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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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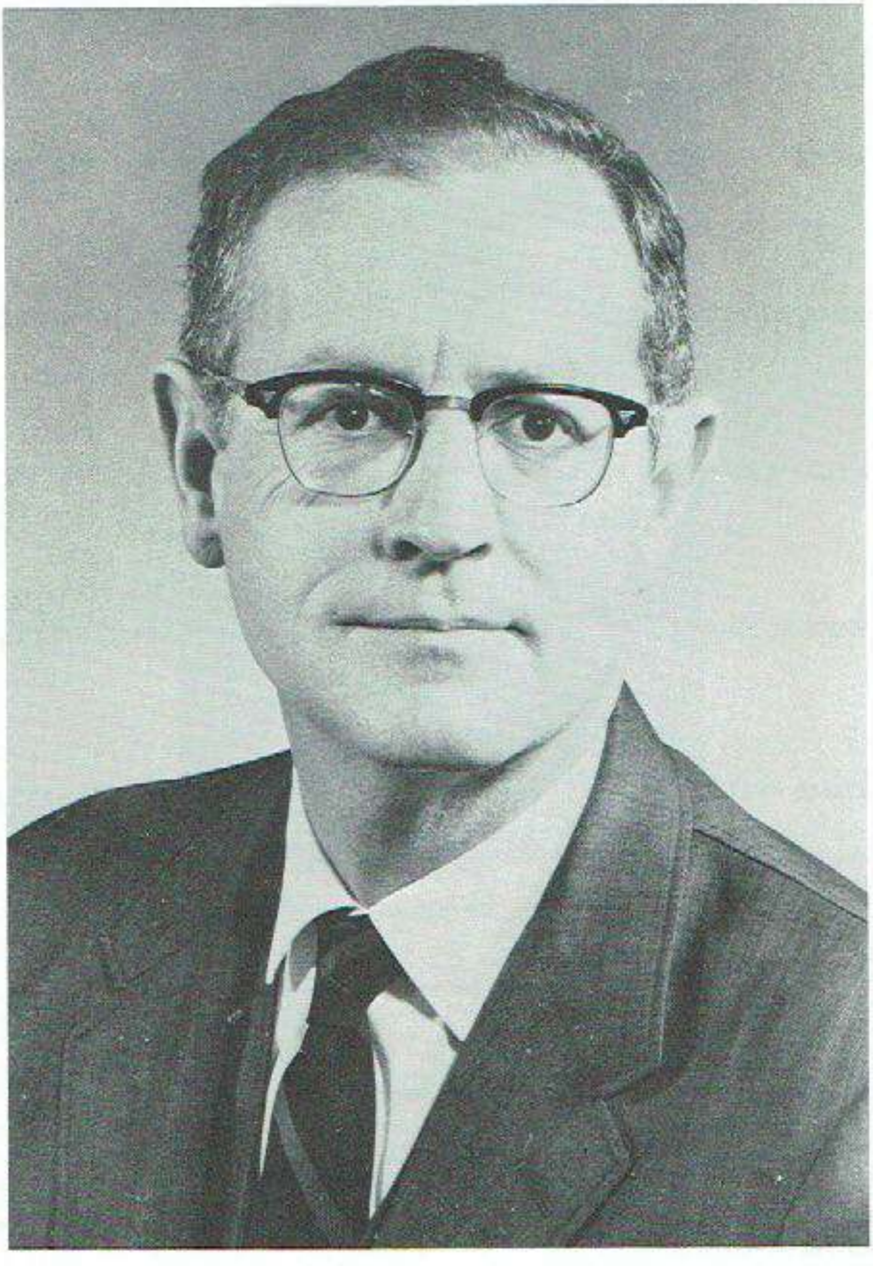


Edward J. Wasp

Award Citation

☐ To Edward J. Wasp for his contributions toward the development and application of long distance pipeline slurry transport of coal and other finely divided solid materials.

"If I have seen further, it is by standing on ye shoulders of giants."

Sir Isaac Newton

Introduction

One of the most exciting aspects of the transportation industry today is the emergence of pipelines as a viable method of bulk freight transportation. High-tonnage, long-distance transportation of coal, iron, copper, phosphate, limestone and other minerals by pipeline provides a reliable and economic alternative to other forms of bulk transportation such as truck, barge and rail. Slurry pipelines have now been effectively transporting solids for over a quarter of a century.

A slurry pipeline may be defined as: a two-phase flow pipeline which transports a solid material dispersed in a liquid-carrying vehicle.

Background and History

Probably the first documented contributor to the understanding of hydraulics was Archimedes, who lived in Greece from 287 to 212 B.C. Ten manuscripts of Archimedes are known. The one most important to hydraulics and slurry transport is a two-volume analysis of hydrostatics and flotation. In this document Archimedes derived three propositions which are still the basic theorems of hydrostatics.

The first pipelines were used by the Greeks and Romans in conjunction with aqueducts for transporting water. The first Roman aqueduct was constructed in 312 B.C. Not until the late 1850's, however, was there any record of solids being transported by pipeline. Solids were transported in a pipe in California in placer mining operations, in which gold was recovered from deposits by washing. Hydraulic elevators raised water and gravel to a higher elevation so that gravity sluices could be used to separate the gold from the sand and gravel. The elevators were venturi type devices in which water under pressure raised the ore 30 to 55 feet.

The mining industry later used pipeline transportation of solids in connection with phosphate deposits, removal of overburden and disposal of tailings. One of the oldest applications of solids transport is dredging and placing of hydraulic fills. Although the technology for dredging and placer mining is quite different from the technology for long distance slurry pipelines, it was as a result of these applications that some of the earliest investigations into the field of slurry pipelines began.

In 1891 Wallace C. Andrews was granted a patent for a "Method of Transportation" which involved pumping finely divided coal in slurry form. Andrews, who was the founder of the New York Steam Company, built a test facility to demonstrate his concept. The test site was at Madison Avenue and E. 58th Street in New York City. (See Figure 1) In 1893 the concept was demonstrated at the Colombian World's Fair in Chicago and won an award. Andrews died tragically in a fire in 1899 and the coal pipeline work was not continued by his successors.

The first recorded commercial coal slurry pipeline was only 660 yards long. It was designed by an electrical engineer, Gilbert G. Bell, to move coal from barges on the Thames River in London to a powerhouse through 8-inch tubes. The system, which went into operation in 1914, transported 50 tons per hour of a 50% mixture of coal and water at a velocity of four feet per second.

The major advancements in slurry pipeline technology took place in the early 1950's. Long distance pipeline transport of oil and gas was, by then, a mature

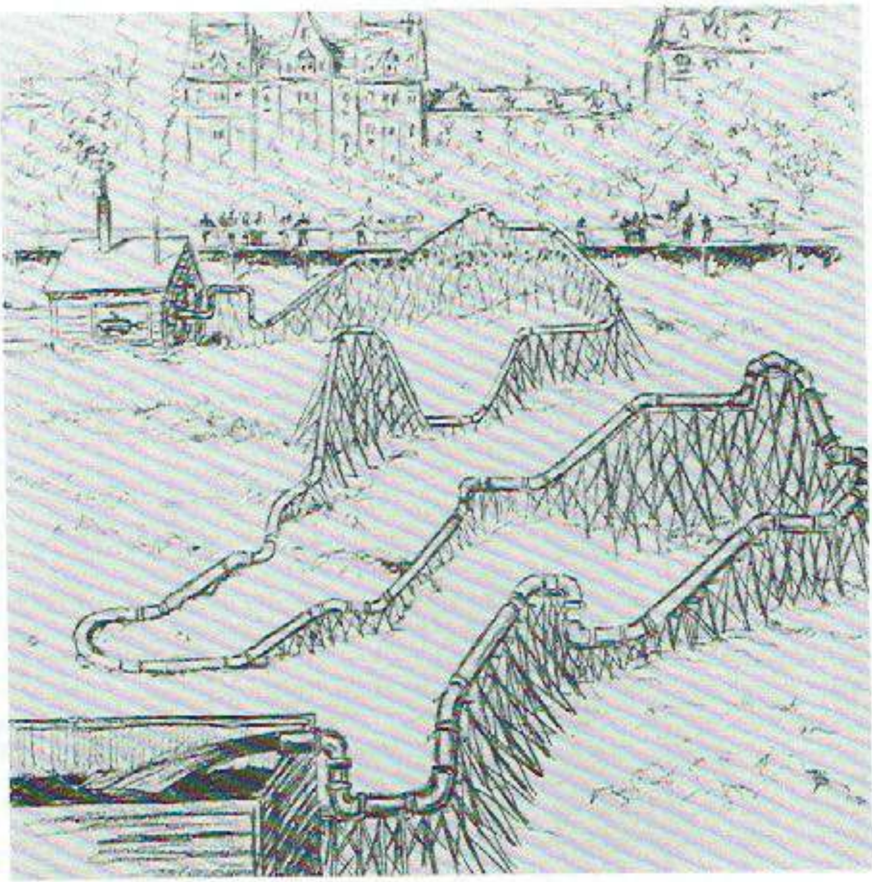


Fig. 1. Andrews' Test Facility for Pumping Coal

technology with hundreds of thousands of miles of pipelines operating around the world. Interest was high in applying the same efficient pipeline transport techniques to the movement of solid materials. The early 50's saw a number of intensive development programs underway. In France, Robert Durand at Neyrpic was conducting tests with uniformly graded sands. American Gilsonite Co. was preparing to build their 72-mile, 6-inch gilsonite pipeline in Utah, and in the eastern United States Consolidation Coal had launched an extensive effort to develop the technology to move coal long distances by pipeline. George Love, Chairman of the Board of Consolidation Coal, perceived the benefits of the efficient pipeline transport of a coal and Eric Reichl, Consolidation's manager of research, concurred. They hired a chemical engineer in 1951 to manage an extensive slurry pipeline development program. That engineer was Edward J. Wasp. The development program culminated in construction of the first long distance coal pipeline in the world. It was a 108-mile, 10-inch diameter pipeline, capable of transporting 1.3 million tons per year of coal from the mines in Cadiz, Ohio, to the Cleveland Electric Illuminating Company's power plant at Eastlake, Ohio. (See Figure 2) The development work done by Wasp and his co-workers served as the basis for the new generation of slurry pipelines.

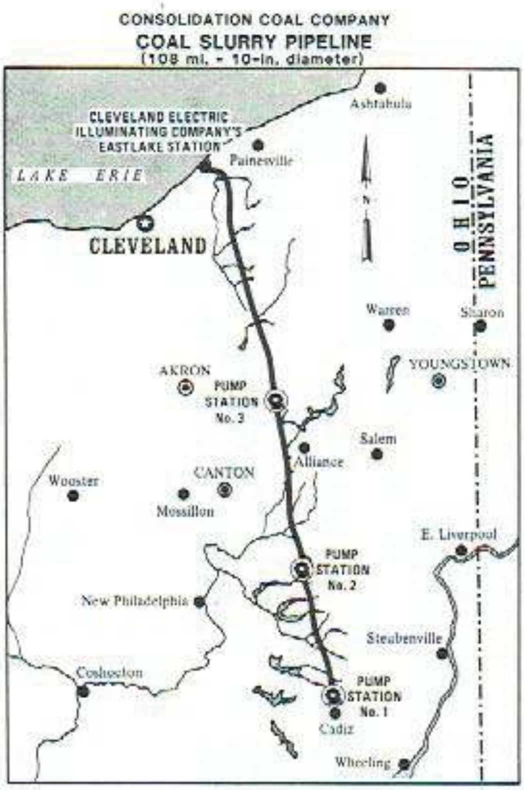


Fig. 2.

System Economics and Design

The primary reason for utilization of slurry pipelines is economics. A slurry pipeline system can save millions (or in the case of the planned ultra-large U.S. coal pipelines, billions) of dollars in transportation costs. Slurry pipelines are particularly well suited to transportation of high volumes over moderate to long distances. They enjoy the same dramatic economy of scale as gas and oil pipelines. A significant attraction of slurry pipelines is their relative resistance to inflation since they are capital intensive. Seventy percent of the unit transportation cost may be capital related fixed costs which are not subject to inflation. Hence, there is a high degree of stability in pipeline transportation costs over the life of the project. The systems also lend themselves to central supervisory control so that a multi-pump station pipeline can be operated remotely by one man.

A slurry pipeline system normally contains the following elements (See Figure 3):

- Mine
- Vehicle (e.g., water) supply system
- Slurry preparation plant
- Storage at mine site
- Pump stations
- Main pipeline
- Communications and control system
- Storage at terminal
- Separation (e.g., dewatering) facilities
- Utilization (e.g., power plant)

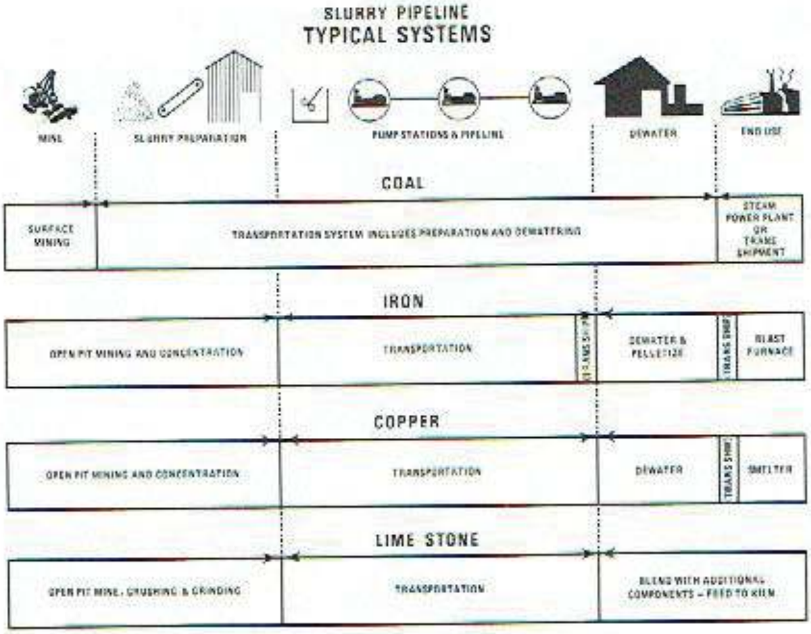


Fig. 3.

In general, almost any finely ground mineral that is not harmed by addition of a carrying vehicle such as water, can be transported by pipeline.

For coal slurries, it is usually necessary, for hydraulic purposes, to grind the coal to minus 14 mesh (i.e., a size such that all the particles will pass through a screen with .05-inch openings). See Figure 4 for conversion from mesh to inches or microns. The slurry mixture is usually about 50 percent solids by weight. For mineral slurries, often no additional grinding is required. Most metallurgical processes that produce mineral concentrates go through a slurry stage with fine grinding. This explains why the slurry pipeline concept has been so readily accepted in the minerals industry. It is a very natural extension of minerals processing; the pipe is simply a "long spot" in the process. Table 1 shows typical maximum particle sizes and concentrations of transported minerals.

Slurry pipelines are normally installed below ground in the same manner as oil and gas pipelines. Pump stations can be 60 to 100 miles apart. The resultant system has very little impact on the environment, since most of it is underground and out of sight.

Even though the construction and operation of a slurry system is quite similar to oil pipelines, the design requires greater technical sophistication. The behavior of non-newtonian fluids in a long distance pipeline can be quite complex. Consideration must be given to selection of the solids size consist, solids concentration, slurry rheology, calculation of friction losses in homo-heterogeneous flow, determination of critical velocity, prediction of corrosion-erosion losses, allowance for surge pressures, etc.

In addition, there are special mechanical considerations for pumps, valves and piping due to the severe service caused by abrasive slurries. In order to design a system that can be shut down and restarted, that will not wear out the pipe, and that can be operated under predictable and stable flow conditions, it is necessary to put fairly strict limits on process variables such as size consist

SLURRY FLOW REGIMES

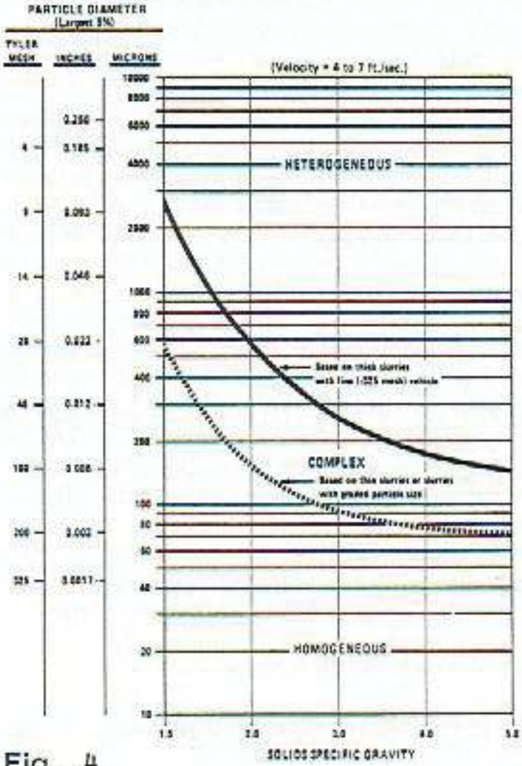


Fig. 4.

Table 1

Properties of Transported Minerals

	Solids, Sp Gr	Approximate Maximum Particle Size	Typical Slurry Concentration % Solids by Weight
Coal	1.4	8 Mesh (2.380 mm)	50
Limestone	2.7	48 Mesh (0.297 mm)	70
Phosphate Concentrate	3.2	65 Mesh (0.210 mm)	60
Copper Concentrate	4.3	65 Mesh (0.210 mm)	55
Iron Concentrate	5.0	100 Mesh (0.149 mm)	60

and solids concentration. Figure 4 shows slurry flow regimes as a function of size consist and specific gravity of the solids. This chart represents a generalization based on experience with commercial pipeline slurries at normal pipeline velocities of four to seven feet per second. Most slurries fall into the complex or compound flow regime portion of Figure 4.

To transport solids successfully in slurry form, enough energy in the form of turbulence must be imparted to the slurry to keep the solids in suspension. The operating velocity in the pipeline must be high enough to provide this turbulence. As shown in Figure 5, if the velocity is not maintained at a high enough level, the coarser particles will tend to move toward the bottom of the pipe, causing wear and increasing the risk of plugging. Therefore, velocity considerations are very important.

As previously noted, mineral concentrates (e.g., iron, copper and phosphate) often go through a slurry stage in their processing. Therefore, pipeline transportation does not add any water requirements over and above those of the normal process. For coal pipelines there is an incremental requirement for a liquid vehicle. Coal slurry pipelines usually use water as a vehicle, because of its wide availability. Actual requirements depend on the solids concentration pumped and the surface moisture in the coal delivered to the pipeline preparation plant. Typical water requirements are shown in Table 2.

Although the water requirements are significant, they normally are only about 15% of the required power plant makeup water. Hence the conventional practice is to use the slurry water as a part of the power plant makeup water.

Table 2

Typical Coal Slurry Pipeline Water Requirements

Throughput (million tons/year)	Annual Water Requirements (acre-ft)
5.0	3,800
10.0	7,500
20.0	15,000
30.0	22,500

Dewatering, or more generally, separation of solids from the liquid vehicle, may be accomplished in a variety of ways. Mechanical devices such as centrifuges and vacuum filters can be used. These devices have an upper limit in the final moisture content of the product. If a drier product is desired, then all or part of the output of the centrifuge or vacuum filter can be thermally dried using commercial driers. In addition, dewatering is often preceded by some sort of thickening or decantation. Since dewatering is an integral part of the overall system, it directly affects the system economics and slurry pipeline design.

Experience

Since the 1950's experience with slurry pipelines has been significant and varied. Slurry pipelines are now in operation throughout the world, carrying coal, iron concentrate, copper concentrate, limestone and phosphate as well as hundreds of types of tailings and wastes.

Slurry pipelines can move material from areas which are difficult or impossible to reach directly by rail or truck. As a result, many slurry lines are located in remote areas. Two examples are the Savage River iron concentrate pipeline in the rain forest area of Tasmania, Australia, and the Calavaras limestone pipeline in the Sierra Nevada foothills of California in the United States.

Table 3 summarizes the major slurry pipeline systems by product and system characteristics. Some significant statistics obtained from this table are:

- Total length of the twenty-seven major slurry pipelines currently installed or in the design or construction phases exceeds 1700 miles.
- These pipelines are capable of transporting more than 60 million tons of product per year.
- Total operating experience exceeds 150 years.
- Of the twenty-seven pipelines, six have multiple pump stations.
- Nine of the pipelines transport iron concentrate.

CRITICAL VELOCITIES IN SLURRY SYSTEMS

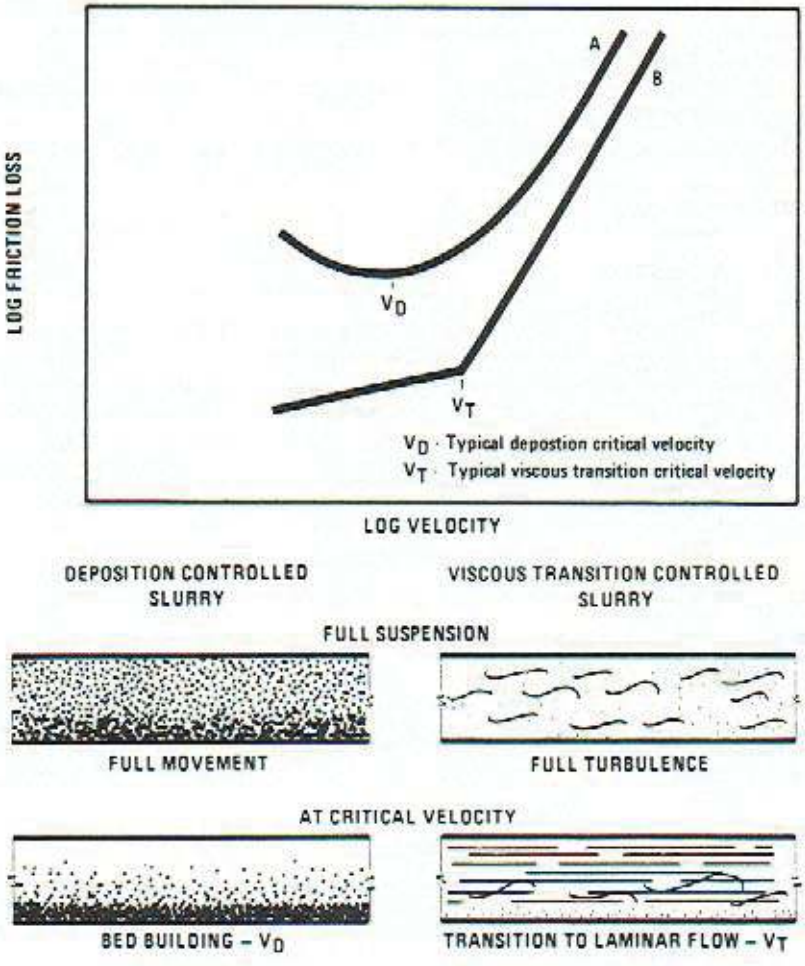


Fig. 5. Slurry Pipeline Velocity

Table 3

Summary of major slurry pipeline systems

Slurry material	System	Length (miles)	Diameter (inches)	Annual throughput (million tons/year)	Initial operation
Coal	Consolidation, Ohio	108	10	1.3	1957
	Black Mesa, Arizona	273	18	4.8	1970
	Belovo-Novosibirsk, USSR	155	N/A	N/A	N/A
Limestone	Calaveras, Californa	17	7	1.5	1971
	Rugby, England	57	10	1.7	1964
	Voest Apline, Trinidad	N/A	N/A	N/A	N/A
	Trinidad	6	8	0.6	1959
	Gladstone, Australia	15	8	1.8	1981
Copper concentrate	Bougainville	17	6	1.0	1972
	West Irian	69	4	0.3	1972
	KBI, Turkey	40	5	1.0	1973
	Pinto Valley, Arizona	11	4	0.4	1974
Iron concentrate	Savage River, Tasmania	53	9	2.3	1967
	Waipipi, New Zealand				
	(Land)	4	8	1.0	1971
	(Offshore)	1.8	12	1.0	1971
	Pena Colorada, Mexico	30	9	1.8	1974
	Las Truchas, Mexico	17	10	1.5	1976
	Sierra Grande, Argentina	20	8	2.1	1976
	Samarco, Brazil	245	20	12.0	1977
	Chongin, North Korea	61	N/A	4.5	1975
	Kudremukh, India	44	18	7.5	1980
	La Perla-Hercules, Mexico	53/183	8/14	4.5	1982
Gilsonite	American Gilsonite, Utah	72	6	0.4	1957
Copper tailings	Japan	44	12	0.6	1968
Nickel refinery tailings	Western Mining, Australia,	4.3	4	0.1	1970
Phosphate concentrate	Valep, Brazil	74	9	2.0	1978
	Goiasfertil, Brazil	9	6	0.9	1981
Kaolin	Freeport, Georgia	24	10	N/A	1976

Black Mesa Coal Pipeline

The longest slurry pipeline in operation to date is the 273-mile Black Mesa Coal Pipeline, which traverses the state of Arizona. (See Figure 6) It was commissioned in the fall of 1970. This 18-inch diameter pipeline can transport over 5½ million tons of coal annually from the mine site in the Navajo-Hopi Indian reservation to the Mohave power plant site on the Nevada side of the Colorado River, south of Davis Dam. The coal supplies all of the fuel requirements for the two 750-Mw generating units at Mohave.

The <2-inch coal provided at the mine site by Peabody Coal Co. is reduced to ¾ inch by impactors, and then ground to pass 14 mesh in three parallel rod-mill lines. From the rod mills, the slurry is stored in three agitated slurry tanks that feed the initial pump station. Three additional pump stations are required along the route. Pumps are electric-powered 1700 hp double-acting duplex piston pumps, the largest of this type in existence. Each station has three of these pumps in parallel, except Station Two, which has four. The pipeline system is owned and operated by Black Mesa Pipeline Inc., a subsidiary of the Southern Pacific Transportation Co.

At the power plant, the coal discharges into one of three 24-hour holding tanks, and is then pumped to centrifuges for dewatering. There are 20 centrifuges for each 750-Mw. generating unit. The dewatered coal, at about 25% total moisture, then goes through a mill and is blown into the boiler with heated air.

The slurry preparations facilities and the pipeline were designed and started up under the direction of E.J. Wasp.

Savage River Pipeline

The first long-distance iron-concentrate pipeline in the world is the 53-mile, 9⅝-inch diameter slurry pipeline operated by Pickands Mather & Co. It was also designed and started up under the direction of E.J. Wasp. This line is in the island state of Tasmania, Australia, and traverses some exceedingly rugged terrain (See Figure 7) over its route from the minesite concentrator at Savage River to the pelletizing and shipping facilities at Port Latta. In fact, the ore deposit was known for more than 100 years but was considered inaccessible even though it was only 50 miles from tide water. The slurry pipeline concept

BLACK MESA PIPELINE

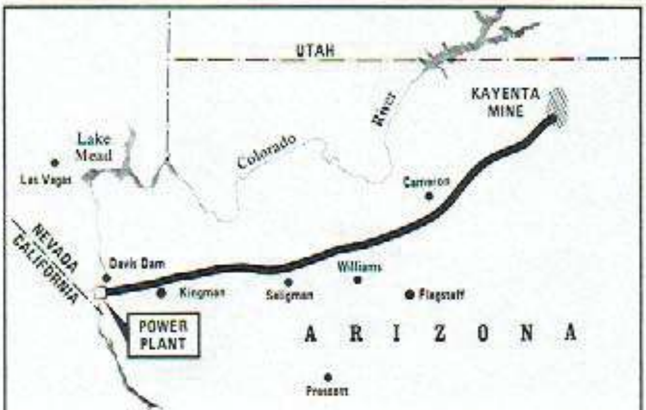


Fig. 6.

made development of that ore body economical. The pipeline, which has been in operation since November 1967, is designed to transport 2.25 million long-tons of iron concentrate per year.

A single pump station (consisting of four electric-motor-driven 600-hp plunger pumps) is used. Design concentration is 60% solids by weight. The material is 100% <100 mesh.

SAVAGE RIVER CROSSING

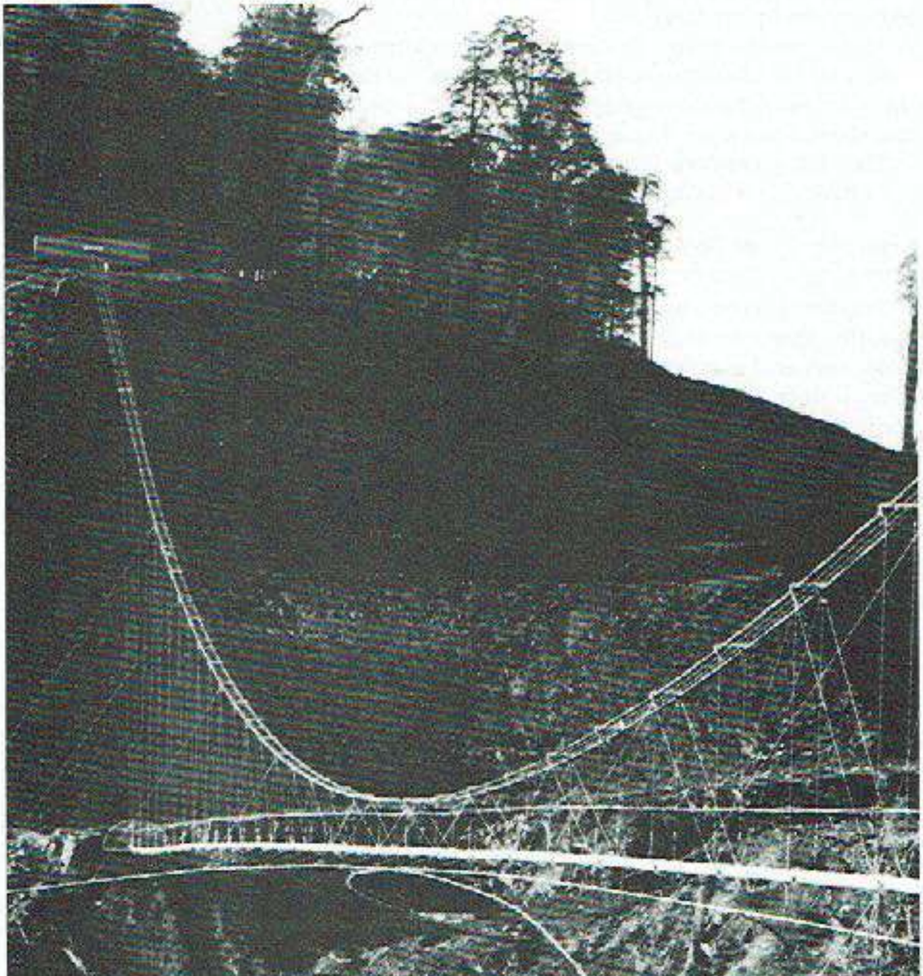


Fig. 7.

Consolidation Coal Pipeline

Additional mention should be made of the landmark 108-mile, 10-inch coal slurry pipeline put into operation in 1957 by Consolidation Coal Co. As noted, the line extends from Cadiz, Ohio, to Eastlake, Ohio, and uses three pumping stations, each containing three 450-hp, positive-displacement double-acting, duplex piston pumps. (See Figure 8) Flowrate is 1,100 gpm., or about one-fourth of the Black Mesa line.

This pipeline was operated very successfully for a period of six years and experienced a 98% availability factor. As a result of the pipeline, the railroads made radical tariff reductions not only on the 1.3 million tons/yr. of pipeline coal, but on all 5 million tons/yr. of coal transported from that region in Ohio.

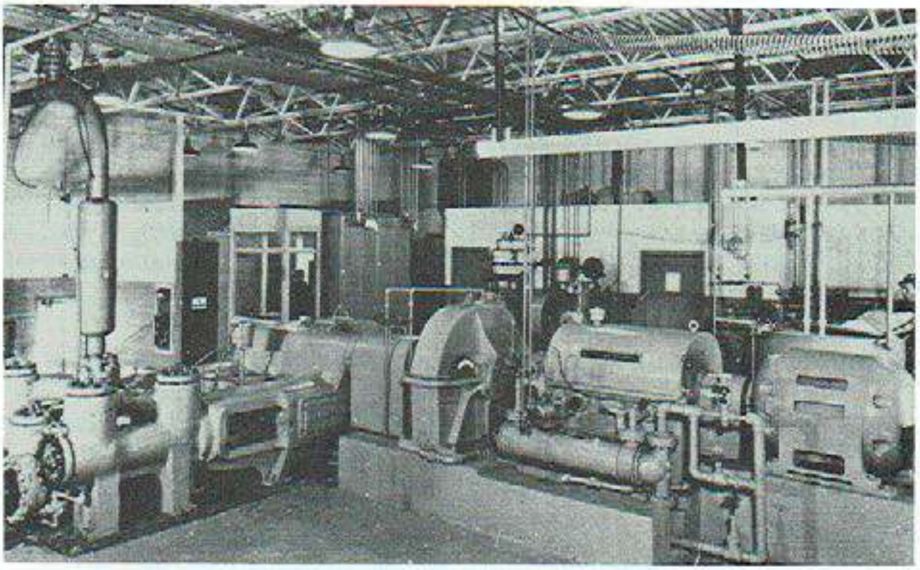


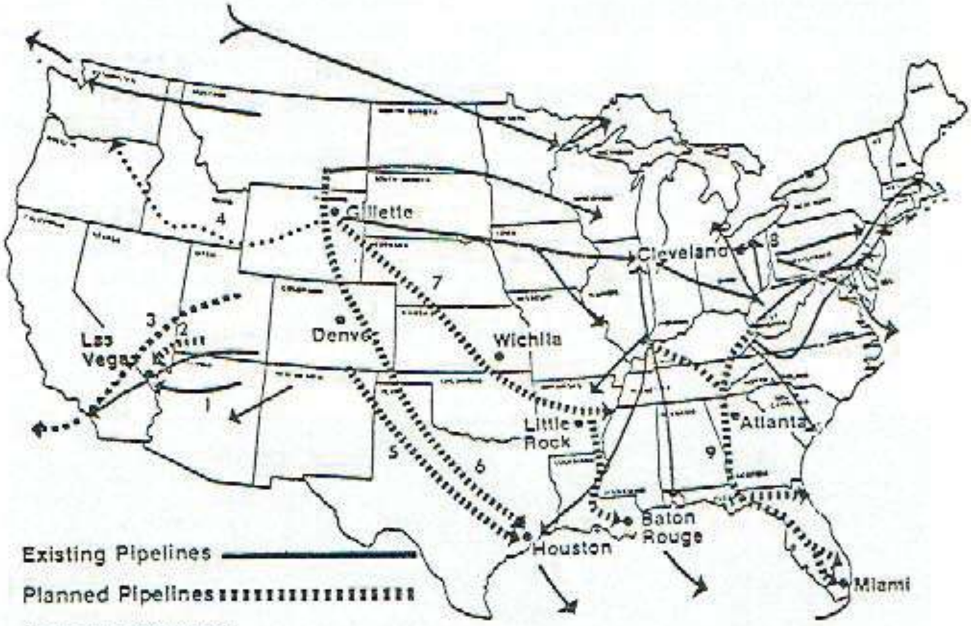
Fig. 8. Wilson-Snyder 220-P Double Acting Duplex Piston Pump Consolidation Coal Pipeline

Other Systems

The largest capacity line built to date is the Samarco iron concentrate pipeline in Brazil with a design throughput of 12 million tons per year. It is 245 miles in length. Plans are now in various stages of development for lines of 1000 miles or more in length, to carry coal from the western and eastern coal fields of the United States to distant markets. These lines will have capacities of 10 to 25 million tons per year or more. (See Figure 9 for U.S. planned coal pipelines).

Technology Development

It is a surprise to many people to realize that some of the major contributors to the slurry pipeline industry are not only contemporaries, but are still active in the field. This is a result, in part, of the exponential rate of development that



Pipeline System	Length	Annual Capacity
1. Black Mesa Pipeline	273 miles	4,800,000 tons
2. Alton Pipeline	183 miles	11,600,000 tons
3. BPAC	645 miles	10,000,000 tons
4. Gulf Interstate-Northwest Pipeline	1100 miles	10,000,000 tons
5. San Marco Pipeline	900 miles	15,000,000 tons
6. Texas Eastern Pipeline	1260 miles	22,000,000 tons
7. ETSI Pipeline	1378 miles	25,000,000 tons
8. Ohio Pipeline	108 miles	1,300,000 tons
9. Florida Pipeline	1500 miles	40,000,000 tons

Fig. 9. Planned U.S. Coal Pipeline

becomes possible by building on the work of others and, also, due to the fact that many of the scientific contributors made some of their most significant technical achievements when they were fairly young. This is true of Edward J. Wasp, who early in his career, developed his classic treatment of homogeneous-heterogeneous flow.

When he came to Consolidation Coal Company in 1951, he became Manager of Process Engineering and Development. The major project he took over was research on the hydraulic transport of coal which Consolidation had started in 1949. Four years later, in 1955, the major research was completed and the decision was made to construct a 108-mile commercial system. In 1957 the pipeline system with three pumping stations was in operation—a remarkable feat! This landmark facility and the research on which it was based were major breakthroughs for the technology and for the development of the slurry pipeline industry.

In reviewing this landmark development work, it is instructive to consider what was *not* known at the time. The relationship between size consist and flow conditions was not known. The relationship between corrosion and abrasion, also was not known. One of the major concerns Wasp and his co-workers had was internal corrosion/erosion of the pipe. They wanted the pipe to last the life of the overall system. They constructed a one-mile test loop and installed a short section, which was cut into 10 horizontal sections like barrel staves. (See Figure 10) These sections could be weighed and examined after various slurries were run through them. They had to wait weeks for the weight losses to be significant enough to use in their correlations. They started with ⅜-inch coal and found that the losses on the bottom of the pipe were enormous compared to the top of the pipe.

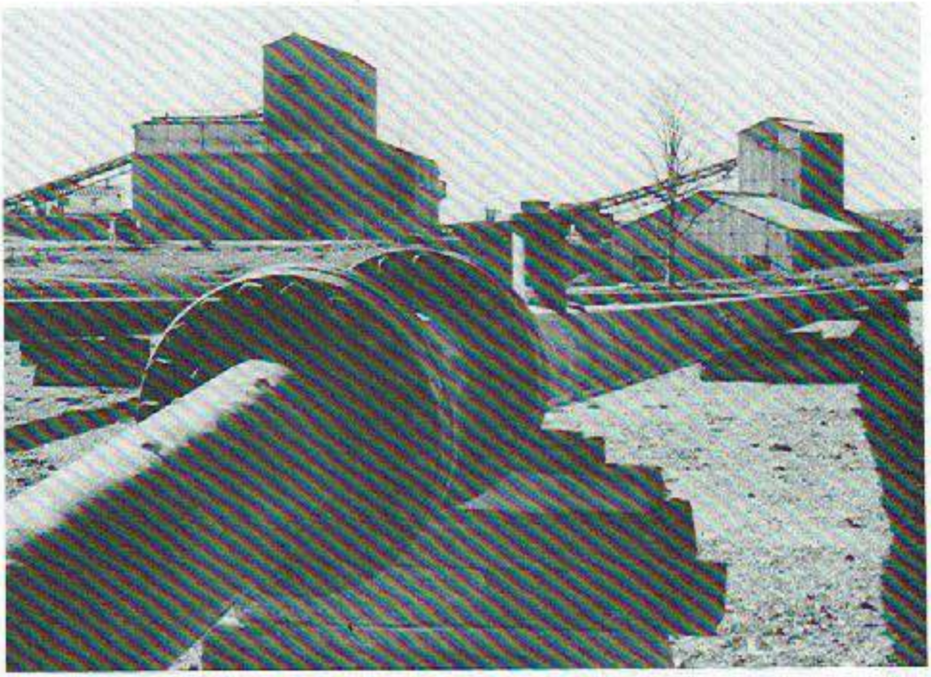


Fig. 10. Consolidation Coal Test Loop

In order to isolate corrosion from erosion, they used stainless steel pipe. This eliminated the corrosive effects so they could concentrate on the erosive effects. With stainless steel they still had high losses in the sliding bed regime. Wasp then made the coal fine enough so that it did not drag on the bottom of the pipe. This illustrates a fundamental philosophy, which has greatly benefited the industry. Wasp states in the preface to his book, *Solid-Liquid Flow—Slurry Pipeline Transportation:*

"A basic conviction arose as a result of the enormous development effort that went into the design of that [the Consolidation Coal] system. The conviction was that the key to the design of slurry systems which would operate reliably lay, not in the selection of exotic materials or the design of special equipment, but in the understanding and control of the slurry environment. More specifically, it was felt that if the flow was homogeneous, the pipeline would be stable. That is, the pressure drop would be constant with time, and also two other results would naturally follow. One result was that if the corrosive environment were controlled and made benign, the wear in the pipe would be uniform and of such magnitude that a pipe life of over half a century could be expected. The second result was that in a homogeneous regime the coal itself would not undergo any attrition during its travel, even over very long distances."

This philosophy allowed the use of conventional materials and well established construction techniques that had been developed in the oil and gas industry over the first half of the century. The adoption of this fundamental philosophy was instrumental in making the slurry transportation industry viable.

Next they initiated a program of taking slurry samples in the top, middle and bottom of the pipe at the test loop at Piney Fork Number 9 and Georgetown, coal preparation plant sites in Ohio. Figure 11 shows the pipeline crew in the early '50s. The top, middle and bottom samples provided data with which parametric variations such as velocity, concentration, size consist, etc. could be correlated. The ability to evaluate the size consist over the vertical cross-section of the pipe is fundamental to the industry's current work with slurries. In the extensive literature search that went on concurrently with Consolidation Coal's experimental work, Wasp discovered a paper by Hassam M. Ismail entitled, "Turbulent Transfer Mechanism and Suspended Sediment in Closed Channels," published by the American Society of Civil Engineers in 1951. The work was done with sand

Fig. 11. Consolidation Coal Pipeline Crew - Early' 50's

in closed rectangular channels. Wasp and his co-workers converted Ismail's formulas from the rectangular cross-section to the circular pipe and then, using data from the 12-inch test loop and later from the 10-inch commercial pipeline in Ohio, established an approximation for predicting C/C_A's, (i.e., size consist concentration along the pipe vertical axis). This relationship was tested with the Ohio pipeline data and gave excellent results and became a fundamental part of the Wasp method of calculating pressure drops in homo-heterogeneous flow.

During the period of the Consolidation Coal development program Wasp was influenced by some work done nearly 50 years earlier by Albert Einstein. Early in his career Einstein had briefly been involved in sediment transport and in 1906 he published an article on the viscosity of dilute solutions. Einstein believed that a mixture of solids and water had a viscosity different from that of the suspending medium. Einstein's credibility was instrumental in moving Wasp into this aspect of the development of slurry flow technology. Experimental techniques to measure slurry viscosity then became basic to the correlations and later to the theory developed to describe complex flow phenomena. Systematically, Wasp evaluated the parameters affecting viscosity and determined that the major variable in establishing viscosity was concentration, not temperature or fines level. He then concurrently increased the concentration and decreased the size consist until he achieved an acceptable balance. At this point, as he had predicted, the corrosion/erosion also came under control. Further, understanding the rheology of the slurry paved the way for Wasp to develop a method of predicting the pressure drops in the pipeline without use of test loops.

Perhaps one of the most difficult problems was to separate the coal particle attrition between that caused by the pump and that caused by the pipeline. In the one-mile recirculating loop more than 100 passes had to be made to simulate the 108-mile transit from Cadiz to Eastlake, Ohio. Wasp was finally able to show experimentally that the pump, not the pipe, caused the coal attrition. Commercial operation verified the experiments that showed negligible attrition in the pipeline.

Another problem in interpreting the loop data was that the pressure drops decreased with time. This decrease was later attributed to a limited inventory of fast settlers that were laid out early in the run and to attrition caused by the centrifugal pump in the loop. At the time, however, Consolidation Coal was faced with the problem of whether to design for the "zero mile" pressure drops or the lower pressure drops. They designed the line for "zero mile" pressure drops, which was verified in commercial operation.

Difficulties in interpretation and the excessive time required to obtain data caused Wasp to develop bench scale tests and mathematical models for prediction of slurry hydraulics. These techniques were developed in the late '60s and early '70s in San Francisco while Wasp was in charge of the slurry activities in the Pipeline Division at Bechtel.

During his tenure as Manager of the slurry activities at Bechtel, Wasp not only furthered his own capabilities in the slurry field but he searched for young, talented people and assembled an outstanding group. By his example and leadership, he was able to instill a dedication for technical excellence in research, combined with practical applications. He inspired desire for involvement in personal development and established a legacy that has had a tremendous effect on the slurry industry.

In the mid '70s Wasp's career moved toward the commercial end of the slurry industry. He still had a very high technical interest, but felt he could contribute more at this particular point in commercial development of the next generation of ultra-large coal pipeline systems. As of this writing, Wasp is Executive Vice

President of the ETSI Pipeline Project. ETSI plans to move 25 million tons of coal per year some 1400 miles from Wyoming to Arkansas. The ETSI pipeline now appears to be close to being constructed, due in great measure to Wasp's efforts.

The industry is fortunate that as a young man Mr. Wasp had the vision to see opportunities in the then depressed coal business. His contributions to the slurry pipeline industry have been major. His influence will be dominant in the industry for years to come.

Quotations and data for this document have been freely taken from:

(1) Thompson, T.L., "From Reynolds to Wasp—Development of an Industry," presented at Sixth International Technical Conference of the Slurry Transport Association, Las Vegas, Nevada, March, 1981.

(2) *The Transportation of Solids in Steel Pipelines,* Colorado School of Mines Research Foundation, Golden, Colorado, 1963.

(3) *Fifty Years of New York Steam Service—The Story of the Founding and Development of a Public Utility,* Published by the New York Steam Corporation, New York, 1932.

(4) Wasp, E.J.; Kenny, J.P. and Gandhi, R.L., *Solid-Liquid Flow Slurry Pipeline Transportation,* TransTech Publications, Clausthal, Germany, 1977.

(5) Thompson, T.L., and Aude, T.C., "Slurry Pipelines—Design Research and Experience," *Journal of Pipelines,* Elsevier Scientific Publishing Co., Amsterdam, The Netherlands, January 1981.

Acknowledgement

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Edward J. Wasp

Edward J. Wasp was born in the Bronx in New York City on June 6, 1923. He received a B.S. in chemical engineering in 1945 from Cooper Union, an M.S. in chemical engineering in 1947 from New York University, and a Master's degree in mathematics from the University of Pittsburgh in 1961. He also spent many years at nights working toward a Doctorate in mathematics at the University of Pittsburgh. A change in employers and a move to California, however, forced him to stop work just short of obtaining a Ph.D. His formal education continued and in 1973 he earned a Master's degree in Business Administration from Golden Gate University in San Francisco.

Following graduation from Cooper Union, Mr. Wasp worked six years for Foster Wheeler and Petro Chem Development in the area of gas and liquid fired heaters. He joined Consolidation Coal in 1951 and became manager of process engineering and development, heading up their extensive development program on coal transportation by pipeline. This research led to the construction of the world's first long distance coal pipeline. He was also responsible for development work in synthetic fuels, a field which he has pursued throughout his career.

Mr. Wasp joined Bechtel in 1963 and after serving two years as manager of process development for the Refinery and Chemical Division, was transferred to the Pipeline Division and assumed the lead for all slurry pipeline activities. More than a dozen slurry pipelines were designed under his direction, including the Black Mesa coal pipeline in Arizona and the world's first long distance iron concentrate pipeline, the Savage River pipeline in Tasmania, Australia.

Mr. Wasp is now Executive Vice President of the ETSI Pipeline Project, a joint venture of Bechtel, Atlantic-Richfield, Lehman Brothers, Kuhn-Loeb, Kansas-Nebraska Natural Gas Co. and Texas Eastern Corporation. He directs all operational activities for that 1400-mile project which is scheduled to begin operation in 1985.

Mr. Wasp holds 20 patents in the fields of solids pipelines and coal processing. He has authored more than 30 articles on the subject of slurry pipelines and is the principal author of *Solid-Liquid Flow Slurry Pipeline Transportation* published in 1977. He is listed in *American Men of Science*.

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.

1979 to *Leslie J. Clark* for his contributions to the conceptualization and initial development of the sea transport of liquefied natural gas.

1980 to *William M. Allen, Malcolm T. Stamper, Joseph F. Sutter* and *Everette L. Webb* and Citations to the employees of *Boeing Commercial Airplane Company* for their leadership in the development, successful introduction and acceptance of wide-body jet aircraft for commercial service.