dynamic deformation of a pipe with a plastic yeild-hinge behind an arially propagating crack; 2) a fluid-mechanics·treatment of the arial variations in the gas pressure acting on the pipe walls; 3) an energy-based dynamic fracture mechanics formulation for the crack-driving force; and

4) measured values of the dynamic energy absorption rate for pipeline steels. Comparisons given in the paper show that the steady-state crack speeds predicted by the model are in reasonably good agreement with the crack speeds measured in full-scale tests, both with and without backfill. The analysis further reveals the existence of a maximum steady-state crack-driving force as a function of the basic mechanical properties of the pipe steel and the pipeline geometry and operating conditions. Quantitative estimates of this quantity provided by the model offer a basis for comparison with the empirical crack-arrest design criteria for pipelines developed by AISI, the American Gas Association, the British Gas Council, and British Steel. These are also shown to be in substantial agreement with the predictions of the model developed in this paper.

J0430
Poynton, W.A., Shannon, R.W.E., et al.
THE DESIGN AND APPLICATION OF SHEAR FRACTURE PROPAGATION STUDIES.
Journal of Engineering Materials and Technology, October 1974, pp. 323-329.

Shear fracture propagation is studied using an analysis based upon the thermodynamic equlibrium of a constant velocity fracture. This equation is shown to describe the behavior of all full scale test which exhibit constant velocity propagation. This equation is developed to identify the conditions for fracture arrest; the resulting formulation is again consistent with full scale test behavior. The paper also discusses the application of the theory to existing and new pipelines.

J0440
Reiser, A.
MECHANICAL STRESS LIMITS OF POLYETHYLENE OUTER COATINGS OF PIPES.
Gas Wasserfach Gas Erdgas, Vol. 118, July 7, 1977, pp. 289-293.

Tests of the mechanical stress limits of the polyethylene outer coating during the laying of steel pipes in the ground showed that the polymer coating by itself does not offer effective passive corrosion protection during the filling and packing of the trench and that additional protective measures are required to ensure acceptable corrosion resistance. Of the measures tested, which included encasing in protective mats or in a bed of gravel or sand, the method of encasing in sand was found to be the most effective. 4 refs. in German.

J0450
Rice, J.R.
A PATH INDEPENDENT INTEGRAL AND THE APPROXIMATE ANALYSIS OF STRAIN CONCENTRATION BY NOTCHES AND CRACKS.
Journal of Applied Mechanics, June 1968, pp. 379-386.

This paper describes an experiment in which a line integral is exhibited which has the same value for all paths surrounding the tip of a notch in the two-dimensional strain field of an elastic or deformation-type elastic-plastic

material. Appropriate integration path choices serve both to relate the integral to the near tip deformations and, in many cases, to permit its direct evaluation. This averaged measure of the near tip field leads to approximate solutions for several strain-concentration problems. Contained perfectly plastic deformation near a crack tip is analyzed for the plane-strain case with the aid of the slip-line theory. Near tip stresses are shown to be significantly elevated by hydrostatic tension, and a strain singularity results varying inversely with distance from the tip in centered fan regions above and below the tip. Approximate estimates are given for the strain intensity, plastic zone size, and crack tip opening displacement, and the important role of large geometry changes in crack blunting is noted. Another application leads to a general solution for crack tip separations in the Barenblatt-Dugdale crack model. A proof follows on the equivalence of the Griffith energy balance and cohesive force theories of elastic brittle fracture, and hardening behavior is included in a model for plane-stress yielding. A final application leads to approximate estimates of strain concentrations at smooth-ended notch tips in elastic and elastic-plastic materials.

J0460
Robertson, A.
GAS LINES FIND INHIBITORS INCREASE FLOW, REDUCE INTERNAL CORROSION.
Pipeline Gas Journal, Vol. 205, No. 3, March 1978, pp. 28-30.

In the past, gas gathering and transmission companies in the U.S. have been concerned with the problem of external corrosion of their lines and have developed cathodic protection methods to a finely tuned degree. But now, because of increased throughput of corrosive elements in the pipelines in their care, engineering staffs are more aware of corrosion on the internal surfaces of the lines. Common types of internal pipeline corrosion are described, the availability and types of inhibitors are discussed, and it is shown to set up an inhibitor program to deal effectively with the problem of internal corrosion in pipelines.

J0470
Royston, J.H.
USE OF COLD APPLIED ELASTOMERICTAPES ON THE TRANS-ALASKAN PIPELINE.
Corrosion '77, March 14-18, 1977, Publ. by NACE, Houston, TX, 1977, pp. 144.1-144.4

Cold-applied elastomeric films represent a different family of properties not normally found in pressure sensitive tapes, cola tar derivatives or laminates. Elastomers can be described as elastic rubber-like compounds occuring naturally or produced synthetically. Because of their extremely high electrical insulating values and superior acid, alkaline and water resistance, plus the great advantage of being practically unaffected in temperatures from -40°F to 185°F elastomers have found increasing uses for protecting pipelines.

J0480
Schmitz-Pranghe, N., von Baeckmann, W.
POLYETHYLENE-EXTRUSION-COATING OF BURIED STEEL PIPE, PROPERTIES, EXPERIENCES, VALUATION.
Corrosion '77, March 14-18, 1977, Publ. by NACE, Houston, TX 1977, pp. 142.1-142.22.

Polyethylene coatings have high mechanical resistance and adhesion and high resistance to electric currents. The cathodic protection current requirements to electric currents. The cathodic protection current requirements are very low. The protective current requirements measured over longer periods on buried pipelines remain at an almost constantly low level. The coatings have a high mechanical and aging resistance in the case of fully stablished PE, low permeation rates for oxygen and water vapor and a broad temperature application range. The paper describes manufacture and operating experience in the Federal Republic of Germany. 18 refs.

J0490
Vermilyea, D.A. and Tedman, C.S.
A SIMPLE CREVICE CORROSION THEORY.
Journal of Electrochemical Society, Vol. 117, No. 4, 1970, pp. 437-440.

A simple theory for the concentration and potential variation in a crevice is compared with experimental results from a model crevice. A consequence of the theory, confirmed by experiments, is that a small potential difference in a crevice can cause a large concentration change and a corresponding large increase in corrosion current at a given applied potential. The theory gives a simple way to estiamte concentrations in crevices in real corrosion situations.

J0500
Wullaert, R.A.
APPLICATIONS OF THE INSTRUMENTED CHARPY IMPACT TEST.
American Society for Testing and Materials, ASTM STP466, 1970, pp. 148-164.

Studies involving the application of the instrumented Charpy impact test are presented. The studies were concerned with the effect of strain rate, alloying, and irradiation on the ductile-brittle transition temperature (DBTT) and fracture behavior of pressure vessel steels.

The effect of strain rate on a 0.02C and 0.02C-3.5Ni steel was evaluated by comparing instrumented Charpy tests with three-point slow bend tests on Charpy V-notch specimens. Increasing the strain rate (1) increased the DBTT, (2) increased the yield stress, and (3) decreased the temperature dependence of the yield stress. The strain rate sensitivity of the yield stress was mainly responsible for the increase in the DBTT.

The instrumented Charpy test was used to determine why small nickel additions to steel are so effective in lowering the ductile-brittle transition temperature. The decrease in the DBTT was shown to be related to the decrease in the strain rate and temperature dependence of the yield stress produced by nickel.

The effect of irradiation on A212-B steel was evaluated by use of the instrumented Charpy impact test. Irradiating A212-B steel at approximately 260 C to a fluence of 9.4×10^{18} n/cm^2 (>1 Mev) increased the DBTT 56C. Irradiation increased the dynamic yield stress 30 percent but reduced the strain rate sensitivity of the yield stress. The increase in the ductile-brittle transition temperature was shown to be almost entirely due to the radiation-induced increase in the dynamic yield stress.

B0010
Allman, W.B.
DETERMINATION OF STRESSES AND STRUCTURAL PERFORMANCE IN POLYETHYENE GAS PIPE AND SOCKET FITTINGS DUE TO INTERNAL PRESSURE AND EXTERNAL SOIL LOADS.
American Gas Assoc. Operation Sect Proceedings, Los Angeles, CA, and Bal Harbour, FL, May 5-7 and May 19-21, 1975, pp. D178-D195.

Techniques and experimental work as it applies to polyethylene pipe and socket fittings and procedures which provide a basis for polyethylene gas distribution system design are discussed and presented in graphical, tabular, and equation form.

B0020
American Society for Metals (Canadian Council).
MATERIALS ENGINEERING IN THE ARTIC
Proceedings of an International Conference, St. Jovite, Quebec, Canada, September 27-October 1, 1976.

This volume compiles 38 scientific and engineering papers presented at a week long conference, sponsored by the Canadian Council of the ASM, on the development of engineering materials for use in an Artic environment.

Ten of the papers deal with pipelines and 11 of the 38 papers cover fractures-safe design.

B0030
American Society for Testing and Materials
FRACTURE TOUGHNESS EVALUATION BY R-CURVE METHODS.
Symposium sponsored by the Committee E-24 on Fracture Testing of Metals ASTM, 1971. ASTM Special Technical Publication STP 527.

This volume presents a collection of papers discussing the past, current and future developments and applications of R-Curve technology.

The term R-Curve refers to the relationship between the amount a crack grows and the applied stress intensity factor for a given material and thickness. R-Curve concepts can be applied for instability condition predictions. Many variations of the R-Curve approach are explained in a number of the papers. The application of R-Curve methods have shown that a singular Kc-value can not be used to predict instability conditions in all types and sizes of sheet specimen. Specimen configuration and dimensions determine the level of material instability.

The seven papers included in the volume are: Crack Growth Resistance Curves (R-Curves)-Literature Review; R-Curve Determination Using a Crack-Line Wedge-Loaded (CLWL) specimen; Measuring K_R-Curves for Thin Sheets; Fracture Extension Resistance (R-Curve) Characteristics for Three High-Strength Steels; Plane Stress Fracture Testing Using Center-Cracked Panels; Comparison of R-Curves Determined from Different Specimen Types; A Note on the Use of a Simple Technique for Failure Prediction Using Resistance Curves.

B0040
Asperger, R.G., Davidson, J.R.
CORROSION CONTROL IN GAS PROCESSING PLANTS WHICH REMOVE BOTH CO_2 AND H_2S.
Proceedings of the Gas Cond Conf. 26th Annual, Univ. of Okla, Norman, March 8-10, 1976, Sponsored by Univ. of Okla., 1976, Paper B, 19 p.

This paper reviews the mechanisms of corrosion in amine units. It discusses how this corrosion can be properly measured and evaluated by electronic methods. Then data is presented from the field and laboratory which illustrates the energy and other operational and capital savings which can be achieved through using higher amine concentrations along with good corrosion control technology. Considerable energy savings can be achieved by operating units at 30% MEA instead of 15-20%. If the gas being removed is mostly H_2S, it is theoretically possible to run existing or grass-roots plants at even higher amine concentrations which is limited primarily by the heat of reaction liberated in the absorber. Corrosion at high amine concentrations should no longer be the limiting factor in saving energy or expanding capacity for existing MEA units.

B0050
Atterbury, T.J. and Eiber, R.J.
PIPE MANUFACTURING VARIABLES.
Pipeline Research Committee of American Gas Association, 4th Symposium on Line Pipe Research, Dallas, TX, November 18-19, 1969, pp. K-1 - K-10.

This paper presents results from tests conducted to provide quantitative information about the effects of specific production practices on strength and toughness properties of pipe, with the end result of defining methods for improving strength and toughness.

The research results presented here were obtained from 34 laboratory heats that were produced with specific variations in chemistry and rolling practice. The variables investigated were chemical composition, rolling practices, heat treatment and pipe forming.

B0060
Azar, J.J., Vincent, P., et al.
BENDING AND FATIGUE CHARACTERISTICS OF PIPE CONNECTIONS FOR OFFSHORE PIPELINES.
Society of Petroleum Engineers, Paper No. 2609, 1969.

An experimental program has been performed to determine the suitability of various pipe connections for use in offshore pipelines and, more particuarly, in lines placed by the controlled catenary method. The types of connections chosen were the welded, the full runout buttress, a special hydrail and the 8-round API connections. Test data showed, both in the static and cyclic tests, that the welded connection is superior to the threaded connections; however, considering the severity of the tests, it can also be concluded that the full runout buttress thread is satisfactory for subsea pipeline service.

B0070
Bakker, W.T.
REFRACTORY APPLICATIONS IN GASIFIERS.
Ninth Synthetic Pipeline Gas Symposium, Chicago IL, October 31-November 2, 1977, pp. 447-463.

The scope and the initial results of a refractory evaluation and engineering development program, sponsored by ERDA, are reviewed in this paper. A summary of refractory practices in petrochemical, blast furnace and utility is also given by the author.

B0080
Barlo, T.J.
STRESS-CORROSION CRACKING STEEL SUSCEPTIBILITY.
American Gas Association 6th Symposium on Line Pipe Research, Houston, TX, October 29-November 1, 1979, pp. P-1 - P-17.

The metallurgical factors that control the susceptibility of steel are examined while under conditions that were found to influence the generation of stress-corrosion cracking. These conditions are: the environment next to the pipe, the potential at the pipe surface, the state of stress, the temperature, and the condition of the steel. These tests found that there were five major metallurgical factors that influence the threshold stress of the steel. The microstructure, thermomechanical history of the steel, and surface treatment are the three principal factors involved in the susceptibility of steel to stress corrosion cracking.

B0081
Barlo, T.J.
EFFECTS OF HYDROSTATIC RETESTS ON STRESS CORROSION CRACKING
American Gas Association 6th Symposium on Line Pipe Research, Houston, Texas, October 20-November 1, 1979, S-1 - S-10.

This paper discusses research undertaken by the AGA sponsored Pipe line Research Committee to determine which hydrostatic retest conditions may be most beneficial. The results of this research showed that hydrostatic retesting is beneficial and that it is the most reliable method available to date to locate and remove stress corrosion cracks in an operating pipeline.

B0090
Begley, J.A. and Landes, J.D.
THE J INTEGRAL AS A FRACTURE CRITERION.
Fracture Toughness, Proceedings of the 1971 National Symposium on Fracture Mechanics, Part 2, ASTM STP 514, American Society for Testing and Materials, 1972, pp. 1-20.

Experiments supporting the validity of a J_{Ic} fracture criterion are presented in this paper. Values of the J integral were determined experimentally for two steel alloys, one of low and the other of intermediate strength. A review is given of the analytic support for the J_{Ic} fracture criterion. The range of applicability of the J_{Ic} concept, its limitations, and its advantages are also discussed.

The path independent J integral, as formulated by Rice, can be viewed as a parameter which is an average measure of the crack tip elastic-plastic field. This together with the fact that J can be evaluated experimentally, makes a critical J value an attractive elastic-plastic fracture criterion. The J_{Ic} fracture criterion refers to crack initiation under plane strain conditions from essentially elastic to fully plastic behavior.

B0100
Bell, D.L.
AN OPERATIONAL REMOTE SENSING MARINE PIPELINE MAPPING SYSTEM.
Proceedings of the 26th Annual Petroleum Mechanical Engineering Conference, Houston, September 1971.

Based upon our recent studies in acoustic propagation theory and over two (2) years of worldwide field operations, a highly portable remote sensing system has evolved which permits the rapid and accurate assessment of pipeline location and orientation at production rates approaching twenty miles per operation day. This paper presents the technical background, operation, interpretation, and results of a joint magnetic-acoustic marine pipeline detection and mapping system (PIPESCOPE).

B0101
Berry, W.E. and Payer, J.H.
INTERNAL STRESS CORROSION CRACKING BY AQUEOUS SOLUTIONS OF CO AND CO2.
American Gas Association 6th Symposium on Line Pipe Research, Houston, Texas, October 29-November 1, 1980, pp. Z-1 - Z-18.

The results of a research program undertaken by the AGA sponsored Pipeline Research Committee, to determine the consequences of CO-CO2 stress corrosion cracking on the operation of gas transmission pipelines, are summarized in this paper. The existing data has shown that the dehydration of gas to prevent condensation of water in the pipeline appears to be the surest method to control CO-CO2 stress corrosion cracking.

B0110
Bohenenkamp, K.
CAUSTIC CRACKING OF MILD STEEL.
Fundamental Aspects of Stress Corrosion Cracking, Conference Proceedings sponsored by the Ohio State University, Department of Metallurgical Engineering, September 11-15, 1967, pp. 374-383.

This paper gives an account of experiments conducted in boiling solutions on specimens of different steels to investigate the mechanistic processess of stress corrosion. The experimental results show, among other things, the intergranular stress corrosion of mild steel in sodium hydroxide is limited to the region of the passivation potential.

B0120
Boulger, F.W.
ROLE OF MANUFACTURING VARIABLES ON THE PROPERTIES OF LINE PIPE.
Pipeline Research Committee of American Gas Association Symposium on Line Pipe Research, Dallas, TX, November 17-18, 1965, pp. 161-196.

This paper gives a summary of the results from experimental studies, conducted over a five year period, on the effects of manufacturing variables on metallurgical properties of line pipe steels and their performance in laboratory tests. An emphasis is placed on the strength and toughness characteristics.

B0130
Brando, P. and Sebastiana, G.
DETERMINATION OF SEALINES ELASTIC CURVES AND STRESSES TO BE EXPECTED DURING LAYING OPERATION.
Offshore Technology Conference, Paper No. 1354, April 19-21, 1971, Houston, TX.

The article describes a finite elements calculation procedure to determine sealines elastic curves and stresses expected during laying operations, both in presence and in absence of barge applied tension. The present method overcomes the difficulties encountered by other authors in determining complete curves which tend asymptotically to the stiffened catenary contour when deep water high tension and sealines with low specific gravity are to be considered. This method can also be used for small tension cases in shallow waters where the stiffened catenary formula.

B0140
Bright, G.F.
GAS SYSTEM SAFETY RELIEF VALVES.
Selected papers of the Heart of America Annual Gas Measurement Inst., 23rd, Liberal, Kans, Oct. 21-22, 1975, Sponsored by Petroleum Industry of Southwest Kansas through Univ. of Kansas Southwest Reg. Cent., Garden City, 1975, 8 p.

This paper on safety relief valves used in gas systems discusses four types of upsets that can occur and proposes corrections to assure that these upsets do not take place again. The four problems associated with the malfunctioning of relief valves that the operator must deal with are: (1) the noise produced when the relief valve has blown; (2) the destruction of the relief valve at a gate station by rapid opening and closing; (3) the popping of the relief valve which throws the compressor into surge and shuts it down; and (4) polluting gas discharge into the atmosphere when a relief valve pops. A modulating mode relief valve that alleviates these problems is also discussed.

B0150
Bush, H.E., Beasley, A.E.
EFFECT AND CONTROL OF CORROSION IN GAS STORAGE WELLS AND LINES.
American Gas Association Operation Sect. Proceedings, Los Angeles, CA, and Bal Harbour, FL, May 5-7 and May 19-21, 1975, pp. T205-T208.

Causes, monitoring, and corrosion rate criteria are discussed and presented on graphical, tabular, and equation form.

B0160
Chapman, W.H., Gibbons, R.E.
FEASIBILITY OF INTERNAL, INPLACE COATING FOR CORROSION CONTROL.
American Gas Association Operation Sect. Proceedings, 1976, Las Vegas, Nev., May 3-5, 1976, paper 76-T-45, 2 p.

Method of applying a coating in-place, developed by El Paso Natural Gas Company and believed to be more effective in combating internal corrosion problems, at least on some lines is presented. Internal, in-place coatings cover the weld area, and should be effective without inhibitors. The process is feasible and guidelines are established to make this a successful method of corrosion prevention.

B0170
Clarke, J.A. (Ed.); Coles, N.G. (Ed.).
PROCEEDINGS OF THE INTERNATIONAL CONFERENCE ON THE INTERNAL AND EXTERNAL PROTECTION OF PIPES, 1ST, 1975
Proceedings of the Int. Conf. on the Intern and External Protection of Pipes, 1st, Univ. of Durham, Engl., Sept. 9-11, 1975, various pages.

Proceedings include 38 papers on protective materials for pipe coatings, methods of pipe corrosion control, and methods of reducing pipe erosion and wear. Among the protective materials discussed are thermoplastic polymers, polyethylene, a zinc-base sprayed coating, cement mortar linings, asphalts, coal tar enamels, epoxy resins, glass-reinforced plastic, concrete mixed with iron ore, fused cast basalt, and ceramic linings. Applications of these materials include high-pressure pipelines, submarine and buried pipes, drinking water pipes, sewage systems, natural gas pipelines, and long-distance slurry pipelines. Also discussed are the prediction of corrosion in pipelines, the control of corrosion caused by bacteria, and cathodic protection of buried pipelines.

B0171
Clerehugh, G.
ON-LINE INSPECTION IN BRITISH GAS.
American Gas Association 6th Symposium on Line Pipe Research, Houston, Texas, October 29-November 1, 1980, PP. ZZ-1 - ZZ-28.

This paper contains an overview of the development of the British Gas On-Line Inspection system. In addition, the salient points of field operations are outlined and the current progress of this system is reviewed.

B0180
Davis, G.W.
STATIC ELECTRICITY AND LIGHTNING EFFECTS ON PLASTIC PIPE.
American Gas Association Operation Sect. Proceedings, Los Angeles, CA and Bal Harbour, FL, May 5-7 and May 19-21, 1975, pp. D-175 -D-177.

Results of laboratory and research studies are reported, and prevention measures are commended.

B0190
Day, R.A.
WHAT'S NEW IN PLASTIC PIPE RESEARCH?
American Gas Association Operation Sect Proceedings, 1975, Los Angeles, CA and Bal Harbour, May 5-7 and May 19-21, 1975, pp. D171-D172.

Data on long-term stress-rupture tests, outdoor exposure effect, heat-fused polyethylene joints, polymer aging, and external loading, are analyzed.

B0200
Dejong, J.
DEVELOPMENT AND UTILIZATION OF A DEEPWATER PIPELINE CONNECTOR.
Offshore Technology Conference, Volume II, April-May 1973, pp. 1149-1162.

This article describes a deepwater pipeline connector system which utilizes a one-atmosphere, subsea work chamber and connector chamber to encapsulate the pipe connection work area. The device makes use of the high seawater pressure that is present for pulling one pipe end close to the other and through the port on the connector chamber. The pipe-joining operation is controlled and the pipe is welded within the manned work chamber. The pipe connection operation is described for pipes laid by both the lay barge and bottom-pull methods. The basic connector system can be used for joining pipes during construction and repairing damaged pipe sections. Also, the chambers can be used to encapsulate pipeline valves and controls for subsea maintenance, servicing, and manual operations.

B0210
Dejong, J. and Feller, M.D.
THISTLE "A" PLATFORM PIPELINE CONNECTION.
10th Annual Offshore Technology Conference, Houston, TX, May 8-11, 1978, pp. 2557-2570.

In this paper an account is given of the entire pipeline connection project at the Thistle "A" platform in the North Sea. During 1977, three welded 16-inch pipeline-to-riser connections were successfully made in dry one-atmosphere chambers at the base of the Thistle "A" platform. The experience gained by using this riser-pipeline/platform-riser connection method, which was developed by Lockheed Petroleum Services Ltd., has led to the further development and expansion of this application to cope with larger-diameter pipelines and greater water depths.

B0220
DeLeon, C.
DOT TECHNICAL STUDY REPORT ON INDUSTRY'S PRACTICES USING PLASTIC PIPE IN GAS PIPELINE FACILITIES.
American Gas Association Operation Sect Proceedings, 1976, Distrib. Conf. Boston, MA, May 24-26, 1976, Paper 76-D-19, 2 p.

State-of-the-art review of the use of plastic pipe in gas facilities, giving emphasis to the potential safety problems and the possible need for regulations or other appropriate action to provide solutions to the problems is presented. Extensive data are assembled from a review of both foreign and domestic technical literature, standards, and codes. The pipeline failure reports operators made to OPSO and reports of gas accidents investigated by State agencies, OPSO, and the National Transportation Safety Board are studied. Also, the major source of information reviewed is from 58 questionnaires completed by experienced plastic pipe users, plus direct contacts by the study contractor with all major plastic pipe manufacturers and users of plastic pipe in gas, water, and sewer systems.

B0230
Doerfler, T.E.
USE OF STATISTICAL METHODS TO IMPROVE THE SAFETY OF GAS DISTRIBUTION SYSTEMS.
American Gas Association Operation Sect Proceedings, 1976, Distrib. Conf. Boston, MA, May 24-26, 1976, Paper 76-D-29, 2 p.

It is demonstrated that a simple statistical model can be used to assist in identifying, classifying and ranking leak-prone areas in the underground pipeline system. Based on a statistical analysis of physical characteristics, leak frequency and other relevant data descriptive of individual service lines, the model provides an objective technique for determining the likelihood of leak occurrence for individual services or any combination of services in a specified location. Using known quantitative and qualitative system characteristics contained in the company's service record file, the model is used to predict leak-prone neighborhoods. Subsequent detection surveys conducted in these areas reveal a strong agreement between actual and predicted leak occurrence.

B0231
Drouin, A.H., Herd, D.P. et al.
REMOTE INSTALLATIONS OF WELLHEAD TO PRODUCTION FACILITY PIPING IN A SUBSEA PRODUCTION SYSTEM.
Offshore Technology Conference, Vol. 1, Apr. 1971, pp. 1337-1348.

The development of a guidance and connector system is discussed for the remote connection of multiple pipelines from wellheads to the subsea control station of oil production facilities. The system was designed to allow the use of a single guideline for each connector, rather than four guidelines per connector as in most conventional systems. An articulated support frame was designed to allow relative movement between the connectors, while at the same time keeping them within known dimensional variations to ensure proper alinement of the connectors with the wellheads for the connection of the piping assembly was built and tested to evaluate the installation and retrieval characteristics of the design concept, and to determine the influence of the piping loads and the effect of the support frame on the alinement of the connectors. Several modifications were made to the model before satisfactory results were obtained, and then a full scale prototype was built and tested.

B0240
Duffy, A.R.
FULL-SCALE STUDIES.
Pipeline Research Committee of American Gas Association Symposium on Line Pipe Research, Dallas, TX, November 17-18, 1965, pp. 43-82.

This paper discusses two types of full-scale tests investigating all facets of propagating fractures in order to learn how pipe fractures and what factors influence the manner in which it does. The principle factors being investigated are material properties, temperature, nominal stress level, diameter, wall thickness, and backfill.

One test involves short lengths of pipe (20 ft.) that were fractured in a concrete pit. The purpose of this test is to obtain full-scale fracture data conveniently and economically.

The second experiment was conducted on buried line pipe pressurized with natural gas. A service environment was created for this test. The test results show that the most important single factor in determining how a pipe length will fracture is the material-temperature interrelation.

B0250
Duffy, A.R.
STUDIES OF HYDROSTATIC TESTS LEVELS AND DEFECT BEHAVIOR.
Pipeline Research Committee of American Gas Association Symposium on Line Pipe Research, Dallas, TX, November 17-18, 1965, pp. 139-159.

One of the concerns of this paper is the identification of the causes that stimulate a defect to become unstable with rapid propagation occurring. The other focus of the paper is the presentation of an investigation looking into the relationship beteen hydrostatic test levels and the number and size of the defects removed.

B0260
Duffy, A.R.
THE PRESENT NG-18 PROGRAM.
Pipeline Research Committee of American Gas Association 5th Symposium on Line Pipe Research, November 20-22, 1974, pp. E1-E-A4.

The present NG-18 program, a research activity sponsored by the AGA to research pipeline failure, basic format and involvements are reviewed in this paper.

The main areas of concern in this program are: Field Failure Investigations, Survey of OPS Failure Data, Fracture Fundamentals, Full-Scale Experiments, and Hydrogen Stress Cracking. This paper also provides an extensive bibliography.

B0270
Duffy, A.R.
HYDROSTATIC TESTING.
Pipeline Research Committee of American Gas Association 4th Symposium on Line Pipe Research, Dallas, TX, November 18-19, 1969, pp. H-1 - H-19.

A summary of research results pertinent to hydrostatic testing and a discussion of their implication is given in this paper, which was presented to an AGA symposium on line pipe research.

B0271
Edminston, K.
NEW SYSTEM REPAIRS PIPE LINE IN 190-FOOT WATER.
Ocean Industry, Vol. 6, No. 1, Jan. 1971, pp. 35-38.

This article describes a system designed to repair pipeliners in deep water. The system is composed of a pipe lineup frame, underwater habitat, frame and habital control console, and umbilical cords. This system can handle the repair of pipelines up to 48 inches in diameter.

B0280
Eiber, R.J.
FRACTURE PROPAGATION.
Pipeline Research Committee of American Gas Association 4th Symposium on Line Pipe Research, Dallas, TX, November 18-19, 1969, pp. I-1 - I-20.

This is an indepth description of an experimental program conducted by the Pipeline Research Committee of the A.G.A. The characteristics that control the extent or arrest of shear fractures are investigated. The experimental results indicate that the characteristics of propagating fractures exhibit an abrupt transition as the temperature of the pipe is increased, changing from relatively high-speed cleavage fractures to relatively slow-speed shear fractures.

B0290
Eiber, R.J.
FIELD FAILURE INVESTIGATIONS.
Pipeline Research Committee of American Gas Association 5th Symposium on Line Pipe Research, November 20-22, 1975, pp. G1-G19.

The field failure investigation phase of the NG-18 program is examined in this paper. This phase of the program was initiated to determine the causes of failures and the arrest characteristics of the fractures in pipelines. Fifty-two investigations have been conducted and are summarized in this paper. Pictorial explanations also offer support to the discussions.

B0291
Eiber, R.J.
CAUSES OF PIPELINE FAILURES.
American Gas Association 6th Symposium on Line Pipe Research. Houston, Texas, October 29-November 1, 1979, pp. C-1 - C-20.

A somewhat detailed overview of pipeline failures is presented in this paper. A discussion on how to use the fracture surface to locate the origin of features is given. This discussion looks specifically at the characteristics of the origin, the origin in the base metal and the origin associated with the weld.

B0300
Eiber, R.J.
FRACTURE PROPAGATION CONTROL METHODS.
American Gas Association 6th Symposium on Line Pipe Research, Houston, TX, October 29 - November 1, 1979, pp. L-1 - L-16.

This presentation is divided into discussions of brittle and ductile fracture control. In both types of fracture, control is discussed from the viewpoint of the inherent fracture toughness of the steel line pipe. The use of mechanical crack arrestors is also reviewed.

B0310
Fessler, R.R.
STRESS-CORROSION CRACKING.
Pipeline Research Committee of American Gas Association 4th Symposium on Line Pipe Research, Dallas, TX, November 18-19, 1969, pp. F1-F18.

The purpose of this paper is to describe the various approaches that are undertaken to find ways to prevent stress-corrosion cracking (SCC) of pipelines. This paper also contains summaries of some of the preliminary findings using these approaches. One investigation found that for pipe already in the ground, the most promising solution to the problem of SCC involves the use of chemical inhibitors in certain areas and to specify the most effective inhibitors.

B0311
Fessler, R.R.
OVERVIEW OF SOLUTIONS TO THE STRESS CORROSION CRACKING PROBLEM
American Gas Association 6th Symposium on Line Pipe Research, Houston, Texas, October 20-November 1, 1980, pp. V-1 - V-10.

This paper summarizes the status of the present research with respect to solving the stress corrosion cracking problem, recognizing that the findings must be considered as tentative and subject to alteration depending upon the nature of future research results. Remedial measures that are discussed include: hydrostatic retesting, lowering discharge temperatures, and the potential effectiveness of interrupted cathodic protection. These techniques can be applied to present pipelines. Several other methods have been shown to be effective for future pipelines. These are: the use of better coatings, inhibitors in the coating system, and shot peening or grit blasting.

B0320
Fisher, R.M.
LEAK SURVEY QUALITY INDEX.
American Gas Association Operation Sect Proceedings, Los Angeles, CA, and Bal Harbour, FL, May 5-7 and May 19-21, 1975, pp. D72-D74.

Control system and practice are discussed and presented in graphical form.

B0321
Fletcher, E.E. and Fessler, R.R.
LABORATORY STUDIES OF INTERRUPTED CATHODIC PROTECTION
American Gas Association 6th Symposium on Line Pipe Research, Houston, Texas, October 29-November 1, 1980, pp. T-1 - T-20.

This paper summarized progres made on laboratory studies investigating interrupted cathodic protection as a means of preventing stress corrosion cracking of pipelines. The studies conducted demonstrated that stress corrosion cracking can be prevented with some types of cyclic potentials, even though the potential gets into the critical range for cracking during each cycle. The research also indicated that pitting corrosion can be prevented with interrupted cathodic protection, even during the portion of the cycle when the cathodic-production currents are not flowing.

B0330
Fukuda, Minoru, et al.
THE STUDY ON THE PROPAGATING SHEAR FRACTURE BY FULL SCALE BURST TESTS AT ATHENS.
Sumitomo Metal Industries, Ltd., Bulletin No. 054-74, March 1974, pp. 1-21.

This paper contains a description of the metallurgy involved in separations. It was found that the clusters of crystal grains with (100) plane parallel to the plate surface are the main sources of separation cracks. Two series of the full-scale all-gas burst test of 48" large dimater pipes were carried out to determine the effects of separations. The results of these tests are presented and some discussion is given. No influences of separation on fracture length, fracture speed, and absorbed plastic energy of propagating shear fracture are recognized.

B0340
Gouch, A.
SOME OBSERVATIONS ON PIPELINE WELDING.
Int. Inst. of Wld., Public Sess & Met Technol Conf. Sydney, Australia, Aug. 21-28, 1976, Sponsored by Int. Inst. of Weld, London, Engl. 1976, 5 p.

This paper is concerned with the nature and origin of a number of welding defects encountered in constructing the 1331 km Moomba-Sydney natural gas pipeline. The general features of the design, including the hydrostatic testing procedures are discussed briefly and the observed defects in the girth welds are considered in terms of these.

B0350
Graf, F.L.
GAS PIPELINE LEAK LOCATION AND MEASUREMENT.
American Gas Association Operation Sect Proceedings, Los Angeles, CA and Bal Harbour, FL, May 5-7 and May 19-21, 1975, pp. D42-D44.

Use of deep probes in air and vacuum testing to reduce repair expenses is discussed.

B0360
Graff, W.F.
WELDED TUBULAR CONNECTIONS OF RECTANGULAR AND CIRCULAR HOLLOW SECTIONS.
Structural Meeting ASCE, El Paso, TX, October 10, 1970.

This paper is a review of the experimental investigations regarding the behavior of structural connections formed by welding together directly tubes of rectangular or circular cross section. Relatively few investigations have been conducted on rectangular tubes, although in Britain alone use of this hollow section has increased so markedly that the structural advisory service of the steel company, Stewarts and Lloyds, Ltd., reported that production increased from 3,000 tons in 1959 to 70,000 tons in 1964.

The work relating to rectangular tubes is summarized in Part I of the paper. There have been many investigations of welded joints using circular tubes or pipes and Part II reviews this extensive wealth of information, beginning with static strength determinations and extending through recent studies of fatigue behavior.

B0370
Green, R.A. and Pincus, G.
THE PERFORMANCE OF SELECTED PIPELINE COUPLING.
Offshore Technology Conference, Vol. II, April-May 1973, pp. 11281-11290.

This paper describes an investigation to determine the performance of several types of subsea mechanical pipe coupling under the loading conditions of internal pressure, tension forces, and bending stresses, simulating actual working conditions. The variation of stress and strain in the pipe adjacent to the test pipe couplings was also studied.

B0380
Groeneveld, T.P.
HYDROGEN STRESS CRACKING
Pipeline Research Committee of American Gas Association 4th Symposium on Line Pipe Research, Dallas, TX, November 18-19, 1969, pp. E-1 - E-15.

Hydrogen stress cracking is a time-dependent failure mechanism that can cause cracks to initiate and grow in high strength steels, that are loaded to stresses below their yield strengths when the steel contains atomic hydrogen in solution.

An experimental program, initiated by the NG-18 research program, investigated HSC behavior of high-strength line pipe and work on hard spots. The major conclusions derived from this research effort in HSC behavior of heat-treated high-strength line pipe have shown that the rate at which steels accept hydrogen from their environment is one of the most important factors influencing their susceptibility to hydrogen stress cracking. Although the program wasn't able to completely identify all the parameters, methods to minimize or prevent the occurrence of HSC in hard spots have been developed and are listed.

B0381
Groeneveld, T.P. and Fessler, R.R.
HYDROGEN STRESS CRACKING OVERVIEW AND CONTROLS.
American Gas Association 6th Symposium on Line Pipe Research, Houston, Texas, October 29-November 1, 1980, pp. Y-1 - Y-25.

A research program sponsored by the Pipeline Research Committee of the American Gas Association is being conducted to determine the maximum strength of steel that could be used for line pipe without encountering HSC failures. The progress report is summarized in this paper. A number of tables and photographs are used to illustrate the experimental procedures and results.

B0390
Haase, W.H.
ACOUSTIC VALVE OPERATING SYSTEM.
Offshore Technology Conference, Paper No. 1175, April 1970.

As offshore pipeline systems expand into areas great distances from shore, and into deep waters, a method for locating and controlling isolated underwater valves is required.

The Bendix approach to fulfilling this requirement is the Acoustic Valve Operating System (AVOS). The system features coded interrogation, coded command, and five-year life. The coding, accomplished by using multiple frequencies, is designed to prevent unauthorized or accidental valve actuation.

A selected valve can be located from a three-mile distance, and can be commanded to open or close from one-half mile. Range to the valve and actual status are automatically displayed and updated by a frequency coded reply to each interrogation.

In addition to performance requirements, the data presented includes design considerations, hardware items, and test data resulting from a Gulf installation.

B0400
Hann, G.T.
FUNDAMENTAL STUDIES OF FRACTURE PROPAGATION.
Pipeline Research Committee of the American Gas Association Symposium on Line Pipe Research, Dallas, TX, November 17-18, 1965, pp. 21-24.

This paper reviews the basic principles of physics and metallurgy that offer explanations for fracture propagation. These principles are the transfer points for different technologies that enter the line pipe fracture problem: steel chemistry, processing, line pipe design, etc. The explanations are reduced to common terms and numbers. Equations are then developed and assembled into a comprehensive analysis. The preliminary results of a computer analysis is also included.

B0410
Hahn, G.T. and Rosenfield, A.R.
FUNDAMENTAL FRACTURE MECHANISMS.
Pipeline Research Committee of American Gas Association 4th Symposium on Line Pipe Research, Dallas, TX, November 18-19, 1969, pp. J-1 - J-17.

The relations between the yield strength and toughness and the composition and the microstructure of steel are examined in this paper.

B0420
Harper, R.A.
WEKO-SEAL FOR CAST IRON JOINT REPAIR.
American Gas Association Operation Sect Proceedings, 1976, Distrib. Conf. Boston, MA, May 24-26, 1976, Paper 76-D-52, 6 p.

Use of internal sealing to repair joints as small as 20 inches in diameter and above, is described. Process avoids costly street openings.

B0430
Harris, G.M.
CORROSION OF UNDERGROUND PIPELINES BY PLASTIC TAPE PIPELINE COATINGS.
American Gas Association Operation Sect Proceedings, Published by American Gas Association (Cat. No. X50477). Arlington, VA 1977, pp. D.52-D.57.

This paper reports on the history of plastic pipeline coatings since 1950. Plastic tape coatings are discussed in terms of chemical composition, inherent chemical, electrical and physical properties and application techniques. The performance characteristics of the two types of plastic tape pipeline coatings in common use are discussed and contrasted. The in-service underground performance of plastic tape pipeline coatings is presented by means of actual case histories on pipelines which have been coated with plastic tape during the past 20 years.

B0440
Haught, J.W.
NEW METHODS AND DEVELOPMENTS FOR CORROSION CONTROL.
American Gas Association Operation Sect Proceedings, Los Angeles, CA, and Bal Harbour, FL, May 5-7 and May 19-21, 1975, pp. D53-D54.

Various devices for protection are described based on factory specifications.

B0450
Haynes, M.D.
LEMAN GAS COMPRESSION PROJECT SOUTHERN NORTH SEA.
Offshore Technology 8th Annual Conference Proceedings, Houston, TX, May 3-6, 1976, pp. 617-623.

This paper is a case history of the design, construction and installation of a gas compression station in the Southern North Sea - U.K. Sector. It is one of the three compression platforms serving the Leman Field. The water depth in this area is 117 ft. and the compressor platform structure is a conventional eight-leg/52-inch diameter/jacket weighing approximately 650 tons. The station is located at the inlet of a 30-inch diameter gas transmission line. The nominal capacity of the station and line is 900 psia. The station is designed for four turbine/compressor units with two units initially installed.

B0460
Husock, B.
EVALUATION OF CORROSION ACTIVITY ON BARE STEEL TRANSMISSION LINES.
American Gas Association Operation Section Proceedings, Las Vegas, Nev., May 3-5, 1976, Paper 76-T-17, 7 p.

The Soil Resistivity-Probability Method described makes possible the use of electrical survey measurements on bare pipelines to determine the areas in which cathodic protection should be applied. The statistical procedure has the built-in flexibility necessary to make it applicable to the wide variety of conditions encountered in underground corrosion. Although the pipeline in the example is cathodically protected in the designated areas by means of an impressed current system with distributed anodes, the evaluation method does not in any way limit the methods used in providing cathodic protection.

B0470
Ikeda, A., et al.
HYDROGEN-INDUCED CRACKING (HIC) SUSCEPTIBILITY OF VARIOUS STEEL LINE PIPES IN THE WET H2S ENVIRONMENT.
Corrosion/78, The International Corrosion Forum Devoted Exclusively to the Protection and Performance of Materials, March 6-10, 1978, Albert Thomas Convention Center, Houston, TX, pp. 94-115.

HIC susceptibility of commercial line pipe and the development of HIC resistant line pipe are described and discussed in relation to the environmental factors. Many schematic illustrations, graphs, and photographs are used to show the test procedures and results.

B0480
Jirsa, J.O., Wilhoit, J.O., Jr., et al.
EFFECT OF CONCRETE COATING ON THE RIGIDITY OF 12-3/4" LINE PIPE.
Offshore Technology Conference, Paper No. 1074, May 1969.

Bending stresses involved when laying pipelines in deep water from a lay barge is a problem that will become more and more critical as new oil and gas fields are being discovered at greater distances from shore in deeper water. This trend toward deeper water and greater distances means that improvements in the design of the pipelines as well as in laying methods and equipment are being made. The minimum radius of curvature to which the pipe can be subjected in the laying operation depends on the behavior of the pipe and the concrete coating. Failure may be due to the pipe and coating becoming fully plastic, to local buckling, to the spalling of the concrete, or to a combination of these. In any event, to insure successful deep-water pipe construction, the bending stresses involved must be determined. These stresses are due to the unsupported buoyed weight of the pipe and to currents, barge motion, etc. To estimate these stresses, for a given moment, the flexural rigidity of the coated pipe is required. During pipelaying operations the pipe has two flexural rigidities. In the field joint length, the concrete coating is still fluid and makes no contribution to the rigidity of the pipe. However, in the length that has a solidified concrete coating the concrete could be expected to increase the flexural rigidity.

This paper reports the results of tests of four 12-3/4" by 0.406 -in. x-52 pipes in which the effect of the concrete coating on the flexural rigidity was studied. Moment-radius of curvature relationships determined from strain and deflection measurements were compared with analytical results computed for both bare and coated pipes. The tests also provide some insight into the effect of joints on the behavior of the pipe.

B0490
Jirsa, J.O., et al.
OVALING OF PIPELINES UNDER PURE BENDING.
Offshore Technology Conference, Paper No. 1569, May 1972.

The influence of ovaling on the flexural behavior of pipelines stressed beyond the elastic limit was studied. Six pipes, with diameter ranging from 10-3/4 to 20 in. and diameter-to-thickness ratio varying from about 30 to 80, were tested. Four of the pipes tested were uncoated and two were coated with concrete.

Moment-curvature relationships into the plastic region of behavior were obtained experimentally, and ovaling was measured at all stages of loading. Theoretical moment-curvature and ovaling values were computed. Computed values were compared with experimental results, resulting in the conclusions that moment-curvature and ovalization curvature relationships can be predicted for bare pipe under monotonic loading, and that ovaling does not significantly reduce the moment capacity of the pipes until strains well into the plastic region are reached.

B0500
Kanninen, M.F.
THEORETICAL MODEL OF PROPAGATING FRACTURE IN PIPE.
Pipeline Research Committee of AGA 5th Symposium on Line Pipe Research, November 20-22, 1974, pp. I-1, I-11.

An outline of the development of a theroetical model for an axial crack propagating along an unbackfilled pipe under steady-state conditions is contained in this paper. Particular account is taken of the interaction between the pipe deformation and the dynamics of the escaping gas. The result is expressed in terms of the dynamic energy release rate parameter of fracture mechanics. This quantity is found to be a function of the steady-state crack speed, the pipe dimensions and maechanical properties, the gas properties, and the pipeline operating conditions. A comparison made between full-scale test results and the single instance in which an estimate of the critical value of the dynamic energy release can be made, shows good agreement between theory and experiment.

B0510
Kiefner, J.F.
CORRODED PIPE: STRENGTH AND METHODS.
Pipeline Research Committee of AGA 5th Symposium on Line Pipe Research, November 20-22, 1974, pp. L-1 - L-23.

The Texas Eastern Transmission Corporation and the Pipeline Research Committee have developed a reliable criterion for determining the remaining strength of corroded pipe. The basis of this criterion is explained, along with results of a research effort sponsored by the Pipeline Research Committee in which the effectiveness of repair methods was evaluated. The latter effort established the degree of reliability of some possible remedies for corroded sections which otherwise might affect adversely the serviceability of the pipe.

B0520
Kiefner, J.F.
FRACTURE INITIATION.
Pipeline Research Committee of American Gas Association 4th Symposium on Line Pipe Research, Dallas, Texas, November 18-19, 1969, pp. G-1 - G-33.

The Fracture Initiation Phase of NG-18 research (AGA Pipeline Research Committee) consists of studies of conditions and circumstances that result in the destructive rupturing or leaking of pipeline materials. This paper presents a discussion of the relationship between flaw size and failure stress, developed through a union of experimental results and theoretical considerations. In addition, the results of tests of pipe materials containing a variety of simulated defects is discussed, along with a general description of the behavior of the defects.

B0530
Kiefner, J.F.
DEFECT REPAIR PROCEDURES.
American Gas Association 6th Symposium on the Line Pipe Research, Houston Texas, Texas, October 29, - November 1, 1979, pp. I-1 - I-31.

The Pipeline Research Committee of the A.G.A. commissioned a 6-year study of repair methods involving welded split sleeves and deposited weld metal. The results of this study are summarized in this paper. Essentially, these studies have produced:

a. Conclusive evidence that a full encirclement sleeve with welded ends constitutes a safe and dependable means of repairing almost any of the known kinds of pipeline defects.

b. A clear demonstration of the effectiveness of an easily applied sleeve with nonwelded ends for repairing a wide variety of nonleaking defects.

c. A demonstration of the usefullness and feasibility of directly deposited weld metal as a means of repairing certain kinds of nonleaking defects.

d. A set of criteria for selecting a suitable repair method and repair conditions for most of the known kinds of pipeline defects.

B0540
Krossmann, D.
AUTOMATION OF THE DISPATCHING IN PIPELINE PROJECTS.
Dtsch Ges fuer Mineraloelwiss and Kohlechem, 24th Symp: Compend 74/75, Hamburg, Ger. Sep. 30 - 30 Oct 3, 1974, pp. 830-843.

Dispatching functions as performed on gas, oil and product pipelines, and distribution networks are discussed, and various technical aspects of automation, such as measurement and control techniques, local control, communications, control center, process computer and its peripherals are described. Several examples are given to show how these dispatching functions can be solved.

Also, the economics of various automated devices performing such functions are examined. In German.

B0550
Lacey, J.E.
'ARE YOU SURE? - ACCIDENT PREVENTION COMMITTEE MINITALK.' -
American Gas Assoc. Operation Sect. Proceeding, Paper 76-D-36, 6 p., Pap 76-D-62, 2 p.

Various safety aspects are discussed, and personal attitudes to accident prevention are considered.

B0560
Langner, C.G.
THE ARTICULATED STINGER: A NEW TOOL FOR LAYING OFFSHORE PIPELINES.
Offshore Technology Conference, Paper no. OTC 1073, Volume II, May 1969, pp. 1137-1146.

This paper describes a pipe support structure or stinger designed for laying offshore pipelines from a large barge. The stinger consists of several adjustable buoyant segments connected in series by special hinge joints which provide a limited degree of vertical, lateral, and torsional flexibility. The advantages of this articulated stinger over the conventional type of straight, stiff stinger are discussed. Vertical stinger flexibility, in combination with an applied pipe tension, increases the water depth capability of the stinger, and reduces the required stinger length. Lateral and torsional flexibility increases the weather capability of the stinger. The use of the articulated stinger to lay pipelines in deep water is discussed and illustrated. The performance of the articulated stinger in model tests and a prototype situation are also discussed.

B0570
Lucas, O., and Taylor, J.S.
PREDICTING PIPELINE RESPONSE TO BURIED EXPLOSIVE CHANGES.
American Gas Assoc. Operation Sect. Proceedings, Publ by AM Gas Assoc (Cat. No. X05477), Arlington Va., 1977, pp. T.212 - T.219.

This paper reviews the work of the AGA Pipeline Research Committee in its effort to make available to the gas transmission industry reliable analytical procedures for practicing pipeline response to buried explosive charges. The basic problem of blasting within 100 ft of pipelines and the presently available knowledge is discussed. Each of three project work phases is reviewed. Phase I covered literature search and analytical development work, while Phase II focused on sealed test experiments and development of a preliminary analytical procedure for predicting maximum incremental stresses in the pipe caused by biasing. Phase III will include full scale blasting tests.

B0580
Maxey. G.M., et al
FRACTURE INITIATION AND PROPAGATION IN UNDERWATER PIPELINES.
10th Annual Offshore Technology Conference, Houston Texas, May 8-11, 1978, pp. 2197-2202.

A description of a research program sponsored by the Pipeline Research Committee of the American Gas Association is contained in this paper. The problem of fracture in underwater pipelines is investigated by means of medium and small-scaled pipe experiments.

The objective of this research is to obtain an understanding of fracture initiation and propagation in underwater pipelines. The pipes test corresponded to a similar specimen which had been tested in a conventional pressure vessel experiment (above ground). A minimum number of variables were changed so that a direct comparison could be made between the results of the above-ground test specimens and the underwater specimens.

The data obtained from this study indicates that the external pressure is effective in limiting the crack driving forces for both crack initiation and fracture propagation. It also concluded that ductile fracture initiation and brittle fracture propagation are controlled by the differential pressure between the inside and outside of the pipe.

B0590
Maxey, W.A.
FRACTURE INITIATION CONTROL CONCEPTS.
American Gas Association 6th Symposium on Line Pipe Research.
Houston Texas, October 29 - November 1, 1979, pp. H1-H12.

This paper discusses several fracture initiation control concepts to provide the necessary background and guidance for specifying toughness requirements toward limiting fracture initiation at current technology. With regard to the toughness requirements for mechanical damage, the concept presented is in the preliminary stage of development. The technique used to evaluate flaw size tolerance is the Charpy Plateau Energy Test.

B0600
Maxey, W.A.
FRACTURE PROPAGATION STUDIES.
American Gas Association 6th Symposium on Line Pipe Research.
Houston, Texas, October 29 - November 1, 1979, J-L - J-19.

The intent of this paper is to review past and current work relating to the effects of the environment surrounding the pipe, and the fluid within the pipe on fracture propagation. Two primary types of fracture propagation behavior exist; this behavior relative to the external environment and the internal fluid also is reviewed.

B0610
Maxey, W.A.
FRACTURE INITIATION, PROPAGATION AND ARREST.
Pipeline Research Committee of AGA 5th Symposium on Line Pipe Research,
November 20-22, 1974, pp. J1-J31.

Over 300 experiments were conducted by the AGA sponsored NG-18 program, examining the behavior of defects and the fracture propagation and arrest characteristics in pipe line materials. The results of these experiments are summarized in this paper.

B0620
May, D.
PIPE TO SOIL READINGS BY OTHER THAN CATHODIC PROTECTION PERSONNEL.
American Gas Assoc Operation Sec Proceedings, 1976, Distrib Conf. Boston, Mass. May 24-26, 1976 Paper 76-D-25, 2 p.

In an attempt to eliminate the underutilization of technical talent and to provide a cathodic protection monitoring capability that was impossible with the old practice. Public Service Company purchased a number of pipe to soil potential meters, consisting of a relatively high resistance volt meter, a copper-copper sulfate half cell, and a wire lead with an alligator clip. An instrument was issued to each Gas Street (main and service maintenance and installation) Crew, each Gas Shop (meter and regulator installation) Crew, and each contractor crew inspector. These personnel were given training in the use and care of the instruments and were asked to take pipe to soil potential readings each time they worked on the mains, services, or outside meter sets. These readings are later transcribed to the cathodic protection records by office clerical personnel, who had received training in this additional duty.

B0630
Mayfield, M.E., et al.
FRACTURE INITIATION TOLERANCE OF LINE PIPE.
American Gas Association 6th Symposium on Line Pipe Research. Houston, Texas, October 29 - November 1, 1978, pp. F-1 - F-14.

This paper addresses fracture initiation as it pertains to mechanical damage defects. This discussion of mechanical damage research is limited to dent and gouge defects. The research data indicated the ability to accurately predict the failure stress of mechanical damage flaws hasn't been developed. However, the variable that influence such failures have been identified. A continuing research effort in this field should provide an understanding of the fracture initiation process for such defects and the ability to predict their behavior.

B0640
McAmis, J.W.
INSULATING REQUIREMENTS TO PROTECT EXISTING COATED DISTRIBUTION SYSTEMS.
American Gas Assoc Operation Sect Proceedings, Los Angeles, Calif. and Bal Harbour, Fla, May 5-7 and May 19-21, 1975, pp. D46-D47.

Anti-corrosion measures and procedures are described.

B0650
McClure, G.M.
THE NG-L PROJECT: HISTORICAL PERSPECTIVE.
Pipeline Research Committee of American Gas Association 5th Symposium on Line Pipe Research, November 20-22, 1974, pp. D1-D8.

This paper gives an overview of the development of a AGA research committee which was founded to investigate the strength and toughness properties of line pipe. A description of the first three stages of the Pipeline Research Committee's activities with an emphasis being placed on its technical accomplishments is contained in this paper.

B0660
McHenry, H.I.
FITNESS FOR PURPOSE EVALUATION OF DEFECTS IN PIPELINE GIRTHWELDS.
Pub. in Proceedings of the Structural Integrity Technology Conference Held at Washington, DC on May 9-11, 1979, pp. 39-44, (PB80-104359).

Fracture-mechanics principles are used to calculate allowable-flaw-size curves according to guidelines set by OPSO. All flaws are considered to be surface cracks. Initially, the curves are calculated by determining the largest flaw that would not grow through the pipe thickness during thirty years of worst-case operation. The curves are then modified by incorporating safety factors contained in the OPSO documents. This procedure defines accept and reject regions on a flaw-length versus flaw-depth plot. Curves defining these regions are developed using four distinct elastic-plastic fracture-mechanics methods: a critical crack-opening-displacement model, the Draft British Standard method, a plastic-instability model, and a semi-empirical model. Maximum stress, worst-case fatigue, a minimum toughness are assumed in all models. Separate sets of curves are developed for planar flaws, for non-planar flaws, and for arc burns.

B0670
McIsaac, J.
ABC'S OF DEVELOPING A NOTIFICATION SYSTEM.
American Gas Assoc Operation Sect Proceedings, 1976, Distrib Conf. Boston, Mass, May 24-26, 1976, Paper 76-D-6, 2 p.

Establishing a central telephone communication system to aid contractors in notifying underground facilities operators of their plans to excavate is discussed. Legal and economic aspects of system are evaluated.

B0680
McPhail, J.F., et al.
OFFSHORE PIPELINE CONSTRUCTION STRESS MEASUREMENT.
Offshore Technology Conference, Volume 1, May 1972, pp. 1607-1618.

This paper describes a study undertaken to determine the bending stresses in offshore pipeline during construction operations when being laid from a lay barge with a stinger. The construction-induced bending stresses and pipe profile were measured in an instrumented section of a pipe as it traveled from the lay barge to the ocean floor, while barge motions, pipe tensions, and pipe travel relative to the lay barge were recorded

simultaneously on the barge. Static bending stresses and pipe profiles, as well as wave-induced dynamic stresses and vertical motion of the barge stinger hinge, were determined from the measurements and compared with calculated values from theoretical solutions. Horizontal bending stresses induced by crosscurrents were also measured. The instumentation procedures are described, and graphic examples of the comparison between measured and calculated values of static and dynamic bending are given.

B0681
Mercer, W.L.
STRESS CORROSION CRACKING - CONTROL THROUGH UNDERSTANDING.
American Gas Association 6th Symposium on Line Pipe Research, Houston, Texas, October 29-November 1, 1980, pp. W-1 - W-32.

This paper contains a brief review of work on stress corrosion cracking in gas transmission pipelines conducted by the British Gas Corporation Engineering Research Station during the past 8 years. A predictive model has been developed from laboratory studies and applied to field studies. In addition to corrosion studies, an account of the collection methods and results of extensive field data is given. This examination indicated that the moisture content of the soil and its ability to cause coating damage and introduce localised variations in the level of cathodic protection, are vital factors in stress corrosion cracking.

B0690
Milo, V.P., and Kowalchuk, A.
CORROSION AND OTHER PROBLEMS IN THE PRODUCTION AND PROCESSING OF WET SOUR NATURAL GAS.
World Gas Conference, 13th, London, England, Jun 7-11, 1976, Publ by Int Gas Union, London, Engl, 1976, Tech Program, Paper IGU/A-176, 20 p.

This paper summarizes twenty-five years' experience in the production and processing of sour gas. Emphasis is placed on corrosion and materials selection with particular reference to current practice. There are a number of new solutions that can be used in processing the sour gas. The amines are still an economical solution, provided that some general guidelines are followed on towers, equipment, exchange tubes, filtration and operating conditions. Inhibitors have been successful in reducing corrosion, both in the field and plant, but may cause other problems if incompatibility with the total system is overlooked.

B0700
Milz, E.A. and Broussard, D.E.
TECHNICAL CAPABILITIES IN OFFSHORE PIPELINE OPERATIONS TO MAXIMIZE SAFETY.
Offshore Technology Conference, Volume II, May 1972, pp. 11809-11826.

A detailed discussion of the various factors that might be considered in the design, construction and operation of offshore pipelines is given in this paper. Design considerations including corrosion, route surveying and bottom conditions, and wave and current forces, are discussed. Various available construction methods are described, along with operational procedures, methods of detecting leaks and breaks in the pipelines, and maintenance and repair techniques.

B0710
Miller, D.R.
DESIGN AND CONSTRUCTION OF SUBMARINE PIPELINES.
American Society of Civil Engineers, Transportation Engineering Conference, Paper No. 205, May 1965.

Parameters for the design and construction of major submarine pipelines for water supply and waste disposal are discussed. Examples are given for the pulling of protected steel pipelines into place along the bottom. Structural design calculations include buckling of thin-wall pipe, sag, stress analysis, and testing.

B0720

Miller, P.D.
ONE-CALL SYSTEMS FOR DAMAGE PREVENTION-CALL MISS DIG.
American Gas Assoc Operation Sect Proceedings, 1975, Los Angeles, Calif. and Bal Harbour, Fla, May 5-7 and May 19-21, 1975, pp. D84-D85.

Computer and teletype network operation is described.

B0730
Miyoshi, Eiji, et al.
DEVELOPMENT OF SUMITOMO HIGH TOUGHNESS PROCESS (SHT) FOR ARTIC GRADE LINE PIPE.
The Petroleum Division of the American Society of Mechanical Engineers, Energy Technology Conference and Exhibit, Houston, Texas, September 18-22, 1977, pp. 1-10.

Sumitomo Metal Industries, has developed a innovative two step rolling process of line pipe steel for Artic uses. The SHT process, which is described in this paper, remarkably improves the low temperature toughness of HSLA steels without any loss of strength and also keeps high mill productivity. A specially equipped furnace in the rolling line is essential to the production of this type of artic-grade line pipe.

B0740
Montgomery, P.R
CONTROLLING A 25,000 H.P. GAS COMPRESSOR STATION WITH A MINI-COMPUTER.
American Gas Assoc Operation Sect Proceedings, 1975, for Meet. Los Angeles, Clif. and Bal Harbour, Fla, May 5-7 and May 19-21, 1975, pp. T11-T15.

Relay-logic supervisory system is described and presented in graphical forces.

B0750
Niebala, R.M.
ALTERNATING CURRENT CORROSION.
American Gas Assoc Operation Sect Proceeding, 1976, Las Vegas, Nev, May 3-5, 1976, Paper 76-T, 1 p.

"Index to Articles on Alternating Current Corrosion" to summarize and analyze existing information regarding alternating current corrosion of steel pipe and galvanic anode materials.

B0760
Osborne, W.H.
PIPELINE CONTROL ROOM DESIGN TO SPEED HUMAN REACTION
IEEE Petroleum Chem Inc. 22nd Annual Conference, Milwaukee, WI, Sept. 15-17, 1975, pp. 113-118.

The man in the pipeline control room (the dispatcher) is responsible for the minute by minute management of the pipeline system. He must keep the hydraulics in balance and deliver the correct product at the right time and in the right quantity at the right place. He is required to do this by operating the pipeline in its most efficient dynamic form. Small computers have made it possible to present more information to aid the dispatcher in decision making. Illustrations from many pipeline operating companies show how this new equipment is being used to speed human reaction.

B0770
Ovunc, B. and Mallareddy, H.
STRESS ANALYSIS OF OFFSHORE PIPELINES.
Offshore Technology Conference, April 22-24, 1970, Houston, TX, Paper No. 1222.

The intent of this presentation is to describe an iterative method for determining the stresses and the three-dimensional nonlinear configuration of subsea pipelines suspended between the ocean floor and a lay barge with or without stinger. If a stinger is used, it may be considered as composed by elements of desired length, rigidly or semi-rigidly connected or hinged to each other. The final shape of the pipeline can be improved and the stresses at the critical area can be minimized by applying a sufficient amount of tension from the barge to the pipeline.

The stiffness matrix method is used to determine the final deformed configuration and the stresses at every assumed nodal point. The external loads such as the pipe's own weight, coating weight, buoyant forces, drag forces are considered as static forces. The effect of dynamic loads and plastic deformations are not taken into account, but as it will be mentioned later, they can be introduced to the computation without any difficulty.

A general and flexible computer program has been prepared to perform the analysis. The information related to the characteristics of the pipeline and the stinger, boundary conditions, external loads, slope of the pipeline on the laybarge, the depth and the slope of the sea floor, and the velocities of the sea current and th liquid passing through the pipe are supplied to the computer as data. All the required information is printed out on the output sheet.

B0780
Ovunc, B. and Mallareddy, H.
STRESS ANALYSIS OF OFFSHORE PIPELINES UNDER DYNAMIC LOADS.
Off shore Technology Conference, April 19-21, 1971, Houston, TX, Paper No. 1361.

The intent of this presentation is to describe a method for determining the natural frequencies, modal shapes and the stresses induced by dynamic loads applied to subsea pipelines suspended between the ocean floor and the laybarge or stinger.

The method presented herein is general and applicable to any dynamic loading condition. The barge motion is considered as the support motion of the pipeline. A general and flexible computer program has been prepared to perform the analysis.

B0790
Paris, P.C.
FRACTURE MECHANICS IN THE ELASTIC-PLASTIC REGIME.
Flaw Growth and Fracture, Tenth National Symposium on Fracture Mechanics, August 23-25, 1976, sponsored by the American Society for Testing and Materials' Committee E-24 on Fracture Testing of Metals, pp. 3-27.

The primary purpose of this paper is to explain in simple terms the J-integral methods of elastic-plastic fracture mechanics. Its rationale as an extension of the linear-elastic fracture mechanics is emphasized. Other methods, such as crack-opening displacement and equivalent-energy methods, are contrasted with the J-integral methods for both analysis and applications to material characterization. Finally, the broad applicability and usefulness of the J-integral methods are also emphasized.

B0791
Parkins, R.N.
INTERRUPTED CATHODIC PROTECTION CONCEPTS.
American Gas Association 6th Symposium on Line Pipe Research, Houston, Texas, October 29-November 1, 1980, pp. U-1 - U-16

The electrochemical concepts involved in stress corrosion cracking and its avoidance are the subject of this paper. Requirements for cracking, potential drops along crevices, time dependent changes along crevices, and stress corrosion crack propagation at non-steady potentials are discussed.

B0800
Patel, M.R.
AUXILIARY LINE EVALUATION FOR LOSS-OF-COOLANT ACCIDENT USING TIME-HISTORY PLASTIC ANALYSIS.
Paper presented at the Energy Technology Conf. Houston, TX, Sept. 18-23, 1977, Published by ASME (PVP-PB-022). New York, NY, 1977, pp. 23-37.

A method of performing nonlinear, dynamic time history analysis of an auxiliary line for a loss-of-coolant accident is described. Effect of plastic deformation in both the piping and supports is considered. The analysis includes the pre-break condition loads, i.e., normal condition pressure, thermal, deadweight and steady state hydraulic loads. A simple procedure of using single-acting gap-spring elements for modeling a snubber is described which allows to input different stiffnesses in tension and compression without inducing any preload due to nondynamic motion. In the illustrative analysis, the break is simulated by releasing the break location node from its normal condition position. The piping is assumed to have kinematic strain-hardening which is defined by material property input. Behavior of snubber frames is approximated by elastic-perfectly plastic load deformation curves and is modeled with double-acting spring-slider elements. Primary output of the analysis includes stress intensities in the auxiliary line, nozzle and valve loads, and the elastic-plastic deformation of supports.

B0810
Paz, M. and Michelow, J.
STIFFNESS ANALYSIS OF NETWORK PIPES CONVEYING FLUID.
Paper presented at Int. Conf. on Pressure Vessel Technology, 3rd, Pt 1: Anal. Des. and Insp. Tokyo, Japan, April 19-22, 1977, Published by ASME, New York, NY, 1977, pp. 143-148.

In this paper the general dynamics stiffness matrix for a pipe containing a flowing fluid is obtained directly from the corresponding differential equation. The terms of the matrix are expanded into a power series as a function of the two variables: the fluid velocity, and the vibrating frequency.

B0820
Peterson, R.C.
ULTRASONIC DETECTION OF INTERNAL CORROSION.
American Gas Association Operation Sect. Proceedings, 1977, Published by American Gas Association (Cat. No. X50477). Arlington, VA, 1977, pp. C.61-D.65.

An Ultrasonic Imaging System which simulatneously presents multiple three-dimensional images of either the near surface or the far surface of a pipeline wall is described. These fully interpreted images present the length, geometry, width and depth of anomalies in the form of three-dimensional pictures which can constantly describe corrosion, pits, erosion, corrosion, or the loss of material from the inner surface of the pipe wall. The system represents a major breakthrough in the fields of detection and monitoring of corrosion and stress corrosion cracking for in-service pipelines.

B0830
Petro, P.
PERFORMANCE-PLASTIC VS STEEL PIPING.
American Gas Association Operation Sect. Proceedings, 1975, Los Angeles, CA and Bal Harbour, FL, May 5-7 and May 19-21, 1975, pp. D167-D170.

A comparative tabulated survey is presented.

B0840
Phelps, T. and Delaune, Jr.
ON-SITE WELDED REPAIRS TO OFFSHORE STRUCTURE USING DRY UNDERWATER HABITATS.
10th Annual Offshore Technology, Houston, TX, May 8-11, 1978, pp. 2572-2580.

An explanation of hyperbaric welding techniques and procedures is presented in this paper. A large number of key abilities and skills other than welding are required for over-all success in carrying out a successful program of underwater repairs of structures. These required skills and abilities are reviewed herein.

B0850
Phillips, R.D; Crider, C.
MINI-COMPUTERS USED IN METERING AND LEAK DETECTION SYSTEMS FOR LIQUID PETROLEUM PRODUCTS PIPELINES.
IEEE Petroleum Chem. Ind. 22nd Annual Conference, Milwaukee, WI, Sept. 15-17, 1975, pp. 129-135.

The use of mini-computers as part of a product metering system is new and relatively expensive. The use of mini-computers is discussed on the basis of their advantage, practical limitations and disadvantages; and Colonial Pipeline Company's approach and design of computer aided metering systems. The paper gives a summary of leak detection systems to date with success and problems of each. Colonial Pipeline Company's uses a mini-computer to control 10 independent lateral lines using pressure drop, flow rate, meter-in versus meter-out to autmatically shut down the line and close out as required. Design of the system, operating procedures, problems and evaluation are discussed.

B0860
Powers, J.T. and Finn, L.D.
STRESS ANALYSIS OF OFFSHORE PIPELINES DURING INSTALLATION.
Offshore Technology Conference, May 18-21, 1969, Houston, TX, Paper No. 1071.

A finite-beam-element, intial-value analysis procedure determines stresses in a subsea pipeline suspended between the ocean floor and a laybarge or stinger. The basic theory, its advantages over other theories, and a comparison of results with the results of analytical procedures based on other theories are included. The finite-element theory is applicable over a wide range of marine pipelaying problems, and compares favorably with other accepted theories in the ranges of their applicability.

B0870
Prakash, S., Nayak, G.C, et al.
ANALYSIS OF BURIED PIPE UNDER EMBANKMENT.
Paper presented and discussed at the Int. Conf. on Number Methods in Geomech, 2nd, Va Polytech Inst. and State Univ. Blacksburg, June 1976, Vol. 2, pp. 886-900.

Plane strain finite element programs with isoparametric elements have been developed and used to investigate the problem of projecting conduits on the following lines: Assessment of assumptions involved in Marston-Spangler theory; the effect of various parameters such as height of fill/diameter ratio, diameter/thickness ratio of the pipe, backfill properties and bedding angle; detailed soil pressure distribution on the pipe surface and standardization of these variations for design recommendations; the effect of sequential construction by considering the linear and nonlinear soil behaviour; the effect of nonlinear behavior of soil.

B0880
Redshaw, P., et al.
EXPLOSIVE WELDING - THE DEEPWATER PIPELINE CONNECTION/REPAIR SOLUTION.
10th Annual Offshore Technology Conference, Houston, TX, May 8-11, 1978, pp. 2581-2591.

The physical aspects of explosive welding and the application of the underlying principles to making pipeline connections under water, are described herein. The associated systems of pipe preparation, flushing and drying, dewatering, welding, and subsequent inspection are discussed with an emphasis placed on the minimal requirement for operator skill.

B0890
Reese, L.C. and Casbarian, A.O.
PIPE SOIL INTERACTION FOR A BURIED OFFSHORE PIPELINE.
Society of Petroleum Engineers, Paper No. 2343, September 1968.

Much study has been given to the design of pipelines for marshy areas or offshore locations; however, it is apparent that some confusion exists in regard to certain design parameters. In this discussion, the equilibrium under static conditions of a submerged pipeline will be considered.

B0900
Rosenfield, A.R. and Hahn, G.T.
METALLURIGICAL ORIGINS OF FRACTURE TOUGHNESS.
Pipeline Research Committee of AGA 5th Symposium on Line Pipe Research, November 2-22, 1974, pp. H1-H11.

The AGA sponsored N-18 research programs in fracture fundamentals at Battelle-Columbus Labs is the focus of this paper. The metallurgical studies in the Fracture Fundamental phase of NG-18 concentrates on two goals: (1) Determining the mechanisms which control fracture in pipeline steels. (2) Relating their fracture resistance to metallurgical variables. Progress reports are given on the status of the research goals.

B0910
Ross, W.
EFFECTS OF ELECTRIC FAULTING ON PLASTIC GAS PIPE IN JOINT TRENCH.
American Gas Association Operation Sect. Proceedings, 1975, Los Angeles, CA and Bal Harbour, FL, May 5-7 and May 19-21, 1975, pp. D94-D97.

Test program is described and presented graphically. Resutls are analyzed.

B0920
Russo, R.A.
CATHODIC PROTECTION MONITORING OF A GAS DISTRIBUTION SYSTEM USING ELECTRONIC DATA PROCESSING.
American Gas Association Operation Sect. Proceedings, 1976, Distrib. Conf. Boston, MA, May 24-26, 1976, Paper 76-D-3, 2 p.

The system adopted is designed to schedule and initiate field testing, check results, identify problem areas and satisfy all reporting and record keeping required by the regulatory agencies. A computer (IBM 370/155) is programmed to prepare annual test tickets, monitor progress and insure that all test tickets are returned properly completed. If test tickets are not returned, the computer will also report that the test was not performed. The objectives of the whole program are to assure management and regulatory authorities of adequate protection and regulatory conformance, reduce clerical costs, provide a data analysis tool for the cathodic protection engineer, and to provide an easily read history to aid in the field work on the cathodic protection system.

B0930
Sarrate, M., Marrapodi, et al.
APPLICATION OF MICROFRACTOGRAPHIC TECHNIQUES FOR THE DETERMINATION OF THE ORIGIN OF A FAILURE PRODUCED IN A STEEL PIPELINE.
Interamerican Conf. on Materials Technology, 4th Proceedings, Caracas, Venezuela, June 29 - July 4, 1975, pp. 61-72.

The failure of a steel gas pipeline destroyed by an explosion is analyzed using scanning electron microscopy. (In Spanish).

B0940
Sharp, J.W.
PROTECTING BARE STEEL - CHOOSING THE PROPER CRITERION.
American Gas Association Operation Sect. Proceedings, 1975, Los Angeles, CA and Bal Harbour, FL, May 5-7 and May 19-21, 1975, pp. D48-D49.

Testing methods are described and explained.

B0950
Small, S.W., Tamburello, R.D., et al.
SUBMARINE PIPELINE SUPPORT BY MARINE SEDIMENTS.
Offshore Technology Conference, Paper No. 1357, April 1971.

This paper deals with the submarine pipeline installed on the bottom. It summarizes the state-of-the-art in submarine pipeline foundation design as extracted from publications available to the practicing engineer. In particular, it covers the quantitative evaluation of initial settlement. - Various methods of analysis, using accepted theories of soil mechanics, are compared and evaluated.

B0960
Smith, L.
SUBMARINE PIPELINE SETTLEMENT AND STABILITY AGAINST THE INFLUENCE OF HORIZONTAL FORCES.
University of Houston, December 1971.

This study will deal with the analysis of the initial settlement of a submerged pipeline, evaluating this settlement as a function of the soil bearing capacity and active loads, further, covering the analysis of the active and passive soil forces which occur with a lateral displacement of the pipeline.

B0970
Smith, R.B.
ANALYSIS OF OPS FAILURE DATA
Pipeline Research Committee of American Gas Association 5th Symposium on Line Pipe Research, November 20-22, 1974, pp. F1-F9.

The NG-18 program maintains a constant surveillance over OPS accident data, in order to educate the NG018 personnel in the causes of pipeline failures.

This paper gives an account of analysis done by the NG-18 committee using OPS failure data. A discussion of various factors contributing to line failures is also included in this paper.

B0980
Smith, R.B.
FIELD FAILURE SURVEY AND INVESTIGATION: I. SURVEY.
Pipeline Research Committee of American Gas Association 4th Symposium on Line Pipe Research, Dallas, TX, November 18-19, 1969, pp. D1-D19.

The Field Failure Investigation phase of the NG018 program (AGA Pipeline Research Committee) is comprised of two components. One is a constant surveillance over pipeline failures caused by external mechanical equipment. The second component of this phase of the NG-18 program is a statistical survey of leaks and breaks. The objective of this survey is to provide the industry with a complete and accurate account of failure statistics which would provide additional guidance in planning and conducting the program of line pipe research. It is this second phase of the Field Failure Investigation program that is reviewed in this paper.

B0990
Smith, R.B. and Gideon, D.N.
STATISTICAL ANALYSIS OF DOT-OPSO DATA.
American Gas Association 6th Symposium on Line Pipe Research, Houston, TX, October 29 - November 1, 1979, D-1-D-9.

The Field Failure Investigation phase of the NG-18 program, sponsored by AGA, has been reviewing and assessing DOT-OPSO data in order to provide the industry with a record of failure statistics. These statistics will provide additional guidance in planning and conducting the program of line pipe research. This statistical survey was initiated with the collection of data exclusively from the Pipeline Research Committee companies This presentation is based mainly on 1970-1975 data and analysis with comments wherever possible based on the 1976-1977 data.

B1000
Stein, E.M.
ROLE OF MANUFACTURING VARIABLES IN FRACTURE TOUGHNESS.
Pipeline Research Committee of the AGA 5th Symposium on Line Pipe Research, November 20-22, 1974, pp. K1-K16.

The Manufacturing Variable phase of the line pipe reserach program sponsored by the AGA (NG-18 program) has been studying the metallurgical factors that influence the quality and incidence of hook cracks in electric-resistance welded (ERW) pipe. The experimental procedures and results are reviewed in this paper.

B1010
Steinmetz, G.F.
NEW LIFE FOR OLD GAS MAINS.
American Gas Association Operation Sect. Proceedings, 1975, Los Angeles, CA adn Bal Harbour, FL, May 5-7 and May 19-21, 1975, pp. D92-D93.

Prevention and stopping of leakage is discussed.

B1020
Vinogradov, V.N., Afanassiev, V.P., et al.
INFLUENCE OF AGGRESSIVE MEDIA OF GAS AND GAS-CONDENSATE ON THE DURABILITY OF OPERATION EQUIPMENT AND INSTRUMENTS.
13th World Gas Conference, London, England, June 7-11, 1976, Published by Int. Gas Union, London, England, 1976, Paper IGU/A2-76, 18 p.

The paper deals with the principal data on the influence of carbon dioxide impurities in natural gas produced and the reliability of gas-field equipment. The investigation of the mechanism of gas-abrasive wear of the field equipment has resulted in obtaining the criteria and the equation of simularity as well as the model for this process. The calculation technique and the prediction of the life of gas-field equipment functioning under the conditions of gas-abrasive wear have been established. The process of corrosive mechanical wear of gas-field equipment and its run has been investigated. The mechanism and the kinetics of corrosive mechanical wear has been determined.

B1030
Vogt, G.
FULL-SCALE FRACTURE BEHAVIOR OF PIPELINES. (EPRG).
American Gas Association 6th Symposium on Line Pipe Research, Houston, TX, October 29 - November 1, 1979, pp. M1-M20.

This paper describes a research program which was designed to study unstable shear fracture propagation in gas transmission line pipe. Special emphasis was placed on an evaluation of the influence of separations on fracture behavior. A series of 12 full-scale experiments was carried out according to a factorial design involving the parameters impact value, hoop stress level, and diameter. Some of the tests used steels showing differing amounts of separation on the fracture surfaces. The research program was proposed and sponsored by a group of European pipe manufacturers and was conducted by the British Gas Corporation.

B1040
Warmac, C.J.
LATEST DEVELOPMENT IN PLATE FORMING EQUIPMENT FOR WELDED PIPE.
Mech. Work and Steel Process 17th Conference, Pittsburg, PA, Jan 22-2, 1975, pp. 338-354.

Wall thicknesses are increasing, going up as high as 1-1/4 inch for the high yield strength materials. With the thicker walls and smaller diameters, a higher concentration of forces is required to obtain a suitable product. Edge

break equipment requires that deeper crimped edges are presented to the O-ing operation. This introduces a necessity to contain flat plate so that it does not slip or skid out of the die during the forming operation. The U-ing press will have to increase in capacity. The O-ing press becomes quite heavy in tonnage since the concentration of the load on a shorter length of pipe at a higher yield strength requires this additional tonnage.

B1Q50
Wesson, H.R., and Lott, J.L.
EFFECTIVENSS OF FIRE RESISTANT COATINGS APPLIED TO STRUCTURAL STEELS EXPOSED TO DIRECT FLAMES CONTACT, RADIANT HEAT FLUXES, AND MECHANICAL AND CRYOGENIC THERMAL SHOCK.
American Gas Association Operation Sect. Proceedings, 1977, Published by American Gas Association (Cat. No. X50477), Arlington, VA, 1977, pp. T.172-T.180.

The different types of fireproof coatings that are commonly available, the results of extensive fire testing on these coatings, and engineering correlations of the experimental data that can be used for determination of the required coating thicknesses for a desired period of protection in various heating envionments are presented and discussed. These types of coatings are also finding applications where simultaneous low temperature (cryogenic liquid impinging conditions) and high temperature (flames contact conditions) protection is required for the structural steels in LPG, LNG, and SNG facilities.

B1060
Wilhoit, J.C., Jr. and Merwin, J.E.
THE EFFECT OF AXIAL TENSION ON MOMENT CARRYING CAPACITY OF LINE PIPE STRESSED BEYOND THE ELASTIC LIMIT.
Offshore Technology Conference, April 19-21, 1971, Houston, TX.

The question of pipe ovalization and its effect on moment-curvature relationships in the elastic case have been treated by Brazier and others. The effect of ovalization in the nonlinear (strain hardening) case has been treated numerically by Ades. Ades' analysis employed the principle of least work for the cylindrical tube under pure bending when part of the tube is beyond the elastic limit. The tube is allowed to assume that elliptical cross section which minimizes the strain energy. Ades' analysis has been successfully employed to predict results which were obtained experimentally in pipe bending tests at Rice University. Since tension is generally employed in offshore pipeline laying operations, the importance of this effect on Ades' analysis is worth investigating. The relationships between the reduction in maximum moment carrying capacity as the axial tension is increased is desired. The pipe is allowed to deform beyond the elastic limit and the effect of pipe ovalization is included.

B1070
Wilkins, J.R.
OFFSHORE PIPELINE STRESS ANALYSIS.
Offshore Technology Conference, April 22-24 1970, Houston, TX, Paper No. 1227.

This paper presents a method for analyzing the stresses induced in a submarine pipeline during installation. The analysis procedure utilizes finite difference equations and load-deflection curves to form a mathematical model of the pipeline-stinger-laybarge system from the deck of the barge to the sea floor. Example problems of both possible future deepwater pipelines and contemporary problems are given. A description of field tests involved 1-inch and 2-1/2-inch nominal pipe under varying tension and the results of a comparison of theoretical deflection with the test deflections are given. The basic equation for this analysis method and their derivations are given.

B1080
Wilkowski, G.M., Maxey, W.A., et al.
COMPARISONS BETWEEN PLASTIC R-CURVE TOUGHNESS MEASUREMENTS, IMPACT ENERGY DATA AND FULL-SCALE DUCTILE FRACTURE BEHAVIOR OF CYLINDRICAL VESSLES.
American Society for Testing and Materials, Pressure Vessels and Piping Conference, San Francisco, CA, June 25-29, 1979, pp. 120.

This paper review an experiment in which the crack growth resistance of line-pipe steels has been evaluated using a reinforced double cantilever beam specimen. For the structural steels examined, this specimen was found to be necessary to confine the plasticity to the crack tip area, hence an energy balance analysis of the data could be used to evaluate the ductile fracture resistance. Attempts to measure the toughness of these classes of steels by flat plate or bend speciments have shown test specimen geometry dependence. The reinforced DCB, however, produced duplicate R-curves with grossly different initial crack lengths. The initiation toughness, R_i, and eventual steady-state propagation toughness R_p, from the reinforced double cantilever beam data, were compared to the plateau energy of Charpy V-notch, standard DWTT, and precracked DWTT impact specimens. The results showed that the shear fracture initiation toughness was equal to the Charpy plateau energy per unit of fracture area for steels with Charpy plateau energy of 4 to 50 ft-lb. The steady-state propagation toughness data along with the work of Kanninen, Fearnehough and Koshiga indicate that: (a) the dynamic fracture resistance of a ductile plane stress fracture is independent of crack speed; and (b) the dynamic fracture resistance is equal to the standard pressed notch DWTT (E/A) for steels with less than 50 ft-lb of Charpy plateau energy. For steels with greater than 50 ft-lb of Charpy plateau energy, R_p was equal to the statically precracked DWTT (E/A). These equalities for fracture initiation and propagation toughness appear to occur more from coincidence rather than through a theoretical basis.

B1090
Wilkowski, G.M.
FRACTURE INITIATION TOUGHNESS MEASUREMENT METHODS.
American Gas Association 6th Symposium on Line Pipe Research, Houston, TX, October 29 - November 1, 1979, G-1 - G-31.

A discussion of tests used to evaluate fracture toughness of line pipe

steels is presented in this paper. The temperature dependence of fracture initiation is reviewed. The Charpy Plateau Energy test, DWTT Plateau energy test, the reinforced double cantilever beam test, COD test for plastic fracture toughness and the instrumented Charpy test evaluation of plastic fracture toughness are described and assessed. Twenty-eight graphs and tables illustrate the test procedures and results.

B1100
Wilkowski, G.M.
FRACTURE PROPAGATION TOUGHNESS MEASUREMENTS.
American Gas Association 6th Symposium on Line Pipe Research. Houston, TX. October 29 - November 1. 1979. pp. K-1 - K-32.

The scope of this progress report is to present recent data that indicate differences between the initiation and propagation toughness levels in line-pipe steels. Secondly, to discuss the prediction of the fracture propagation transition temperature and the toughness levels where the distinction between initiation and propagation toughness differences become important.

B1101
Williams, D.N.
METALLURGICAL FACTORS.
American Gas Association 6th Symposium on Line Pipe Research, Houston, Texas, October 29-November 1, 1980, pp. X-1 - X-14.

Five research areas were examined by the Physical and Process Metallurgy Phase of the NG-18 Line Pipe Research Program, in order to anticipate problems areas that could effect the performance of line pipe. The results of this research are summarized in this paper.

B1120
Young, H.A.
PIPELINES SURVEILLANCE SYSTEM.
Proceedings of 30th Annual Symposium Instrum. Process Ind., 1975, Tex A&M Univ. College Station, January 22-24, 1975, pp. 4-7.

The pipeline system control, discussed here, encompasses ten product pipelines in three right-of-ways that are under continuous surveillance by a computer controlled system that interrogates pipeline data every six seconds and alerts the operator of leaks or some abnormal condition. Turbine meters that are placed in some of these lines are being used for accounting purposes and product custody transfer.

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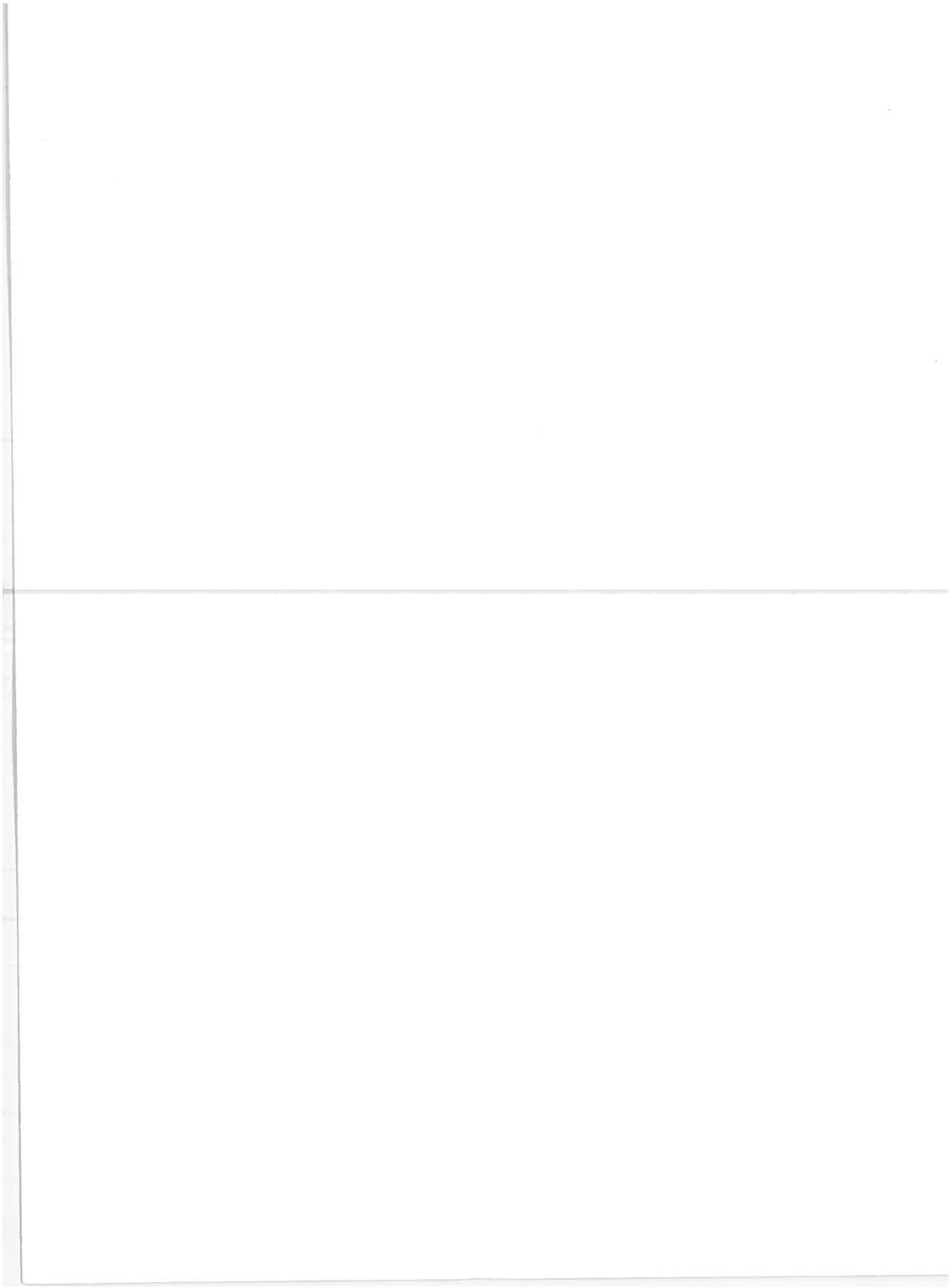

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