The Elmer A. Sperry Award 1987

for advancing the art of transportation

The Elmer A. Sperry Medal

The Elmer A. Sperry 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 for man's purposes."

Presentation of

The Elmer A. Sperry Award for 1987

to

Harry R. Wetenkamp

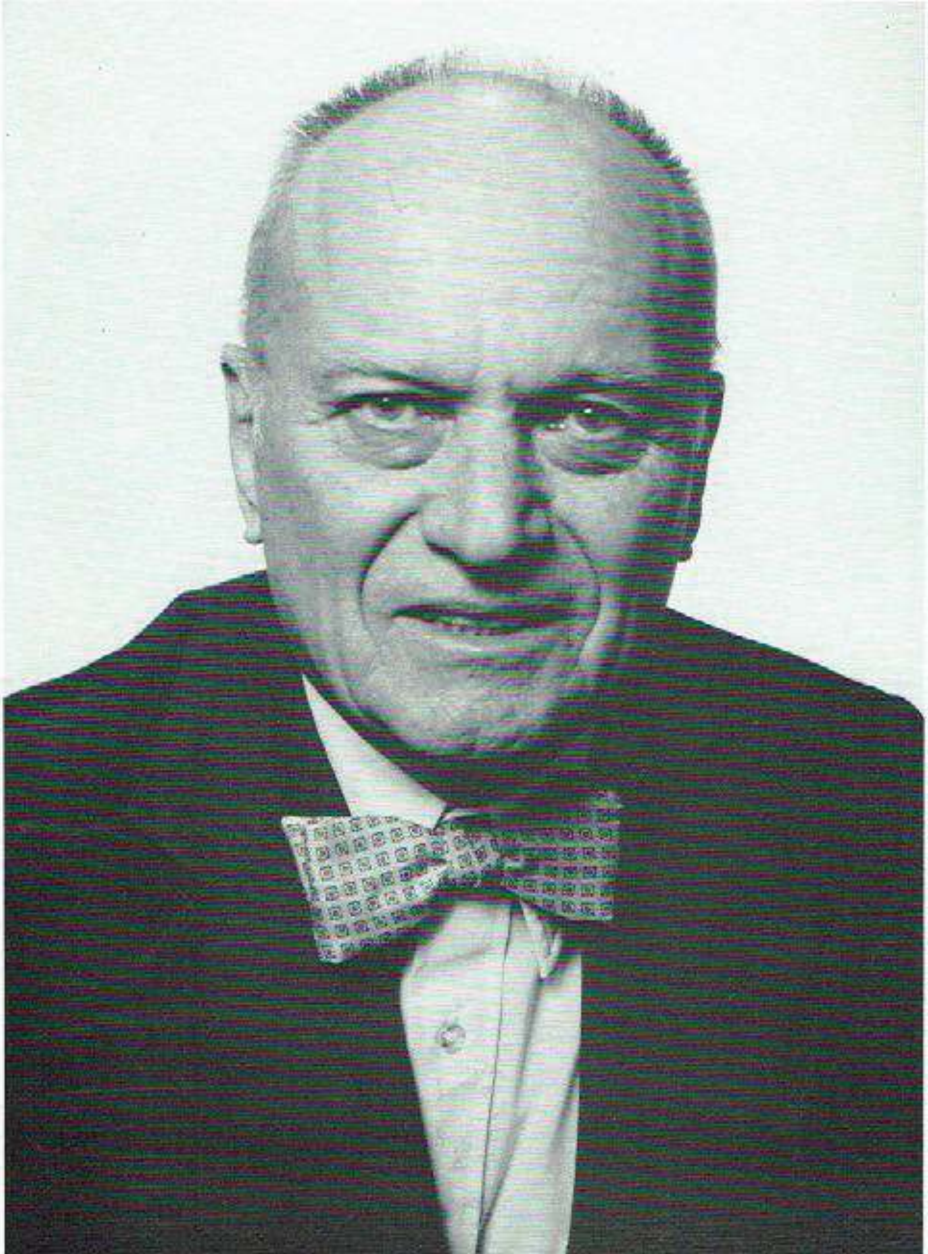
by

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 American Society
of Mechanical Engineers
Honors Assembly

Wednesday, December 10, 1986, Anaheim, California



Harry R. Wetenkamp

AWARD CITATION

To Harry R. Wetenkamp for his contributions toward the development and application of curved plate railroad wheel designs.

BIOGRAPHY OF THE AWARDEE

HARRY R. WETENKAMP

Harry R. Wetenkamp was born January 25, 1919, in Champaign, Illinois. He graduated from the University of Illinois with a Bachelor of Science degree in Mechanical Engineering in 1942 and a Master of Science degree in Theoretical and Applied Mechanics in 1950. Since that time he has taught and conducted research at the University of Illinois and was named professor in 1959. He is co-author of a book "Mechanical Behavior of Solids", a bulletin "The Effect of Brake Shoe Action on Thermal Cracking and Failure of Wrought Steel Railway Car Wheels", and numerous technical papers. He has supervised three students who received Ph.D. degrees and four who received M.S. degrees. He received the Everitt Undergraduate Teaching Award in 1977. Professor Wetenkamp has conducted and is continuing major research and consultation for many companies on railroad wheels, brake shoes, crane hooks, and other mechanical products. His work on the effect of brake shoe action and the failure of railway car wheels had a major influence on the development of improved wheel geometry.

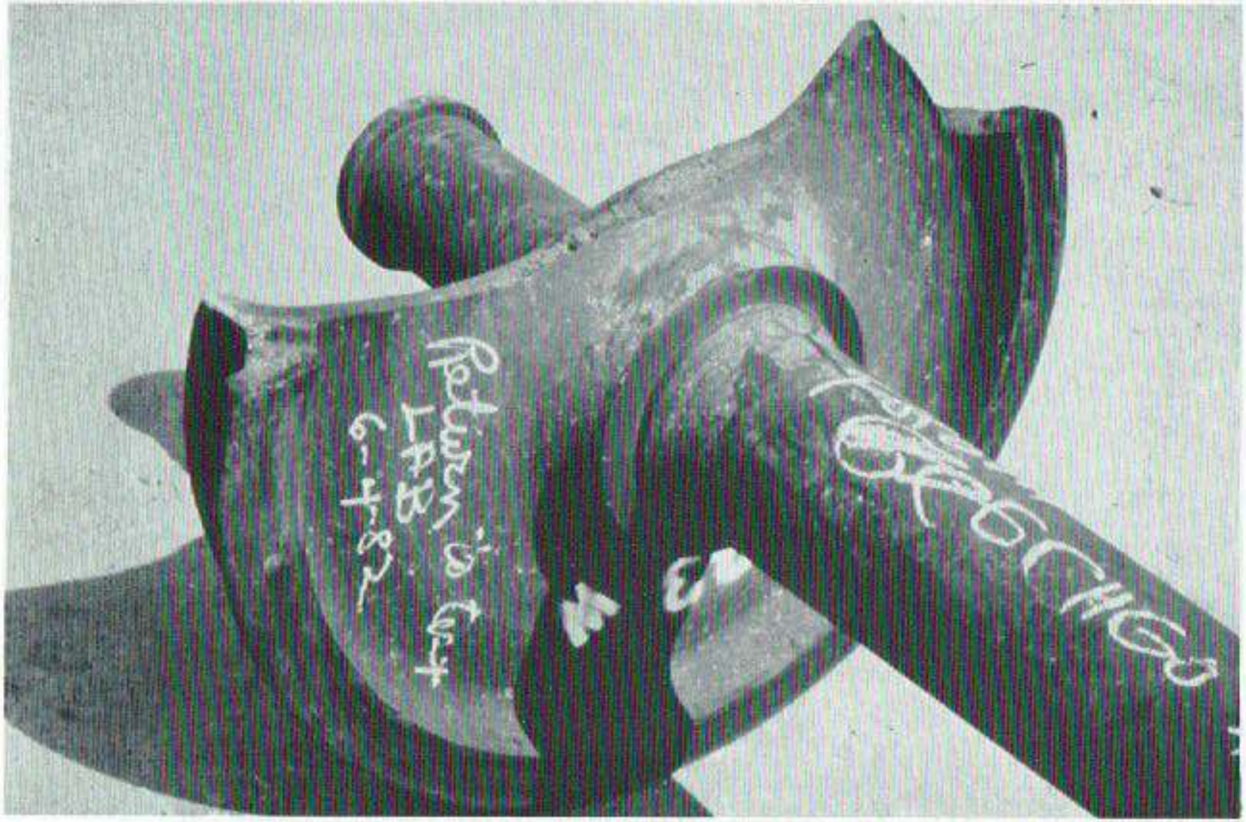


FIGURE 1. Straight plate steel freight car wheel which fractured in service due to thermal stresses developed by on tread braking.

ADVANCED DESIGN RAILROAD WHEELS

BACKGROUND AND HISTORY

Horse drawn loads were first pulled over rails in European mines in the 1500's. A board track was laid on the ground so the cars would not be stuck in the mud or have difficulty negotiating the rough, rocky, mine pathways. The flangeless, spoked, wooden wheels on these freight cars were similar to those used on regular horsedrawn, street wagons. To improve the service life of the wooden wheels, metal strips were fastened to the rims. These were later replaced by single flange cast iron wheels. The first iron wheels manufactured in America were cast in 1829 at a foundry in Maryland. In 1943, an all-time record of 3,306,463 chilled iron wheels were shipped from 44 foundries in the United States and Canada.

Trains are usually brought to a stop by applying brake shoes to the tread of the wheels, causing a high rate of thermal energy input. The colder, inner portion of the wheels prevents the tread from expanding uniformly, producing metal deformation and high stresses with consequent fracture such as shown in Figure 1. In some cases, derailments occur due to these wheel fractures.

Because passenger trains in the late 1800's and early 1900's traveled at faster speeds than freight trains, wheel fractures were more common on passenger trains, compelling a change to steel wheels. Iron wheels continued to be the predominant type of wheel used on freight cars until the 1950's. With the advent of the high-powered diesel locomotive, a new concept of freight service evolved. The new cars had to carry greatly increased loads at speeds which had been inconceivable for freight service, Figure 2. The chilled iron wheels could not take the increased mechanical forces and braking, and railroads started to switch from iron to steel wheels for freight as well.

The last iron wheels for railroads were cast in 1963. These wheels are now prohibited in freight car interchange service. Today steel, one piece wheels are the only approved wheels for regular railroad service in North America.

STEEL WHEEL DESIGN

Steel wheels prior to the 1960's generally had straight plates connected at the center of the rim and center of the hub, as shown in Figure 3a. The plates were generally thicker near the hub and became progressively thinner near the rim. Extensive dynamometer testing of full size, straight plate, steel wheels was conducted at the University of Illinois, Figure 4, in the late 1940's and early 1950's. Although most of this work concerned the effect of heat treatment and chemistry on wheel fracture, it also included an evaluation of plate thickness. The results of this work were published in 1950 in a historic University of Illinois bulletin "The Effect of Brake Shoe Action on Thermal Cracking and on Failure of Wrought Steel Railway Car Wheels" by Wetenkamp, Sidebottom and Schrader. Increasing the plate thickness was found to lower plate stresses due to mechanical loading and, in some cases, while the wheel was hot, to reduce the plate stresses due to thermal loading. However, a thinner more flexible plate definitely reduces the amount of inelastic yielding that will occur in the rim of the wheel when subjected to friction heating. The adverse tensile residual stresses developed in the rim of the wheel upon cooling is of major importance. The University of Illinois bulletin points out the greater propensity for thermal crack progression in thicker, typical straight plate wheels. For example, in a standard dynamometer drag test at the University, 1-inch thick plate wheels with a 1-inch thick tread, saw cut to simulate a thermal crack, fractured at an average of 28 drags, whereas, ¾-inch and ½-inch plate wheels did not fracture during the complete 50-cycle drag tests.

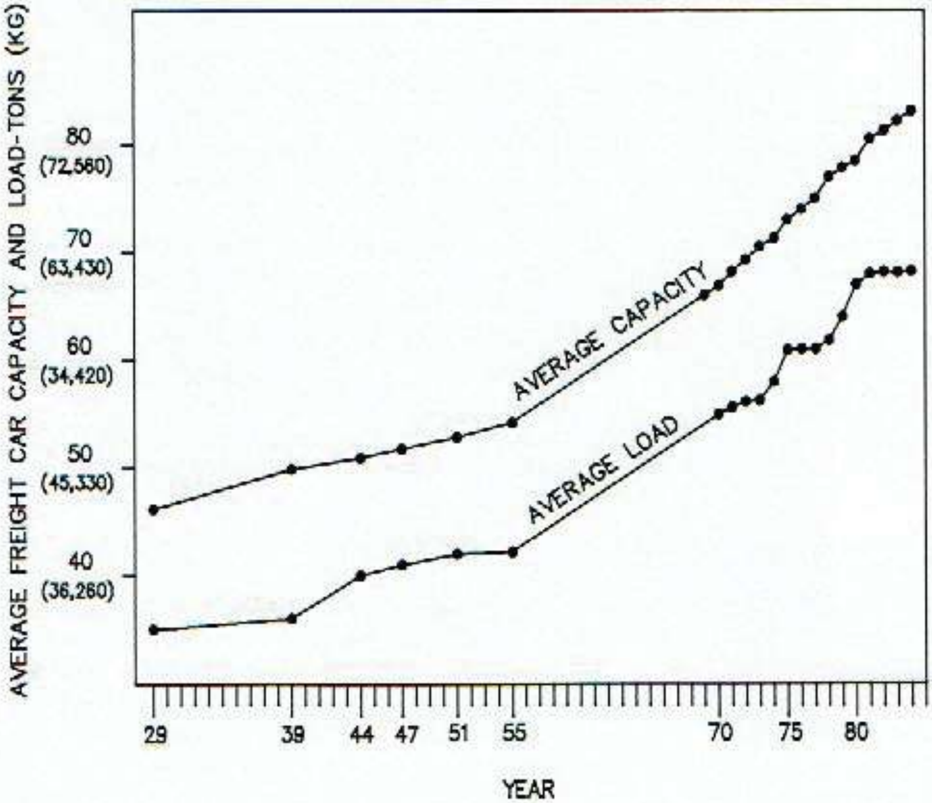


FIGURE 2. Average freight car capacity and load by year

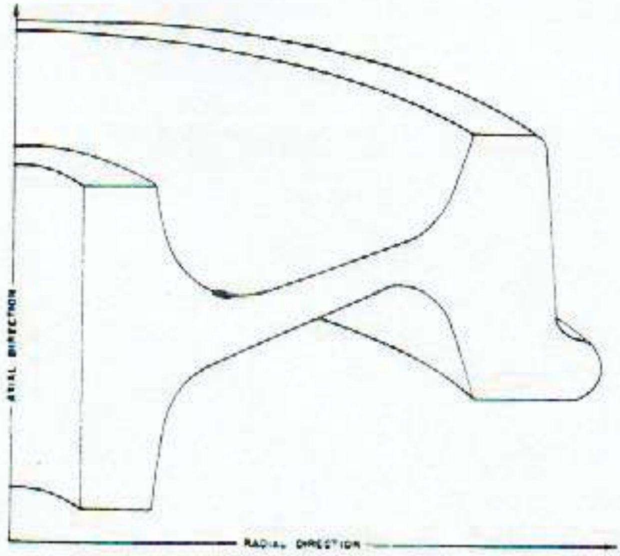


FIGURE 3a. Straight plate wheel.

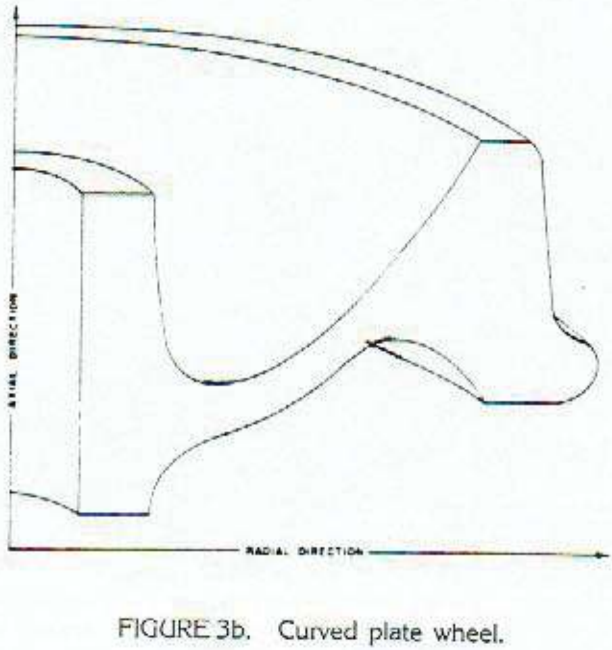


FIGURE 3b. Curved plate wheel.

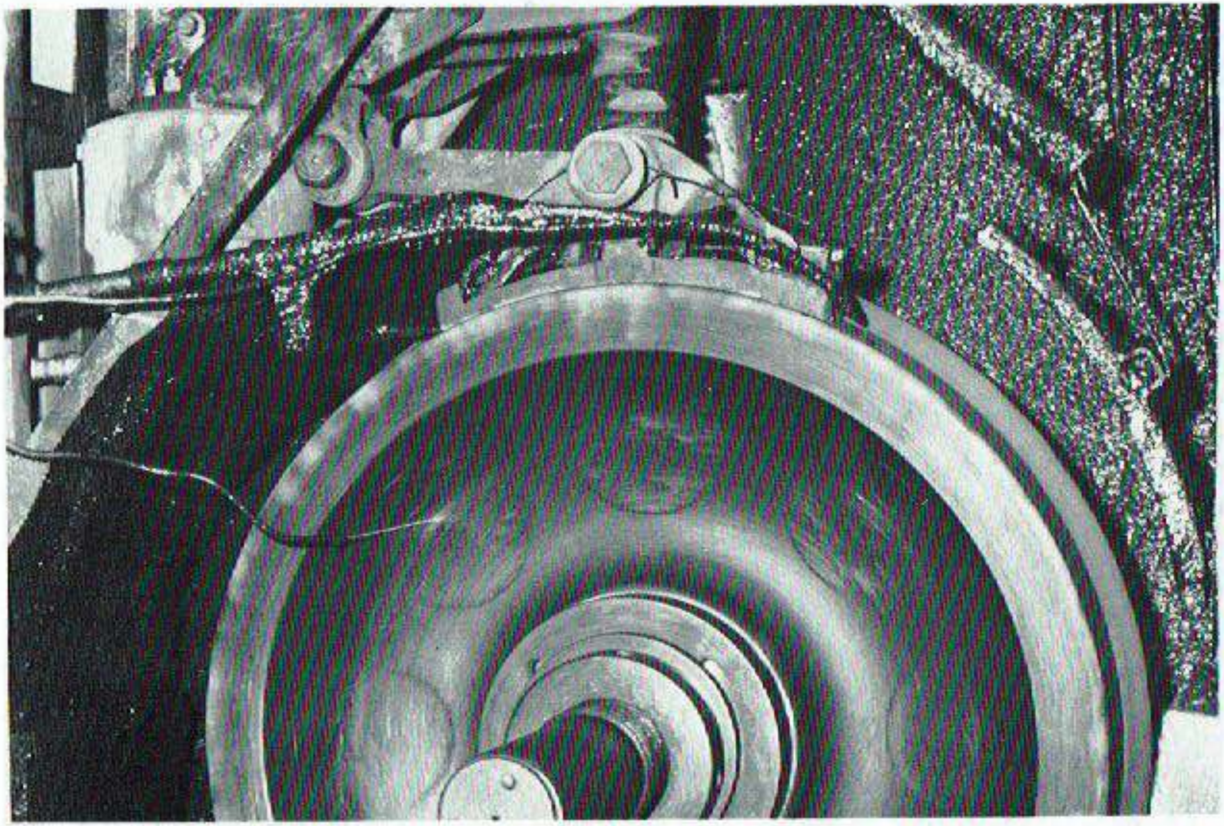


FIGURE 4. Wheel testing dynamometer at the University of Illinois. A brake shoe is forced vertically against the tread of the rotating railroad wheel.

In addition to dynamometers, induction coils have also been used to evaluate the stresses in wheels and progression of thermal cracks. A high frequency generator is used with the induction coil to create a controlled source of heat on a full size wheel to simulate a brake application. Professor Wetenkamp of the University of Illinois assisted in developing the tests and the equipment for monitoring and recording the data from these tests and has been used as a consultant for dynamometer and induction coil designs by many organizations in countries around the world.

In the late 1950's, Professor Wetenkamp and Harold C. Keysor (now deceased)* discussed, corresponded and proposed various designs of freight car wheels. Keysor proposed parabolic fillets and Wetenkamp proposed straight inclined plates to increase plate flexibility. The designs proposed by each were cast and evaluated by Griffin Wheel Company. On December 5, 1958, Keysor filed for a patent on a parabolic design and, with a continuation-in-part of this application, received a patent with claims for the parabolic fillets in 1962. The first parabolic plate designs were placed in service in December, 1960 by the Griffin Wheel Company. After Keysor retired in late 1958, Wetenkamp continued wheel design work. The first of the modern designs, with parabolic fillets and a deep dish plate connected closer to the back hub face, was the 28"-1W design which was placed in service in 1962 by Griffin. The induction coil tests had indicated straight plate, parabolic fillet, 28"-1W wheels would develop excessive plate stresses.

In the 1960's, with the advent of computers, it became feasible to simulate and calculate mathematically the stresses in wheels. The initial programs were elastic and therefore, could not calculate the stresses due to inelastic yielding. However the development of residual stresses could be interpreted by determining if stresses exceeded the yield strength of the material. Using these techniques, H. R. Wetenkamp presented a comparison of various plate designs in the 1973 ASME report "Comparison of Thermal Stresses Developed in S Plate, Straight Plate and Deep Dish Wheels" and noted the benefits of the curved plate design in resisting the growth of thermal cracks.

Since that time, finite element stress analysis programs have been developed which determine changes in residual stresses caused by inelastic yielding, and they fortify and clarify the University of Illinois dynamometer results. Thicker straight plate wheels when subjected to severe, long, on-tread braking, yield plastically, and when cooled, develop higher tensile circumferential rim residual stresses than thinner plate wheels of the same configuration.

These stress programs help to explain why the thicker straight plate wheels have a greater propensity for progression of thermal cracks which develop on the tread, flange, and back rim face. Wetenkamp and Kipp presented one of the first papers, "Safe Thermal Loads for a 33 Inch Railroad Wheel" in 1975.

*The convenants of the Sperry Board of Award prevent its presentation to a person deceased at the time of selection.

An inelastic analysis was used to evaluate wheel designs. In another paper, in 1978, they pointed out the superiority of the curved plate designs due to lower accumulation of residual stresses.

The failure statistics of 28" one-wear straight plate wheel designs verify the theories presented in these reports. The Association of American Railroads (AAR) B-28 design wheels were straight plate wheels with a minimum plate thickness of ⅝". When these wheels developed a large number of plate failures during the early 1970's, the AAR changed the minimum specified plate thickness to ¾", increased the fillet radii, and designated this design D-28. Manufacturing of the D-28 was started January 1, 1974. The number of 28-inch wheels which fractured due to thermal cracks and plate cracks from 1975 through 1979 are shown in Figure 5. The service failure data of these wheels illustrates and verifies the dynamometer and finite element stress analysis of straight plate wheels, that is, thickening the plate decreases plate failures but increases the incidence of wheel fractures caused by progression of thermal cracks. The superiority of the curved plate designs was also verified in service and is illustrated in the failure statistics shown in Figure 5. With the verification of the superior performance in North America service of the 28" and other diameters of the deep dish parabolic wheel design, most manufacturers discontinued the straight plate freight car wheel design.

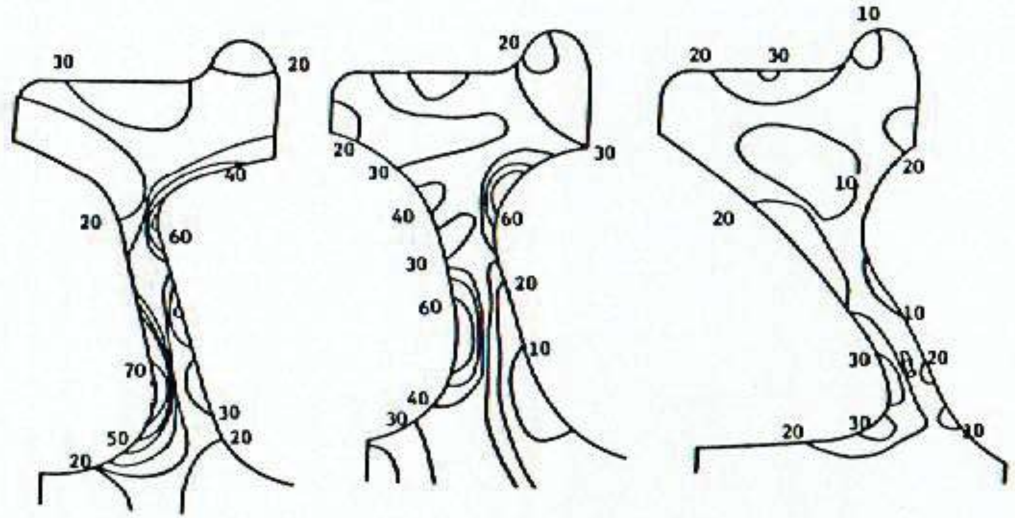
Considerable service testing of wheels has taken place to verify wheel temperatures used in stress analysis programs and to verify dynamometer results. To determine braking effort in service it is necessary to measure perpendicular brake shoe loads and tangential braking loads (retarding frictional forces). This can not be determined with sufficient accuracy from brake air cylinder pressure, and therefore, Professor Wetenkamp developed an instrumented brake head to measure these forces. The instrumentation permits visual display of retardation force or brake shoe load so that adjustments of cylinder pressure can be made to obtain either a specific horsepower or brake shoe load during test runs.

The pressure developed at the interface of the wheel and brake shoe is uneven and thus the temperature distribution along the wheel surface is not uniform. This nonuniform heating of the tread causes local hot spots, which are instrumental in the initiation of thermal cracks. To measure the temperature of these spots during the wheel rotation, the University of Illinois developed a silicon pin diode device which could rapidly measure radiation without being in contact with the wheel. Silicon pin diodes and instrumented brake heads were used in service tests evaluating wheels on the Union Pacific (Figure 6) and the Santa Fe Railroads. Papers discussing the results of these trials were co-authored by Professor Wetenkamp.

Wheels that are subjected to severe on-tread braking discolor. Initially they develop a blue color. With time and proper atmospheric conditions, this blue color turns to reddish brown. In the 1960's, one of the thick straight plate wheel designs had a high incidence of fractures in service; railroads used discoloration as a guide to identify wheels that had been heated excessively and were likely

FIGURE 5. Incidence ($x10^{-4}$) of Fractured 28-Inch (722 mm) Wheels 1975-1979

	STRAIGHT PLATE DESIGNS		DEEP DISH PARABOLIC DESIGNS
	5/8" Minimum Plate Mfg. 1961-1973	3/4" Minimum Plate Mfg. 1974-1979	3/4" Minimum Plate Mfg. 1962-1979
Fractured Plates	1.08	0.57	0.00
Thermal Crack Fractures	0.47	7.57	0.09



Constant Effective Stress Lines (in 10 ksi) Subjected to 50 hp (37 Kw) on-Tread Braking for 15 Minutes.

FIGURE 6. Union Pacific test train used to evaluate the effect of braking on railroad wheels.

to experience dangerous stress. This was later included in the Association of American Railroads (AAR) and Federal Railway Administration (FRA) safety rules. The FRA rule today states: "A railroad may not . . . continue in service a car, if a wheel on the car shows signs of having been overheated as evidenced by reddish-brown discoloration on the front and back of the rim that extends more than four inches into that plate area."

Wheel failure statistics from the AAR and FRA indicated that during 1980 and 1981, of the derailments caused by thermal failures of wheels, 94% were straight plate wheels and 6% curved plate wheels, although approximately 50% of the wheels in service were curved plate designs.

The curved plate wheel design, first introduced over twenty years ago, dramatically decreased the incidence of wheel fractures and derailments in North America. This resulted in large savings of lives and money. Professor Harry R. Wetenkamp is the individual most responsible for these designs.

Data, ideas and quotations for this document have been freely taken from:

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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 Geoffry 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.

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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 Fuji* 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. Nellsen* 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 to *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 Commerical Airplane Company* for their leadership in the development, successful introduction and acceptance of wide-body jet aircraft for commercial service.

1981 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.

1982 to *Jorg Brenneisen, Ehrhard Futterlieb, Joachim Korber, Edmund Muller, G. Reiner Nill, Manfred Schulz, Herbert Stemmler* and *Werner Teich* for their contributions to the development and application of solid state adjustable frequency induction motor transmission to diesel and electric motor locomotives in heavy freight and passenger service.

1983 to *Sir George Edwards, OM, CBE, FRS, General Henri Ziegler, CBE, CVO, LM, CG; Sir Stanley Hooker, CBE, FRS* (in memoriam); *Sir Archibald Russell, CBE, FRS;* and *M. Andre Turcat, Ld'H, GG;* commemorating their outstanding international contributions to the successful introduction and subsequent safe service of commercial supersonic aircraft exemplified by the Concorde.

1984 to *Frederick Aronowitz, Joseph E. Killpatrick, Warren M. Macek* and *Theodore J. Podgorski* for the conception of the principles and development of a ring laser gyroscopic system incorporated in a new series of commercial jet liners and other vehicles.

1985 to *Richard K. Quinn, Carlton E. Tripp,* and *George H. Plude* for the inclusion of numerous innovative design concepts and an unusual method of construction of the first, 1,000-foot self-unloading Great Lakes vessel, the M/V Stewart J. Cort, which revolutionized the economics of Great Lakes transportation.

1986 to *George W. Jeffs, Dr. William R. Lucas, Dr. George E. Mueller, George F. Page, Robert F. Thompson* and *John F. Yardley* for significant personal and technical contributions to the concept and achievement of a reusable Space Transportation System.