THE ELMER A. SPERRY AWARD FOR 1979

...FOR ADVANCING THE ART OF TRANSPORTATION

The Elmer A. Sperry Medal

Purpose of the Award

The Elmer A. Sperry Award shall be given in recognition of a distinguished engineering contribution which, through application, proved in actual service, has advanced the art of transportation whether by land, sea or air.

In the words of Edmondo Quattrocchi, the sculptor of the Elmer A. Sperry Medal:

"This Sperry medal symbolizes the struggle of man's mind against the forces of nature. The horse represents the primitive state of uncontrolled power. This, as suggested by the clouds and celestial fragments, is essentially the same in all the elements. The Gyroscope, superimposed on these, represents the bringing of this power under control of man's purposes."

Presentation of

THE ELMER A. SPERRY AWARD FOR 1979

to

Leslie J. Clark

by

The Board of Award under the sponsorship of

The American Society of Mechanical Engineers
Institute of Electrical and Electronics Engineers
Society of Automotive Engineers
The Society of Naval Architects and Marine Engineers
American Institute of Aeronautics and Astronautics

At the Annual Meeting Banquet of the
Society of Naval Architects and Marine Engineers

Friday, November 14, 1980 □ New York Hilton □ New York, N.Y.

Elmer Ambrose Sperry 1860-1930

Founding of the Award

The Elmer A. Sperry Award commemorates the life and achievements of Dr. Elmer A. Sperry (1860-1930) by seeking to encourage progress in the engineering of transportation. Much of the great scope of the inventiveness of Dr. Sperry contributed either directly or indirectly to advancement of the art of transportation. His contributions have been factors of improvement of movement of men and goods by land, sea and air.

The award was established in 1955 by Dr. Sperry's daughter, Mrs. Robert Brooke Lea, and his son, Elmer A. Sperry, Jr.

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Elmer A. Sperry, III

Leslie J. Clark

Award Citation

To Leslie J. Clark for his contributions to the conceptualization and initial development of the sea transport of liquefied natural gas.

Introduction

In the United States, natural gas is used in over half of all residences and commercial establishments. It serves almost 50 million customers. It provides about 30% of all the energy used in this country. We get about 95% of our natural gas from domestic sources. Most other industrial countries use it extensively but do not have their own supply. Demands are increasing and supply dwindling.

Accordingly, it has been a matter of concern to many people that natural gas which is generally available where there are oil fields, is so frequently flared and wasted. In December 1977, it was estimated that the world's supply of natural gas, at the rate it was then being used, would last 200 years. But why waste it? Why not conserve and economically transport this fuel to needy industrial countries?

To make such an operation possible, it is necessary to refrigerate the gas, to a very low temperature. Under this condition, it condenses to a liquid and shrinks to a small fraction of the volume it occupies as a free gas. It can then be transported in insulated tanks specially designed for the purpose.

The design and engineering problems involved in the accomplishment of this objective were unusual and varied. They necessitated close coordination of the fields of cryogenics, metallurgy, chemical engineering and naval architecture. There were problems associated with the physical properties of materials and insulants at low temperatures and the large contraction movements and strains induced by temperature change. There were problems in handling a boiling liquid continually releasing gas which, if trapped, could build up dangerous pressures. These problems had to be faced on a large scale and assessed against the potential hazard of fire and explosion.

Transporting LNG by ship involves safety of life at sea. It affects other uses of our ports, and rivers and harbors. Thus, this requires from the outset that there be close cooperation and liaison with national and local government authorities and with regulatory bodies as well as with industry. The successful implementation of such a project confirms the effectiveness of this cooperation and it affirms how the imagination, perseverance and technical skill of a team of engineers can be harnessed in endeavor and achievement.

Natural gas consists mainly of methane. Methane cannot be liquefied by the application of pressure alone; its temperature must be lowered to at least its critical level of -116.5°F, in which state a pressure of 673 lbs/sq. in. is necessary to liquefy it. Alternatively, when cooled to -260°F, it will liquefy at atmospheric pressure. As a liquid, the volume is reduced to one six-hundredths of that as a gas and the liquefied natural gas specific gravity is 0.45. In this concentrated liquid form, the transportation of gaseous energy becomes economically feasible.

First Inland Waterway Transport of LNG

The first practical development incorporating these principles was undertaken by William Wood Prince, then President of Union Stockyard and Transit Company of Chicago. He had a need for fuel gas supplies for the stockyards and associated packing stations in Chicago, and an incidental need for inexpensive refrigeration in the cold storage installations. He was convinced that it should be possible to liquefy gas (a known technology) which he could obtain cheaply in the Louisiana oil and gas fields, store it in land based tanks (also a known technology), transfer it to barges and transport it up the Mississippi to Chicago where it could be stored and regasified. The missing link was river transportation. But he believed that this could be solved in a practical and economical manner. This was 1951.

By early 1952, Mr. Prince, with the courage of his convictions, selected a consulting engineer of proven experience and ingenuity in the refrigeration field—Willard L. Morrison—to direct a small group to carry out an urgent study of the feasibility of such a project. His assignment, according to a letter from a friend written some years later, "consisted of having to formulate a comprehensive scheme, provide the design of all the necessary equipment which could be manufactured with the least capital investment and operated at the lowest cost and with the maximum of safety at every stage." (A patent had been granted in 1915 to G.L. Cabot for an idea to handle and transport liquefied gas by river barge. There is no record, however, that such a craft was ever built.)

Morrison planned that the liquefaction plant and the storage tank would be barge mounted. This would allow movement from field to field. It would also form a basis for the river transport barge. The design of the liquefaction plant represented relatively few problems, except for its size. Its capacity was well in excess of the several peak-load shaving plants then in existence in the United States. Material and design techniques were available.

The transport barge, however, presented a novel problem since not only was conventional land storage not readily adaptable to water-borne craft, but such tanks were themselves in a state of flux after the Cleveland incident of 1944. There, a relatively newly built LNG storage tank constructed of 3½% nickel, low carbon steel, had failed catastrophically, causing considerable local damage and loss of life. (Historically, the only other significant accident related to LNG was the Staten Island fire and explosion in 1972. Here, the unusual tank construction resulted in retained gas pockets, and apparently a spark from a workman during tank repair set off this catastrophe. The accident occurred almost a year after the tank had been emptied of LNG.)

Morrison's team therefore had to start from first principles. They reviewed all possible materials suitable for safe operation at -260°F, the boiling point of methane. These could be conveniently divided into two general categories:

(a) materials of construction—for tanks, piping and equipment;

(b) materials for insulation—load bearing and non load bearing.

In the first category came such well known materials as stainless steels, aluminum, nickel-alloy steels, aluminum bronze, copper and some of the precious metals such as silver. Of these, only the first three were likely to be available in commercial quantities at remotely realistic prices. Stainless steels were widely used in the cryogenic industry but there was little or no experience of the use of aluminum in larger structures and its welding was known to present problems.

As far as alloy steels were concerned, it was well known that, by increasing the nickel content, the low-temperature properties of the resulting alloy could be improved. In the early fifties, the newly developed nine per cent nickel steel had had limited use ashore. However, not only was there a dearth of experimental or service experience to justify its consideration for large scale shipboard application, but the failure of the tank at Cleveland caused designers to be cautious in the use of any nickel-bearing steel for this type of service. At any rate, the phenomenon of brittle fracture was not yet well enough understood. Nor was there sufficient correlation of laboratory tests with service experience, to enable designers to feel secure with anything other than 18-8 stainless steel.

For insulating materials the choice appeared to be limited to mineral-based powders, fibrous materials such as glass, and wood. The latter was a potential load-bearing material.

The overall concept of an insulated tank containment arrangement seemed to resolve itself into the choice of two clearly divided alternatives, both of which would control the rate of evaporation of the cargo:

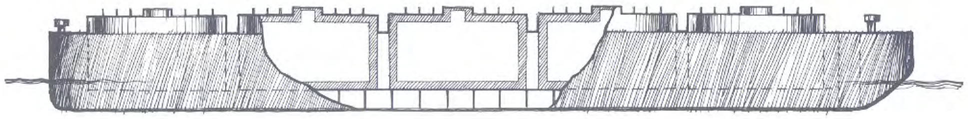
(a) insulation outside—a tank constructed of a material able to operate at LNG temperatures, outside which must be fitted sufficient insulation to protect the ship or barge structure.

(b) insulation inside—a tank constructed of a material having no special low temperature properties, inside which must be fitted insulation capable of containing the liquid and protecting the tank structure from the low temperature of the cargo.

In either case it was judged advisable to design the tank to be as free from undesirable stress concentrations as possible—leading to the use of cylindrical or spherical shapes.

Both the exterior and interior insulated alternatives presented considerable design problems. Exterior insulation required that the tank be able to expand and contract freely and at the same time be securely located in the barge. The insulation had to be able to accommodate this movement if it were attached to the tank. Interior insulation required very careful attention to system design to ensure that the insulation remained liquid-tight for the whole of its working life. This arrangement would mean a considerable cost saving in not

Figure 1: LNG Barge — Methane



L=264' B=52' Capacity approx. 5550m³ Draft fully loaded 7'4½"

using cryogenic structural materials, the welding techniques for many of which had yet to be established.

After due deliberation the second alternative was chosen, using wood as an insulating material. Wood was a readily available material which could be worked and assembled to reasonably close tolerances by existing techniques. The low temperature properties of available woods, however, were not known; therefore, a comprehensive series of tests was commissioned to establish the low temperature properties of three commonly used woods—Douglas fir, Sitka spruce and balsa. With the favorable early testing of balsa wood, the second of the two options, (b), described above—inside tank insulation was chosen.

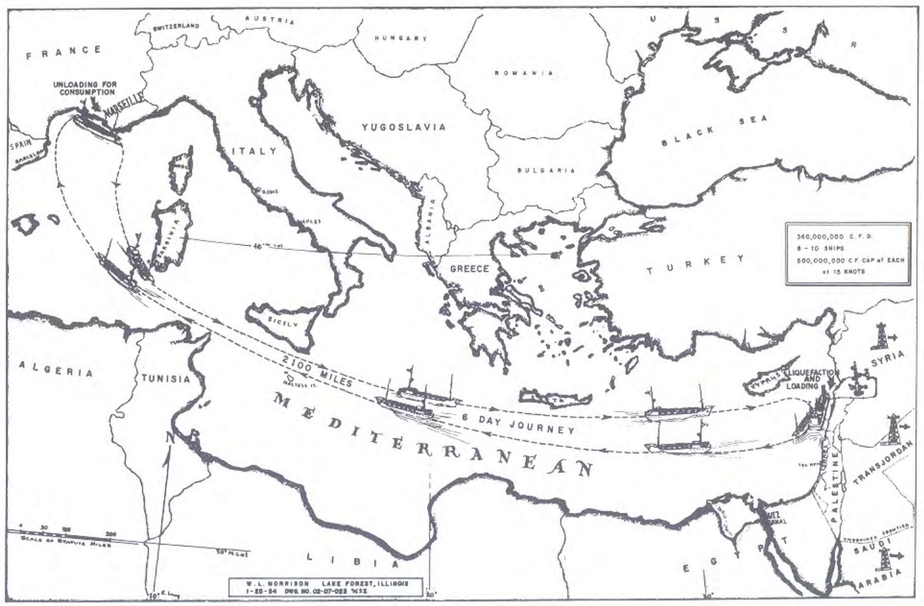
A prototype barge was ordered from Ingalls Shipyard in Pascagoula, Miss., in 1953. This barge had five vertical cylindrical tanks, internally insulated with balsa and constructed with a double hull for protection in event of collision.

By the mid-1950's there had been much progress and applications had been made for many patents. Much design information on materials and equipment, so vital to the overall project, was developed in this phase. And much was learned about the characteristics of the LNG cargo itself. But classification approvals for the projected designs were in difficulty. The low temperature tests on the tank insulation, in spite of the extreme care and ingenuity in its installation, were not successful. The only recourse was to revert to the first option, (a) — use of cryogenic material for the tank and location of the insulation outside for future designs.

Sea Transport of LNG

There is no doubt of visionaries having dreams of LNG beyond river barge transportation. A map

Figure 2: An Early Ocean Going Project



of the Mediterranean Sea drawn by or for Morrison in January 1954, shows an LNG transport plan — Syria to France.

The LNG concept had far wider application than the river barge scheme. Others, in Europe as well as in the United States, were beginning to think of ocean transport. Thus, whatever was developed had to be adaptable to a sea-going ship large enough to exploit the potential markets which undoubtedly existed for the movement of gas from overseas producers to consumers in the industrial countries of the world.

In June of 1954, a report which had been prepared by the International Bank, on shipping LNG from Kuwait to the United Kingdom, was brought to the attention of the British Gas Council by a chance meeting on the "Queen Elizabeth." The Council was sufficiently interested to arrange for an immediate visit of one of the British gas industry's senior engineers, Leslie J. Clark, to evaluate the U.S. work. His reports were optimistic, and he continued to maintain a technical liaison with the basic American team working on this project, now called "Constock." That group, made up of the Continental Oil Company and the Union Stockyards, had joined technical and financial forces to work on this problem.

By the end of 1955, Mr. Clark, who was then Development Engineer for the North Thames Gas Board (and later became Chairman of North Thames and Chairman of the Northern Board) and his superior, Dr. J. Burns, the Gas Board's Chief Engineer, were so impressed by what they had seen of Constock's work, that they wrote in a paper "Liquid Methane," presented in June 1956, which is now a classic, the following:

"Natural gas is one of the world's major sources of energy, but is not so readily transportable over long distances as solid and liquid fuels . . . Such gas could be liquefied under atmospheric pressure at temperatures around –260°F and transported in special ships containing insulated tanks and delivered to this country . . . There is at present no precedent . . . for the equipment associated with suitable ocean-going ships . . . some of the design problems are discussed in the paper . . . it is believed that they are capable of satisfactory solutions. The economics of a project are reviewed in broad terms . . . and it is concluded that the scheme has promise . . ."

While the research, testing and design studies were being carried out, Leslie Clark's early interest, enthusiasm, and belief that the project had promise, led to continuing discussions with many individuals and organizations in both the U.S. and England. Everyone was most cooperative and helpful, but the entire area was new. It thus became clear that the quickest way of satisfying their doubts and queries was to demonstrate the technical feasibility of the project. This could best be done by mounting a full-scale sea trial for conveying the LNG from the well head in Louisiana to the Thames. Consequently, in late 1957, a joint trial project was undertaken by Constock and the British Gas Council.

Transportation at sea meant involving classification societies, regulatory authorities, and naval architects. James J. Henry, then president (and now chairman) of J.J. Henry Co., Inc., a forward-thinking firm of naval architects, was chosen to contribute his special skills and those of his organization to the project. Mr. Henry's company has been deeply involved in LNG transport ever since. For this project, they developed the innovative ship arrangement that remains to this day, the norm in the construction of LNG carriers. They adapted shore-based cryogenic-liquid handling techniques to the marine environment — an early example of what is known in contemporary terms as technology transfer. Most important, they furnished to their shore-bound associates in the project insight into the relationship between ship, containment, and cargo.

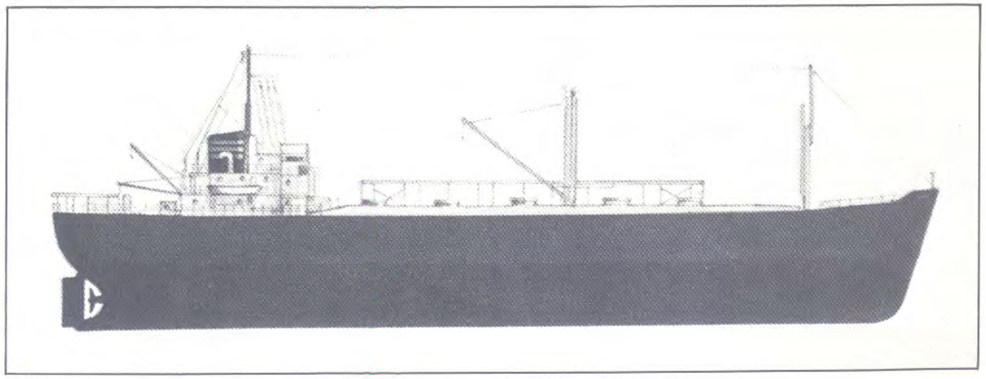
So many other individuals and organizations were involved in the many facets of the design and construction that it is not possible to tell of their contributions here. Suffice it to say that the excellent coordination and cooperation of all, in the United States and abroad, provided a first ship's cargo in record time.

In the interest of speed, it was decided to convert an existing cargo ship into an LNG carrier. The ship had to be large enough to cross the Atlantic under winter conditions and to try out all the design features required in larger ships. Moreover, it had to be small enough to avoid an unduly high expenditure of capital. As it was, about $5 million was the cost of the experiment.

The ship selected was a CI-M-AVI, 338 feet long, constructed during World War II. Five tanks were installed for a total capacity of about 5,000 cubic meters of LNG (32,000 barrels or about 2,200 tons). The tanks were made of aluminum and were welded. They were rectangular, similar in design to a prototype tank tested many months earlier using liquid nitrogen at –320°F. Rectangular-shaped tanks better utilized the underdeck volume of the ship. The insulation was composed of pre-fabricated, sandwich-type, panels of balsa faced front and back with maple and fir plywood. Great care was taken with the conversion of this ship. For example, the humidity in the area of the insulation was maintained at 30% and the temperature at 80°F throughout the construction period. Cargo tank welds were given 100% x-ray examination.

Constock purchased a site near Lake Charles for liquefaction and loading and the North Thames Gas Board provided a site at Canvey

Figure 3: M.V. Methane Pioneer



Island for the reception terminal with storage and gasification equipment.

The ship was named "Methane Pioneer," and a pioneer she indeed was. She left Lake Charles with a full cargo of LNG on her first historic 5,064 mile voyage on 28 January 1959, making an average speed of 9.4 knots and meeting some heavy weather in mid-Atlantic and fog in the English Channel. She appeared out of the mist at Canvey Island on the morning of 20 February to an excited and perhaps rather relieved reception party, after 23 days at sea, the technical staff aboard, perhaps not quite as excited was certainly relieved.

During that first trip, at one rolling up to 30° (a 45° roll was recorded on a later crossing), she demonstrated to the complete satisfaction of all that the transportation of LNG by sea, at least from a technical point of view, was a practical proposition. The subsequent six trips served only to consolidate this opinion.

The ship was fully warmed up on her return to Lake Charles, her tanks inspected and found in good order.

During this and subsequent trips considerable data was amassed on such items as daily boil off, temperature gradients, cargo behaviour (no strange phenomena in relation to the manner and mechanics of boiling were observed — or heard), cool-down and warm-up procedures and times — all essential preliminaries to the design of a commercial scale venture.

Upon completion of this first trip, there was great excitement even among sober-minded men. There seemed no limit to the potential expansion of the LNG market. World gas reserves are far in excess of all oil discovered in the world so far. Here was an abundant, clean fuel, currently being wasted for an age with ever-increasing concern about pollution and ever-dwindling supplies of fuel oil. Here was a technology for shipping it across the high seas, proven by seven very successful trans-Atlantic voyages by the world's only LNG ship. Together, these provided a glittering prospect indeed.

Conclusion

In the past twenty years, commercial project has followed commercial project. LNG was first shipped from Algeria to the United Kingdom and France, then to Spain and the United States; from Libya to Italy and Spain, and from the Middle East, Brunei, Indonesia and Alaska to Japan. Shipyards in ten different countries have built the 52 LNG ships now in existence and have under construction or on order 17 more (31 December 1979). As of the same date these ships have made almost 5000 voyages — 67% to Europe; 29% to Japan and about 4% to the U.S. There are two shipyards in the United States which have completed 11. Seven more are on order.

During this period, the size of the LNG carrier has grown from 27,400 cubic meters, about the length and beam of a 50,000 ton tanker, in the case of Methane Princess and Methane Progress to about 130,000 cubic meters corresponding in size to a tanker of, say, 250,000 tons. Virtually all of the LNG carriers completed in recent years and on order are in the 125,000 to 130,000 cubic meter range. Ships of up to 200,000 cubic meters capacity have been proposed.

As for the containment systems, there are many. There is no end to the ingenuity and tenacity of the men who, either by accident or by design, follow the first who entered this endeavor. Although the growth pattern seems impossible to continue, it must be remembered that this relatively new source of supply will respond to an energy hungry world which is deeply indebted to all who contributed and especially to the individual being honored now by the Elmer A. Sperry Board of Award.

Quotations, ideas and data for this story have been freely taken from:

(1) The Institute of Mechanical Engineers — "The Thirty-eighth Thomas Lowe Gray Lecture — Marine Transport of Liquefied Natural Gas" by L.J. Clark, B.E.M., M.Sc. (Eng.) (Member)

(2) "Natural Gas by Sea" by Roger Ffooks, 1979.

(3) "LNG Fact Book, December 1977" — American Gas Association

(4) "Record of Voyages Completed by the World Fleet of LNG Carriers," compiled by William duBarry Thomas for El Paso LNG Company.

Leslie J. Clark
CBE, BEM, M.Sc (Eng), F. Eng, F.I.C.E., F.I. Mech. E, F.I. Gas E, F. Inst. Energy, M.I.E.E., M.I. Chem. E. Honorary President - International Gas Union

After graduating in engineering Mr. Clark served as a pupil in Mechanical Engineering at Beckton Gas Works (then the largest in the world). Subsequently he held several senior engineering appointments in the Gas Light and Coke Company and became chief engineer of the North Thames Gas Board in 1962. Thereafter he was appointed Deputy Chairman of that Board and then Chairman of the Northern Gas Board in 1967, where he remained until 1975.

During this period Mr. Clark gave much time to the work of the professional engineering institutions. Being a member of six Chartered Institutions he presented several technical papers, mainly in the energy field in which he was particularly interested, and he was elected President of the Institution of Gas Engineers in 1965/66. Subsequently he became President of the International Gas Union from 1973 to 1976 and has travelled widely in pursuing studies related to world energy problems.

Apart from administering large scale engineering operations he pioneered the research and development work leading up to the first commercial project for the marine transportation of liquefied natural gas using cryogenic techniques. He was also the innovator of several new developments related to gas production and transmission.

Mr. Clark has always been interested in the wider problems of energy supply and use, and has been associated with the work of the Conservation Commission of the World Energy Conference over the last three years following its initiation by Wilson Campbell.

He has served on the Court of the University of Newcastle Upon Tyne and the Council of the University of Durham. Also on the Boards of some engineering companies, which includes Darchem Limited and the Chairmanship of Victor Products (Wallsend) Limited.

He was invited to become a founder member of the Fellowship of Engineering and is Chairman of the C.E.I. - Northern Branch and Vice Chairman of the Committee for Regional Affairs.

Previous Elmer A. Sperry Awards

1955 to *William Francis Gibbs* and his Associates for development of the S.S. United States.

1956 to *Donald W. Douglas* and his Associates for the DC series of air transport planes.

1957 to *Harold L. Hamilton, Richard M. Dilworth* and *Eugene W. Kettering* and Citation to their Associates for the diesel-electric locomotive.

1958 to *Ferdinand Porsche* (in memoriam) and *Heinz Nordhoff* and Citation to their Associates for development of the Volkswagen automobile.

1959 to *Sir Geoffrey De Havilland, Major Frank B. Halford* (in memoriam) and *Charles C. Walker* and Citation to their Associates for the first jet-powered aircraft and engines.

1960 to *Frederick Darcy Braddon* and Citation to the Engineering Department of the Marine Division, *Sperry Gyroscope Company,* for the three-axis gyroscopic navigational reference.

1961 to *Robert Gilmore Letourneau* and Citation to the Research and Development Division, *Firestone Tire and Rubber Company,* for high speed, large capacity, earth moving equipment and giant size tires.

1962 to *Lloyd J. Hibbard* for application of the ingitron rectifier to railroad motive power.

1963 to *Earl A. Thompson* and Citation to his Associates for design and development of the first notably successful automobile transmission.

1964 to *Igor Sikorsky* and *Michael E. Gluhareff* and Citation to the Engineering Department of the Sikorsky Aircraft Division, *United Aircraft Corporation,* for the invention and development of the high-lift helicopter leading to the Skycrane.

1965 to *Maynard L. Pennell, Richard L. Rouzie, John E. Steiner, William H. Cook* and *Richard L. Loesch, Jr.* and Citation to the Commercial Airplane Division, *The Boeing Company,* for the concept, design, development, production and practical application of the family of jet transports exemplified by the 707, 720, and 727.

1966 to *Hideo Shima, Matsutaro Fujii* and *Shigenari Oishi* and Citation to the *Japanese National Railways* for the design, development and construction of the New Tokaido Line with its many important advances in railroad transportation.

1967 to *Edward R. Dye* (in memoriam), *Hugh DeHaven* and *Robert A. Wolf* and Citation to the research engineers of *Cornell Aeronautical Laboratory* and the staff of the Crash Injury Research projects of the *Cornell University Medical College.*

1968 to *Christopher S. Cockerell* and *Richard Stanton-Jones* and Citation to the men and women of the *British Hovercraft Corporation* for the design, construction and application of a family of commercially useful Hovercraft.

1969 to *Douglas C. MacMillan, M. Neilsen* and *Edward L. Teale, Jr.* and Citations to Wilbert C. Gumprich and the organizations of *George G. Sharp, Inc., Babcock and Wilcox Company,* and the *New York Shipbuilding Corporation,* for the design and construction of the N.S. Savannah, the first nuclear ship with reactor, to be operated for commercial purposes.

1970 to *Charles Stark Draper* and Citations to the personnel of the *MIT Instrumentation Laboratories:* Delco Electronics Division, *General Motors Corporation,* and Aero Products Division, *Litton Systems,* for the successful application of inertial guidance systems to commercial air navigation.

1971 to *Sedgwick N. Wight* (in memoriam), and *George W. Baughman* and Citations to William D. Hailes, Lloyd V. Lewis, Clarence S. Snavely, Herbert A. Wallace, and the employees of *General Railway Signal Company*, and the Signal & Communications Division, *Westinghouse Air Brake Company*, for development of Centralized Traffic Control on railways.

1972 to *Leonard S. Hobbs* and *Perry W. Pratt* and the dedicated engineers of the Pratt & Whitney Aircraft Division of *United Aircraft Corporation* for the design and development of the JT-3 turbo jet engine.

1975 to *Jerome L. Goldman, Frank A. Nemec* and *James J. Henry* and Citations to the naval architects and marine engineers of *Friede and Goldman, Inc.*, and *Alfred W. Schwendtner* for revolutionizing marine cargo transport through the design and development of barge carrying general cargo vessels.

1977 to *Clifford L. Eastburg* and *Harley J. Urbach* and Citations to the Railroad Engineering Department of *The Timken Company* for the development, subsequent improvement, manufacture and application of tapered roller bearings for railroad and industrial uses.

1978 to *Robert Puiseux* and Citations to the employees of the *Manufacture Francais des Pneumatiques Michelin* for the design, development and application of the radial tire.