Marine Pipelines: An Annotated Bibliography

by

George L. Bowie and Robert L. Wiegel

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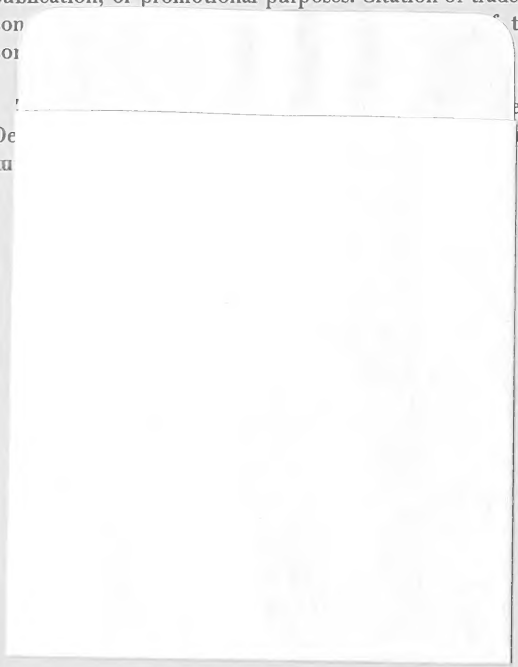

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20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

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.

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PREFACE

This report is published to provide coastal engineers with a comprehensive bibliography on marine pipelines. The work was supported by a grant from Continuing Education in Engineering (University Extension) and the College of Engineering, University of California, Berkeley, California, for use in the short course "Harbors, Ports, and Offshore Terminals" in January 1975. This bibliography is published under the coastal construction research program of the U.S. Army Coastal Engineering Research Center (CERC).

The report was prepared by George L. Bowie, Research Assistant, and Robert L. Wiegel, Professor of Civil Engineering, University of California, Berkeley.

Thorndike Saville, Jr., Technical Director, CERC, was the monitor for the report.

Comments on this report are invited.

Approved for publication in accordance with Public Law 166, 79th Congress, approved 31 July 1945, as supplemented by Public Law 172, 88th Congress, approved 7 November 1963.

Wilson P. Andrews

WILSON P. ANDREWS
LTC, Corps of Engineers
Acting Commander and Director

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MARINE PIPELINES: AN ANNOTATED BIBLIOGRAPHY

by

George L. Bowie and Robert L. Wiegel

I. INTRODUCTION

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 (used for powerplant cooling water systems), and may be short or more than 100 miles long. Pipelines are installed on various types of bottoms, and can be subjected to large forces induced by waves and currents. The problems encountered in installing and repairing pipelines are discussed.

Each entry of the bibliography has a reference number, author or source, and title. Most of the entries also include keywords and annotations.

II. SUBJECT HEADINGS

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Sicily
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Tasmania
Venezuela, Lake Maracaibo
Wales, Baglan Bay
Wales, Port Talbot
Washington, Puget Sound
Washington, Seattle

IV. ANNOTATED BIBLIOGRAPHY

1. **ALDRIDGE, C.**, "What's Involved in Planning and Constructing an Offshore Pipeline," *Oil and Gas Journal,* June 1952, pp. 174–179.

Keywords: Coating, Construction methods

Article discusses several problems and limitations involved in various aspects of offshore pipeline construction. Methods of laying offshore pipelines are described briefly, including the lay barge and push-pull methods. Some techniques and limitations are discussed for several operations involved in pipeline construction, including weight coating of the pipe and field joints, and the construction of laterals and tie-ins to existing lines which involves problems in locating and raising the lines, welding, and coating valves.

2. **ALDRIDGE, C.**, "Planning the Offshore Line," *Pipe Line Industry,* May 1956, pp. 39–41.

3. **ALDRIDGE, C.**, "Offshore Pipeline Planning and Construction," *Oil and Gas Journal,* June 1956, pp. 174–179.

Keywords: Oil pipeline, Pipeline construction

Several factors that should be considered in the construction of an offshore pipeline, including weather, water depth, distance from shore, pipeline location, and pipe burial, are

discussed. The economic advantages of pipelining crude oil from offshore, as compared to moving it by barge, are also discussed. The lay barge and push-pull methods of laying submarine pipelines and their limitations are described briefly.

4. **ALDRIDGE, C.**, "Offshore Pipeline Planning and Construction," *Proceedings of the American Petroleum Institute,* Vol. 36, Pt. 5, 1956, pp. 29–31.

5. **ALKHALIL, F.** "Dynamic Response of Submerged Pipelines," Ph.D. Thesis, Department of Civil Engineering, University of California, Berkeley, Calif., 1973.

6. **ALTERMAN, I.**, "Discussion of Wave Force Coefficients for Offshore Pipelines," *Journal of the Waterways and Harbors Division,* Vol. 88, No. WW4, Nov. 1962, pp. 149–152.

Keywords: Offshore pipeline, Wave forces

Report briefly discusses wave-induced forces on an exposed pipeline. Equations are given for the horizontal force and the vertical uplift force on the exposed cylinder.

7. **ALTERMAN, I.**, and **HAMLIN, N.**, "Discussion on Wave Forces on Submerged Structures," *Journal of the Hydraulic Division,* Vol. 85, No. HY5, May 1959, pp. 183–185.

Keywords: Submerged cylinder, Wave forces

Proceedings Paper 1893, authored by E. F. Brater, J. S. McNown, and L. D. Stair, November 1958, on the wave-induced forces on a cylinder located on a seabed is discussed briefly.

8. **AMERICAN SOCIETY OF CIVIL ENGINEERS**, "Pipeline Location: Specifications for Aerial Photography," Progress Report of the Task Committee on Pipeline Location, *Journal of the Pipeline Division,* Vol. 90, No. PL1, Jan. 1964, pp. 7–12.

Keywords: Aerial photos, Pipeline location

An outline of specifications is presented to assure adequate quality in services contracted with a commercial photogrammetric company for pipeline location and engineering purposes. Specifications for aerial vertical photos (negatives and prints) and indexes of the photos are given.

9. **AMERICAN SOCIETY OF CIVIL ENGINEERS**, "Pipeline Location: Bibliography," Progress Report of the Task Committee on Pipeline Location, *Journal of the Pipeline Division,* Vol. 90, No. PL1, Jan. 1964, pp. 13–19.

Keywords: Aerial photogrammetry, Bibliography, Pipeline location

Bibliography covers reference material on all phases of pipeline location, including the preliminary survey, electronic distance measurement, aerial photogrammetry, right-of-way acquisition, legal aspects, type of terrain encountered, and general information sources.

10. **AMERICAN SOCIETY OF CIVIL ENGINEERS,** "Guide to Good Practice for Highway Pipeline Crossings," Report of the Committee on Pipeline Crossings, *Journal of the Highway Division,* No. HW1, Jan. 1964, pp. 19–52.

Keywords: Highway pipeline crossing

Paper summarizes highway pipeline-crossing practices. The following topics are discussed: (a) Pipe location and alinement; (b) burial; (c) encasement and protection; (d) vents, drains, and markers; (e) uncased carriers; (f) hazardous transmittants; (g) restrictions against varied use; and (h) design loads and stresses. Factors that should be considered in the installation of a pipeline through an existing highway, or in the construction of a highway over an existing pipeline, are also discussed.

11. **AMERICAN SOCIETY OF CIVIL ENGINEERS,** "Economic Aspects of Mitigating Pipeline Corrosion," Committee on Pipeline Planning, Task Force Report, *Journal of the Pipeline Division,* Vol. 90, No. PL1, Jan. 1964, pp. 89–153.

Keywords: Pipeline corrosion

A summary of the results collected from questionnaires concerning pipeline corrosion distributed to companies in the oil, gas, product, and water industries using pipelines is presented. The information includes the selection of external pipe coatings, application of cathodic protection systems, use of high-strength thin-walled pipe, and the determination of operating pressures on existing pipelines that have suffered corrosion deterioration. The questions and responses are presented in tabular form. A list of areas that need further study and investigation is given as determined from the results of the questionnaire responses.

12. **AMERICAN SOCIETY OF CIVIL ENGINEERS,** "ASCE Preliminary Research on Pipeline Flotation," Report of the Pipeline Flotation Research Council, *Journal of the Pipeline Division,* Vol. 92, No. PL1, Mar. 1966, pp. 27–71.

Keywords: Pipeline flotation, Sediment

Report discusses the problem of pipeline flotation in saturated soils and sediments both during and after construction. Pipe flotation experiments were carried out to determine design criteria for pipeline stability in saturated sediments. From the results of the experiments, preliminary tables were developed to determine the bulk specific gravity of a pipe that will not undergo flotation or sinking for a given set of sediment conditions. The tables are presented with the necessary bulk specific gravity of the pipe determined as a function of the bulk specific gravity or density of the sediments, the shear strength of the sediments, and the pipe diameter. Examples are given to illustrate the use of the tables in calculations, and plans for further research in this area are discussed.

13. **AMERICAN SOCIETY OF CIVIL ENGINEERS,** "Pipelines in the Ocean," Final Report of the Task Committee on Pipelines in the Ocean, Pipelines Planning Committee, Pipeline Division, 1973.

14. **ANONYMOUS**, "How to Determine the Buoyancy of Bare and Concrete Coated Steel Pipe in Water and Mud," *Pipe Line Industry*, Oct. 1956, p. 74.

15. **ANONYMOUS**, "Setting up an Offshore Platform is Easy if You Know What You are Doing," *Oil and Gas Journal*, June 1960, pp. 82–83.

Keywords: Offshore oil platform, Santa Barbara, California

Article briefly describes the installation of an offshore oil platform off the coast of Santa Barbara, California.

16. **ANONYMOUS**, "Blasting Methods for Outfall Sewer," *Western Construction*, May 1962, pp. 62–64.

Keywords: Construction methods, Outfall sewer, San Diego, California

Several construction methods used in the initial construction phases of an ocean outfall in San Diego, California, are described. Liquid explosives in plastic tubes were used to blast a smooth bed for the pipe where it crossed a sawtooth ledge offshore, and also to blast a trench for the pipeline in the shallow inshore water and surf zone. A prefabricated steel trestle was constructed to place the 9-foot-diameter concrete pipeline through the surf zone; foundation holes for this trestle were drilled with precision, using a special drilling rig.

17. **ANONYMOUS**, "Determination of Net Buoyancy of Submerged Pipelines, Engineering and Design–3," Gas Distribution Manual, *Pipe Line Industry*, Vol. 19, No. 5, Nov. 1963, pp. 66–67.

18. **ANONYMOUS**, "Nuclear Power: The Year of Reckoning," *Engineering*, Apr. 1964.

Keywords: Great Britain, Nuclear power station, Reactors

A program for the development of nuclear power in Great Britain is briefly discussed. The program consists of four nuclear power stations and nine reactors to be built between 1970 and 1975. The program is flexible; the use of "advanced gas-cooled reactor" or "boiling water reactor" systems in the power stations is undecided.

19. **ANONYMOUS**, "Cook Inlet Line Laid in Fluid Tidal Flats," *World Petroleum*, Vol. 38, No. 8, Aug. 1967, pp. 56–60.

Keywords: Cook Inlet, Alaska, Oil pipeline

The construction of a 42-mile, 20-inch-diameter crude oil pipeline on the northwest shore of Cook Inlet, Alaska, is described. The pipeline was laid along two tidal flats separated by a headland. The clearing, grading, and ditching along the pipeline route, as well as the pipe stringing, taping, and anchoring processes, are discussed. Due to the extreme environmental conditions present in the area, several problems were encountered during grading and especially during ditching operations.

20. **ANONYMOUS,** "Cooling Water Intakes at Wylfa Nuclear Power Station," *Civil Engineering and Public Works Review,* Vol. 63, No. 744, July 1968, pp. 759–780.

21. **ANONYMOUS,** "10,000-Foot-Long Sea Outfall at Hastings in Sussex," *Civil Engineering and Public Works Review,* Vol. 63, No. 746, Sept. 1968.

Keywords: Outfall pipeline, Sussex, England

Report describes the construction of an ocean outfall off the coast of Sussex, England. The outfall is a 27-inch-diameter steel pipe which extends 10,000 feet offshore. The pipes were coated before construction, and welded into strings at the construction site. The pipe strings were pulled out, joined offshore and buried in a trench throughout its entire length.

22. **ANONYMOUS,** "Techite Pipe for Subaqueous Pipelines," Brochure on Techite RPM Pipe, United Technology Division of United Aircraft Corporation, 1968.

23. **ANONYMOUS,** "Deep Pipelaying Under the Adriatic," *Marine Engineers Journal,* Vol. 81, No. 2, Feb. 1969, p. 8.

Keywords: Deepwater pipelines

Article briefly describes several available methods for laying underwater pipelines in deep water, and includes a brief description of a typical deepwater submarine pipe.

24. **ANONYMOUS,** "Recent Advances in Dry Underwater Pipeline Welding," *Welding Engineer,* Vol. 54, No. 2, Feb. 1969, pp. 43–45.

Keywords: Repairs, Welding chamber

Article describes a system that allows high-quality, high-strength welds on submarine pipelines without raising the pipeline to the surface. The system consists of a dry hyperbaric welding chamber which is placed on the pipe without moving it. This system can be used to weld hot-tap connections, pipeline and riser tie-ins, and also to repair damaged pipelines and risers.

25. **ANONYMOUS,** "Work Ship Features New Design Pipelaying Ramp," *Marine Engineers Journal,* Vol. 81, No. 2, Feb. 1969, p. 5.

Keywords: Construction vessel, Pipeline ramp

A construction and pipelaying vessel, whose equipment includes a hinged, above-water pipelaying ramp to lay submarine pipelines in deep water by the catenary and tension method, is described.

26. **ANONYMOUS,** "Largest Submarine Outfall in the U.K.," *The Dock & Harbour Authority,* Vol. L, No. 583, May 1969, p. 14.

Keywords: Great Britain, Submarine outfall sewer

Article briefly describes a submarine outfall sewer constructed off the shore of Great Britain. The pipes were welded and coated onshore and pulled to sea by a barge and winch anchored offshore. The pipe was laid in a dredged trench which was then backfilled.

27. **ANONYMOUS**, "Intake Pipes Headed for Underwater Service at Palisades Plant," *Bechtel Briefs,* May 1969, p. 18.

Keywords: Cooling water pipeline, Lake Michigan

Brief note discusses the placement of an 11-foot-diameter steel pipeline in Lake Michigan. The pipeline is a cooling water intake pipe for a nuclear powerplant in Michigan.

28. **ANONYMOUS**, "Terminal Facilities at Bacton," *World Petroleum,* Vol. 40, No. 5, May 1969, pp. 24–25.

29. **ANONYMOUS**, "Sheet Piling Used for Outfall Pumping Station," *Civil Engineering and Public Works Review,* Vol. 64, No. 756, July 1969, p. 667.

Keywords: Great Britain, Outfall pumping station

The construction of trade effluent tanks and a pumping station for a sea outfall in Great Britain is described.

30. **ANONYMOUS**, "Bulldozer, Pipeline Barge Gets to Bottom of the Job," *Engineering News-Record,* Vol. 183, No. 20, Nov. 1969, p. 22.

Keywords: Barge, Bass Strait, Australia, Bulldozer

A semisubmersible pipelaying barge and an underwater bulldozer used to lay a 60-mile oil pipeline across Bass Strait between Tasmania and the Australian mainland are described. The barge can operate under difficult weather and sea conditions because the deck and superstructure are above water and supported by columns connected to submerged pontoons.

31. **ANONYMOUS**, "Slurried Mineral Ore System," *Ocean Industry,* Vol. 4, No. 11, Nov. 1969, p. 39.

Keywords: Minerals, Slurry

Report describes a slurry system developed to handle iron, copper, lead, zinc, and manganese ore. The ore is loaded and discharged in a slurry form aboard large, economical tankers which can anchor in deep water offshore and pump the slurrified cargo ashore through a pipeline. The advantages of such a system are also discussed.

32. **ANONYMOUS**, "Sea Plough Used to Lay Submarine Pipeline," *The Dock & Harbour Authority,* Vol. 50, No. 591, Jan. 1970, p. 387.

Keywords: Gas pipeline, Great Britain, River Exe

A 20-inch-diameter gas main to be laid across the River Exe in Great Britain is discussed briefly. The pipeline will be laid in a deep channel gouged by a 36-ton sea plow.

33. **ANONYMOUS**, "Tension Shoes for Pipelaying Barge," *Ocean Industry,* Vol. 5, No. 1, Jan. 1970, p. 18.

Keywords: Pipelaying barge, Tension shoe system

The operation and advantages of a hydraulic track-type tension shoe system to be used on pipelaying barges are described.

34. ANONYMOUS, "Big Oil Pipe Pull Begins at Weekend," *The Natal Mercury,* South Africa, Feb. 1970.

Keywords: Durban, South Africa, Offshore terminal, Onshore storage

Report describes an oil pipeline constructed onshore and pulled to sea by barge to connect an offshore terminal with onshore storage facilities at Durban, South Africa.

35. ANONYMOUS, "Critical Phase of Off-shore Oil Plan Completed," *Cape Argus,* Capetown, South Africa, Mar. 1970.

Keywords: Deep-sea oil terminal, Durban, South Africa, Onshore tank farm

An oil pipeline constructed onshore and pulled to sea by barge to connect a tank farm onshore to a deep-sea oil terminal at Durban, South Africa, is described briefly.

36. ANONYMOUS, "New Lay Barge for 48-inch Pipe," *Ocean Industry,* Vol. 5, No. 4, Apr. 1970, pp. 86–87.

Keywords: Deepwater installation, Lay barge

A lay barge utilizing a centrally located lay slot method designed to be capable of laying 48-inch-diameter pipelines in deep water is described.

37. ANONYMOUS, "Take a Look at the Most Innovative and Widely Discussed Pipelaying Barge Afloat," *Flour-o-scope,* Fluor Corporation, Summer 1970.

Keywords: Reel-type barge, Steel pipe

Report provides a general description of a reel-type barge that is capable of laying 12-inch-diameter heavy-walled steel pipe.

38. ANONYMOUS, "Underwater Outfall is Biggest So Far in U.K.," *Hydrospace,* Vol. 3, No. 4, Aug. 1970, pp. 34–36.

Keywords: Great Britain, Sewage outfall pipe

The laying of a 48-inch-diameter sewage outfall pipe extending 2.5 miles to sea off the coast of Great Britain is described briefly. Welded strings of pipe were pulled to sea by barge.

39. ANONYMOUS, "Uni-Pipe Polyethylene Pipe," *Civil Engineering,* Vol. 40, No. 8, Aug. 1970, p. 84.

Keywords: Polyethylene pipe, Waste pipelines

Article briefly describes high-density polyethylene piping used for sewage and waste disposal. The pipe is flexible, can be laid around obstacles, and is highly resistant to chemicals, abrasion, frost, and inert aggressive soils. It is nonporous, absorbs stress caused by soil movements, and is reportedly unaffected by vibration. The pipe is buoyant, so it may be towed in waterways, and then weighted with concrete collars and sunk by filling with water.

40. ANONYMOUS, "Story-High Steel Outfall Runs 3 Miles Under Lake," *Engineering News-Record,* Vol. 185, No. 12, Sept. 1970, pp. 82–83.

Keywords: Lake Ontario, Outfall pipeline, Rochester, New York

The construction of a 10-foot-diameter steel sewer outfall over 3 miles long laid in a dredged trench at the bottom of Lake Ontario near Rochester, New York, is described. The pipe is laid in 80-foot sections, lowered by a derrick, and divers bolt the sections together. The trench is backfilled after the pipes are laid.

41. ANONYMOUS, "New Pipeline Tie-in Equipment," *Hydrospace,* Vol. 3, No. 5, Oct. 1970, p. 11.

Keywords: Platform risers, Tie-in equipment

Article provides a brief description of pipeline tie-in equipment that simplifies the underwater connection of pipelines to platform risers, or laterals to main lines, and may also be used to remove and replace a section of pipe without having to raise the existing pipe to the surface.

42. ANONYMOUS, "World's Biggest Pipelaying Sled," *Hydrospace,* Vol. 3, No. 5, Oct. 1970, p. 22.

Keywords: Pipelaying sled, Polyethylene pipe

Article describes an underwater pipelaying sled designed to embed a 48-inch-diameter polyethylene pipe to a depth of 15 feet below the seabed in water depths exceeding 100 feet in a single operation.

43. ANONYMOUS, "World's Biggest Underwater Sled Commissioned," *The Dock & Harbour Authority,* Vol. 50, No. 600, Oct. 1970.

Keywords: Pipelaying sled, Polyethylene pipe

An underwater sled designed to embed 48-inch-diameter polyethylene pipes 15 feet below the ocean floor in water depths exceeding 100 feet is described briefly.

44. ANONYMOUS, "Italy Plans a Gas Pipe Line Across the Mediterranean," *Ocean Industry,* Vol. 5, No. 11, Nov. 1970, p. 43.

Keywords: Gas pipeline, Italy, Mediterranean Sea, North Africa, Sicily

Plans for a natural gas pipeline system extending from North Africa across the Mediterranean Sea and the island of Sicily to the Italian mainland are discussed briefly.

45. ANONYMOUS, "New Methods Devised to Lay Pipe in Deep Water," *World Oil,* Dec. 1970, p. 50–52.

Keywords: Reverse J-tube method, Tension method

Article discusses two methods for making pipe connections at deepwater platforms. The "reverse J-tube" method for laying a pipeline originating at a platform is described. The pipe

is welded on the platform in a vertical position, then pulled down through the J-tube and out toward the shore until it can be connected in shallower water with the rest of the pipeline that has been laid from the shore. The "tension" method for making deepwater connections at the platforms is also discussed. Axial tension is applied to a pipeline with a tug to control bending stresses as the line is raised to the surface for attachment of a riser and then lowered back to the bottom.

46. ANONYMOUS, "New Pipeline Alignment System," *Ocean Industry,* Vol. 5, No. 12, Dec. 1970, p. 48.

Keywords: Diving bell, Pipeline alinement system

Report describes an underwater pipeline alinement system for making repairs, for riser tie-ins and hot taps, and for connecting new lines. A diving bell is locked to the pipe to permit welders to move to and from the habitat without diving apparatus.

47. ANONYMOUS, "Pulling Pipelines," *Hydrospace*, Vol. 4, No. 2, Apr. 1971, pp. 26–27.

Keywords: Oil terminal, River Thames, Tank farm

Article describes the construction methods used to lay two pipelines in Great Britain. One was a 36-inch-diameter pipeline connecting an offshore oil terminal with a tank farm onshore. The pipeline was assembled onshore, pulled out with a barge, and laid in a dredged trench. The other pipeline was a 24-inch-diameter gasline laid across the River Thames. The pipeline was assembled on one shore and pulled across the river in a dredged trench by a winch installed on the opposite shore.

48. ANONYMOUS, "Pulling a Huge Pipe Line Across the Sea Floor," *Ocean Industry,* Vol. 6, No. 6, June 1971, p. 32.

Keywords: Gulf of Trieste, Italy, Water pipeline

Report covers the construction of a 52-inch-diameter waterline laid along a 12-mile route across the Gulf of Trieste in Italy. The pipe was welded and concrete-coated onshore and pulled to sea by a winch mounted on an anchored barge.

49. ANONYMOUS, "Coal Tar Coating Protects Underwater Effluent Line," *Civil Engineering,* Vol. 42, No. 2, Feb. 1972, p. 88.

Keywords: Coal tar enamel, Lake Ontario

Brief note discusses a sewage outfall pipeline in Lake Ontario coated with coal tar enamel to protect it from corrosion.

50. ANONYMOUS, "L & M Pull 52nd Subsea Outfall," *Hydrospace,* Vol. 5, No. 4, Aug. 1972, p. 34.

Keywords: Outfall pipeline, South Wales

Article briefly describes the construction of an outfall pipe laid off the South Wales coast at a depth of 60 feet. The pipe was assembled onshore, pulled to sea by barge, and lowered into the sandy seabed by a jetting machine.

51. ANONYMOUS, "Subsea Sewer Outfall in 90 Feet of Water," *Hydrospace,* Vol. 5, No. 4, Aug. 1972. p. 31.

Keywords: Scotland, Sewer pipeline

The construction of a submarine sewer outfall in Scotland is discussed briefly. The 18-inch-diameter outfall, ending in 90 feet of water, was laid by divers in a trench protected with concrete bagwork before backfilling to the original bed level.

52. ANONYMOUS, "Gas Pipeline Across Mediterranean?," *Ocean Industry,* Vol. 7, No. 9, Sept. 1972, p. 48.

Keywords: Gas pipeline, Mediterranean Sea, Strait of Gibralter

Survey work for potential shore approaches for gas transmission pipelines in the Strait of Gibralter and the western Mediterranean Sea is discussed briefly.

53. ANONYMOUS, "Cannes Outfall Laid at Record Depth of 279 Feet," *Offshore Services,* Oct. 1972, p. 53.

Keywords: Cannes, France, Outfall pipeline

Article briefly describes a 4,000-foot-long outfall laid at a depth of 279 feet at Cannes, France. The pipe sections were welded and coated onshore and pulled to sea by barge. The pipe was laid in a dredged trench and then backfilled.

54. ANONYMOUS, "Large Diameter Line Laid Offshore Cannes," *Ocean Industry,* Vol. 7, No. 12, Dec. 1972, pp. 22–23.

Keywords: Cannes, France, Waste pipeline

The design of the waste water disposal system for the city of Cannes, France, is described. The system includes the collection of waste water in secondary pipe mains, converging in a main-line sanitary sewer system paralleling the seacoast, a sewage treatment plant, and an ocean outfall discharging the treated waste water into the Mediterranean Sea.

55. ANONYMOUS, "Submarine Surveys 13 Miles of Pipeline in 17 Days," *Ocean Industry,* Vol. 7, No. 12, Dec. 1972, p. 46.

Keywords: Gas pipeline, Surveying system

Brief report describes a submersible system used in an underwater survey of a submarine gas pipeline. The survey included the production of full video tape recordings, scour details, burial points, saddle weight locations, and the conditions of sacrificial anodes.

56. ANONYMOUS, "World's Largest Floating Rubber Pipeline," *The Dock & Harbour Authority,* Vol. LIII, No. 629, Mar. 1973, p. 455.

Keywords: Dunkirk Harbor, Holland, Floating rubber pipeline

Report describes a 36-inch-diameter integral floating rubber discharge line being used in conjunction with a rigid arm mooring in dredging operations at the Dunkirk Harbor entrance in Holland. The integral floating hose connects the dredger to the rigid arm mooring which is connected to an underwater steel pipe leading to shore.

57. ANONYMOUS, "Coating the Forties Pipe," *Offshore Services,* Vol. 6, No. 4, June 1973, p. 23.

Keywords: Concrete pipe coating

Article describes the design and coating process of a special concrete pipe coating resistant to heavy impact in order to protect the pipeline from damage by the impact of fishing trawl boards, anchors, and cables.

58. ANONYMOUS, "Ekofisk Field and Teesside Pipeline," *Offshore Services,* Vol. 6, No. 4, June 1973, pp. 21–22.

Keywords: Ekofish, Norway, Oil pipeline, Teesside, England

Report describes a submarine oil pipeline project which will carry pumped oil in a 34-inch-diameter pipeline a distance of 216 miles from the Ekofisk oilfield off the Norway coast to Teesside, England. The pipeline will be laid in three sections by three different contractors. The work to be performed by each contractor is summarized briefly.

59. ANONYMOUS, "Submarine for Subsea Pipe Line Operations," *Ocean Industry,* Aug. 1973, p. 35.

Keywords: Deepwater pipeline, Work submarine

A submarine designed as an underwater work ship is briefly described for installing, inspecting, and maintaining pipelines in deep water. The submarine tows pipe sections to the job site, alines the sections with built-in alinement clamps, and then the sections are welded in a dry hyperbaric environment extending from the submarine's basic habitat housing. The crew can work at water depths of up to 600 feet.

60. ARIE, M., and KIYA, M., "Lift of a Cylinder in Shear Flow Subjected to an Interference of a Plane Wall," *Proceedings of the United States-Japan Seminar on Similitude in Fluid Mechanics,* Sept. 1967, pp. 33–60.

Keywords: Circular cylinder, Stream function

Paper describes an analytical study of shear flow across a circular cylinder subjected to an interference of a plane wall. The stream function, velocity distribution, and pressure distribution on the surface of the cylinder are derived analytically, assuming an inviscid fluid. The cylinder experiences a transverse lift force toward the wall for a uniform flow; for a shear flow with a certain amount of velocity gradient, the lift force is away from the wall. Experiments were carried out in a wind tunnel to verify the trends of the analytical results with respect to the change of lift coefficient of a cylinder in shear flow. Graphical curves are presented to illustrate the results of the analysis and experiments.

61. ARMSTRONG, E. L., "The Undersea Aqueduct–A New Concept in Transportation," *Transportation Engineering Journal,* Vol. 98, No. TE2, May 1972, pp. 303–310.

Keywords: Freshwater pipeline, Undersea aqueduct

The possibility of an undersea aqueduct along the continental shelves for the transport of freshwater from areas where it is available to the highly populated areas where it is

needed is discussed. The advantages of an undersea aqueduct, as compared with an overland aqueduct, are discussed briefly. Possible pipe materials, anchoring systems, pipeline fabrication and installation procedures, inspection, maintenance, and ecological considerations are also discussed.

62. **ARON, H.**, "Large Bore HD Polyethylene Pipe," *Pipes and Pipelines International,* London, Vol. 13, No. 4, Apr. 1968, pp. 39–43.

63. **ARRIENS, J. L.**, "Progress in Offshore Pipelines," *Pipes and Pipelines International,* London, Vol. 11, No. 7, July 1966, pp. 28–33.

64. **ATTERBURY, T. J.**, and **SORENSON, J. E.**, "The Technology of Offshore Pipelines," *Littoral Lines,* Vol. II, No. 3, Mar. 1967.

Keywords: Lay barge, Offshore pipeline

Some problems involved in laying offshore pipelines are discussed, including the problem of high-bending stresses that develop during the laying operations from a lay barge with a stinger. Concrete weight coats and trenching are also mentioned.

65. **BATTELLE MEMORIAL INSTITUTE**, "The Technology of Offshore Pipelines," *Littoral Lines,* Vol. II, No. 3, Mar. 1967.

Keywords: Lay barge, Offshore pipeline

Article briefly discusses some problems involved in laying offshore pipelines, including the problem of high-bending stresses that develop during the laying operations from a lay barge with a stinger. Concrete weight coats and trenching are also mentioned.

66. **BEATTIE, J. F.**, and **BROWN, L. P.**, "Lift and Drag Forces on a Submerged Circular Cylinder," *Offshore Technology Conference,* Vol. I, Apr. 1971, pp. I319–I328.

Keywords: Circular cylinder, Lift and drag forces

Paper discusses the results of a laboratory investigation of the lift and drag forces on a submerged circular cylinder located adjacent to a plane wall. Circular cylinders ranging in diameter from 6 to 30 inches were tested in a semi-infinite flow stream in both wind and water tunnels. Cylinders of both smooth and rough surfaces were tested in horizontal and vertical positions. The lift and drag coefficients were empirically correlated with the Reynolds number, and the experimental results are presented in several graphs.

67. **BECKMAN, H.**, "An Investigation of Forces Acting on Offshore Pipe Lines Due to Wave Action," Rice University, Houston, Tex.

68. **BECKMANN, H.,** and **THIBODEAUX, M. H.,** "Wave Force Coefficients for Offshore Pipelines," *Journal of the Waterways and Harbors Division,* Vol. 88, No. WW2, May 1962, pp. 125–138. Discussions by I. Alterman, Vol. 88, No. WW4, Nov. 1962, pp. 149–150; B. W. Wilson and R. O. Reid, Vol. 89, No. WW1, Feb. 1963, pp. 61–65; and H. Beckmann and M. H. Thibodeaux, Vol. 89, No. WW3, Aug. 1963, pp. 53–55.

Keywords: Submarine pipeline, Wave forces

Article discusses the evaluation of coefficients of drag, lift, and inertia that may be used to calculate drag, lift, and inertia forces due to wave action on submarine pipelines in contact with a smooth, hard-surfaced ocean floor. The forces on pipelines of both circular and trapezoidal cross sections are considered.

69. **BERRY, W. H.,** "Pipelines from North Sea Block 49/26 to the Norfolk Coast," *Journal of the Petroleum Institute,* Vol. 54, No. 532, Apr. 1968, pp. 104–106.

70. **BISHOP, R. W.,** and **FLETT, P. F.,** "Diving and Salvage," *Proceedings of the Institution of Civil Engineers,* Vol. 21, Sess. 1961-62, Feb. 1962, pp. 347–366.

71. **BLUMBERG, R.,** "Hurricane Winds, Waves and Currents Test Marine Pipeline Design," *Pipe Line Industry,* June-Nov. 1964.

Keywords: Gulf of Mexico, Hurricane Carla, Pipelines

Article discusses the damage to pipelines and associated structures of oil and gas operations resulting from the high winds, waves, tides, currents, and shifting bottom conditions and scouring caused by hurricanes in the Gulf of Mexico. A description of the damage and destruction of Hurricane Carla to pipelines and facilities, and a discussion of the above-mentioned factors which caused the damage for specific cases are given. The influence of pipeline orientation and burial are also included in the discussion.

72. **BLUMBERG, R.,** "Design for Environmental Extremes," *Pipe Line Industry,* Vol. 25, No. 4, Oct. 1966, pp. 31–34.

73. **BLUMBERG, R., OSBORN, C.,** and **TAKER, S. A.,** "Analysis of Ocean Engineering Problems in Offshore Pipelining," *Offshore Technology Conference,* Vol. I, Apr. 1971, pp. I297–I308.

Keywords: Lay barge, Stingers

Paper discusses many of the ocean engineering problems that should be considered in the planning and installation of offshore pipelines by the lay barge method. Lay barge design considerations are discussed briefly. Straight, curved, and articulated stingers are discussed and compared, including the advantages and problems associated with each type. Problems occurring during the pipelaying operations are discussed, including monitoring and maintaining the correct tension level and profile of the pipeline and stinger, anchoring the lay barge to minimize movements, lowering the pipeline and stinger to the ocean floor during rough weather and sea conditions, breakdown and maintenance of pipelaying

equipment, and safety considerations. Systems operation management is also discussed, including project planning, personnel, pipelaying operations, and coordination between the onshore planning and management and the offshore pipelaying operations.

74. **BOMBA, J.,** "Submarine Pipe Construction Methods," *Petroleum Engineer,* Vol. 32, Dec. 1960, pp. D28–D32.

75. **BOMBA, J. G.,** "Submarine Pipeline Construction Methods," *Pipeline Engineer,* Dec. 1960 and Feb. 1961; also in *A Collection of Papers on Underground Pipeline Corrosion,* Vol. 9, 1967 (Library of Congress Catalog Card No. 59-54031), pp. 1–11.

Keywords: Gas pipelines, Hudson River, Hyperion sewage system, Los Angeles, California, Mississippi River

Construction methods used to lay submarine pipelines in the ocean and across rivers are described. The construction of the Hyperion sludge discharge outfall for Los Angeles, California, is discussed. The 7-mile, 22-inch-diameter pipeline was laid with the use of a buoyant pulling sled, a dual cable system, and pulling barge and winch. A wooden trestle launchway was constructed 900 feet offshore due to heavy surf and tidal variations. The inshore part of the line was buried using a jet trencher. The construction of two gas pipelines, one across the Mississippi River, and one across the Hudson River, is also discussed. These pipelines were laid in the form of downstream catenaries, requiring accurate horizontal positioning of the lines during installation. The positioning and pulling techniques used to lay these lines are described.

76. **BOMBA, J. G.,** and **SEEDS, K. J.,** "Pipelining in 600 feet of Water–A Case Study of Washington Natural Gas Company's Puget Sound Crossing," *Offshore Technology Conference,* Paper No. OTC 1188, Vol. 1, Apr. 1970, pp. I379–I396.

Keywords: Current and wave forces, Gas pipeline, Puget Sound, Washington

Proceedings paper describes the design, construction, and inspection of two 8-inch-diameter gaslines laid across Puget Sound, Washington, in maximum depths of 670 feet. The design considerations are discussed, which include the hydrographic survey, pipe burial and coating, determination of the installation stresses, the stability of the pipeline with respect to current and wave-induced forces, vibrations due to vortex shedding across spanning sections, and environmental stresses due to external pressure, bending stresses, and tension. The pipeline construction and installation procedures are also described. A bottom-pull method was used in which the pipe strings were welded onshore and pulled out by barge. Once installed, the pipeline was inspected with an underwater television system.

77. **BOWLUS, F., LUDWIG, H. F.,** and **MELBERG, L.,** "Pull-out Method Cuts Costs in Placing Oregon Outfall Sewer," *Western Construction,* Mar. 1964.

Keywords: Oregon, Outfall pipeline

The construction method used to lay a 35-inch-diameter ocean outfall in Oregon is described. The pipeline was welded and coated onshore and pulled out by a large ship anchored offshore. The same ship was also used to excavate a trench through a sandbar for the pipe.

78. **BRANDO, P.,** and **SEBASTIANI, G.,** "Determination of Elastic Curves and Stresses to be Expected During Laying Operations," *Offshore Technology Conference,* Vol. I, Apr. 1971, pp. I279–I292.

Keywords: Stresses, Submarine pipeline

Paper describes a finite element method for determination of sea line elastic curves and stresses on a submarine pipeline during laying operations from a lay barge. The calculation procedure considers both tension applied at the lay barge and no tension applied. The method can also be used for pipelines laid on sloping bottoms and in the presence of side currents. The steps of the calculation procedure are described, and the results of the analysis are presented in terms of dimensionless parameters. Dimensionless graphs with tension, deformation angle, bending movement, shear, and deflection data illustrate the complete elastic curve over a large range of values of the pipe weight, stiffness, and bottom tension. The results of the analysis are compared with other theories, and an example is given to illustrate the computation procedure with the dimensionless graphs.

79. **BRATER, E. F.,** and **WALLACE, R.,** "Wave Forces on Submerged Pipe Lines," *Proceedings of the 13th International Conference on Coastal Engineering,* Vol. III, July 1972, pp. 1703–1722.

Keywords: Submerged pipeline, Wave-induced forces

Paper presents the results of a laboratory investigation of the horizontal wave-induced forces on a submerged pipeline. The total horizontal wave force on the submerged pipe is assumed to be composed of two parts—a drag force due to the orbital velocities, and an inertial force due to the orbital accelerations. Values of the horizontal components of the orbital velocities and accelerations were calculated using the airy theory, and the values of the coefficients of drag and mass were determined from the force data of the model pipeline. The tests were run for a pipe suspended at various elevations above the bottom, including very close to the bottom and in a trench. The coefficient of mass appears to have the largest values for a pipe located near the bottom, and lowest values for a pipe located in a trench. The coefficient of drag appears to decrease with an increase in Reynolds number.

80. **BREWER, W. V.**, and **DIXON, D. A.**, "Influence of Lay Barge Motions on a Deep Water Pipeline Laid under Tension," *Offshore Technology Conference*, Paper No. OTC 1072, Vol. II, May 1968, pp. II23–II36.

Keywords: Bending stresses, Lay barge

A mathematical study of the sensitivity of a pipeline being laid under tension to lay barge motions is described. The effects of surge, heave, and pitch on the bending stresses at the critical points at the top and bottom of the suspended part of a pipeline being laid under tension were studied for water depths ranging from shallow to deep (1,000 feet). The influence of a sloping rather than a horizontal sea floor was also studied. The results of the study are presented in the form of graphical curves, and several examples illustrate the use of these curves and the basic conclusions derived from the study. The basic equations of the mathematical analysis and their derivation are given in the appendix.

81. **BROOKS, J. K.**, and **BROWN, J. S. D.**, "Construction of 60-inch-diameter Outfall Sewer for Morecambe and Heysham Corporation," *Proceedings of the Institution of Civil Engineers*, Vol. 5, No. 2, Aug. 1956, pp. 302–324.

Keywords: Great Britain, Morecambe Bay, Outfall pipeline

Paper describes in detail the construction of a 60-inch-diameter ocean outfall sewer in Morecambe Bay in Great Britain. Various construction methods considered before the actual construction method was finally adopted are all briefly discussed. The project began with a short promenade section under a seawall which was carried out in a steel sheet-piled trench which continued across the beach section to the waterline. The pipe was laid in this trench for the landward beach part of the project, and the seaward part of the outfall was constructed by driving a 2,000-foot-long working gantry with a rail level at midtide level. Steel-piled cofferdams were driven from the gantry in which the underwater part of the pipeline was laid. The steel pipe was covered with a 12-inch-minimum concrete cover.

82. **BROWN, R. J.**, "Soil Mechanics Important in Marine Pipeline Construction," *Oil and Gas Journal*, Sept. 1957, p. 151.

83. **BROWN, R. J.**, "High-accuracy Control Systems for Submarine Pipelines," *Oil and Gas Journal*, Vol. 58, June 1960, pp. 108–111.

Keywords: Submarine pipeline, Survey instruments

Methods and equipment that may be used to accurately locate submarine pipelines during installation operations are described. Survey instruments for locating submarine pipelines across rivers along catenary routes, and tellurometers for accurately locating offshore pipelines along selected routes are discussed. The instruments and survey methods are described, including the advantages and disadvantages of the control systems and their accuracy limitations in various situations.

84. BROWN, R. J., "Hydrodynamic Forces on a Submarine Pipeline," *Journal of the Pipeline Division,* Vol. 93, No. PL1, Mar. 1967, pp. 9–19.

Keywords: Hydrodynamic forces, Submarine pipeline

A model investigation of the current-induced hydrodynamic forces on a submarine pipeline is described. The hydrodynamic forces on a submarine pipeline subject to current action consist of a drag force and a lift force. These forces were determined for the model pipe sections by measuring the pressure distribution around the pipe section. The coefficients of drag and lift can then be determined from the measured flow velocities, and drag and lift forces. The effect of spoilers on the pipe in altering the hydrodynamic forces and their coefficients was also investigated.

85. BROWN, R. J., "Pipelines Can be Designed to Resist Impact from Dragging Anchors and Fishing Boats," *Offshore Technology Conference,* Vol. I, May 1972, pp. I579–I586.

Keywords: Exposed pipeline, Pipe protection system

Paper discusses several factors that should be considered in the design of exposed submarine pipelines to resist damage by dragging anchors and fishing boats. The various types of risks to submarine pipelines and extent of damage associated with each risk are discussed. The available systems for pipe protection are briefly described along with the advantages and limitations of each type. An example is given which illustrates the application of the various types of pipe protection systems to various situations.

86. BROWN, R. J., "Pipeline Design to Reduce Anchor and Fishing Boat Damage," *Transportation Engineering Journal,* Vol. 99, No. TE2, May 1973, pp. 199–210.

Keywords: Protection methods, Unburied pipeline

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

87. BRUNDAGE, H. T., "Corrosion and 33 Years of Submarine Pipelining," *Pipe Line Industry,* May 1957, pp. 45–47.

88. BUNTAIN, D., ed., "Hydraulic Transport of Minerals in Pipelines," *Mining and Minerals Engineering,* Vol. 5, No. 9, Oct. 1969, pp. 25–30; Vol. 5, No. 10, Nov. 1969, pp. 16–19.

Keywords: Hydraulic transport, Pipeline, Solids

The hydraulic transport of solids in pipelines is discussed. The various types of mixtures and modes of motion in the pipe are explained descriptively, and various practical

considerations of such a system are also discussed. Economic advantages and disadvantages of solid transport in pipes are discussed briefly and examples are cited. A brief description of the experimental approach used in studying solid transport in pipes is also included.

89. **BURKE, B. G.,** "An Analysis of Marine Risers for Deep Water," *Offshore Technology Conference,* Vol. I, Apr.-May 1973, pp. I449–I464.

Keywords: Bending stresses, Drilling vessel

An analytical model to calculate the static and dynamic behavior of marine risers supported from floating drilling vessels is presented. A computer-oriented numerical integration method is used which allows variation of the parameters along the length of the riser. The mathematical model is described, and the basic equations of the analysis are given. The method of solution of the equations in the model is given in the appendix. The static analysis includes the effect of top tension, horizontal offset of the vessel, and current forces on the riser. The analysis of the dynamic response, due to vessel motion and wave forces, includes the bottom angle, maximum bending stress, and top stress as the basic parameters. A 16-inch-diameter marine riser was analyzed for water depths ranging from 400 to 2,000 feet to illustrate the results of the analysis, and also to determine important factors involved in extending existing riser design into deeper water. The results and conclusions of the analysis are discussed and illustrated in several graphical relationships between the parameters.

90. **CAIN, G. H., and GORDON, M.,** "Modern Techniques for Underwater Hot Tapping," *Offshore Technology Conference,* Vol. II, Apr.-May 1973, pp. II291–II294.

Keywords: Submarine pipeline, Underwater hot tap

Paper describes the techniques used in hot-tapping submarine pipelines. The procedure and equipment are described, and several examples are given illustrating the application of underwater hot tapping to several situations. The examples include a gathering line tied-in to a transmission line, a gathering line tied-in to an offshore platform, and the recovery of trapped crude oil in a sunken tanker.

91. **THE CALIFORNIA COMPANY,** "Hurricane Carla, Gulf of Mexico, September 8-14, 1961, with Supplementary Report, Hurricane Hattie, Off British Honduras, October 27-31, 1961," Engineering Reports, New Orleans Production Department, Dec. 1961.

Keywords: British Honduras, Hurricane Carla, Hurricane Hattie, Louisiana-Texas gulf coast

The physical damage caused by Hurricane Carla on the offshore oil operations of the Louisiana-Texas gulf coast is summarized. The various types of damage are listed, along with conclusions and new techniques to be applied to the correction and prevention of structural damage by future hurricanes. Cost estimates of damage and production losses are also given. Damage to offshore drilling rigs located off the British Honduras coast from Hurricane Hattie is discussed in the supplementary report.

92. **CAMPBELL, E. E.**, "How a Line was Tapped Under 22 Feet of Water in the Gulf," *Pipe Line Industry,* Nov. 1955, pp. 40–45.

93. **CATES, W. H.**, "Design of Flexible Steel Pipe Under External Loads," *Journal of the Pipeline Division,* Vol. 90, No. PL1, Jan. 1964, pp. 21–31.

Keywords: Flexible pipeline

Article describes a design method for calculating the wall thickness of buried, flexible steel pipelines subjected to external dead and live loads which are greater than the internal loads on the pipe. Tables of dead loads due to earth cover, live loads due to H-20 truckloads or E-72 railroad loads, and pipe deflections due to the combined loads, are presented as functions of the pipe diameter and depth of cover, along with the necessary equations for calculating the required pipe wall thickness. The tables cover a range of pipe diameters from 24 to 150 inches and a range of earth covers from 4 to 15 feet.

94. **CHANG, K. S.**, "Transverse Forces on Cylinders Due to Vortex Shedding in Waves," M.S. Thesis, Massachusetts Institute of Technology, Cambridge, Mass., Jan. 1964.

Keywords: Circular cylinder, Wave forces

Thesis presents a laboratory investigation of transverse lift forces on a vertical circular cylinder due to vortex shedding induced by the motion of shallow-water waves. Theoretical models for the phenomena are derived and discussed. The experimental equipment and procedure are described, and samples of the obtained data are included in the report. Values of the coefficient of the lift force induced by the vortex shedding in waves were determined, and a correlation was found between the value of the lift coefficient and the wave frequency. The results of the experimental investigation are plotted and compared with the theoretical models derived, and the conclusions are discussed.

95. **CHIN, A. G., and DIRKS, M. C.**, "Placing Pipelines and Outfalls Under Water for Seattle Metro Trunk Sewers," *Civil Engineering,* Vol. 37, No. 12, Dec. 1967, pp. 54–55.

Keywords: Seattle, Washington, Sewer pipeline

Article describes the design and construction of two underwater sewerlines in Seattle, Washington, including a line which passes under a lake and a deep ocean outfall. The ocean outfall was constructed of 96-inch-inside-diameter reinforced concrete sections, with tongue and groove O-ring neoprene rubber gasket joints. Divers coordinated the placing of the pipe sections from the bottom. The pipeline under the lake was constructed of 48-inch-inside-diameter prestressed concrete beams with a square outside configuration. These beams rested on reinforced concrete pile caps supported by four steel piles. Special joints, consisting of a rocker plate bearing system with a double O-ring gasket joint, were designed for the project.

96. **COLLINS, S. V.**, "Submarine Trenches," *Oil and Gas Journal,* Aug. 1958, pp. 111–112.

97. **COOK, F. E.**, "Coating Performance in a Marine Environment," *Corrosion,* Aug. 1960, pp. 117–120.

98. **CORLEY, C. B., Jr.**, and **WARNER, D. G.**, "Requirements for New Technology in Offshore Pipeline Construction," *Offshore Technology Conference,* Paper No. OTC 1183, Vol. I, Apr. 1970, pp. I351–I356.

Keywords: Installation techniques, Offshore pipeline

Paper discusses the methods available for constructing offshore pipelines, and possible improvements to these methods that should be developed in the near future. These developments should increase the depth and rough water capabilities of the present pipeline installation techniques, as well as increasing the efficiency and reducing the costs of the present methods. The developments discussed include better and faster pipe-joining and welding methods, improved mooring and positioning systems for the lay barges, development of high-angle ramps, extension of pipe-tensioning ability, improved motion characteristics of the lay barges, shortened or eliminated stingers, improved weather shutdown and recovery procedures, and better pipe transfer and handling systems.

99. **COX, H. D., et al.**, *Tension Pipe Laying Method,* U.S. Patent No. 3,331,212, Patent Office, Washington, D.C., 18 July 1967.

100. **CRAWFORD, D. W.**, "A History of Protective Coatings for the Offshore Industry: 1947-1972," *Offshore Technology Conference,* Vol. I, May 1972, pp. I671–I676.

Keywords: Corrosion, Offshore structures, Protective coatings

The various types of coatings available for protecting offshore structures against corrosion are reviewed. The types of coatings discussed include vinyls, epoxies, chlorinated rubber, inorganic zinc coatings, zinc-rich organic coatings, and acrylics. The characteristics of each type are described, along with the advantages, disadvantages, or limitations of each type of coating.

101. **DALEY, G. C.**, "Optimization of Tension Level and Stinger Length for Offshore Pipeline Installation," *Offshore Technology Conference,* Vol. II, Apr.-May 1973, pp. II473–II483.

Keywords: Lay barge, Offshore pipeline

An analysis method is described for optimizing certain operational parameters in laying offshore pipelines under tension from a lay barge with stinger. The method involves the optimization of the tension level with respect to either the minimum stinger length or the maximum radius of curvature of the stinger. Network charts are obtained for the various operational parameters of the pipeline and pipelaying system by a computerized finite element iterative solution which calculates a set of curves each for the stinger and the pipeline. The optimum solution is determined by overlaying the two sets of curves to obtain the points where the pipeline solution line intersects the stinger network chart. The basic equations of the analysis and their derivation, along with examples illustrating the procedure, are given.

102. **DEFONG, J.**, "Development and Utilization of a Deepwater Pipeline Connector," *Offshore Technology Conference,* Vol. II, Apr.-May 1973, pp. II149–II162.

Keywords: Pipeline connector system

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 seawater pressure available at large depths 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 one-atmosphere 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. Modified connector chambers can be used for making platform-user connections and pipeline tie-ins. The chambers can also be used to encapsulate pipeline valves and controls for subsea maintenance, servicing, and manual operation. A manifold chamber can be used with single-point mooring systems for simplified installation and replacement of the SPM hoses, and the installation of valves and other controls.

103. **DEPARTMENT OF THE INTERIOR**, "California Undersea Aqueduct Prereconnaissance Study," Bureau of Reclamation, Dec. 1969.

104. **DIXON, D. A.**, and **RUTLEDGE, D. R.**, "Stiffened Catenary Calculations in Pipeline Laying Problems," *Transactions, American Society of Mechanical Engineers,* Vol. 90, Feb. 1968, p. 153.

Keywords: Bending stresses, Lay barge, Pipeline laying

Paper describes 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. 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 required 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. Dimensionless curves are given for application of the results of the analyses, and examples are given to illustrate their use, and to compare the two methods.

105. **DOMINGUEZ, R. F.**, "Predicting Behavior of Suspended Pipelines in the Sea," *Offshore Technology Conference,* Vol. I, May 1972, pp. I619–I628.

Keywords: Computer analysis, Hydrodynamic forces

Paper describes a computer-oriented analytical method that enables the determination of the static and dynamic behavior of pipeline systems suspended below the sea surface. The

behavior of the pipeline can be evaluated for two- and three-dimensional systems and subject to both structural and fluid dynamic loads due to wave and current action. The dynamic response of the system and the dynamic forces and stresses within the system depend on the initially unknown pipeline configuration, as well as the induced hydrodynamic forces, the structural loads, and the restraints imposed by the termination and mooring points of the system. The method involves a self-correcting iterative procedure that converges to simultaneously satisfy the equilibrium requirements and boundary conditions. It is based on a set of geometric location equations and the use of the principles of elementary statics. An applied example to a ball-jointed pipeline system is given.

106. **DROUIN, A. H., HERD, D. P.,** and **MORRILL, C. D.,** "Remote Installations of Wellhead to Production Facility Piping in a Subsea Production System," *Offshore Technology Conference,* Vol. I, Apr. 1971, pp. I337–I348.

Keywords: Pipeline connector system, Wellhead installation

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 assemblies. A working scale model of the guidance and connector system and 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.

107. **DUNCAN, C. C.,** "Plowing Cables Under the Sea," *Institute of Electrical and Electronic Engineers Transactions on Communication Technology,* Vol. Com-17, No. 1, Feb. 1969, pp. 74–82.

Keywords: Sea plow, Submarine telephone cables

Paper describes a sea plow designed to bury submarine telephone cables under the sea bottom. The cables are buried on the continental shelves, where they were previously subjected to damage by fishing boards and scallop dredges, in areas where the cable crossed fishing grounds. The operation and important features of the sea plow are discussed, as well as specific cases in which the plow has been used successfully to prevent further damage to existing cables, or to lay new cables across areas which would have previously been avoided due to heavy fishing activity. Bottom surveys along the proposed cable route which must be carried out before the burial of the cable with the sea plow are also discussed briefly.

108. **EDMINSTON, K.**, "New System Repairs Pipe Line in 190-foot Water," *Ocean Industry,* Vol. 6, No. 1, Jan. 1971, pp. 35–38.

Keywords: Deepwater pipelines, Repair habitat

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

109. **FINN, L. D.**, and **POWERS, J. T.**, "Stress Analysis of Offshore Pipelines During Installation," Esso Production Research Co., Humble Pipeline Co., 1969.

110. **FLANIGAN, O.**, "Effect of Uphill Flow on Pressure Drop in Design of Two Phase Gathering System," *Oil and Gas Journal,* Mar. 1958, pp. 132–133.

111. **FONT, J. B.**, "Discussion of Hydrodynamic Forces on a Submarine Pipeline," *Journal of the Pipeline Division,* Vol. 93, No. PL3, Nov. 1967, pp. 77–79.

112. **FORD, S. E. H.**, and **ELLIOTT, S. G.**, "Investigation and Design of the Plover Cove Water Scheme," *Proceedings of the Institution of Civil Engineers,* Vol. 32, Oct. 1965, pp. 255–293; discussion in Vol. 35, Oct. 1966, pp. 343–358.

Keywords: Freshwater reservoir, Hong Kong

A summary is presented of the investigations and design work for a freshwater reservoir to be constructed in an inlet of the sea for Hong Kong water supply. Problems associated with such a system, e.g., salinity, biology, and closure effects of weather, as well as problems associated with the foundation, abutments, and design of the dam, are discussed.

113. **FREEMAN, J. C.**, "What the Gulf Can do to a Pipeline," *Pipe Line Industry,* May 1956, pp. 28–31.

114. **GAMMON, K. M.**, and **PEDGRIFT, G. F.**, "The Selection and Investigation of Potential Nuclear Power Station Sites in Suffolk," *Proceedings of the Institution of Civil Engineers,* Vol. 21, Sess. 1961-62, Jan. 1962, pp. 139–160. Discussions by F. H. E. Myers, E. Usher, and K. M. Gammon and G. F. Pedgrift, *Proceedings of the Institution of Civil Engineers,* Vol. 23, Sess. 1962-63, Dec. 1962, pp. 790–792.

Keywords: Nuclear power station site, Suffolk, Great Britain

Paper presents an investigation for potential nuclear power station sites on the coast of Suffolk, Great Britain. The basic technical requirements of a power station site, the method for selecting sites worthy of investigation, and the limitations of available data are discussed. The suitability of several sites determined to be worthy of investigation are also discussed. Additional surveys were made at the most promising site to determine possible limitations on the ultimate development of this site, and this was followed by a detailed investigation at the site to provide information for design purposes.

115. GARCIA, D. J., WILHOIT, J. C., Jr., and MERWIN, J. E., "Bending Moments Induced in Laying Offshore Pipeline under Tension," *Petroleum Mechanical Engineering Conference,* 67-PET-8, Sept. 1967.

116. GARCIA, D. J., WILHOIT, J. C., Jr., and MERWIN, J. E., "Current Induced Bending Moments in Laying Offshore Pipeline," *Petroleum Mechanical Engineering Conference,* 68-PET-6, Sept. 1968.

117. GAYLE, D. R., Jr., "Work with the Weather—It's Cheaper," *Pipe Line Industry,* May 1966, pp. 35–38.

118. GERWICK, B. C., Jr., and LLOYD, S. H., "Semisubmersible Lay Barge Meets Bass Straits Challenge," *Oil and Gas Journal,* Annual Pipeline Issue, Oct. 1970.

Keywords: Derrick, Pipelaying barge

Article describes the design characteristics and operation of a semisubmersible derrick and pipelaying barge. The barge was designed to operate efficiently under adverse sea and climatic conditions, using column stabilization to minimize motion, and twin hulls for rapid towing. The barge was designed with natural periods longer than the periods of waves and conventional barges, minimizing resonance effects and motion due to wave action. The pipelaying equipment includes a track-type tensioning system, an automatic pipe-handling system, an automatic lineup station, a column-stabilized stinger, and welding, X-ray, and field joint stations.

119. GLENN, A. H., "Normal Wind and Wave Conditions, Storm Tide and Wave Crest Elevations, and 20-Year Wave and Current Forces on Submarine Pipelines, Las Mareas Area, Puerto Rico," consulting report to Phillips Petroleum Co., Nov. 1965.

Keywords: Current forces, Las Mareas, Puerto Rico

Data and analysis of wind and wave conditions, storm tide and wave crest elevations, and wave and current forces on a submarine pipeline are given for the vicinity of Las Mareas, Puerto Rico. This report is the result of an investigation of the meteorological and oceanographic factors of interest in the planning and design of a proposed offshore tanker terminal and onshore installations.

120. GOUDY, A. P., "Shek Pik Submarine Pipeline, Hong Kong Water Supply," *Proceedings of the Institution of Civil Engineers,* Vol. 35, Sept. 1966, pp. 145–169.

121. GRACE, R. A., "The Effects of Clearance and Orientation on Wave-Induced Forces on Pipelines: Results of Laboratory Experiments," Technical Report No. 15, University of Hawaii, J. K. K. Look Laboratory, Honolulu, Hawaii, Apr. 1971.

122. **GRACE, R. A.**, "Submarine Pipeline Design Against Wave Action," Quarterly Publication of J. K. K. Look Laboratory of Oceanographic Engineering, Vol. 2, No. 2, University of Hawaii, Honolulu, Hawaii, Apr. 1971.

Keywords: Model pipeline, Wave-induced forces

Publication discusses the small amount of available experimental data obtained from model pipelines that can be used to pick coefficients for the design of submarine pipelines against wave-induced forces.

123. **GRACE, R. A.**, "Available Data for the Design of Unburied, Submarine Pipelines to Withstand Wave Action," *Engineering Dynamics of the Coastal Zone,* The Institute of Engineers, Australia, May 1973, pp. 59–65.

Keywords: Submarine pipeline, Wave-induced forces

Report discusses a method to calculate the wave-induced forces on an unburied submarine pipeline. The Morison equation is used, in which the total wave-induced force is equal to the sum of the drag and lift forces due to the water velocity, and the inertial force due to the water particle acceleration. Linear wave theory is used, and values of the coefficients of drag, inertia, and lift that must be used in the Morison equations are given for various conditions, as determined from the data available on wave-induced forces from several studies. The variation of the wave force coefficients with changes in the orientation of the pipeline with respect to the wave fronts, and with changes in the relative clearance of the pipeline from the bottom of the sea floor, with respect to the pipe diameter, are also discussed. These variations in the force coefficients are presented in graphs and tables.

124. **GREEN, J. E.**, and **HOWARD, H. L.**, "The Design and Construction of Underwater Pipelines," *Proceedings of the Fourth World Petroleum Congress,* Sec. VIII/B, Paper 3, 1955, pp. 95–114.

125. **GREEN, R. A.**, and **PINCUS, G.**, "The Performance of Selected Pipeline Couplings," *Offshore Technology Conference,* Vol. II, Apr.-May 1973, pp. II281–II290.

Keywords: Pipe couplings

An investigation to determine the performance of several types of subsea mechanical pipe couplings under the loading conditions of internal pressure, tension forces, and bending stresses, simulating actual working conditions, is described. The variation of stress and strain in the pipe adjacent to the tested pipe couplings was also studied. The apparatus and instrumentation used in the tests are discussed, along with the experimental procedure and the results of the tests.

126. **HARMSTORF, R.**, and **McBRIDE, J. V.**, "Underwater Apparatus for Deep Embedment of Cables and Pipes in Submarine Subsoil," *Ocean Science and Ocean Engineering,* Vol. 2, 1965, pp. 657–662.

Keywords: Deep-sea sled, Pipeline embedment

Article describes a deep-sea sled with apparatus designed to deeply embed cables and small-diameter pipelines. The high-pressure water jets cut a narrow path for an injector which guides the cable or pipe to the bottom, and the subsoil comes together immediately, giving deep embedment protection.

127. **HELFINSTINE, R. A.,** and **SHUPE, J. W.,** "Lift and Drag on a Model Offshore Pipeline," *Offshore Technology Conference,* Vol. I, May 1972, pp. 1563–1572.

Keywords: Flow forces, Model pipeline

Paper discusses a laboratory investigation of the lift and drag forces on a model pipeline resting on the ocean floor in a uniform current. The forces were measured on a model pipeline in a wind tunnel, covering a Reynolds number range of 5×10^4 to 1.3×10^5, simulating moderate offshore conditions. The coefficients of lift and drag were determined for both smooth and rough cylinders, and were plotted against Reynolds' number. The experimental equipment and procedure are discussed, along with the results of the investigation. A brief literature survey and discussion of the theory are also given.

128. **HOBBS, H.,** "Criteria for Design and Construction of Submarine Pipelines," *Pipes and Pipelines International,* Vol. II, No. 7, July 1966, pp. 24–27.

129. **HOLZ, P.,** "Single Buoy Mooring at Durban Nearing Completion," *The Dock & Harbour Authority,* Vol. 51, No. 595, May 1970, pp. 18–19.

Keywords: Construction methods, Durban, South Africa

Article describes the construction methods used to lay a 42-inch-diameter oil pipeline to a single-buoy mooring system 8,500 feet off the shore of Durban, South Africa. The pipe was assembled onshore and pulled out to the oil terminal site by barge.

130. **HOUGH, C. M.,** "Pipe Forcing for Outfalls," *The Dock & Harbour Authority,* Vol. XLVI, No. 554, Dec. 1966.

Keywords: Outfall pipeline, Pipe-jacking method

Article describes a pipe-jacking process that can be used in the construction of sea and river outfalls. This method falls somewhere between shield tunneling and thrust boring by auger. Large-diameter concrete pipes are jacked through the ground, and the displaced material is excavated at the face of the pipeline and removed through the back of the pipeline to the thrusting pit.

131. **HYDRAULIC RESEARCH STATION,** "Submarine Pipelines, A Model Investigation of the Wave Forces," Report No. 158, Wallingford, Berkshire, England, July 1961.

Keywords: Model pipeline, Wave-induced forces

A report on the results of experiments carried out to investigate the wave-induced forces on a model submarine pipeline. The model was scaled to reproduce the orbits, orbital velocities, and orbital accelerations at the bed of the prototype with respect to the diameter of the prototype pipeline, but no attempt was made to reproduce to scale the large water depths and wave heights of the prototype. Experimental instrumentation was set up to measure the wave profile, orbit lengths, orbit velocities, horizontal forces, and vertical forces on the pipeline model. The wave force data were analyzed using the Morison method, in which a drag force term is added to an inertial force term to determine the total force on the pipeline. The data were plotted in terms of three dimensionless parameters which include all of the parameters on which the force on the pipe was assumed to depend.

132. IDES, O. D., and RICHARDS, R. T., "Thermal Electric Stations in Japan," *Civil Engineering,* Feb. 1960, pp. 46–49.

133. JILLINGS, D. S., "Construction Insurance for Harbours and Offshore Pipelines," *Proceedings of the Engineering Committee on Oceanic Resources Symposium on the Challenge to South African Engineers,* 1972.

Keywords: Construction insurance, Offshore pipeline

Construction insurance on the capital works and liabilities of coastal construction projects involving water risks, such as harbors and offshore pipelines, is discussed. The extent of typical coverage for both damage insurance and public liability policies is listed separately, along with the normal restrictions and exclusions that go with each type of insurance. Detailed information concerning the construction project must be supplied to the insurers before they decide to accept a particular risk, and if so, on what terms, conditions, and premium rating levels. This information is also outlined in the paper.

134. JIRSA, J. O., et al., "Effect of Concrete Coating on the Rigidity of 12 ¾-inch Line Pipe," *Offshore Technology Conference,* Paper No. OTC 1074, Vol. II, May 1968, pp. II47–II58.

Keywords: Concrete coating, Submarine pipeline

Tests are described which determine the effects of concrete coating on the flexural rigidity of submarine pipelines subject to bending stresses during construction operations, and also the effects of joints on the behavior of pipe. The results of the tests are discussed and several graphs illustrating the results of the test data are presented.

135. JIRSA, J. O., et al., "Ovaling of Pipelines Under Pure Bending," *Offshore Technology Conference,* Vol. I, May 1972, pp. I573–I578.

Keywords: Bending stresses, Ovaling

Paper discusses an investigation of the ovaling effect on the flexural behavior of pipelines stressed beyond the elastic limit. Several pipe sections, uncoated and coated with concrete, were tested for flexure, deflections, and curvature; ovaling was also measured. Moment-curvature and ovaling-curvature relationships were determined from the tests, and analytical values of these relationships were computed, using a strain energy method, and compared with the experimental results. The effect of ovaling on the moment capacity of pipe sections was determined for both the experimental and analytical results.

136. JOHANSSON, B., and REINIUS, E., *Wave Forces Acting on a Pipe at the Bottom of the Sea,* Royal Institute of Technology and Vattenbyggnadsbyran, Stockholm, Sweden, 1963.

137. **JOHNSON, P. K.**, "RB-2's Laying Rate: 4,000 feet/hour," *Oil and Gas Journal,* Annual Pipeline Issue, Oct. 1970.

Keywords: Coatings, Reel-type pipelaying barge

Article describes the operation and performance of a reel-type pipelaying barge capable of laying 12-inch-diameter pipelines. The pipe-handling and pipe-straightening equipment is described. Tests were conducted to evaluate the effects of strain reversals due to the spooling and unspooling of the pipe on the properties of the pipe, including ovaling, tensile properties, and weld ductility; the results of these tests are discussed. Coatings for corrosion protection of reeled pipelines are discussed, along with problems due to coating defects and damage arising from the reeling and pipelaying operations.

138. **JOHNSON, P. K.**, "A Reel-type Pipelaying Barge," *Civil Engineering,* Vol. 41, No. 10, Oct. 1971, pp. 45–47.

Keywords: Pipe coating, Reel-type pipelaying barge

A reel-type pipelaying barge that can lay thick-walled steel pipelines up to 12 inches in diameter is described. The pipelaying procedure, the design of the pipe-handling equipment, and problems involving damage to the plastic pipe coatings are also discussed.

139. **KAZANJIAN, G. A., LYNCH, R. P.,** and **PILIA, F. J.**, "Pipeline Hot-tap Welding under 110 Feet of Water," *Proceedings of the Offshore Exploration Conference,* 1968, pp. 563–586.

Keywords: Underwater chamber, Welds

Proceedings paper describes a welding system in which high-quality, high-strength welds are obtained in tapping newly fabricated pipelines to existing pipelines. The welding is done in a dry, high-pressure environment similar to land-based operations, with the use of a specially designed underwater welding chamber capable of handling pipes up to 24 inches in diameter. It is used in conjunction with a submersible decompression chamber to transport the welders from the boat to the welding chamber at the bottom.

140. **KEELING, H. J.**, "Corrosion Protection Features of the Hyperion Ocean Outfall," *15th Annual Conference, National Association of Corrosion Engineers,* Mar. 1959; also in *A Collection of Papers on Underground Pipeline Corrosion,* Vol. 9, 1967 (Library of Congress Catalog Card No. 59-54031), pp. 13–20.

Keywords: Corrosion protection, Hyperion outfall, Los Angeles, California

Paper describes the design and construction of the corrosion protection system used in the Hyperion ocean outfall in Los Angeles, California. The corrosion protection system was designed to provide a useful life of at least 100 years, because the steel pipeline is terminated in water too deep to make it accessible to the conventional diving methods used to inspect, test, and repair submarine pipelines. An impressed current corrosion protection system was used rather than sacrificial anodes, due to the relatively short lifetime and the

difficulty of replacement of sacrificial anodes. The steel pipe was coated with coal-tar enamel, fiberglass reinforcing, and bonded asbestos felt. A steel mesh-reinforced cement-mortar shield was applied over the coating, and cement mortar was also used to line the inside of the pipe. The pipe sections were assembled onshore and pulled out to sea by barge. A cathodic protection was used during the installation of the pipeline, which provided continuous testing to detect any damage to the coating. This testing made repairs possible before the pipe was laid at inaccessible depths on the sea bottom.

141. **KEMSEY-BOURNE, K.,** "New Ways with Large Bore Plastic Pipe," *Pipes and Pipelines International,* Vol. 12, No. 10, Oct. 1967, pp. 29–32.

142. **KEY, J. W.,** and **JOHNSON, P. K.,** "Design of a Reel-type Pipelaying Barge," *National Meeting on Transportation Engineering,* July 1970.

Keywords: Bending stresses, Reel-type pipelaying barge

Article describes a reel-type pipelaying barge designed to lay 4- to 12-inch-diameter heavy-walled steel pipe. The design of the reel and associated pipe-handling equipment are described, and the results of tests to determine the effects of reversed bending on the pipe during the reeling and unreeling processes are summarized.

143. **KEY, J. W., JOHNSON, P. K.,** and **RUSSELL, L. R.,** "Design, Characteristics and Performance of the Fluor RB-2 Reel-Type Pipelaying Barge," *Offshore Technology Conference,* Paper No. OTC 1226, Vol. I, pp. I759–I768.

Keywords: Reel-type pipelaying barge, Thick-walled steel pipe

A reel-type pipelaying barge capable of laying thick-walled steel pipe with diameters up to 12 inches is described. The advantages of this pipe-laying technique are discussed, and the basic components of the reel pipe-laying system are described. A brief summary of the results of technical investigations of particular concern to this pipelaying method, including low cycle fatigue, weld ductility, ovaling of the pipe, straightness of the pipe, and the minimum radius of the reel, is also included.

144. **KOLKMAN, P. A.,** and **VAN DER WEIDS, J.,** "Elastic Similarity Models as a Tool for Offshore Engineering Development," *Symposium on Offshore Hydrodynamics,* Apr. 1972.

Keywords: Elastic similarity models, Offshore engineering development

A discussion is presented of the elastic similarity modeling techniques as applied to the study of the interaction between hydrodynamic forces and structural behavior of offshore structures. Scale relationships are derived and briefly discussed for water currents in closed conduit flow, currents and waves at free surface conditions, and elastic structures in water; the scaling laws of the hydraulic models are combined with the relationship expressing the elastic behavior of the structures. The compromises that must be made with respect to elasticity, mass, and dampening, as a result of the practical considerations and materials available for modeling, are discussed. Applications of elastic similarity models to the study of offshore pipelines and drilling platforms are discussed as examples.

145. KRIEG, J. L., "Criteria for Planning an Offshore Pipeline," *Journal of the Pipeline Division,* Vol. 91, No. PL1, July 1965, pp. 15–37.

Keywords: Offshore pipeline, Planning criteria

Many important factors that should be considered in the design and construction of offshore pipelines, including pipeline risers, underwater valves, and offshore pipeline crossings, are discussed. Factors to be considered in locating the offshore pipeline, including alinement, surveying methods, and route marking and navigation aids, are discussed, as well as factors important to the design and construction of the pipeline, including bottom conditions and scour, pipeline burial and burial methods, negative buoyancy, cathodic protection, and stress control. Weld inspection, underwater inspection, and cleaning and testing of the completed pipelines are mentioned, along with the permits and consents that are required for an offshore pipeline.

146. KRIEG, J. L., "Hurricane Risks as They Relate to Offshore Pipelines," *Hurricane Symposium, American Society of Oceanography,* Publication No. 1, Oct. 1966.

Keywords: Hurricane forces, Offshore platforms

The lateral movement and failure of offshore pipelines and platforms due to hurricane-induced wave and current action are discussed. The increasing risk of damage to pipelines from other causes, such as barge anchors and drilling equipment in areas where increasing numbers of pipelines are being laid, is also mentioned briefly. Hurricane probability risk factors used in the design criteria of offshore natural gas pipelines are also discussed.

147. LAI, N. W., et al., "A Bibliography of Offshore Pipeline Literature," TAMU-SG-74-206, Department of Civil Engineering, Texas A&M University, College Station, Tex., June 1973.

148. LAM, M. H., "McDermott Lays Deep-water Pipe Line in Gulf," *Ocean Industry,* Vol. 5, No. 7, July 1970, pp. 57–58.

Keywords: Construction methods, Gulf of Mexico

Article describes pipeline and construction methods used to lay pipelines in 220 feet of water in the Gulf of Mexico. Concrete-coated pipes were supported with a stinger while being laid from a barge, using a "step" method.

149. LAMBERT, D. E., "Hurricane Betsy—Petroleum's Most Expensive Storm," *World Oil,* Oct. 1965.

Keywords: Gulf of Mexico, Hurricane Betsy

Article describes the destruction and damage to oil and gas production facilities in the Gulf of Mexico and Mississippi River Delta area caused by Hurricane Betsy in 1965. The losses to the petroleum industry from Hurricane Betsy are estimated to be over $100 million.

150. LAMPIETTI, F. J., "Pendulation of Pipes and Cables in Water," *Journal of Engineering for Industry,* Aug. 1964, pp. 299–304.

Keywords: Drilling operation, Finite-difference method, Wind and wave forces

A finite-difference method is described and formulated for calculating the lateral motions of pipes and cables hanging below a ship due to the continuous displacement of the ships by the forces of winds and waves. The method is intended for calculation with digital computers and can be used to solve problems for the condition of a fixed lower end of the pipe or cable, as with drilling operations with the tip well down below the sea floor, or for the condition of a free lower end, as with the problem of reentering a drill hole on the ocean floor, or the accurate emplacement of the anchors for deep-moored positioning buoys.

151. LANGNER, C. G., "The Articulated Stinger: A New Tool for Laying Offshore Pipelines," *Offshore Technology Conference,* Paper No. OTC 1073, Vol. II, May 1968, pp. II37–II46.

Keywords: Articulated stinger, Lay barge

Paper describes a pipe support structure or stinger designed for laying offshore pipelines from a lay 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 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 briefly discussed.

152. LAROCK, J. B., "Discussion of Hydrodynamic Forces on a Submarine Pipeline," *Journal of the Pipeline Division,* Vol. 93, No. PL3, Nov. 1967, pp. 75–77.

153. LAWRENCE, J. B., "Latest Developments in Marine Pipe Laying," *The Boat Work,* Vol. 24, No. 3, Mar. 1967.

154. LEDFORD, R. C., "Design of Submarine Pipelines for Stability," *The Petroleum Engineer,* Vol. 25, No. 5, May 1953, pp. D70–D76.

Keywords: Pipeline coating, Submarine pipeline

Article discusses the problem of providing the correct weight coat to a submarine pipeline to keep it in place under varying bottom conditions. The pipes must be designed to remain in an equilibrium condition when buried. If the pipe and weight coating are too light, the pipe will rise out of its trench and be exposed to damage by wave and current forces, dragging anchors, etc. If the pipe is too heavy, it may sink lower into the bottom sediments, possibly resulting in excessive stresses which also cause damage to the pipeline. A summary of the results of tests carried out to determine the minimum thickness of concrete coatings for specific requirements in submarine pipelines is also included.

155. MACLEOD, D. C., "Durban's Submarine Outfalls, with Special Reference to Measures Taken to Prevent Pollution," *Proceedings of the Engineering Committee on Oceanic Resources Symposium on the Ocean's Challenge to South African Engineers,* Nov. 1972.

Keywords: Durban, South Africa, Submarine outfalls, Waste pipeline

A summary is presented of investigations carried out to study the effects of two major sea outfalls discharging settled sewage and industrial wastes off the coast of Durban, South Africa, on the environment and marine life of the area. Field studies and model experiments were carried out to obtain data on which to base decisions on the feasibility of the proposals, and also to establish design criteria for the proposed outfalls. After the outfalls were designed and constructed, further investigating and monitoring were carried out to evaluate the performance of the completed submarine outfalls. The economic considerations and costs of the project are also briefly discussed.

156. MANLEY, R. B., Jr., "An Evaluation of the Erosion-Corrosion Survey Program in the Vermillion Block 14 Field," *Offshore Technology Conference,* Vol. I, May 1972, pp. I629–I641.

Keywords: Erosion-Corrosion survey, Pipeline thickness measurements

Paper describes a survey method used to determine the thinning of pipe walls due to erosion and corrosion, so that ruptures in production equipment piping can be detected before they occur, allowing the weak pipe sections to be replaced. Ultrasonic wall thickness measurements were made periodically at all critical points in a pipeline system, and a computer analysis was made of the data to determine the rates of thinning of the pipe walls at the critical sections. The equipment, procedure, and results of the survey are discussed, along with the method of computer analysis.

157. MASSAD, A. H., "Cathodic Protection of Offshore Structures," *Petroleum Engineer,* Vol. 29, No. 5, May 1957, pp. B73–B74, B76, B80.

Keywords: Cathodic protection system, Submerged pipe

Cathodic protection systems for offshore oil platforms and submerged piping equipment are reviewed. Magnesium anode and impressed current systems are both discussed. Impressed current systems are more economical for most situations due to their relatively long service life, but they can only be used where a permanent electrical power supply is available. Several examples of the application of cathodic protection systems for specific situations are discussed.

158. McCAMMON, L. B., and LEE, F. C., "Undersea Aqueduct System," *Journal of the American Water-Works Association,* Vol. 58, July 1966, pp. 885–892.

159. McGHEE, E., "Storm Warnings are Coming Down for Gulf of Mexico Drillers," *Oil and Gas Journal,* June 1960, pp. 99–101.

Keywords: Gulf of Mexico, Offshore drillers, Storm warnings

The offshore oil situation in the Gulf of Mexico from 1957 to 1960 is discussed. The adverse situation and problems of both the offshore oil operators and the drilling contractors are described, as well as the interrelationships between the two. The problems discussed include the longtime lag between investment and income, the problem of finding enough oil to make the investment worthwhile, the rapid obsolescence of drilling equipment, and the decrease in allowables and crude prices which causes a decrease in the rate of new drilling, which in turn forces drilling equipment and contractors to be out of work, or else to operate at a loss. Changes in the situation and improvements in the efficiency of drilling operations and well completions which help to solve some of these problems are also discussed.

160. McKAIN, D. W., "An 84-inch Outfall Laid Off Long Island," *Ocean Industry,* Vol. 8, No. 7, July 1973, pp. 40–41.

Keywords: Construction methods, Long Island, New York, Submarine pipeline outfall

Article describes the construction of an 84-inch-diameter concrete outfall sewer submarine pipeline laid off the coast of Long Island, New York. The prestressed concrete pipe was constructed with precast concrete caps and cradles, and placed on piles driven into the ocean floor. The piles were driven from a barge, using top and bottom templates, and the pile cutoffs were made using a special chain saw system. The massive pipe sections were placed from a pipelaying barge equipped with two derrick booms to handle the pipes. External ballast tanks and interior ballast compartments were placed in the barge hull to stabilize the barge during the pipe-handling operations.

161. McKENNA, H. A., "Giant New Winch Built to Pull Undersea Pipe," *Undersea Technology,* Sept. 1969, pp. 40–42.

Keywords: Hydraulic winch, Offshore pipeline

A large hydraulic winch system that can be used to pull offshore submarine pipelines is described. The design specifications, operation characteristics, and advantages of the winch system are discussed.

162. McNAMERA, E. J., "Seven-mile Hot Pipe Line in the Gulf of Mexico," *Civil Engineering,* Vol. 30, No. 4, Apr. 1960, pp. 47–49.

Keywords: Hot pipeline, Gulf of Mexico

Article describes the construction of a hot submarine pipeline designed to transport molten sulphur 7 miles from an offshore manmade island near the sulphur mine in the Gulf of Mexico to the onshore storage and loading installations on the Louisiana coast. The pipe consists of a 6-inch-diameter sulphur line, which runs inside a hot waterline. The hot

waterline is covered with insulation and a jacket, and encased in another 14-inch-diameter coated pipe. The multiple lines were assembled, welded, tested onshore, and pulled out by barge. The pipe was laid in a dredged trench, and pretensioned to compensate for thermal expansion once the line is in use.

163. **McPHAIL, J. F., et al.,** "Offshore Pipeline Construction Stress Measurement," *Offshore Technology Conference,* Vol. I, May 1972, pp. I607–I618.

Keywords: Bending stresses, Offshore pipeline

Paper describes a study to determine the bending stresses in an offshore pipeline during construction operations when being laid from a lay barge with 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 tension, 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 the theoretical solutions. Horizontal bending stresses induced by crosscurrents were also measured. The instrumentation procedures are described, and graphical examples of the comparison between measured and calculated values of static and dynamic bending stresses are given.

164. **MILLER, D. R.,** "Marine Studies for the Design and Construction of Offshore Pipelines," *Proceedings of the Coastal Engineering Specialty Conference,* Oct. 1965, pp. 991–1006.

165. **MILZ, E. A.,** and **BROUSSARD, D. E.,** "Technical Capabilities in Offshore Pipeline Operations to Maximize Safety," *Offshore Technology Conference,* Vol. II, May 1972, pp. II809–II826.

Keywords: Offshore pipeline operations, Pipeline design considerations

A detailed discussion of the various factors that must be considered in the design, construction, and operation of offshore pipelines is given. 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 and methods of detecting leaks and breaks in the pipelines, and maintenance and repair techniques.

166. **MOORE, J. J.,** "The Economics of Offshore Pipelining," *National Meeting on Transportation Engineering,* July 1970.

Keywords: Economics, Offshore pipeline technology

The development and importance of offshore pipelining technology, including economic aspects and expected future trends, are discussed.

167. OAKLEY, H. R., and DYER, E. A., "Investigation of Sea Outfalls for Tynside Sewage Disposal," *Proceedings of the Institution of Civil Engineers,* Vol. 33, Feb. 1966, pp. 201–230; discussion in Vol. 30, Mar. 1967, pp. 633–649.

Keywords: Outfall pipeline

Paper discusses the results of a study for a proposed sewage outfall off the coast of Great Britain. The investigation included the following: (a) A bacteriological and biological survey; (b) float, current meter, and drift card observations; (c) operation of tidal model with imposed wind-induced currents to supplement the oceanographic data taken; and (d) a feasibility study to determine construction difficulties.

168. O'CONNELL, H. E., "New Techniques for Offshore Pipelining," *Pipeline Construction,* July 1957; also in *A Collection of Papers on Underground Pipeline Corrosion,* Vol. 3, 1959, pp. 127–133.

Keywords: Los Angeles, California, Outfall pipeline

Paper discusses the procedure and equipment used to lay a 7-mile 22-inch-diameter steel ocean outfall for sludge discharge of the City of Los Angeles. The pipe was welded and coated onshore, launched from a pier, and pulled to sea by a barge and winch anchored offshore. A sled was used in the pipe-pulling operation, and a trenching machine was used to bury the inshore end of the pipeline.

169. O'DONNELL, J. P., "Offshore Pipelining: A Special Report," *Oil and Gas Journal,* Dec. 1966, p. 67.

Keywords: Cook Inlet, Alaska, Louisiana, North Sea, Offshore pipelining, Persian Gulf

Report discusses the expansion of pipelaying operations from the Louisiana gulf and Persian Gulf to the rougher areas of Cook Inlet, Alaska, and the North Sea. The conditions and problems associated with each area are described. Offshore costs and mobilization fees for offshore pipeline projects are discussed and examples of several pipeline projects in these areas are given.

170. O'DONNELL, J. P., "High Costs in Time and Money, Emphasize Continuous Operation," *Oil and Gas Journal,* Vol. 64, No. 50, Dec. 1966, pp. 87–91.

Keywords: Pipeline economics, Submarine pipelines

Article reviews several measures that may be used to reduce the possibility of costly shutdowns of submarine pipelines, or to lessen the installation costs. The methods discussed include the use of mechanical anchors to secure pipelines on the bottom and reduce the required weight coat, burying pipelines, including more valve connections during initial installation for future pipe connections, the use of thicker walled and high-yield strength pipe, pipe-coating methods, cathodic protection systems and in-line generators for corrosion protection, laying dual lines or bundled multiple lines simultaneously, and making safe pipeline crossings.

171. **O'DONNELL, J. P.**, "Subsea Pipeline Challenges are Depth, Cost, Distance," *Oil and Gas Journal,* July 1967, pp. 125–127.

Keywords: S-curve method, Subsea pipelining

Article discusses the limitations of the conventional lay barge and stinger method for economically laying pipelines at large depths, and future developments that will allow pipelines to be laid economically at increasing depths. The S-curve method (long pipelines which can be laid at great depths by assembling the pipe in long sections and installing buoys along its length, with the buoys adjusted so the pipe forms an S-curve with a large radius overbend at the surface and another large radius bend at the bottom) is described. Laying pipelines in deep water from a vertical position, using a derrick in a drilling ship, is also discussed, along with automatic welding methods and encapsulation of pipeline mechanisms for underwater servicing. Cost problems of laying offshore pipelines are discussed along with distance limitations.

172. **O'DONNELL, J. P.**, "Offshore Line Laid under Tension," *Oil and Gas Journal,* Vol. 66, No. 26, June 1968, p. 82.

Keywords: Lay barge method, Oil pipeline, Persian Gulf

Articles describes a submarine oil pipeline laid from Sassan field to a terminal on Qavan Island in the Persian Gulf. The pipeline is 88 miles long, 22 inches in diameter, and laid to a maximum depth of 306 feet. The lay barge method was used to lay the pipe, and a "floating weight" method was used to apply tension to the suspended line. The lay barge, stinger, and pipelaying equipment and operations are briefly described. The laying rates and problems encountered during the laying operations, due to bad weather, fraying tensioning cables, and stinger breakage, are also discussed.

173. **O'DONNELL, J. P.**, "Sea Robin Extends System," *Oil and Gas Journal,* Annual Pipeline Issue, Oct. 1970.

Keywords: Pipelaying equipment

Article describes a lay barge whose pipelaying equipment includes a track-type tensioning system, an articulated stinger, special automatic anchor winch controls, and welding, X-ray, and field joint stations.

174. **OFFSHORE NEWSLETTER**, Vol. 1, No. 7, Oct. 1968.

175. **OVUNC, B.**, and **MALLAREDDY, H.**, "Stress Analysis of Offshore Pipelines," *Offshore Technology Conference,* Paper No. OTC 1222, Vol. I, Apr. 1970, pp. I727–I734.

Keywords: Offshore pipelines, Stress analysis

Paper describes a computer-oriented iterative method to determine the stresses and nonlinear configuration of a submarine pipeline suspended between a lay barge and the ocean floor during the installation operations. A stiffness matrix method is used to determine the stresses and configuration of the suspended pipeline for a lay large with a

straight stinger, an articulated stinger, or without a stinger, and with or without tension applied at the lay barge. The weight of the pipe and coating and the buoyant and drag forces are considered as static forces, although dynamic loads due to lay barge movements or inertial forces may be introduced into the computation. The basic equations and procedure of the analysis are given, along with examples illustrating the application of the method.

176. **OVUNC, B.**, and **MALLAREDDY H.**, "Stress Analysis of Offshore Pipelines Under Dynamic Loads," *Offshore Technology Conference,* Vol. I, Apr. 1971, pp. I349–I356.

Keywords: Offshore pipelines, Stress analysis

A computer-oriented iterative method of analysis to determine the deformation and stresses due to dynamic loads on a submarine pipeline suspended between the ocean floor and the lay barge is discussed. A stiffness matrix method is used to solve the deformed shape of the pipeline under static loads, and a modal analysis is used for the dynamic loads. The dynamic loads are applied to the statically deformed configuration of the pipeline, which is modified to eliminate the terms due to rotations. The pipeline is assumed to consist of finite elements, and the external loads on the members are lumped to the joints and expressed in mass units. The natural frequency and modal shapes are determined from the equations of motion for a multidegree, lumped mass system. The method is general and applicable to any dynamic loading condition. The procedure and equations of the analysis are given, and an example of the application of the method is given for the dynamic loads of lay barge displacements due to wave action.

177. **PEARCE, B. K.**, and **KISHPAUGH, J. A.**, "Prediction of Pipelaying Equipment Performance in Hostile Environments," *Offshore Technology Conference,* Vol. II, Apr.-May 1973, pp. II455–II464.

Keywords: Computer pipelaying model, Environment

Conference paper discusses a computer model that simulates the process of laying offshore pipelines from a lay barge. The computer model predicts probable installation costs and time for completing the project, taking into account work interruptions due to weather, equipment failures, and other factors such as pipe buckling and welding defects. The model simulates pipelaying operations, weather generation, the generation of equipment failures, and pipe-resupplying operations. The model was used to compare the performance of flat-bottomed and small and large semisubmersible lay barges in the rough waters of the northern North Sea and the Grand Banks of Canada. Comparisons of manual and automatic pipe welding, and conventional and wide-truss stingers were also made for these conditions, using the computer model.

178. **PEEBLES, E. E.**, "Sonic Cover Survey of an Offshore Pipeline," *Offshore Technology Conference,* Vol. II, Apr.-May 1973, pp. II295–II298.

Keywords: Offshore pipelines, Survey methods

The electronic and sonic survey methods that can be used to make cover surveys of offshore pipelines are discussed. The equipment used in such a survey is described, which

includes the work boat, radio navigation system, acoustic subbottom profiles, magnetometer, echo sounder, side-scan sonar, and divers. The operational procedure of a specific sonic cover survey is briefly described as an example of the application of the survey methods, and recommendations are given for the requirements of a vessel to be used in such a survey.

179. **PETRAUSKAS, C.,** "Discussion of Regression Model of Wave Forces on Ocean Outfalls," (Proceedings Paper 7275, May 1970, by R. E. Johnson), *Journal of the Waterways, Harbors, and Coastal Engineering Division,* May 1971, pp. 414–417.

180. **PLUNKETT, R.,** "Static Bending Stresses in Catenaries and Drill Strings," *Journal of Engineering for Industry,* Vol. 89, No. 1, Feb. 1967, pp. 31–36.

181. **POSTLEWAITE, W. R.,** and **LUDWIG, M.,** *Method for Laying Submarine Pipe Lines,* Patent No. 3,266,256, Patent Office, Washington, D.C., 16 Aug. 1966.

182. **POWERS, J. T.,** "Stress Analysis of Offshore Pipelines During Installation," *Offshore Technology Conference,* Paper No. OTC 1071, Vol. II, May 1968, pp. II9–II22.

Keywords: Offshore pipeline, Stress analysis

A computer-oriented finite-beam element, initial-value analysis method which may be used to calculate stresses on an offshore pipeline during construction operations when the pipeline is suspended between the ocean floor and a lay barge and stinger is described. Applied tensions, external fluid pressures, depth variations in water currents, pipe stiffness variations due to weakness of the weight coating at the field joints, and support buoys, if used, are all considered in the theory. The method is general and can be applied to the analysis of both two- and three-dimensional forces and deflections in the suspended part of the pipeline under any support condition. Crosscurrents and lateral barge movements can be considered. The use of the finite-element calculation procedure is described and several examples of the calculations are included. The method is compared with other theories and the advantages and limitations are discussed. The basic equations of the method and their derivations are given in the appendix.

183. **PROUDFIT, D. P.,** "Practical Selection of Material for Large Water Pipe," *Transportation Engineering Journal,* Vol. 95, No. TE1, Feb. 1969, pp. 203–212.

Keywords: Material selection, Water pipes

Proceedings paper discusses the factors that should be considered in selecting materials for large water pipes greater than 30 inches in diameter. The materials considered are steel, ductile-iron, and reinforced concrete. Steel and ductile-iron are considered as flexible pipes and reinforced concrete as rigid pipe. Factors to be considered in the selection of a pipeline include deflection limitations of pipe and coatings due to external loads and internal

pressure, shell stress limitations to pipe and coating due to internal pressure, shell thickness, types of corrosion protective coatings, field joints, pipe lengths, blocking and anchorage, trench loads and embedment requirements, construction conditions and methods, fabrication methods, and shipping procedures.

184. **RADBILL, J. R.**, "Computation of Flow-line Installation Stresses," *Proceedings of the Offshore Exploration Conference,* 1968, pp. 383–395.

Keywords: Installation stresses, Submerged pipeline

Paper reviews an analysis which may be used to calculate the stresses which are produced in pipelines during installation as the pipe is placed on the ocean floor from a barge. Calculations are made of the maximum stress, as a function of pipe properties, water depth, and the vector load at the barge, to determine the best pipe tension and angle for laying the pipe from the barge.

185. **RALSTON, D. O.**, and **HERBICH, J. B.**, "The Effects of Waves and Currents on Submerged Pipelines," Sea Grant Publication No. 301, Texas A & M University, College Station, Tex., Mar. 1969.

186. **RAMOS, B., HELIMENAS,** and **MELCHERT, A.**, "Fuerzas Sobre Cilindros Sumergidos y Apoyados en una Superficie Plana," Departamento de Hidraulica, Universidad Central de Venezuela, July 1965.

187. **RANCE, P. J.**, "Investigation of Wind-Induced Currents and Their Effect on the Performance of Sea Outfalls," *Proceedings of the Institute of Civil Engineers,* Vol. 33, Feb. 1966, pp. 231–260; discussion in Vol. 36, Mar. 1967, pp. 633–648.

Keywords: Outfall pipeline, Wind-induced currents

Paper presents a study of the mass movement of surface water for a proposed sewage outfall off the coast of Great Britain. Field investigations using floats were used to determine the relationships between windspeed and surface currents. A model investigation was carried out to determine the circulation pattern due to both tidal and wind-induced currents combined.

188. **REID, R.**, "Oceanographic Considerations in Marine Pipeline Construction," *Gas Age,* Vol. 107, Moore Publishing, New York, Apr. 1951, pp. 46–49.

189. **RIMMER, H. D.**, "Repairs to Sea Outfall Sewer on the Storm Beach in Chesil Cove, Dorset," *Proceedings of the Institution of Civil Engineers,* Vol. 2, No. 4, July 1953, pp. 454–457.

Keywords: Chesil Cove, Dorset, Great Britain, Outfall pipeline repairs

Proceedings paper describes construction methods used to repair an outfall sewer that had been damaged by the grinding of shingle on a constantly shifting storm beach in a cove in Great Britain. The original cast-iron pipe, supported on single cast-iron piles, was to be

replaced by a manganese-steel pipe carried between armour-plate saddles and transoms secured to manganese-steel piles. The work was done from a crib of tubular scaffolding, which was moved on pontoons.

190. **ROADS, N.**, "How to Calculate Pipe Stress in Offshore Construction," *Petroleum Engineer,* Oct. 1968, pp. D20–D23.

191. **ROGERS, W. M.**, and **DUCKWORTH, H. N.**, "Electronic Survey Helps Assure Integrity of Offshore Pipelines," *Offshore Technology Conference,* Vol. II, Apr.-May 1973, pp. II299–II304.

Keywords: Electronic survey device, Offshore pipeline

Paper describes an electronic survey device which evaluates corrosion and mechanical damage to offshore pipelines. The survey device is a self-contained unit consisting of a power section, a transducer section, and a recording section; all three sections are connected with universal joints. The unit travels through the pipeline system, driven by the power section which has scraper cups to center the device in the pipeline and form a seal with the pipe wall, so the survey device is carried through the pipeline by the liquid flowing through it. The transducer section uses a direct current electro-magnetic flux leakage technique to detect defects on either pipe surface and provide signals to the recording section, where the signals are stored on magnetic tape. As the survey device travels through the pipeline, it records points of corrosion or damage, girth welds, valves, speed, and orientation of the device.

192. **SANTI, G.**, "Trenching and Dredging in Deep Water," *Ocean Industry,* Vol. 6, No. 6, June 1971, pp. 30–31.

Keywords: Submersible cutter dredger

A brief discussion of a manned submersible cutter dredger that has a working depth capability of 200 feet is given.

193. **SCHWARTZ, H. I.**, "Hydraulic Trenching of Submarine Pipeline," *Transportation Engineering Journal,* Proceedings Paper 8489, Vol. 97, No. TE4, Nov. 1971, pp. 721–728.

Keywords: Hydraulic trenching, Submarine pipeline

The design, operation, and testing of a hydraulic trenching device designed to bury large-diameter pipelines under varying conditions are discussed.

194. **SERPAS, L. B.**, **BELAZONG, A.**, and **MATTEELLI, R.**, "Selection of Routes for Sub-Mediterranean Pipelines," *Offshore Technology Conference,* Vol. II, Apr.-May 1973, pp. II485–II503.

Keywords: Mediterranean Sea, Pipeline routes

Paper discusses the planning and procedure used in a marine survey to determine feasible paths for pipeline routes across the Mediterranean Sea between North Africa and Sicily. The techniques and instruments used in the surveying operations are described, which

include horizontal positioning, bathymetry, subsoil profiles, side-scan sonar, visual inspection and photography, soils sampling, and current measurements. The results of the survey are discussed along with their accuracy, acceptability, and applicability, and the selection process used to determine the proposed pipeline routes are also discussed briefly.

195. SHERMAN, A. M., and MILLER, D. R., "Submarine Aqueducts Deliver Water to Venezuelan Island," *Civil Engineering,* Vol. 31, Mar. 1961, pp. 41–45.

196. SHORT, T. A., "Pipelines Pinned to Ocean Floor," *Pipeline Engineer,* May 1967.

Keywords: Design criteria, Ocean floor pipeline

Article briefly discusses the design criteria for anchoring pipelines to the sea bottom, including wave and current forces, bottom conditions, and pipeline stability.

197. SHORT, T. A., "Pipeline Anchoring Systems," *Offshore,* June 1967.

Keywords: Anchoring system

Pipeline anchoring and installation systems are discussed briefly. The reasons for anchoring and the advantages of anchoring a pipeline to the sea floor are also discussed.

198. SMALL, S. W., "The Submarine Pipeline as a Structure," *Offshore Technology Conference,* Paper No. OTC 1223, Vol. I, Apr. 1970, pp. I735–I746.

Keywords: Design considerations, Submarine pipeline

The structural design considerations of submarine pipelines are discussed. Structural configurations of submarine pipelines during construction operations by the lay barge, reel barge, bottom-pull, and floating string methods are discussed, as well as the structural configuration of both exposed and buried pipelines during operation. The static and dynamic loading conditions on submarine pipelines are discussed, along with the various structural functions performed by the pipelines under different configurations and loading conditions. The basic approach and steps or functions in the structural analysis of submarine pipelines are discussed, and several secondary factors which may influence the structural analysis are also given.

199. SMALL, S. W., "Submarine Pipelines for Tanker Terminals," *Mechanical Engineering,* Vol. 94, No. 7, July 1972, pp. 23–28.

Keywords: Construction methods, Submarine pipeline, Tanker terminals

The many factors that must be considered in designing and constructing large-diameter submarine pipelines are discussed. Design criteria and the loads due to the bottom soil conditions, hydrostatic and hydrodynamic forces, and operational and construction loads are discussed, along with the imposed stresses and structural and positional stability of the pipeline. Construction methods are also explained briefly.

200. SMALL, S. W., "Structural Considerations in the Design of Submarine Pipelines," *ASCE National Structural Engineering Meeting,* Apr. 1973.

201. SMALL, S. W., and SERPAS, L. B., "Submerged Weight Control for Submarine Pipeline Construction," *Offshore Technology Conference,* Vol. I, May 1972, pp. I595–I596.

Keywords: Submerged pipeline construction, Weight control

The various methods available for controlling the submerged weight of pipelines laid in deep water are discussed. The various methods of adding weight or buoyancy are briefly described. The performance requirements of submerged pipeline weight-controlling methods, including the physical properties, compatibility with operations, reliability, and economics, are discussed, and the individual methods are evaluated in terms of these requirements. The preferred systems for practical use are identified and briefly discussed.

202. SMALL, S. W., TAMBURELLO, R. D., and PIASECKYJ, P. J., "Submarine Pipeline Support by Marine Sediments," *Offshore Technology Conference,* Vol. I, Apr. 1971, pp. I309–I318.

Keywords: Marine soils, Submarine pipeline

Paper discusses the initial settlement of submarine pipelines in cohesive marine soils. A method is developed to calculate the initial settlement of submarine pipelines on the sea floor, and several theories for determining the ultimate bearing capacity of soils are compared. The practical limitations of marine soils sampling and analysis are also briefly discussed.

203. SORENSON, J. E., MESLOH, R. E., and ATTERBURY, T. J., "The Challenge of Offshore Pipeline Construction," *Battelle Research Outlook, Engineering and the Ocean Frontier,* Vol. 1, No. 1, 1969, pp. 27–31.

Keywords: Offshore pipeline construction, Pipelaying methods

Article discusses the various methods presently used to lay pipes, including the lay barge, bottom pull, reel barge, and flotation methods. The limitations of the various methods are given, and suggestions for future development to improve and eliminate some of the problems and limitations of the present pipelaying methods are discussed. Design considerations of the pipe, including wall thickness, concrete-coating density, and specific gravity are briefly discussed.

204. STEWART, T. L., and FRASER, J. P., "Experimental Measurement of Stresses While Laying Pipe Offshore," *Petroleum Mechanical Engineering Conference,* Sept. 1966.

205. STREBELLE, J. R., "How to Use Radiography in Pipeline Construction," *Welding Engineer,* Oct. 1960, pp. 44.

206. SUTKO, A. A., "Discussion of Hydrodynamic Forces on a Submarine Pipeline," *Journal of the Pipeline Division,* Vol. 93, No. PL3, Nov. 1967, pp. 79–80.

207. TAYLOR, D. M., "How are Pipelines Behaving in the Gulf Corrosionwise," *Pipe Line Engineer,* Mar. 1957, pp. 24–25.

208. TOEBES, G. H., and RAMAMURTHY, A. S., "Fluid Elastic Forces on Circular Cylinders," *Journal of the Engineering Mechanics Division,* Vol. 93, No. EM6, Dec. 1967, pp. 1–20.

Keywords: Circular cylinders, Laboratory results, Lift forces

Paper discusses the results of a laboratory investigation of the lift forces acting to oscillate a rigid circular cylinder transverse to the direction of a uniform steady waterflow. The response of the cylinder with respect to the lift forces is dependent on the elastic vibrating motions of the cylinder as well as the fluid flow forces acting on the cylinder. The experimental equipment and procedures are described, and the results of the experiment are discussed in terms of the spectral analysis of the lift force data, and the transfer of energy between the cylinder and the fluid.

209. TOWNSEND, D. R., and FARLEY, D. W., "Design Criteria for Submarine Pipeline Crossings," *Journal of the Hydraulics Division,* Vol. 99, No. HY10, Oct. 1973, pp. 1659–1678.

210. TUBB, M., "Planning California's Subsea Aqueduct," *Ocean Industry,* Vol. 7, No. 9, Sept. 1972, p. 43.

Keywords: Northern California, Water pipeline

A brief discussion of a testing program to determine the best material, i.e., metals, concrete, or plastics, suited to move northern California water by a sea floor pipeline to the southern part of the State is given.

211. TUBB, M., "World's Largest Submarine Oil Pipe Lines," *Ocean Industry,* Vol. 7, No. 11, Nov. 1972, p. 54.

Keywords: Kharg Island, Iran, Offshore oil terminal, Submarine pipeline

Article describes the construction of four submarine pipelines connecting an offshore oil terminal off Kharg Island, Iran, with the nearby shores. The two 56-inch and two 20-inch-diameter lines were welded and concrete-coated onshore, and pulled out to the terminal site by a winch and barge anchored offshore. The lines were buried in a dredged trench.

212. VAN REENAN, E. D., "Geophysical Approach to Submarine Pipeline Surveys," *Offshore Technology Conference,* Paper No. OTC 1187, Vol. I, Apr. 1970, pp. I367–I378.

Keywords: Geophysical methods, Submarine pipeline survey

Paper reviews several geophysical methods and survey devices that may be used in studying submarine pipeline routes. The equipment and methods described include seismic profiling, depth sounders, side-scan sonar, magnetometers, sediment samplers, current meters, and positioning systems. Field procedures are discussed for surveying proposed pipeline routes, as well as for relocating and monitoring existing submarine pipelines.

213. VASSALOTTI, F. J., "Aluminum Pipeline in the Arctic," *The Military Engineer,* Vol. 56, No. 372, July-Aug. 1964, pp. 268–269.

Keywords: Aluminum pipeline, Arctic storage tank

Article describes the construction of an 8-inch-diameter aluminum pipeline from an anchored ship to a storage tank in the Arctic. The pipe sections were welded and pressure-tested onshore, and pulled out on the surface by a winch on a work boat stationed offshore. The pipeline was then sunk by pumping in water, and saddle-type anchors were placed by a crane and divers to compensate for the buoyancy and to stabilize the pipeline.

214. VENNETT, R. M., "Save Weld Hardness Levels to Insure Long Service Life in Offshore Pipelines," *Offshore Technology Conference,* Vol. I, May 1972, pp. I587–I594.

Keywords: Corrosion, Offshore pipelines, Weld hardness

Proceedings paper discusses an investigation of the effect of weld hardness on the cracking susceptibility of offshore pipelines due to stress corrosion or hydrogen sulfide cracking. Automatic welding and sulfate reducing bacteria are briefly discussed as they apply to this investigation. Laboratory cracking tests were made in which stresses were applied to several weld specimens exposed to a corrosive environment of saltwater containing hydrogen sulfide. The hardness of the welds was determined after the cracking tests. The experimental setup and testing procedure are discussed, along with the results of the tests. Recommended hardness limits for pipeline field welds are given from the results of the investigation.

215. WAKEMAN, C. M., "Use of Concrete in Marine Environments," *Journal of the American Concrete Institute,* Apr. 1958, pp. 841–845.

216. WALLACE, W., and ARCHIBALD, G. E., "Trombay Power Station: Cooling Water System," *Journal of the Power Division,* Vol. 82, No. PO1, Feb. 1956, pp. 1–19.

Keywords: Cooling water system, Steel pipeline, Thermal power system, Trombay Island, India

Paper describes the design and construction of the cooling water system for a thermal power station on Trombay Island in Bombay Harbor, India. The cooling water system consists of a cast-in-place, reinforced concrete underground conduit leading into the power station, followed seaward by a steel pipeline supported first by concrete saddle piers resting on an earth embankment over the tidal flat area, and then supported by a rockfill embankment, extending into the harbor about 1,100 feet offshore. This leads to a reinforced concrete trestle which carries the pipeline above water to the offshore intake structure. The intake structure was designed to be constructed in drydock as a reinforced concrete caisson, which was floated to the site and sunk to position.

217. WARD, D. R., "Laying Large Diameter Offshore Pipelines," *Offshore,* Vol. 27, No. 6, June 1967, pp. 52–56.

218. WARREN, B. J., ANGEL, T. A., and GRAY, R., "Saturation Diving—A Tool for Offshore Pipelining," *Offshore Technology Conference,* Vol. II, Apr. 1971, pp. II211–II220.

Keywords: Economics, Offshore pipeline, Saturation diving

Paper discusses the application of saturation diving to several operations involved in the installation and repair of offshore pipelines. The basic principles of saturation diving techniques and the special equipment required are described. Several considerations that increase safety and operational efficiency when using the saturation diving technique are discussed, and the economic considerations of saturation diving are discussed and compared with conventional diving techniques.

219. WELLMAN, L. C., "Submarine Pipeline in Australia," *The Military Engineer,* July-Aug. 1967, pp. 252–256.

Keywords: Sled, Spencer Gulf, Australia, Submarine pipeline

Article describes the construction methods used to lay a 7-mile submarine pipeline for water supply across Spencer Gulf in Australia. A trench was dredged across the gulf, and the pipe was pulled from one side of the gulf to the other, using smaller diameter pipe for the pull strings, with a sled attached to the nose of the 39-inch-diameter pipeline.

220. WELLS, M. J., "Kuwait Prepares for Mammoth Tankers," *World Oil,* Vol. 39, No. 7, July 1968, pp. 26–29.

221. WELLS, M. J., "Sassan Field Now Operating," *World Petroleum,* Vol. 40, No. 2, Feb. 1969, pp. 28–30.

222. WIEGEL, R. L., and DELMONTE, R. C., "Wave-Induced Eddies and "Lift" Forces on Circular Cylinders," HEL 9-19, Hydraulic Engineering Laboratory, University of California, Berkeley, Calif., July 1972.

223. WILHOIT, J. C., Jr., and MERWIN, J. E., "Bending Stress is Critical in Laying Deepwater Pipelines," *Oil and Gas Journal,* Vol. 64, No. 45, Nov. 1966, pp. 85–88.

224. WILHOIT, J. C., Jr., and MERWIN, J. E., "Stinger Configuration," *Oil and Gas Journal,* Vol. 64, No. 46, Nov. 1966, pp. 198–200.

225. WILHOIT, J. C., Jr., and MERWIN, J. E., "Pipe Stresses Induced in Laying Offshore Pipeline," *Journal of Engineering Industry,* Vol. 89, No. 37, Feb. 1967.

Keywords: Bending stresses, Offshore pipeline

An analytical method that can be used to calculate the bending stresses in the unsupported section of a pipeline being laid from a lay barge with stinger is described. Both the case of a pipeline that follows the curvature of the stinger and leaves it at some point, without any change in the direction of the curvature of the pipeline, as well as the case of a

pipeline that tips over the end of the stinger and undergoes a reversal in curvature before coming back into contact with the stinger, are considered. A computer-oriented numerical solution is used to solve the problem for various values of the governing parameters, and the effect of these parameters on the pipeline bending stresses is discussed briefly.

226. 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,* Vol. I, Apr. 1971, pp. I293–I296.

Keywords: Axial tension, Pipelines

Paper discusses an analytical study of the effect of axial tension on the moment carrying capacity of pipelines. The study was made for the case where the pipeline is stressed beyond the elastic limit, with the effect of pipe ovaling taken into consideration. An analysis by Ades, which uses the principle of least work to determine the effect of ovaling on a cylindrical tube under pure bending when part of this tube is beyond the elastic limit, was extended to include the effect of axial tension. The procedure of the analysis and the results of the study are given.

227. WILHOIT, J. C., Jr., and MERWIN, J. E., "Critical Plastic Buckling Parameters for Tubing in Bending Under Axial Tension," *Offshore Technology Conference,* Vol. II, Apr.-May 1973, pp. II465–II472.

Keywords: Axial tension, Bending stresses

Proceedings paper describes experimental tests made with thin-walled steel tubing to verify and compare an analytical theory procedure of predicting the relationship between bending moment and curvature in both the elastic and plastic ranges for tubes subjected to bending plus axial tension. Graphs comparing the theoretical and experimental results are given, along with a discussion of the results and their comparison.

228. WILLIAMSON, J., et al., "Cooling Water Intakes at Wylfa Nuclear Power Station," *Civil Engineering and Public Works Review,* Vol. 63, No. 744, July 1968, pp. 759–761.

Keywords: Anglesey, Great Britain, Nuclear power station

Article briefly describes the design and construction of the intake structures for the cooling water system of a nuclear powerplant at Wylfa Head in Anglesey, Great Britain. The vertical shaft and undersea tunnel were constructed underwater by divers, using large precast concrete blockwork. A tubular steel jetty and headwork structure were constructed by overhand methods to provide both permanent and construction access to the site of the intakes.

229. WILSON, B. W., "Foundation Stability for a Submarine Liquid Sulphur Pipeline," *Journal of the Soil Mechanics and Foundations Division,* Vol. 87, No. SM4, Aug. 1961, pp. 1–37.

Keywords: Gulf of Mexico, Sulphur pipeline

Article describes a study conducted to determine the vertical and lateral stability of a 7-mile-long hot sulphur pipeline to be constructed between the shores of Louisiana and an

offshore sulphur mine in the Gulf of Mexico. The hot pipeline is insulated within an outer casing, and is to be entrenched in the bottom sediments composed in part of fine sand and silt and the remainder cohesive clay, for hurricane protection. The sediment properties are examined along the pipeline route, and the vertical stability of the pipeline is investigated with respect to pipe buoyancy and sediment properties. The thermal stability of the pipeline is studied with respect to possible buckling due to thermal expansion between the fixed ends to the pipeline, and subsidence of the line due to thermal osmosis of the clay and convection currents in the sand induced by the flow of heat from the pipeline to the sediments.

230. **WILSON, B. W.**, "Anticipated Hurricane Effects on a Submarine Pipeline," *Proceedings of the International Association for Hydraulic Research Congress,* 1963, pp. 327–350.

231. **WILSON, J. F.**, and **CALDWELL, H. M.**, "Force and Stability Measurements on Models of Submerged Pipelines," *Offshore Technology Conference,* Paper No. OTC 1224, Vol. I, Apr. 1970, pp. I747–I758.

Keywords: Current forces, Submerged pipeline

A laboratory investigation of current-induced forces on submarine pipelines anchored just above the ocean floor is discussed. Lift and drag forces and vibrations induced by eddy shedding were studied for two parallel pipes located close to the sea floor. The effects of horizontal spacing between the parallel pipes, vertical spacing from the ground plane, and the orientation angle of the pipeline with respect to the current direction were observed. The experimental results were plotted and compared with available data for double and single pipelines with the ground plane absent.

232. **WILSON, R. O.**, and **MARTIN, M. R.**, "Deepwater Pipelining for Central North Sea," *Offshore Technology Conference,* Vol. II, Apr.-May 1973, pp. II305–II314.

Keywords: Construction methods, Ekofisk, Norway

The construction of an oil pipeline system in the Ekofisk Field in the central North Sea is reviewed. The pipeline construction equipment and methods used in the project are described, including special alterations made to the lay barge; pipeline-tensioning techniques; pipe connections, risers, and special pipe-handling techniques; trenching methods; saturation diving operations; and surface position control techniques. Several developments and improvements in pipelaying technology for future projects in rougher and deeper water are also discussed, including special lay barges, improved tensioning techniques, automatic pipe-joining methods, new diving systems, and improvements in logistical planning and implementation on pipeline projects.

233. **YAMAMOTO, T.**, **NATH, J.**, and **SLOTTA, L.**, "Wave Forces on Horizontal Submerged Cylinders," Bull. No. 47, Oregon State University, Corvallis, Oreg., Apr. 1973.

234. ZEITOUN, M. A., and McILHENNY, W. F., "Conceptual Designs of Outfall Systems for Desalination Plants," *Offshore Technology Conference,* Vol. I, Apr. 1971, pp. I451–I462.

Keywords: Desalination plant, Outfall pipeline

Paper discusses the design of outfall systems for the discharge of dense effluents from coastal desalination plants. Vertically directed submerged jets, jets reaching the surface of the receiving water, and jets inclined at angles of 30°, 45°, and 60° with the horizontal were studied. An experimental model investigation and a numerical analysis, were carried out for each case to determine which arrangement gave the maximum dilution. The diffuser design principles are discussed, and conceptual designs and cost estimates were made and compared for desalination plants of various sizes, ranging from 2 to 50 million gallons per day.

V. INDEX

VI. LOCATION INDEX

Bowie, George L.

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