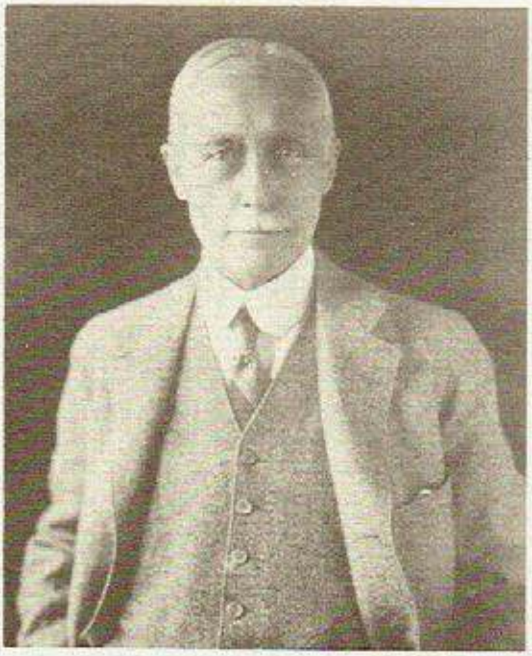
THE ELMER A. SPERRY AWARD FOR 1971



ELMER AMBROSE SPERRY
1860-1930

FOUNDING OF THE AWARD

The 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 in improvement of movement of men and goods by land, by sea, and by air.

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

Presentation of

THE ELMER A. SPERRY AWARD FOR 1971

to

SEDGWICK N. WIGHT

and

GEORGE W. BAUGHMAN

With 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 of Westinghouse Air Brake Company.

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 BANQUET OF THE INTERNATIONAL CONVENTION of the INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS
MARCH 22, 1972 • NEW YORK HILTON HOTEL • NEW YORK CITY

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."

1971 BOARD OF AWARD

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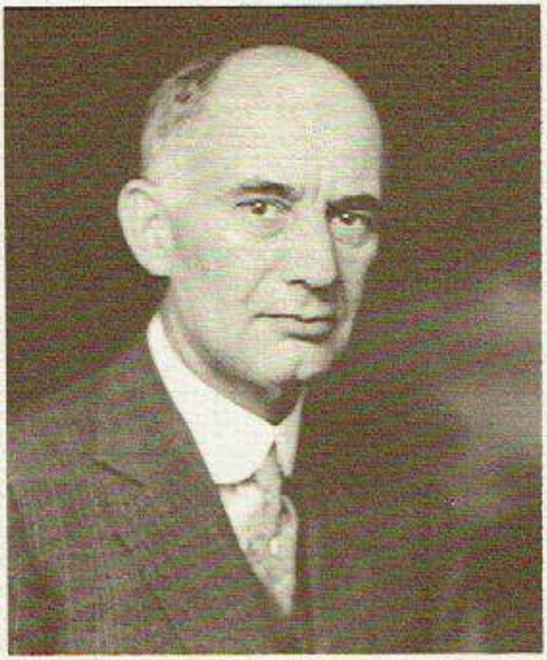


SEDGWICK N. WIGHT

AWARD CITATION

for the Sperry Award for 1971

SEDGWICK N. WIGHT (in memoriam) for his foresight and ingenuity in the planning and execution of the first practical installation of Centralized Traffic Control on a railway. This first installation gained world-wide acclaim.

GEORGE W. BAUGHMAN

AWARD CITATION

for the Sperry Award for 1971

GEORGE W. BAUGHMAN in recognition of his engineering contributions which enlarged the scope and flexibility of application of Centralized Traffic Control on the railways to the extent of exerting a controlling influence in the commercial success of this overall system on a world-wide basis.

CERTIFICATES OF CITATION

for the Sperry Award for 1971

WILLIAM D. HAILES for his outstanding design and development of the apparatus and systems to further the principles of Centralized Traffic Control on railways advocated by Mr. Wight.

LLOYD V. LEWIS (in memoriam) for his outstanding designs of apparatus and systems with important contributions to the long life and reliability of Centralized Traffic Control apparatus used on railways.

CLARENCE S. SNAVELY (in memoriam) for his outstanding designs and developments to realize the greatest practical speed of operation of electromagnetic devices in Centralized Traffic Control on railways.

HERBERT A. WALLACE (in memoriam) for his early concepts and patented inventions outlining the broad fields of application of Centralized Traffic Control on railways.

To the employees of GENERAL RAILWAY SIGNAL COMPANY for their dedication to the pioneering and planning of Centralized Traffic Control for railways with special reference to the placing in service of the first installation which gained world-wide acclaim.

To the employees of the SIGNAL & COMMUNICATIONS DIVISION of WESTINGHOUSE AIR BRAKE COMPANY for their dedication to engineering contributions which exerted a great influence in the success of Centralized Traffic Control for railways on a world-wide basis.

CENTRALIZED TRAFFIC CONTROL

It may come as a surprise to some that Centralized Traffic Control for railways which has existed for quite a number of years should be the subject for the 1971 Sperry Award.

In the continuing study and review of this subject, the Sperry Board of Award was most favorably impressed by letters sent in by the officials of leading railroads indicating the benefits that have been and are continuing to be derived from CTC. It was the magnitude of these benefits that played an important part in the selecting of CTC for the 1971 award. Extensive studies of the history of the system reveal that the first installations were made many years ago, but outstanding engineering contributions made later have had much to do with the overall flexibility and economy of the system. As is frequently the experience, when a new and very different method of operation is introduced, the acceptance of CTC was very cautious and gradual for a number of years. The initial benefits in safety and economy were enhanced by progressive engineering contributions, and a period of excellent growth developed and is continuing.

The primary purpose of Centralized Traffic Control (CTC) is to provide safety and efficiency for rail transportation - safety to persons, goods and equipment; efficiency to keep trains moving with a minimum of delays.

CTC places the control of track switches and wayside signals on many miles of railroad directly in the hands of a centrally located dispatcher. Trains are directed entirely by signal indications.

July 25, 1972 will be the 45th anniversary of the first installation in the world of Centralized Traffic Control. This invention, which heralded a new era in efficient railroad operation, receives the 1971 Sperry Award. Subsequent outstanding engineering contributions have enhanced the initial benefits of safety, economy and efficiency. Today there are over 50,000 miles of track in the United States controlled by CTC; in addition, the system has spread to all countries of the world that have significant railroad operations.

Train Operation Prior to Centralized Traffic Control

Prior to the development of CTC in 1927, a method of train dispatching using written train orders and manual operation of track switches by the train crew provided fairly satisfactory train movements under the conditions that existed at that time. Automatic signaling systems, which had been in service for many years prior to 1927, provided for safety of train movements in that they protected against head-on or rear-end collisions and gave warning of a broken rail.

The dispatcher arranged the details of train scheduling. He carried out this responsibility by issuing train orders to the crew of each train as it entered his territory. The train order was sent by the dispatcher to one of several operators who were located in offices distributed along the railroad. At an operator's location, the train slowed to receive the order. The typical order instructed the train to proceed on the main track and then enter a siding at a specified location and wait there until one or more specified trains had passed.

Actually this method, awkward as it may sound, worked quite well as long as train traffic was relatively uniform and predictable. The method became more unwieldy as traffic density increased and irregularities occurred.

This was the situation that existed on a number of the mainline railroads of the U.S. in the World War II period as the traffic increased and became less uniform. Additional locomotives would not provide the answer and time was not available to install additional tracks. Centralized Traffic Control existed at this time and had demonstrated its ability to the extent that it was looked upon as having definite possibilities to help in this difficult situation.

"Before the advent of CTC, a train dispatcher transmits train orders by telegraph key. Later telephone replaced the telegraph".

The Invention of CTC

Centralized Traffic Control mechanized the work of the dispatcher. The system combined already existing safety features of signaling systems with a supervisory control capability for directing train movements from a central point.

It was not until the idea of decentralizing the safety features while centralizing control facilities was conceived that CTC became feasible. It was this contribution by Sedgwick N. Wight of the General Railway Signal Company that made it possible to design a system that conformed to the "fail-safe" principle and still provided supervisory control of remote switches and signals. The track switches are moved and signals cleared to give a "proceed" indication only if the local safety circuits at the remote point in the field show that it is safe for the train to proceed. The dispatcher at the control office might send a control code to move a switch or clear a signal when it was not safe to do so or the communications portion of the CTC system might fail to deliver the control code exactly as intended because of some detail failure along the CTC line circuit, but the switch would not move and the signal would not clear. In a device or system that is organized and built in accordance with the "fail-safe" principle any failure in the system itself automatically results in a safe condition.

Mr. Wight's concept of decentralizing the safety features while centralizing control facilities ushered in a new era of safe and efficient train operation. His concept was put to practical use on July 25, 1927 on the Toledo and Ohio Central Railroad (now the Penn Central) between Stanley and Berwick, Ohio. The dispatcher at the control panel in Fostoria remotely controlled the switch operating mechanisms and wayside signals along the 40 miles of railroad.

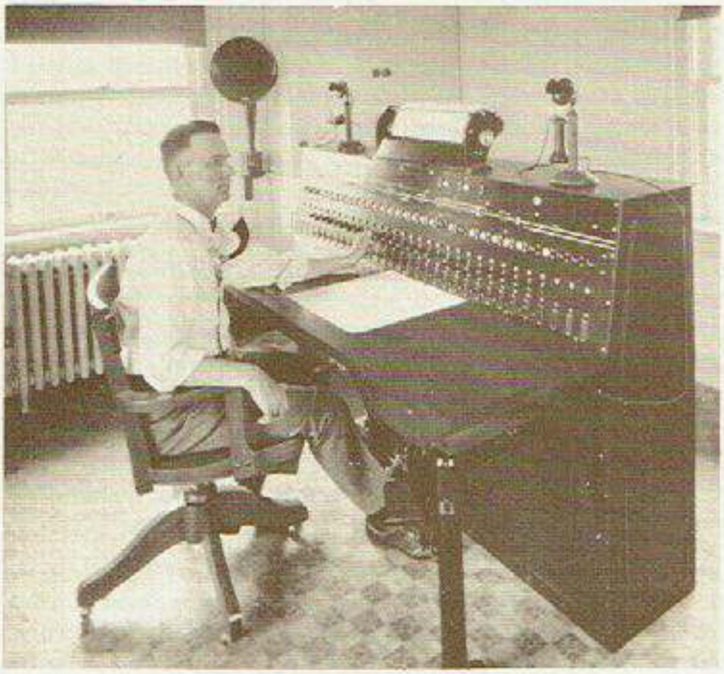
Here is a first-hand account of operation with the new system as given in an address by Mr. J. J. Brinkworth of the New York Central Railroad before the Signal Section of the Association of American Railroads in 1947. "...I was particularly involved in centralized traffic control in 1927...I went to Rochester, to the General Railway Signal Company plant, and saw the actual machine there. I, of course, became acquainted with Mr. S. N. Wight of that Company, who studied out the details of the CTC machine. I went to his house and in the back room we talked it over in detail for hours.

"Then we came to 1927, when the final date was set to install Centralized Traffic Control on the Toledo & Ohio Central and put it into service. Needless to say, we were all over at Fostoria, Ohio, and we watched the progress of the various signals being put in along the approximately 40 miles of the railroad between Toledo and Berwick. Then after a comparatively short time, trains started to move over the piece of single track for the first time without train orders.

"I recall very distinctly, as we had supper in the hotel at Fostoria and got through, I said to the gang, I do not know what you fellows are going to do tonight, but I'm going over to the tower at Fostoria and stay there until I see a non-stop meet. Well, they all decided that if the boss was going over, the rest of the gang had better go, too. So we went over to the tower at Fostoria in the evening. The dispatcher was there and he was just filled up with enthusiasm on this new gadget called Centralized Traffic Control... Along about 10:00 o'clock, he just yelled right out loud, "Here comes a non-stop meet"! Well, we all gathered around the machine and watched the lights that you know all about, watched the lights come towards each other and pass each other without stopping.

"That, to me, and to you, too, was history on American railroads, the first non-stop meet on single track without train orders, of course, that we know of. We waited at Fostoria until the southbound train arrived there and you never saw such enthusiasm in your life as was in the minds and hearts of that crew, the first non-stop meet of which they had ever heard."

Thus occurred the first non-stop meet, today commonplace on thousands of miles of CTC.



World's first CTC control console at Fostoria, Ohio, on Toledo and Ohio Central RR. Now in Smithsonian Institution.

Vital, Fail-Safe Controls and Non-Vital Communications

When the dispatcher positions levers on his control panel, electrical energy is transmitted via a communications circuit to a remote location in the CTC territory to control the wayside signals and track switch operating mechanisms. Safety, or vital circuits at the field location interlock the operation of the switches and signals in such a manner as to prevent their control if conditions are not favorable, for example, if a train has accepted or is occupying a route.

The communications circuit is not a safety circuit - it is referred to as non-vital because no unsafe conditions can result should a failure occur. Also, the cost of a fail-safe communications circuit would be prohibitive.

This combination of vital and non-vital circuits and apparatus provided an overall system which ensured safe and economical train operation.

The Berwick to Stanley installation used a direct wire communication circuit, where separate wires with common returns were used to control and indicate each switch and signal in the territory.

Later, Messrs. H. A. Wallace and C. S. Snavely of the Union Switch & Signal Company (now WABCO - Signal & Communications Division) developed a system using Gill Selectors at each wayside location. Each selector was responsive to a particular code transmitted from the control office. The main feature of this system was its economy with respect to line wire - only two wires were required for the length of an installation. Several installations were made in 1928. At this time about 20 miles was considered as the maximum practical length.

Both GRS and Union Switch & Signal developed various systems in the next few years which kept line wire requirements to a minimum. The limitations of Gill Selectors were soon recognized and two, three and four wire systems were developed which used relays for coding and decoding.

The development of all-relay systems at Union Switch & Signal Company was the responsibility of L.V. Lewis and C.S. Snavely, assisted by A. B. Miller, A. P. Jackel and D. P. Fitzsimmons. At GRS, a special engineering section was established in 1928, under the leadership of W. D. Hailes, for the specific purpose of developing and commercializing CTC systems. Mr. Hailes was assisted by F. W. Brixner, W. M. Barker, A. V. Dasburg, R. C. Leak, and others.

The War Years

The basic principles of CTC were well established by 1939 with a total of 2050 track miles installed in over 100 installations on 37 railroads.

With the approach of World War II, rail traffic increased at an alarming rate on a number of railroads in the U.S. and Canada, particularly in the west. There was not time, nor was it practical, to install additional trackage. CTC was considered to be the most promising solution to handle greatly increased traffic as promptly as possible and over existing track facilities. Even additional locomotives did not offer the degree of help that was needed. At this time, installations up to 60 miles long were considered the maximum capability of existing equipment.

Despite all of the benefits that had been demonstrated, there were limitations that almost completely stalled the CTC program. First there was opposition to the existing line circuit by which all field stations were connected in series and a single break in a line wire could put the entire system out of service. Secondly, during the war, the copper supply was very critical and it was necessary to apply to the War Production Board for permission to buy copper. And thirdly, a serious controversy developed between the operating officers of some railroads and their signal departments. There was almost the ravenous desire of some of the most progressive operating officers to have large installations of hundreds of miles controlled from a headquarters location.

The signal engineers contended that the very large installations should not be considered because of the insurmountable maintenance problems that would develop. Also there was no equipment available to permit the large installations.

There was a temporary compromise by locating the control office in the middle of the territory being controlled with a line extending in each direction. The operating officers and the controllers of the CTC machines objected to this arrangement. The controllers were away from headquarters which was not good from a management standpoint. In addition, the most desirable location for such a control point was usually at a place where it was not desirable for the controller to live and raise a family.

In 1939, George W. Baughman started a development program aimed at overcoming the preceding objections. He was assisted initially by Mr. Norman Agnew, who had a considerable amount of experience both in the laboratory and field installation of CTC.

The objection regarding the vulnerability of the system to a single break in the line was greatly reduced by the development of the multiple line circuit. In the event of a break in the line, the "multiple line" permitted normal operation out to the break and in addition permitted the quick location of the break so it could be repaired promptly.

With the multiple line, one pair of line wires is used for the transmission of codes from the office to a plurality of field stations in accord with the previous standard practice except the line relay at each field station is in multiple with the line. The real novelty, however, was in the transmission of codes from a plurality of field stations to the office with no interruptions to the continuity of the line wires. Of course this included the provision for transmitting one code at a time in the event of two or more stations having codes to transmit. An additional provision is that of storage at each field station so that no information is lost when a field station is locked out temporarily by another field station with higher priority.

The development included suitable filters at each field station so that one pair of line wires could also serve as a voice telephone circuit, a duplex telegraph circuit and for the transmission of carrier frequencies. An indication of the commercial success of the development up to this stage is that more than 100 Union Switch & Signal installations of the CTC Multiple line with voice frequency telephone on the same pair of wires were made by 1945 and it has continued as a standard type of installation.

It is obvious that this multiple use of the line wires represented an economy in the use of copper, which was helpful in obtaining the authorization by the War Production Board for the purchase of copper. There were also some installations made during this period which used a pair of existing telephone wires and thus eliminated entirely the need for new copper for the CTC line.

In 1941 Mr. Baughman's development program took the direction of consolidating and selecting from all previous ideas and concepts to approach a system with the greatest practical flexibility and with economies to improve further the commercial attractiveness of the system. With the assistance of Mr. Arthur P. Jackel the 506 relay code system was developed and first marketed in 1942. Many thousands of miles of this basic system have been installed in the U.S.A., Canada and many other countries.

Electronic Communications Extend Control Distance

It was also recognized at this time that the existing systems had limitations regarding the location of the control center at headquarters and the length of territory that could be controlled from one point. What was needed was a means of extending the distance of control using multiple sections of the relay code system operating over separate carrier circuits.

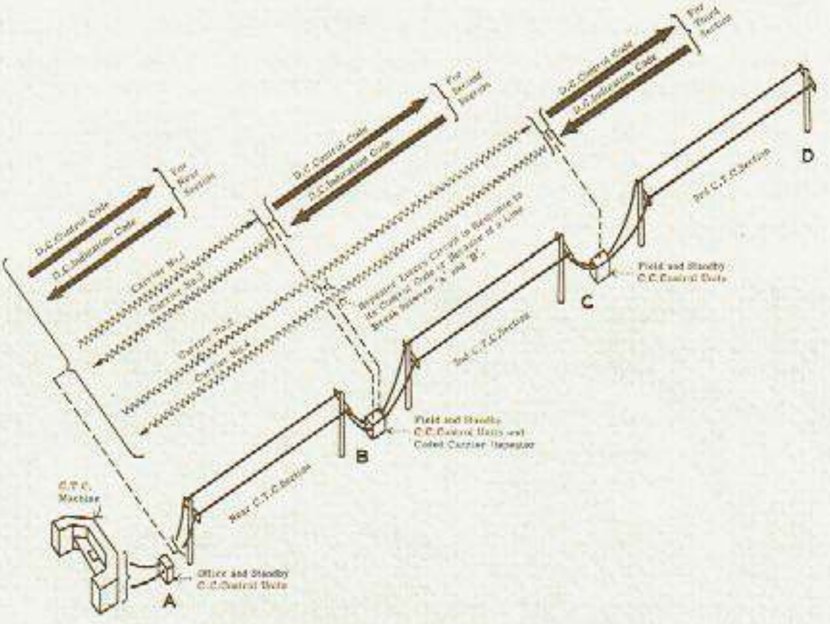
Assisted by Messrs. Norman Agnew and Porter Place in the development and Mr. Fred Tegeler in the field testing, Mr. Baughman produced and field tested the first carrier equipment used for the control of CTC. The field tests were made on the Seaboard Railway in February of 1942.

The use of carrier frequencies proved to be the solution to the problems regarding size of installation and the location of the control office at any desired point. This solution to the problems while it appears to be a reasonable one and quite straightforward had the same experience as many pioneering efforts.

The use of electronic equipment for the control of CTC was at first not readily accepted by the railroads. In the controversy that developed, the Operating Officers of the railroads were urging an increasing size of installation while many technical people were pointing out the fragile nature of the electronic equipment and the large area of a railroad that would be affected in event of an electronic failure. There was a temporary compromise by locating the control office in the middle of the territory being controlled. However, the pressing need to expand the control distance of a CTC dispatcher and to have him located at headquarters prevailed and large carrier controlled installations were made. Standby carrier units were provided with both manual and automatic means to shift from normal to standby. An important by-product of the use of carrier frequencies was their ability to pass a break in the line due to the capacitive circuit network formed by the line wires with respect to ground. Actually, the overall performance was so outstanding that it far surpassed the claims of the sponsor.

Historically, the first carrier controlled section of CTC was placed in service in June, 1942, on the Southern Pacific. A replica of this first carrier unit was recently given to the Smithsonian Institution in Washington. Twenty-five installations on various railroads each having one or more carrier-controlled sections were in service by 1946.

The first installation with more than one carrier-controlled section was completed in 1943 between Las Vegas, Nevada and Yermo, California. This is a three-section installation with approximately 60 miles of railroad in each section and more than 100 field stations in all. It was able to handle the war time traffic with better schedules and fewer locomotives, with overall savings that repaid the investment in less than three years.



"Coded Carrier Control of Large CTC Installations"

The previous sketch represents a simplified diagram of the DC-coding and carrier controls for the Las Vegas to Yermo installation. The lower part of the diagram shows that there is just one pair of line wires. This pair extends the full length of the territory being controlled, which in this case is approximately 180 miles.

The one pair of CTC wires on this installation served to transmit carrier frequencies to and from the two remote sections and at the same time serve as a party-type telephone line with more than 100 phones with individual calling to each phone provided by the CTC system. In addition, there was a phone in each maintainer's home that could be called selectively over this line. It is estimated that 720 miles of copper line wire was saved with respect to technologies that would have been used just a few years before.

A nationally publicized demonstration was made in 1946 to show that CTC was designed to be compatible with commercial communication circuits. The demonstration was a cooperative activity of the Pennsylvania Railroad, Western Union, RCA and Union Switch & Signal. The path for the CTC controls and indications was from a CTC machine in Red Bank, Pa. over a telephone line to Pittsburgh, Pa., over a Western Union telegraph line via Washington, D.C. to the Western Union microwave terminal in Philadelphia, to New York City over microwave, and back to Pittsburgh over a Western Union telegraph line and then over a telephone line to the CTC machine at Red Bank.

Admittedly, there was no doubt in the minds of technical people that this could be done. The purpose was to give clear evidence of the possibilities available in the locations of control points with respect to the territories being controlled.

"Representatives from Pennsylvania RR, Western Union, RCA and Union Switch & Signal at Red Bank, Pa. 1946."

Centralized Traffic Control also found application in urban rail transit systems, one of the first code systems having been installed on the Hudson & Manhatten for the remote control of an interlocking at Exchange Place from Hudson Terminal. However, this was a relatively small single station installation. The first major installation of CTC on a transit line was in 1953 when the New York City Transit Authority modernized the entire Flushing Line between Times Square and Main Street, Flushing with control centers at Times Square and Willets Point.

Almost all transit applications of CTC have been made on the New York City Transit Authority Lines. However, one of the latest provides centralized control of the Delaware River Port Authority's PATCO high speed transit line operating over 14 miles between Philadelphia and Lindenwold, New Jersey, installed in 1969.

Solid-State CTC Systems

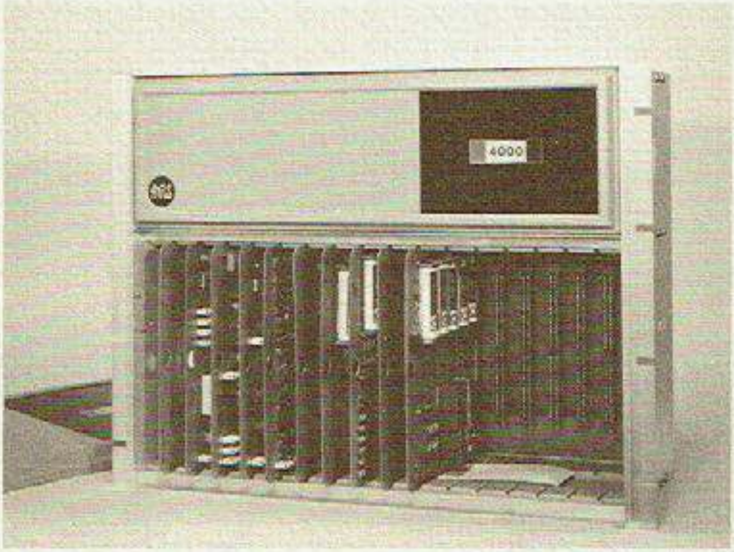
Relay coding systems reached the ultimate in design during the early 1950's. Subsequent refinements increased operating speeds up to 330 data bits per second. With the increasing need to handle even larger installations having heavy traffic on multiple track, a solid-state coding system using transistor circuitry was developed by W. D. Hailes of General Railway Signal in 1955. The first major installation was on the New York Central between Buffalo, New York, and Cleveland, Ohio. This was the first of several installations on the New York Central which enabled the railroad to reduce its four-track main line to two tracks from New York to Chicago.

At Union Switch & Signal, development work in solid-state systems was pioneered by Dr. P. N. Bossart, with major contributions by T. J. Blocker. Subsequent system designs, improvements and variations were made under the direction of W. H. Moore and E. R. Callender. Today many such installations are providing more than adequate service. The first computer operated centralized traffic control system was installed on the Union Railroad near Pittsburgh in 1966. The first completely solid-state control center including field terminals was installed on the Missouri Pacific at Fort Worth, Texas in 1967. The most recent development was an installation on the Canadian National, a dispatching system using integrated circuits and a programmable control system.

"WABCO Solid State Control Center at Ft. Worth, Texas."

With the introduction of integrated circuits, N. B. Coley of General Railway Signal started development of System 4000, an ultra high-speed coding system, which was first installed on the Penn Central at Utica, New York, in 1968. System 4000 transmits at a maximum rate of 1200 data bits per second.

In 1971, C. R. Powdermaker of GRS demonstrated the use of a mini-computer as the office end of a CTC system using System 4000 units at the field stations. The first system was made for the Italian State Railways. The application of a computer brings CTC technology into the space age. Railroads can now establish central control headquarters which consolidate the control of hundreds of field stations, covering even an entire railroad.



"GRS System 4000, the first solid state code system using integrated circuits with speeds up to 1200 data bits per second."

Advantages of CTC

Mr. S. N. Wight's invention and subsequent developments in CTC have contributed greatly to efficient railroad operation. The advantages of train operation by CTC, as documented by the Association of American Railroads, include:

1. Elimination of train orders and the possibility of errors in issuing, transmitting, interpreting and executing train orders.
2. Better supervision of train operation is obtained by the dispatcher, as changing traffic conditions are immediately reflected on his operating board. This enables the dispatcher to change the line-up of train operation with increased facility and safety.
3. Train delays are also reduced, as experience shows that many meets on single track are so well timed that neither train stops.
4. Capacity of the line is increased by the use of power switches and the more frequent and accurate reporting of the passage of trains through the 24 hours which makes it possible for the dispatcher to change his scheme of operation as traffic conditions permit.
5. Increased safety is obtained where power operated switches are used because:
   a. Reduction in number of stops results in less wear and damage to equipment and, consequently, there is less chance of accidents and personal injury.
   b. Power switches may be used to route trains around obstructed track and may serve to give derail protection to trains standing on the main track awaiting a meet.
   c. Eliminates chances of personal injury to trainmen running ahead of a train to open a switch, in operating the switch, or running to catch the train after closing the switch.
   d. Trains are kept in motion a greater portion of the time, and the chances of collisions are reduced.
6. Instructions governing the movement of trains are given by signal indications displayed at the point where action is required, by the control operator to the engineman, eliminating intermediary action by other employees. This concentration of control of train movements eliminates individual judgement which cannot always coordinate to the best advantage in the most expenditious and safe movement of trains.

7. It provides additional protection for a train working between switches at end of sidings, as often other trains can be run around the working train. This form of operation may, in many cases, permit the elimination of yard limits.

8. It provides controlled signals at many points which may be used by the control operator to stop trains when employees report dragging or defective equipment or other unsafe conditions.

9. Its operation shortens the running time over the territory and, consequently, reduces the number of meets per trip, thereby reducing the possibility of accidents.

10. It has brought about a higher standard of maintenance of switches and sidings, increasing safety of operation.

11. Additional protection can be given for the movement of track cars and other maintenance-of-way department equipment, as the control operator can protect these movements by signals.

12. Because there is less standing time on sidings, the "freezing up" of trains in cold weather is less likely to occur.

13. It provides greater safety at times of peak business, as the control operator can more efficiently direct increased traffic.

14. It increases safety by eliminating the necessity of checking train register and identifying trains at meeting points.

15. It increases the over-all efficiency of operation by placing the entire control of trains under the dispatcher.

16. It obviates the immediate need for additional trackage, by increasing the capacity of existing track facilities.

17. It permits reduction of main track and sidings by increasing capacity of the remaining track facilities.

18. It reduces the cost of operation by releasing switchmen and operators.

19. It increases availability of locomotives, cars and operating personnel.

CONCLUSION

Mr. Sedgwick N. Wight's original concept of Centralized Traffic Control, coupled with George W. Baughman's recognition of practical commercial requirements have withstood the test of time and remain valid today. There are many documented benefits derived from the use of CTC which attest to the soundness of their concept. These gentlemen along with contemporary and subsequent innovators in the field of railway signaling have greatly assisted the railroads of the world in their prime goal to move goods faster and with greater efficiency.

ACKNOWLEDGMENT

The Elmer A. Sperry Board of Award expresses its deep appreciation to John W. Hansen of Westinghouse Air Brake Company (WABCO) and to William D. Hailes, C. Alan Ingalsbe and Hall E. Downey of the General Railway Signal Company for the preparation and production of this comprehensive brochure on Centralized Traffic Control.

Printed in U.S.A.

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 groscopic 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 ignitron rectifier to railroad motive power.

1963 to EARL A. THOMPSON and Citation to his Associates for design and development of the first notably successful automatic automobile transmission.

1964 to IGOR SIKORSKY and MICHAEL E. GLUHAREFF and Citation to the SIKORSKY ENGINEERING DEPARTMENT for the invention and development of the high-lift helicopter leading to the Sky Crane.

1965 to MAYNARD L. PENNELL, RICHARD L. ROUZIE, JOHN E. STEINER, WILLIAM H. COOK and RICHARDS 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.

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