1884 1984

A CENTURY OF ELECTRICAL PROGRESS

100 Years With IEEE In The Delaware Valley

Philadelphia Section

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Foreword

The Philadelphia Section of the Institute of Electrical and Elec-ronic Engineers, Incorporated (IEEE) presents this history of electro-technical related accomplishments by individuals and companies in the Delaware Valley during the last 100 years in ribute to the founding of IEEE. It is hoped that the collection of articles will prove to be both interesting and informative for the nontechnical reader as well as the members of the Philadelphia Section. If by reading this document, the reader's appreciation of he tremendous impact of engineering on his or her welfare, com-ort, and security is enhanced, the Philadelphia Section will feel vell rewarded.

Two introductory articles document the history of the IEEE and he role played by the Franklin Institute in stimulating the founding f the American Institute of Electrical Engineers (AIEE), which ater merged with the Institute of Radio Engineers (IRE) to form he IEEE. The remaining articles have been grouped into arbitrar-y broad divisions of electro-technology: Communications/Enter-ainment and Broadcast, Power and Industrial Applications, Rail Transportation, Medical Application, Computers, and Aerospa-e/Military. The reader will note that achievements by companies, s opposed to those by individuals may extend across many or all f the divisions. To properly record the contributions of those ndividuals whose ideas sparked the developments described and nose whose leadership brought forth and many marvelous tech-ical accomplishments we take so much for granted today, would e worthy of several years of effort by a professional historian.

ormal history of the Philadelphia Section (or Branch, as it was nen called) of the AIEE began on February 18, 1903. Dr. Carl lering, the first Chairman, also went on to secure as president of ne national AIEE and as a delegate of the U.S. Government to ne Universal Exposition of 1889 held in Paris, France. The first egular meetings were held in the meeting room of the Engineer's lub of Philadelphia, then 1122 Girard Street.

he Philadelphia Section of the IRE was recognized in the IRE roceedings, December, 1925. Mr. Stuart Ballantine was the first hairman.

is noteworthy that the Philadelphia Section of the AIEE gave irth to the following offsprings: the Delaware Bay Section 1953)—territory, State of Delaware and Salem County, New Jer-ey; the Southern New Jersey Section (1963)—territory, Atlantic, ape May, and Cumberland Counties; and the Princeton-Trenton ivision (1961-62). This division included a subsection of the IRE rganized by T.H. Story in 1945.

The Philadelphia Section of the IRE was originally assigned the geographical areas covered by Philadelphia, Camden and Atlantic City. Later this was expanded to include all of Southern New Jersey and the counties in Southeaster Pennsylvania as far west as Adams, Dauphin and Perry. Subsections that spun off from the Philadelphia Section include Printeton (1945), Lancaster (1947), Lehigh Valley (1957) and Reading (1959). As noted, the Princeton Subsection merged with the AIEE. However, the remaining subsections did not obtain their independence until the time of the merger of the AIEE and IRE in 1963. At that time, the Princeton Subsection became an independent Section.

Events leading up to the merger of the AIEE and IRE are described in the "Capsule History of the IEEE." The role played by the Franklin Institute, as sponsor of the International Electrical Exhibition, 1884, and the National Conference of Electricians, must not be overlooked. These events emphasized the need for a national organization to represent the "practical men," such as Elihu Thompson, Edwin Houston and Thomas Edison, and stimulated the founding of the AIEE.

On behalf of the Philadelphia Section, the Editor apologizes to those individuals or companies that may have been inadvertently omitted from this current history of significant electro-technical accomplishments within the Philadelphia Section of the IEEE. It is especially noted that the history of technical achievements in local RCA Plants did not end in 1976. However, the many outstanding accomplishments by this extraordinary company remain to be chronicled by some future historian.

The time and effort freely given by all those who made this document possible, are sincerely appreciated by the Section. Specifically, the members of the Committee for the publication of this document are recognized here: G.W. Gordan (SM'50), K.A. Fegley (F'57), W.W. Middleton (SM'61), K.A. Ringo (SM'56), A.L. Smith (M'77), and S.R. Warren (F'53).

JOHN C. BRY, JR. (SM'77)

Senior Member of the Engineering Staff
RCA Naval Systems Department
Moorestown, N.J.

February, 1984

Chairpersons of Philadelphia Section

One hundred seventeen engineers have served as Chairmen of AIEE, IRE and IEEE in Philadelphia.

1903-04 C. Hering, AIEE
1904-05 C. E. Hewitt, AIEE
1905-06 H. A. Foster, AIEE
1906-07 C. W. Pike, AIEE
1907-08 W. C. L. Eglin, AIEE
1908-09 J. Stevens, AIEE
1909-10 P. Spencer, AIEE
1910-11 G. Hoadley, AIEE
1911-12 C. Young, AIEE
1912-13 H. A. Horner, AIEE
1913-14 A. R. Cheney, AIEE
1914-15 H. Sanville, AIEE
1915-16 J. H. Tracy, AIEE
1916-17 H. P. Liversidge, AIEE
1917-18 N. Hayward, AIEE
1918-19 W. F. Jones, AIEE
1919-20 C. E. Clewell, AIEE
1920-21 C. E. Bonnie, AIEE
1921-22 P. H. Chase, AIEE
1922-23 E. Tuttle, AIEE
1923-24 R. B. Mateer, AIEE
1924-25 C. D. Fawcett, AIEE
1925-26 S. Ballantine, IRE
1925-26 N. Shute, AIEE
1926-27 L. J. Costa, AIEE
1926-30 J. C. Van Horn, IRE
1927-28 I. M. Stein, AIEE
1928-29 L. M. Deming, AIEE
1929-30 R. H. Silbert, AIEE
1930-31 D. H. Kelley, AIEE
1930-31 W. R. G. Baker, IRE
1931-32 C. N. Johnson, AIEE
1931-32 G. W. Carpenter, IRE
1932-33 L. Fussell, AIEE
1932-33 H. W. Byler, IRE
1933-34 P. S. Harkins, AIEE
1933-34 W. F. Diehl, IRE
1934-35 H. C. Albrecht, AIEE
1934-35 E. D. Cook, IRE
1935-36 R. W. Wilbraham, AIEE
1935-36 K. McIlwain, IRE
1936-37 O. C. Traver, AIEE
1936-37 I. G. Wolff, IRE
1937-38 J. B. Harris, Jr., AIEE
1937-38 A. F. Murray, IRE
1938-39 H. S. Phelps, AIEE
1938-39 H. J. Schrader, IRE
1939-40 E. P. Yerkes, AIEE
1939-40 R. S. Hayes, IRE
1940-41 D. C. Prince, AIEE
1940-41 C. M. Burrill, IRE
1941-42 W. B. Morton, AIEE
1941-42 C. C. Chambers, IRE
1942-43 G. W. Bower, AIEE
1942-43 J. B. Coleman, IRE
1943-44 H. E. Strang, AIEE
1943-44 W. P. West, IRE
1944-45 A. C. Muir, AIEE
1944-45 T. A. Smith, IRE
1945-46 C. T. Pearce, AIEE
1945-46 D. B. Smith, IRE
1946-47 H. A. Dambly, AIEE
1946-47 S. Gubin, IRE
1947-48 W. R. Clark, AIEE
1947-48 P. M. Craig, IRE
1948-49 A. P. Godsho, AIEE
1948-49 A. N. Curtiss, IRE
1949-50 W. F. Henn, AIEE
1949-50 J. T. Brothers, IRE
1950-51 S. R. Warren, Jr., AIEE
1950-51 C. A. Gunther, IRE
1950-52 H. H. Sheppard, AIEE
1951-52 L. M. Rodgers, IRE
1952-53 L. R. Gafy, AIEE
1952-53 C. M. Sinnett, IRE
1953-54 W. F. Denkhaus, AIEE
1953-54 J. G. Brainerd, IRE
1954-55 A. E. Pringle, II, AIEE
1954-55 S. C. Spielman, IRE
1955-56 T. E. Shieber, AIEE
1955-56 C. R. Kraus, IRE
1956-57 M. J. A. Dugan, AIEE
1956-57 M. S. Corington, IRE
1957-58 B. H. Zacherle, AIEE
1957-58 N. Johnson, IRE
1958-59 G. B. Schicicher, AIEE
1958-59 I. L. Auerbach, IRE
1959-60 R. S. Hewett, AIEE
1959-60 W. A. Howard, IRE
1960-61 R. L. Halberstadt, AIEE
1960-61 W. T. Sumerlin, IRE
1961-62 W. O. Mascaro, AIEE
1961-62 R. M. Showers, IRE
1962-63 T. H. Story, AIEE/IEEE
1962-63 H. J. Woll, IRE/IEEE
1963-64 E. W. Boehne, IEEE
1964-65 K. H. Emerson, IEEE
1965-66 W. E. Scholz, IEEE
1966-67 J. E. Snook, IEEE
1967-68 J. E. Casey, IEEE
1968-69 W. W. Middleton, IEEE
1969-70 S. Zebrowitz, IEEE
1970-71 O. M. Salati, IEEE
1971-72 H. O. Wood, IEEE
1972-73 R. Mayer, IEEE
1973-74 E. F. Halfmann, IEEE
1974-75 Fred Haber, IEEE
1975-76 C. Williams, IEEE
1976-77 D. C. Dunn, IEEE
1977-78 V. K. Schutz, IEEE
1978-79 T. L. Fagan, IEEE
1979-80 M. W. Buckley, Jr., IEEE
1980-81 J. C. Bry, Jr., IEEE
1981-82 K. A. Fegley, IEEE
1982-83 G. W. Gordon, IEEE
1983-84 A. L. Smith, IEEE
1984-85 J. E. Bauer, IEEE

Fellows in the Philadelphia Section as of February 4, 1984

J. N. Zemel
I. L. Auerbach
H. Bany
A. D. Beard
S. D. Bedrosian
D. Beeman
T. A. Benham
M. Berkowitz
R. S. Berkowitz
W. S. Bloor
J. Bordogna
W. E. Bradley
J. G. Brainerd
H. B. Bryans
B. Chance
R. G. Clapp
N. Cohn
M. S. Corrington
W. F. Denkhaus
S. B. Disson
A. Dorne
I. K. Dortort
D. H. Ewing
N. H. Farhat
K. A. Fegley
J. H. Felker
J. F. Fisher
G. L. Fredendall
D. Garfinkel
H. L. Garner
T. M. Gluyas
K. W. Goff
L. M. Goldsmith
C. A. Gunther
F. Haber
E. S. Halfmann
C. W. Hargens, 3rd
G. E. Heberlein
J. Hilibrand
R. P. Hinton
L. P. Hynes
L. M. Ilgenfritz
H. K. Jenny
L. F. Jones
A. K. Joshi
I. Katz
A. H. Kidder
H. Kimel
W. R. Koch
C. R. Kraus
E. S. Krendel
H. Krutter
Y. H. Ku
J. W. Leas
A. H. Lind
E. Lohse
R. C. Machler
J. Marsten
R. Mayer
W. McAdam
L. D. McConnell
V. R. Monshaw
S. B. Morehouse, PE
J. T. Nessmith, Jr.
V. L. Newhouse
A. Noordergraaf
E. C. Okress
M. Ouyang
J. D. Palmer
D. J. Parker
W. T. Patton
V. E. Phillips
N. S. Prywes
L. R. Quarles
H. H. Race
J. M. Reed
E. G. Ramberg
F. X. Rettenmeyer
L. Riebman
C. W. Ross
M. Rubinoff
O. M. Salati
H. N. Schneider
W. R. Schofield
A. C. Schroeder
H. P. Schwan
W. M. Scott, Jr.
AB Shafritz
W. C. Shen
S. M. Sherman
E. B. Shew
R. B. Shores
R. M. Showers
D. B. Smith
T. A. Smith
I. Somos
L. M. Spandorfer
R. C. Spencer
W. O. Stadlin
R. A. Stampfl
B. D. Steinberg
H. E. Strang
N. Swerdlow
J. C. Tellier
C. H. Titus
K. Tomiyasu
I. Travis
H. Urkowitz
J. Vollmer
S. R. Warren, Jr.
H. R. Wege
W. Weinstock
C. N. Weygandt
W. C. Wiley
W. R. Wilson
O. H. Winn
M. Wolf
H. O. Wood
S. Zebrowitz

Awards

EDISON MEDAL

Nathan Cohn	1982
Herman P. Schwan	1983

FOUNDERS MEDAL

John G. Brainerd	1975

LAMME MEDAL

Nathan Cohn	1968
Y. H. Ku	1972

CHARLES PROTEUS STEINMETZ AWARD

Ralph M. Showers	1982

EMANUEL R. PIORE AWARD

John W. Mauchly	1978
J. Presper Eckert	1978

HARRY DIAMOND MEMORIAL AWARD

Rudolf A. Stampfl	1967

WILLIAM M. HABIRSHAW AWARD

Wilfred F. Skeats	1965 (deceased)

DAVID SARNOFF AWARD

Edward G. Ramberg	1972

IN THE BEGINNING

A Capsule History of the IEEE

the Institute of Electrical and Electronics Engineers ill be celebrating an important milestone — its hundredth ary. As the centennial approaches, the institute's mem- look back on a century of outstanding progress and ments and can count as colleagues, past and present, the f electrical technology. Thanks to the contributions of d others, contemporary society is, in part, the product of engineering. Indeed, the history of the IEEE and its ssors, the American Institute of Electrical Engineers nd the Institute of Radio Engineers (IRE), is part of the the impact of electrical science and technology on the of the twentieth century.

E was born during a period of optimism and enthusiasm. applications for electricity were rapidly increasing, prog- ectrical theory and practice was accelerating, and scien- electricians, as well as entrepreneurs and investors, saw ter growth ahead. With such growth, electrical technol- becoming more complex and practitioners began to feel for a national forum to exchange ideas and experiences rganization to define a new profession.

ring of 1884, a call was issued for a meeting to form a lectrical society and, after some preliminary gatherings, an Institute of Electrical Engineers was established in City on May 13. Impetus had been given to the new on by the planning for an International Electrical Exhibi- held by the Franklin Institute in Philadelphia later that he AIEE quickly gained recognition as a spokesman for electrical engineers.

beginning, wire communications and light and power were the major interests of the AIEE. An early and active t in the development of standards for the electrical in- e institute laid the foundations for all work on electrical done in the United States. During the first three dec- s existence, the AIEE confronted and resolved such oncerns as locating permanent headquarters for the or- ; providing mechanisms for contact with a far-flung hip and with students; and fostering new technical inter- gh committees that were established to meet the chal- ncreasing specialization.

however, the interests and needs of those specializing anding field of radio could no longer be satisfied by a committee meeting two or three times a year. In that large local radio organizations — The Society of Wireless Telegraph Engineers and the Wireless Institute — merged to form a national society for scientists and engineers involved in the development of wireless communications — the Institute of Radio Engineers. Many of the original members of the IRE were members of the AIEE and both organizations continued to have members in common until they merged to form the IEEE in 1963.

The structural development and general activities of the IRE were similar to those of the AIEE. Specialized segments were gathered into professional groups under a central governing body; geographical units and student branches were formed; the creation of extensive literature and the exchange of knowledge was facilitated through meetings and publications; membership grades were established and standards became a major concern.

The nature of radio technology meant that the interests of the IRE went beyond national boundaries. Therefore, the new organization sought and attracted members from many countries and eventually established units in several areas throughout the world.

In the 1930's, the word "electronics" became part of the vocabulary of electrical engineering. Electronics engineers tended to become members of the IRE, but the applications of electron tube technology became so extensive that the technical boundaries differentiating the IRE and the AIEE became difficult to distinguish. After World War II, the two organizations became increasingly competitive. Problems of overlap and duplication of efforts arose, only partially resolved by joint committees and meetings.

Finally, in 1961, the leadership of both the IRE and the AIEE resolved to seek an end to these difficulties through consolidation. The next year a merger plan was formulated and approved and became effective on January 1, 1963. Plans were made for melding the technical activities and geographical units of the two socieities and for establishing a unified publications program for the new organization, the Institute of Electrical and Electronics Engineers.

Almost two decades have passed since the formation of the IEEE. Today the Institute is the largest professional association in the world, with over 200,000 members, and its activities now extend far more widely that its forebears could ever have forseen. It remains, however, just as almost a century ago, the premier spokesman for the most significant and exciting technological field of its time.

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In 1984, the Institute of Electrical and Electronics Engineers (IEEE) will be celebrating an important milestone — its hundredth anniversary. As the centennial approaches, the institute's members can look back on a century of outstanding progress and achievements and can count as colleagues, past and present, the giants of electrical technology. Thanks to the contributions of these and others, contemporary society is, in part, the product of electrical engineering. Indeed, the history of the IEEE and its predecessors, the American Institute of Electrical Engineers (AIEE) and the Institute of Radio Engineers (IRE), is part of the record of the impact of electrical science and technology on the shaping of the twentieth century.

The AIEE was born during a period of optimism and enthusiasm. By 1884, applications for electricity were rapidly increasing, progress in electrical theory and practice was accelerating, and scientists and electricians, as well as entrepreneurs and investors, saw only greater growth ahead. With such growth, electrical technology was becoming more complex and practitioners began to feel the need for a national forum to exchange ideas and experiences and an organization to define a new profession.

In the Spring of 1884, a call was issued for a meeting to form a national electrical society and, after some preliminary gatherings, the American Institute of Electrical Engineers was established in New York City on May 13. Impetus had been given to the new organization by the planning for an International Electrical Exhibition to be held by the Franklin Institute in Philadelphia later that year and the AIEE quickly gained recognition as a spokesman for American electrical engineers.

From the beginning, wire communications and light and power systems were the major interests of the AIEE. An early and active participant in the development of standards for the electrical industry, the institute laid the foundations for all work on electrical standards done in the United States. During the first three decades of its existence, the AIEE confronted and resolved such internal concerns as locating permanent headquarters for the organization; providing mechanisms for contact with a far-flung membership and with students; and fostering new technical interests through committees that were established to meet the challenge of increasing specialization.

By 1912, however, the interests and needs of those specializing in the expanding field of radio could no longer be satisfied by a technical committee meeting two or three times a year. In that year, two large local radio organizations — The Society of Wireless Telegraph Engineers and the Wireless Institute — merged to form a national society for scientists and engineers involved in the development of wireless communications — the Institute of Radio Engineers. Many of the original members of the IRE were members of the AIEE and both organizations continued to have members in common until they merged to form the IEEE in 1963.

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The Franklin Institute and the Electric Arts

B. Singer and J. M. Gibson

The Franklin Institute, founded in 1824 "for the promotion of the mechanic arts," has long been associated with both practical technical matters and the associated theoretical sciences. In the electrical arts, the Institute's activities occupied the full spectrum of its tradition: articles in the Journal of the Franklin Institute, classes for artisans and mechanics, lectures and demonstrations for members and the general public, and, most dramatically, the International Electrical Exhibition of 1884.

These activities began early in the history of the Institute (the first Journal item on an electrical topic appeared in 1827) and became increasingly important throughout the nineteenth century. Samuel Morse came to the Institute in 1838, accompanied by Theodore Vail, to demonstrate the new electrical telegraph to the Committee on Science and the Arts. Public response to electrical devices at the 1876 Centennial Exhibition stimulated the Franklin Institute to add a course in electricity to its regular lecture series. In 1877,the Institute tested a number of dynamos for efficiency and practicality. By 1882, interest at the Institute had developed enough to justify a separate Electrical Section. In 1883, responding to the overwhelming success of European exhibitions devoted to electricity and the rapid advances in electrical technology, the Franklin Institute proposed to hold an International Electrical Exhibition, the first in America.

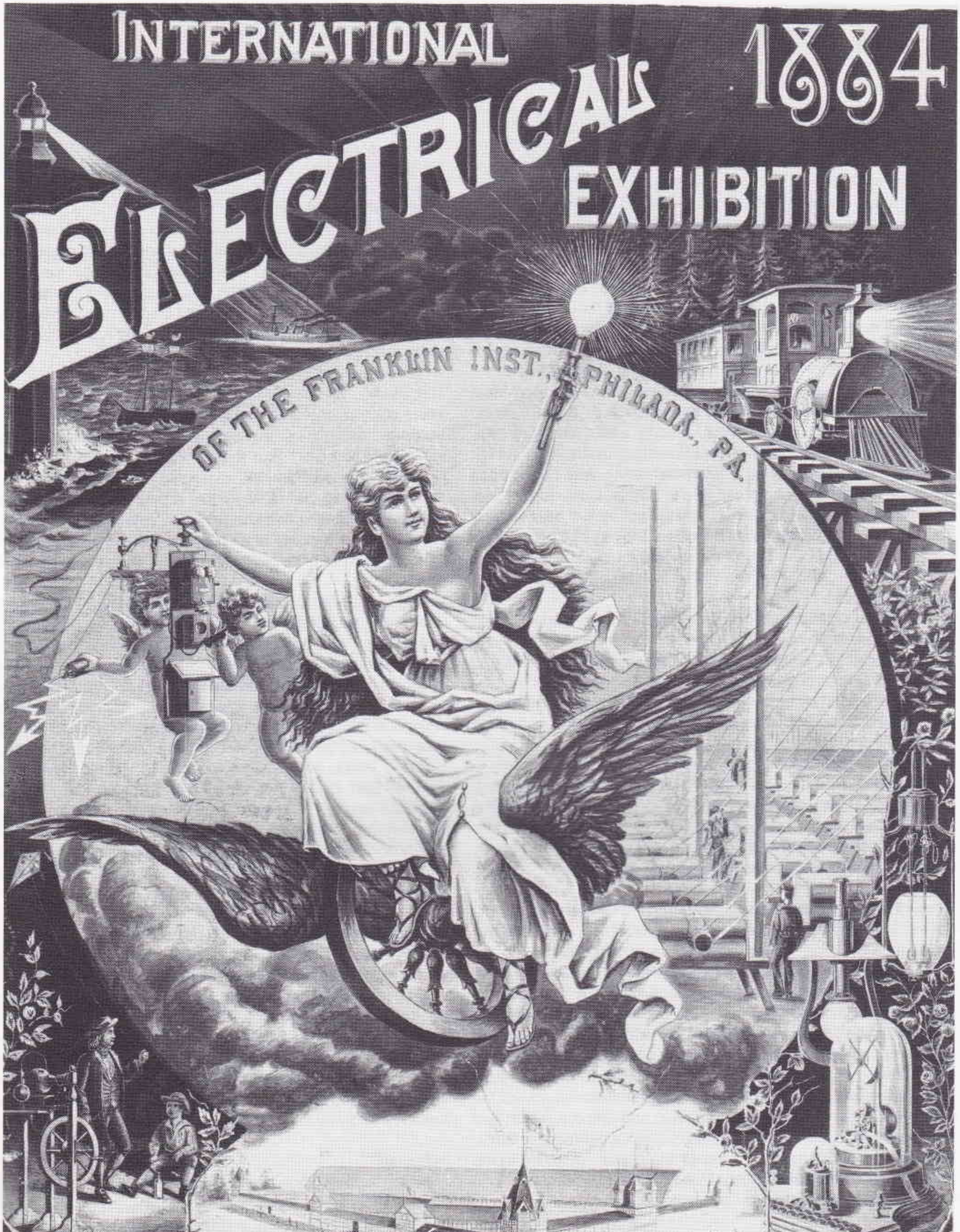
Exhibitions were the great nineteenth century means of promoting the latest inventions and manufacturers and were an important means of communication between practicing inventors. Americans had displayed their wares primarily in their own country (at the Frankl1in Institute alone, over 30 exhibitions were held between 1824 and 1884) until the great 1851 exhibition in the Crystal Palace in London. There for the first time Europeans in great numbers had the opportunity to evaluate the best American products, which compared very favorably with those of Europe. Some electrical devices and curiosities were included in the 1851 Crystal Palace Exhibition, with a larger number among the attractions of the American Centennial Exhibition in 1876. It was not until the 1880s that specialized exhibitions were devoted to electrical matters. The United States was well represented at the Electrical Exhibitions in Paris (1881), Munich (1882), and Vienna (1883), with displays by the electric companies of Edison, Weston, Thomson & Houston, Bell, Farmer and Brush. These Electrical Exhibitions promoted national pride as well as electrical science and technology. Supported by the governments of the respective countries, they were housed and designed to entertain the general public while introducing the latest in practical, luxurious, and simply playful or mysterious electrical contrivances.

National and professional pride motivated the proposal for an International Electrical Exhibition to be held in America; democratic traditions suggested private, rather than government, sponsorship. As the preeminent technologic center in America, the Franklin Institute saw its clear duty. In February 1883, the Institute's Board of Managers began to make definite plans. A site was selected, Congressional approval was obtained for foreign exhibits to enter the country duty-free, and a list of classifications was drawn up which the periodical Electrical World termed a "perfect nomenclatory survey of the whole field of electrical science." An Electrical Congress was also planned, for "scientific men interested in the various departments of pure and applied science." Mindful of its special missions, the Institute also requested historical exhibits, established a Memorial Library collection on electrical subjects, and arranged for special public lectures. For school children, the Institute commissioned Edwin Houston to write a primer on electricity and offered five-dollar gold pieces as prizes for the best essays on "What I saw at the Electrical Exhibition." In the course of the exhibition, competitive testing of dynamos and incandescent lamps was requested by some manufacturers, and was undertaken by the Franklin Institute as a fitting addition to its scientific activities. Reports of the exhibits, and of the subsequent lamp and dynamo testing, appeared as supplements to the Journal over eighteen months from January 1885 to May 1886.

The Exhibits

The Exhibition opened on September 2, 1884, closing as scheduled six weeks later on October 11. Exhibits covered the entire range of subject areas, from production of electricity through measurements, applications, and terrestrial physics. The historical material included over 200 patent models, Morse's first telegraph instrument, apparatus used by Joseph Henry, and artifacts attributed to Benjamin Franklin. Surely the 1884 Exhibition was as exciting and as stimulating to the imagination as the Centennial had been.

Response to the call for exhibits was particularly enthusiastic from the electric lighting companies, which provided free interior and exterior illumination for the exhibition buildings in addition to their formal exhibits. The Brush Electric Company mounted full-sized interiors of a drawing room, a bedroom, an office and a millroom, all lighted by Swan incandescent lights powered by a Brush dynamo. The Thomson-Houston Electric Company's exhibit included a well-organized display illustrating electrical principles, complete with miniature working models of dynamos and arc and incandescent lamps. Another miniature display, this one a waterfall with an


INTERNATIONAL
ELECTRICAL
1884
EXHIBITION
OF THE FRANKLIN INST., PHILADA, PA.
TO OPEN TUE. SEPT. 2nd 1884.
TO CLOSE SAT. OCT. 11th 1884.

electric motor used to recycle the water, was presented by Edward Weston. More significant for the future of electrical engineering was Weston's presentation of scientific instruments for electrical measurement. These and later Weston instruments provided an ever-increasing level of accuracy, essential to all phases of electrical design.

The showmanship and prolific inventive genius of Thomas Edison, represented by six Edison companies, was the basis of the largest, most varied, and most spectacular of the exhibits. Outside the exhibit hall, white and colored incandescent lamps formed a dazzling star atop the southeast tower. Inside, a complete central station and an isolated lighting plant (designed to serve a single building) were in full operation. A puzzling lamp demonstrating what came to be known as the "Edison effect" foreshadowed today's electronics industry. Listed simply as "Apparatus showing conductivity of continuous currents through high vacuum", the tri-polar lamp demonstrated the flow of electrons across a vacuum tube from cathode to anode. Considering electricity to be a sort of fluid, and lacking the concept of the electron, the examiners and other scientific men of the day had no theoretical basis for explaining this phenomenon.

The Conference

The National Conference of Electricians was convened at the Institute from September 8-13. Officially conducted by the United States Electrical Commission (appointed by the President and comprised almost entirely of "pure" scientists), the Conference was well attended by both American and foreign participants and gave scientists and practical electricians a chance to communicate with each other on a wide range of topics. Henry Rowland, President of the Commission, opened the conference with a speech reiterating views he had presented to the American Association for the Advancement of Science in 1883, emphasizing the subordinate role of applied science. Elihu Thomson and Edwin Houston, both of whom had training in practical as well as purely scientific matters, strenuously challenged this view.

Although irreconcilable differences remained between the practical electricians and the scientists on the question of the relative importance of theory and practice, there was agreement on the need for standards of electrical measurement. Sir William Thomson, Vice President of the Commission and later Lord Kelvin, spoke on the importance of accurate standards to both groups. Monroe Snyder, chairman of the examiners of electrical technology at the 1884 Exhibition, also gave an address on the topic and called for the establishment of a National Bureau of Standards. The Conference voted to authorize the Commission to accept the international standards for the ohm, volt, and ampere, which had been referred to them by the United States Department of State. Later Electrical Congresses pursued the matter, resulting in the establishment of the International Electrotechnical Commission in 1904 as the accepted arbiter of electrical standards.

The men who founded the American Institute of Electrical Engineers in the spring of 1884 may have anticipated the tension between scientists and engineers and may have been concerned that the "practical men" would be placed at considerable disadvantage without a national organization that would be the equivalent of the older scientific societies. The exhibition and Conference clearly stimulated the founding of the AIEE, with N.S. Keith's appeal in April 1884 for an organization of electrical engineers to receive foreign "electrical savants, engineers and manufacturers" in Philadelphia. After the Philadelphia Conference, the AIEE held meetings in October, at which technical papers were presented and discussed. These were the first steps in the professionalization of electrical engineering in America, the foundation on which today's IEEE continues to build.

The Tests

Tests of dynamos and lamps followed the exhibition, and were accomplished in the spring of 1885, after many unforeseen problems. Both the tests and the testing equipment had to be designed. The exhibition hall was cleared so that controlled tests could take place, but other factors remained which rendered the testing inconclusive and controversial. The large data base generated by the testing, however, was valuable to the electrical industry in further development of both lamps and dynamos.

Results of the lamp testing were confused both by the lack of universally accepted criteria for evaluation and by the fact that some lamps were tested without the consent of the manufacturers. Testing included "efficiency" with respect to the amount and quality of light, but not the amount of electricity required. The cost of electricity, although an important commercial consideration, was not a factor in the Institute's competition. Lamp life was also measured, but without reference to the amount of light produced: Edison's lamps, which were the longest lasting became much dimmer than their "guaranteed" candlepower long before the 600-hour mark. The results were challenged by Woodhouse & Rawson in England, who had declined to enter the competition and now saw their lamps disparaged. The international controversy which ensued was detrimental to the Institute's reputation, and a far cry from the original intention of the Committee.

Dynamo testing showed little difference between the Weston and Edison machines tested, with no clear-cut winner. The tests had been designed to show the efficiency of each machine under varying loads, and required protracted runs of each machine under the specified conditions with observations made of the potential at the terminals of the machine, the currents in the external circuit and field, and the resistance of the armature. Again questions were raised about the measurements and methods used: the Institute and the instrument makers successfully defended the methods and results in the pages of Electrical World.

Epilogue

Although the exhibition itself was brief with some unresolved tensions and equipment testing problems, the whole affair did further many aspects of electrical engineering: education, professionalization, standardization and measurements, recognition of technological achievement, and state of the art advancement.

The Franklin Institute continued to be active in the electrical arts, although it held no more Electrical Exhibitions. Journal articles on electrical subjects appeared in increasing numbers, the Electrical Section met regularly until the early 20th century, and a number of the public lectures dealt with electricity and related fields. Original research at the Institute languished between the 1880s and the 1920s, due to the rise of university and industrial research centers. This situation changed in 1918 with the bequest of approximately a million dollars from Barnabas H. Bartol to establish a laboratory "for the conduct of researches in the physical sciences and for the investigation of problems of a scientific nature arising in the industries." Work at the Bartol Foundation began in 1925 and concentrated on the investigation of atomic structure and cosmic radiation. During World War II the studies of nuclear and particle physics investigations into solid-state electronic phenomena, and electric discharges in gases were intensified. In 1934 the Institute opened its Science Museum which included a Hall of Electricity that continues to stimulate the minds of young people and adults.

COMMUNICATIONS/ENTERTAINMENT AND BROADCAST

Emile Berliner, Eldridge Johnson, and the Victor Talking Machine Company

Edgar Hutto, Jr.
RCA Corporation, Camden, NJ

Emile Berliner, working in Washington in 1877, sold a telephone invention to Alexander Graham Bell for $75,000 and remained on a $5,000 yearly retainer fee. This invention and the continuous-current transformer brought the German-born Berliner professional prestige and provided him with financial security to pursue an alternate approach to the phonograph. Berliner investigated etching sound as a horizontal pattern on a metal disc. The disc was coated with an acid-resistant material. During recording, the vibrating diaphragm caused the stylus to remove the acid-resistant material from the sound trace on the disc. After an acid-etching process, the disc was used as a master to make stampers for the production of duplicate records in a soft material that hardened when cooled.

Berliner discs provided several advantages over cylinders: ease of duplication; a groove which guided the sound box, eliminating the need for a propelling mechanism; hard groove walls which provided louder reproduction and longer wear; and ease in storage and shipment. However, the process produced extraneous noise. The walls of the grooves were rough due to the etching procedure. Berliner named his hand-propelled reproducing instrument the "Gramophone" and demonstrated it to the Franklin Institute in Philadelphia in May, 1888. A German toymaker was licensed to make miniature Gramophones in 1889. It was not until 1893, after a satisfactory method of producing a stamping matrix for hard rubber records, that Berliner felt he could offer the Gramophone for sale. The United States Gramophone Company was organized by Berliner with the help of friends and relatives.

In the fall of 1895 a group of Philadelphians headed by Thomas S. Parvin provided $25,000 to set up the Berliner Gramophone Company of Philadelphia as a manufacturing unit. Parvin became the president of the company with Berliner a minority stockholder. Berliner's basic disc phonograph patents were held by the U.S. Gramophone Company. The Berliner Gramophone Company's operations were at 1026 Filbert Street and 424 South 10th Street in Philadelphia. The latter was the recording studio but the complex processing of matrices was done by Berliner's Washington facility.

The hand-propelled Gramophone could not maintain constant pitch during playback. Sales were poor and by February, 1896, it was realized that the instrument would have to adopt a spring-wound motor similar to that used by cylinder machines. A design for a clockwork motor originally intended for sewing machines was submitted to the machine shop operator Eldridge R. Johnson of Camden, New Jersey, for the construction of a model. The design proved impractical and was turned down by Berliner. Johnson was attracted by the Gramophone just the same. He later wrote, "It sounded like a partially educated parrot with a sore throat and a cold in the head, but that instrument caught my attention and held it fast and hard. I became interested in it as I had never been interested in anything before." Johnson turned from his wire-stitching machine business and borrowed sufficient capital to develop a satisfactory spring motor for the Gramophone. It operated at uniform speed, could be regulated, was quiet in operation, and was inexpensive to make and easy to use. It has been estimated that between 1896 and 1900 a little less than 25,000 motors were made. From 1896 to the summer of 1898, Johnson made motors, sound boxes, and metal parts, and delivered completed instruments to Berliner Gramophone.

In August, 1900, Leon F. Douglas, who had grossed $3,000 with an Edison Exhibition Model at Chicago in 1878, joined with Johnson and they formed the Consolidated Talking Machine Company. The first recording, listed as number A-1 in Johnson's matrix log, was a recitation by George Broderick of Eugene Field's poem "Departure". It was recorded at the 10th Street studio in Philadelphia in May, 1900. The new Johnson recording process was used for making the record matrices and an improved Gramophone was introduced. The "His Master's Voice" painting of Nipper by Francis Barrat, which had been purchased by the Gramophone Company Ltd. in England and copyrighted in the U.S. by Emile Berliner, was used in Consolidated's catalog and advertising. Nipper and the improved Gramophone were to become one of the most widely used and recognized trademarks in the world.

Johnson introduced paper record labels which replaced the indented legends on Berliner and Zonophone discs. Later, in 1900, the company name was changed to Eldridge Johnson Manufacturing Machinist and in December the trade name "Victor" was introduced for instruments and 7-inch (177.8 mm) records

His Master's Voice

By the fall of 1901, Johnson's disc records had made serious inroads on wax cylinders, which had been recognized by the trade and the public as the standard of quality. Discs were being sold through bicycle and other small shops, while the cylinders were sold by music stores. This changed when Wurlitzer, Grinnell, Lyon and Healy, and Sherman Clay, all large and influential music houses, accepted the Victor machines and records.

When the Berliner Gramophone Company could not pay $350,000 for Johnson's interest, an agreement was reached to pool Berliner's and Johnson's patents and trademarks and Berliner's manufacturing facilities and form a new company to be known as the Victor Talking Machine Company. It was incorporated October 3, 1901, and organized October 5th with Eldridge Johnson, President; Leon F. Douglas, Vice President and General Manager; Thomas S. Parvin, Treasurer; A.C. Middleton, Secretary; and Horace Pettit, General Counsel.

Instruments were assembled in the four-story factory at 120 N. Front St., Camden, using purchased cabinets. The recording laboratory remained at Berliner's 10th and Lombard location in Philadelphia. Records were pressed by the Duranoid Company until the Camden operation at 23 Market St. was begun in 1902. An agreement was made with Gramophone Company, Ltd., to purchase up to 50 percent of Victor's instrument output. The Gramophone Company would sell in the British Empire, excepting Canada and continental Europe. Victor would market in the rest of the world, with Berliner Gramophone of Montreal selling in Canada.

The Victor record catalog, in common with Edison and Columbia, consisted mostly of military bands such as Sousa's, banjo soloists like Vess L. Ossman, recitations, and comic songs. There was no classical music or artist of any stature. In Europe the situation was developing differently. The manager of one of Gramophone's shops in St. Petersburg, Russia, suggested that leading singers of the Imperial Opera be recorded and sold as deluxe, more costly editions with special red labels. Fedor Chaliapin made the first Red Label records and their success in Russia led the office in London to produce an extensive celebrity series. Gaisberg and Owen of the then Gramophone and Typewriter Company went to Italy in March, 1902, and heard at LaScala the new sensational tenor Enrico Caruso. He had previously made recordings for the Anglo-Italian Commerce Company and Zonophone but agreed to record for Gaisberg. The ten records made in Milan with Johnson's improved recording process on April 11, 1902, were an artistic and commercial success. They were regarded as the first completely satisfactory Gramophone records yet made.

The first Victor red label, or Red Seal records, were released in May, 1903. The records were from imported Gramophone Company matrices, including seven of the Caruso Milan recordings. There were also records by Calve, Plancon, and Renaud. The first domestic Red Seal recording was made in Room 826 at Carnegie Hall on April 30, 1903. The artist was an Australian contralto, Ada Crossley. Subsequent Red Seal artists recorded at Carnegie Hall were Louise Homer, Johanna Gadski, and Antonio Scotti. Caruso had made his Metropolitan debut in November, 1903. He was signed to an exclusive contract by Victor. Caruso's voice complemented the acoustic recording and playback processes. Caruso and the talking machine each contributed to the others' fame and success. Caruso's first American recordings were made in Room 826 on February 1, 1904.

1906 saw the introduction of the enclosed horn talking machine. Although a form of the enclosed horn had appeared in Germany, Johnson desired a fine piece of furniture which would be accepted like a piano in living rooms and parlors where there was objection to the exposed horn. The new instrument was named "Victrola", and sold for $200. It was an immediate success. The matrix and shipping departments were moved from Philadelphia to Camden and the Victor cabinet factory was constructed along with a new building for executive offices and the recording laboratory. The first large Dennison Recording Machine was installed in the new laboratory and in January, 1908, a similar machine was installed in the New York recording studio, now located at 234 Fifth Avenue.

Victor's artist roster during the period of 1910-1913 included George M. Cohan and Al Jolson. Dance records were much in demand. Early in 1916 Calvin Child was appointed head of Victor's artist department and Joseph Pasternack became musical director later in the year. Joseph C. Smith was also engaged and the Smith Dance Orchestra was Victor's leading dance orchestra until 1920. In October, 1916, Amelita Galli-Curci's first recordings were made. In January, 1917, the New York recording studio was moved to West 38th Street, and in February Charles Sooy successfully recorded the Original Dixieland Jazz Band after an initial recording had been shelved by Columbia. The recording of "Livery Stable Blues" and "Dixieland Jazz Band One-Step" became a big seller and influenced a new generation of musicians.

The entry of the United States into World War I in April, 1917, had a great impact on the company; however, some notable firsts in recordings were made during that year. Under the direction of Joseph Pasternack, symphony orchestra recordings were made using 51 musicians. It was necessary to use the auditorium on the 8th floor of the Executive Building in Camden to accommodate the orchestra. Based upon the successful recording of the Victor Symphony Orchestra, the initial recordings by the Boston Symphony under the direction of Karl Much and the Philadelphia Orchestra under Leopold Stokowski were made in October, 1917. In November, Victor made Jascha Heifetz's first recordings. In order to accommodate large orchestras, the company purchased the Trinity Baptist Church building located three blocks from the main plant. The new studio gained renown because of its pipe organ and fine acoustics.

The phonograph industry had introduced little basic technological innovation to improve its product. Victor had not completely ignored the possibility of electrical recording but its effort were hardly up to the challenge. James Owens and Albertis Hewitt ducted electrical recording experiments in 1913. Hewitt's diary ws that he used an electromagnetic recording head for mak- recordings from radio and microphone sources. His approach s strictly trial and error.

tor had been cool to an offer made early in 1924 by Bell Labo- ories to demonstrate Maxfield and Harrison's achievement in ctrical recording and improved acoustical playback equipment. December an arrangement was made for a demonstration in nden for the entire technical staff. Both Victor and Columbia ained rights for electrical recording and the re-entrant horn ustical playback system.

xfield was in Camden in late January, 1925, working with Ray- nd Sooy in making arrangements for the new recording equip- nt, which was delivered on February 2. The first experimental ording was made a week later. Olga Samaroff and Alfred Cor- were among the first artists to make Red Seal electrical rec- ings, beginning on March 11. The first popular artist electrical ording was made on March 16 by the Mask and Wig Club Male artet and Orchestra. Victor called the new process "Ortho- nic Recording". A number of the new recordings, including arch Slav" by the Philadelphia Orchestra, were chosen for nonstration of the Credenza Orthophonic Victrola, a hand- und acoustic talking machine with re-entrant horn. Manage- nt ordered 10,000 instruments to be built. This model sold for 0 and was the primary demonstration machine. A total of 19 er models were introduced in 1925 to be followed by 24 more 1926. Victor had signed with RCA for radio chassis and electri- playback apparatus. One of the most elaborate models, dubbed the "Orthophonic Victrola — Orthophonic Electrola and Radiola", could play records acoustically or electrically, contained an eight-tube superheterodyne radio, and had a list price of $1,000. The new instruments and recordings received wide public acceptance.

In June of 1926, the Philadelphia Orchestra made its first recording at the Academy of Music. During the next few years, the orchestra under Stokowski set a world standard for recorded sound.

In December, 1926, it was announced that Eldridge Johnson was selling his interest in the Victor Talking Machine Company to a group of bankers, Speyer and Company, and J. & W. Seligman of New York. Eldridge Johnson's inventiveness and business sense had developed the wheezy instrument and noisy discs of the 1890s into a product line that resulted in the production of nearly 8 million instruments and more than one-half billion records.

On March 15, 1929, the Victor Talking Machine Company was acquired by the Radio Corporation of America as a manufacturing facility.

The Victor Talking Machine Company in slightly less than thirty years made a major impact upon home entertainment through the sale of nearly $700 million in instruments and records. It had spent $52 million for advertising, provided good jobs for 10,000 workers and at least thirty individuals received investment returns of over $1 million. The merger with RCA enabled Victor records to weather the lean depression years better than any other recording company.

RCA
An Historical Perspective

The Years to 1938 — J. C. Warner

Branching out from telecommunications, RCA quickly diversified into broadcasting, radio receivers, and phonographs — manufacturing and merchandising many of its own products.

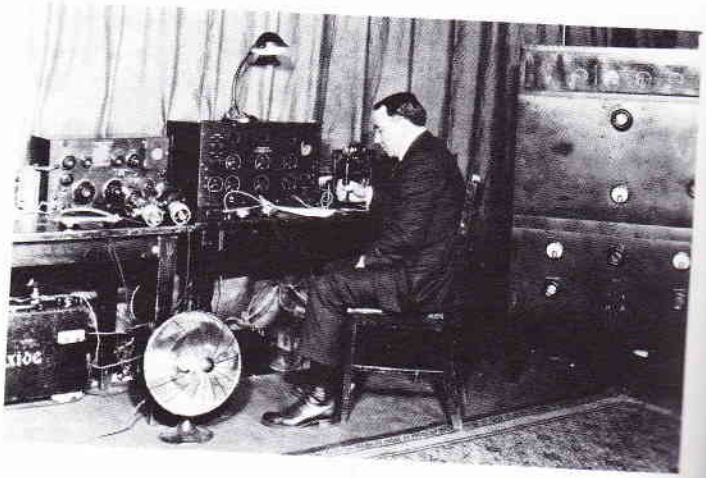
It has often been said that the story of the Radio Corporation of America outlines the larger story of the radio era, i.e. the era of radio broadcasting. Peculiarly enough the company was not organized with radio broadcasting in mind, although it is significant that the man whose name is so closely associated with the history of RCA and who for many years was its active head, Mr. David Sarnoff, had clearly visualized the possibilities of radio broadcasting service and even "electric tuning" long before broadcasting made its first appearance.

During the first year of RCA (1919-1920), attention was directed almost exclusively on communications, but in 1921 the first rumblings of what soon was to become a broadcasting boom began o be heard. A number of experimenters had been playing with the dea of transmitting phonograph music over somewhat crude telehone transmitters.

CA first entered this field on July 2, 1921, when a one-day roadcast was made from a temporary station at Hoboken, N.J., n the occasion of the Dempsey-Carpentier fight. Soon after, CA opened station WDY at Roselle Park, N.J., which continued r some months, when it was later shut down due to interference th station WJZ of the Westinghouse Company in nearby New-k. RCA then went in as half-partner with Westinghouse in the anagement of WJZ. Broadcasting was really on its way.

st prior to the start of broadcasting, RCA had given thought to nishing radio amateurs reception and transmission apparatus. e line of amateur apparatus was expanded as quickly as possi- to include home broadcast receiving equipment and RCA now ered the merchandising field with GE and Westinghouse as nufacturers.

years 1923 through 1925 brought numerous ad-ces. In 1923 two broadcasting stations were opened by RCA ew York and one in Washington. In 1925 the first WJZ trans-er was installed at Bound Brook, N.J. Short-waves came into for long-distance communications, first to supplement the -power long-wave transmitters and later to take over almost f the long-distance service. Transoceanic communications extended to additional European and South American coun- The first superheterodyne receiver was brought out in 1924.



RCA's first broadcasting studio, station WDY, in Roselle Park, N.J.

Radiola 17, the first ac radio.

1925 a receiver was sold with accessories permitting it to be perated from alternating current. In the same year the electrody-amic loudspeaker debuted. Apparatus was developed for elec-cally recording and reproducing records and improvements ere made in tubes greatly reducing the power consumption.

1925, RCA furnished certain components to the Victor Talking achine Company which were built into a radio-phonograph mbination employing a single speaker.

1924 AT&T was actively developing the use of wire lines for rnishing programs to broadcast stations and eventually set up EAF as the source of these programs. In 1926 RCA and its sociates integrated a complete broadcasting service and rmed the National Broadcasting Company. This was a recogni-n by RCA officials that this new service had the possibilities of important industry and that a specialized organization was cessary to develop programs, install new stations and maintain tisfactory continuous broadcasting.

e Victor Talking Machine Company at Camden had been seri-sly affected by the growth of radio and had not been particularly ccessful in its attempts to enter the radio field. In order to obtain nufacturing facilities, RCA purchased the Victor Company, in-ding the manufacturing plant, the phonograph business, and Victor dog trademark. RCA also took over tube manufacturing m GE and Westinghouse and acquired the entire Edison mps Works property of GE at Harrison and the Westinghouse tory at Indianapolis, thereby creating the RCA Victor Company d the RCA Radiotron Company.

1929, the RCA Communications Company was formed to take er all of the business in transoceanic communications.

e new broadcast company acquired station WEAF from the T&T and also took over the stations owned by RCA and thereby eated the real beginning of the network broadcasting industry.

1930 RCA completed the consolidation in the RCA Victor and adiotron companies of all facilities of research, engineering, anufacturing, and sales of RCA products which included phono-aphs and records. In 1932, the Photophone business was taken er by the RCA Victor Company. (The RCA Photophone Com-ny had been organized in 1928 to supply the motion picture ustries with a system for recording sound on film.)

e final step toward an independent RCA took place in 1932. In 30 the government brought suit against RCA concerning cer-n exclusive features of the inter-company agreements. As the sult of a consent decree, all the stock interest of GE and West-house in RCA was disposed of by those companies. RCA was w a self-contained organization with wholly owned subsidiary mpanies operating a broadcasting business, communications business, marine radio business, a radio school, and a manufacturing and merchandising business.

In 1934 the tube business was augmented by the purchase of certain patents from the De Forest Radio Company. This brought about the beginning of transmitting tube manufacturing by RCA Radiotron.

In 1935, the manufacturing and merchandising business was further consolidated by the merger of the RCA Radiotron and RCA Victor Companies into the RCA Manufacturing Co.

The years 1938-1958 — E.W. Engstrom

In 1938, RCA was in transition from a radio communications concern to a broadly diversified electronics organization with a growing interest in such new fields as radar, television, and airborne electronics.

In April 1939, seven years of intensive research, engineering development and field testing by RCA culminated in the introduction, at the New York World's Fair, of the first public television service.

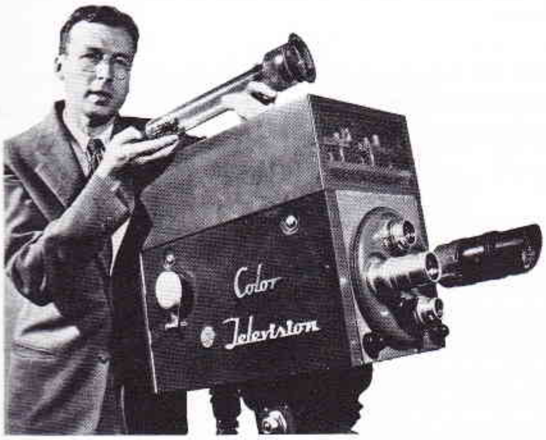
The official inauguration of television service was the harbinger of a new era in mass communications, but it required a keen eye to see in the actual event the shape of the nationwide television service we know today. It was an extremely limited service, covering only the New York metropolitan area, and operating on the "experimental" basis authorized by the Federal Communications Commission. Programs emanating from the NBC transmitter atop the Empire State Building were viewed on a relative handful of 9-inch direct view and 12-inch reflection-type receivers produced at Camden, NJ, for sale in the New York area.

Standing before the iconoscope cameras in front of the RCA Building at the World's Fair on April 20, David Sarnoff announced the beginning of regular television service by NBC. And he added:

> "Now we add sight to sound. It is with a feeling of humbleness that I come to this moment of announcing the birth in this country of a new art so important in its implications that it is bound to affect all society...This miricle of engineering skill which one day will bring the world to the home, also brings a new American industry to serve man's material welfare..."

As the commercial television system expanded, RCA undertook an energetic postwar program of color television research and development. Although mechanical techniques offered promise in terms of early commercial advantage, RCA decided, soon after the war, to strive for an all-electronic color system fully compatible with black-and-white. Outstanding progress was achieved at RCA Laboratories during 1947 and 1948. Several demonstrations were held, showing a color system employing three kinescopes and combined with an optical system to present a composite color picture.

In 1949, the FCC scheduled a series of hearings to consider, among other matters, the establishment of standards for color television transmission. At issue were two competing systems—a noncompatible mechanical system of color and the all- electronic compatible color system advocated by RCA.



As the hearings progressed the research staff of RCA Laboratories, supported by engineering groups at the tube plants at Harrison and Lancaster, PA, moved with full speed to the development of the final basic element in the compatible system—a single tube capable of producing pictures in full color. The result of this extraordinary effort, demonstrated publicly in March, 1950, was the tricolor kinescope, one of the outstanding achievements in early postwar electronics. In the words of General Sarnoff, "Measured in comparison with every major development in radio and television over the past 50 years, this color tube will take its place in the annals of television as a revolutionary and epoch-making device...As the master key to practical color television, it is an outstanding development of our time."

The years 1958-1962 — E.W. Engstrom

The most important development by far to RCA in the years 1958 to 1962 was the emergence of color tv as a new industry and public and public service of massive and mounting proportions.

By 1961, there occurred—finally—the long-awaited color breakthrough. One by one, tv receiver manufacturers abandoned the sidelines and entered the ranks. By the following year, nearly every major tv manufacturer was actively marketing color, and industry volume reached $200 million.

Electronic data processing

In 1958, RCA launched its major venture into the electronic data processing field with the introduction of the RCA 501, a medium-sized commercial business computer and the first fully transistorized system in the industry. By 1960, the Corporation had introduced the compact RCA 301 for medium-size and small businesses, and had announced a coming third entry, the RCA 601, for large enterprises and scientific computation.

In 1959, RCA introduced DaSpan, a computer-to-computer communications system which could span a continent, and gather and coordinate vital data from the many plants of a large industrial enterprise.

The same computer-communications know-how made RCA the supplier to Western Union, the prime contractor of an automatic electronic data switching system for the Air Force Control Logistics Network (ComLogNet) linking 350 bases and stations across the country in the world's most advanced communications systems.

RCA 501 Computer.

Space and defense

On October 4, 1957, the first signals from a man-made object in the skies heralded the dawn of a new era—the Age of Space.

RCA realized that space was preeminently an electronics domain — for tracking, communications, computing and controls. Less than a year later, RCA set up a special division-Astro-Electronic Products-for the development and production of satellites, space-vehicle systems, and associated electronic ground equipment. (That organization is now called the Astro-Electronics Division.)

In December of the same year, the world's first successful satellite radio relay equipment, produced by RCA for the U.S. Army Signal Corps., lofted into orbit aboard an Atlas missile. It broadcast to the world a prerecorded Christmas message from President Eisenhower, and then performed a number of communications experiments never before attempted, looking to a new era in global communications.

The Astro-Electronics Division, Heightstown, N.J., scored a series of achievements.

Among which was a systems development of the first magnitudean integrated ground and space complex for the televised observation of the world's weather via satellites. Between 1960 and 1962, as major elements of the system, RCA developed for the National Aeronautics and Space Administration six Tiros weather observation satellites, all of which were launched and operated with optimum effectiveness. Up to the end of 1962, the Tiros series-ranking as the nation's most successful space venture-provided a total of more than 200,000 televised images of cloud formations and other global weather data for use by weather scientists and forecasters. The average useful life span of the satellites was more than double the operating life called for by the initial design specifications.

Another significant feat was the Relay communications satellite, which after launching in December 1962, experienced initial operating difficulties. These subsequently were overcome, and by early 1963, Relay was transmitting television pictures of remarkable clarity between the United States and Europe, and conducting radio communications with Latin America.

The Astro-Electronics Division has also provided the advanced television equipment for the Ranger lunar probes, television systems and solar-cell power supplies for the second-generation Nimbus weather satellite, and was engaged in the design and construction of the SERT vehicle for the space testing of experimental electric propulsion systems.

Portending still greater growth in years to come, an environmental test facility, most advanced of its kind in the electronics industry, was put into full operation during 1962 at RCA's Space Center, near Princeton, N.J.

The complexities manifested in computer and space electronics are fully matched in the area of defense. From the production of relatively simple hardware for communications, electronics for military purposes has burgeoned into vast and complicated systems—frequently global in scope, integrating multiple techniques and subsystems, and employing the resources of many varied organizations.

In 1958, RCA received one of the largest contracts ever awarded by the Department of Defence, to assume the project management of the Ballistic Missile Early Warning System (BMEWS) to provide advance warning of an enemy missile attack across the polar wastes. As manager of this vast undertaking, it employed 485 large companies and 2415 smaller firms spread over 29 states to get the job done swiftly and efficiently. By the end of 1962, two installations (Ihule, Greenland, and Clear, Alaska) were operative and the third was nearing completion in Yorkshire, England.

The need for virtually instantaneous warning against impending missile attack assumes similar readiness for counterattack. In the past half-decade, RCA contributed significantly to a greatly strengthened defense posture with the development of automatic programmed checkout equipment (APCHE) and launch-control equipment for several series of the Atlas ICBM.

Subsequently, major RCA work on the Minuteman ICBM involved advanced concepts in command-and-control systems, including the sensitive-command and support-information networks, and checkout and test techniques. Especially challenging for both design and production were very high-reliability goals to sophisticated equipment—goals that pushed the state of the art.

By the end of 1962, RCA was deep into such diverse developments and constructions as a flight-control system and checkout for the super-powerful Saturn booster, telemetry equipment for the two-man Gemini space vehicle, miniaturized computers such as Micropac (huilt with micromodules) for military field use, and a variety of communications systems and test apparatus, including a lunar-landing simulator.

The years 1962-1966 — E.W. Engstrom

The years 1962 through 1966 also saw steady advanced in the manufacture of color transmission equipment. A new, all-transistorize tape recorder for both color and black-and-white television, the TR-22, found a ready market among broadcasters and closed-circuit television operators both in the United States and abroad.

By the end of 1966, 450 out of approximately 650 commercial television stations in the country were equipped to originate color programs from film. About 150 stations could originate live color programs.

Computers and industrial electronics

At the end of 1962, the product line consisted largely of the 301 system for medium and small business enterprises and the larger RCA 601 for industrial and scientific use. In 1963, a versatile new unit, the 3301 Realcom, was added to the line as the first computer designed to span the full range of data handling capabilities in a single system—business data processing, high-speed communications, real-time management control, and scientific computation.

In the same year, a significant adjunct to these systems was introduced in the RCA 3488 mass memory, designed to hold several billion characters and to operate with either the 3301 or the 301.

RCA Computer Center, Cherry Hill, N.J.

Progress in circuit design and system concepts led in 1964 to a major step forward. RCA introduced the Spectra 70 series, the first in the industry of a new third generation of computers. The group initially included four compatible general-purpose computers—two of them employing the first monolithic integrated circuits to be used in commercial equipment. A fifth model was added in 1965.

Another significant trend was the growing relationship between computers and communications—bot in the development of computer-to-computer links and in the use of computers to increase the speed and flexibility of communications.

RCA introduced several advanced terminal devices during the 1962-1966 period for communication between computers and users. Among them were a voice response unit that provided spoken replies to inquiries telephoned directly to a computer, and a self-contained video display unit employing integrated circuitry.

Space and military electronics

The most dramatic achievement for RCA in space between 1962 and 1966 occurred in 1964 when NASA's Ranger 7, with a six-camera payload designed and built by RCA's Astro-Electronics Division, reached the mmon and sent back the most detailed photographs ever taken of the lunar surface. This was followed in 1965 with the successful launch of the Ranger 8 and 9 spacecraft, which together obtained and transmitted to earth nearly 13,000 close-up views of the moon.

The Tiros television weather satellite program continued an unbroken series of successes. In 1962, three Tiros satellites, developed by RCA, were placed into orbit, providing television pictures for worldwide weather forecasting.

The following year, two more Tiros satellites were launched, and Relay I, a communications satellite built by RCA for NASA, completed its scheduled year-long mission. Among Relay's achievements were the first space transmission of a color telecast, simultaneous voice relays between the United States and Brazil, and the first trans-Pacific transmission from the United States to Japan.

RCA in 1963 was assigned major roles in the Apollo program, this country's attempt to land astronauts on the moon. The company was selected to develop communications and control systems for the Lunar Excursion Module, which was scheduled to perform the actual landing. In addition, RCA contracted to build the power and communications equipment for the Lunar Orbiter, designed to transmit pictures from an orbit around the moon in search of a suitable landing site. During 1965 and 1966, spacecraft in the Orbiter series returned remarkable pictures of selected areas from altitudes as low as 28 miles above the moon.

The major RCA contributions to the nation's space program in the 1962-1966 period included the picture-taking systems for NASA's experimental Nimbus satellite to map global weather conditions; a second successful Relay communications satellite; three more Tiros weather satellites, and a continuation of the Tiros program under the name of ESSA (Environmental Science Services Administration) which established the first operational weather satellite system.

In other aspects of the space effort, RCA delivered tracking radars for the Apollo Radar Instrumentation Ships and the Apollo Recovery Ships. It provided communications links between NASA headquarters in the United States and various overseas tracking locations, including voice and teletypewriter circuits to tracking vessels at sea, alternate voice/data and teletypewriter circuits to Europe, Africa, the Caribbean, Australia, and several points in the Pacific. RCA computers were developed for test and checkout of the Saturn launch vehicle in the Apollo program.

The years 1966-1971 — J. Hillier

An era came to an end on January 7, 1970, when the Board of Directors accepted the resignation of General David Sarnoff as Chairman of the Board and a Director of RCA. At the same time, the Board elected General Sarnoff the first Honorary Chairman in the Corporation's history. The Board also adopted a resolution of appreciation, which stated, in part, that "more than any other man, David Sarnoff was the architect of RCA's rise to world leadership in electronics."

Computer activities
The Spectra 70/46 was introduced in 1967 and the large-scale Spectra 70/61 two years later to serve the growing market for remote computing systems. These two remote computing systems were the first RCA processors equipped with virtual memory, which means that the main computer memory could be expanded almost limitlessly through a series of auxiliary devices and specially developed software.

SPECTRA 70/61

However, RCA did not concentrate entirely on remote computing. In 1969, the company marketed a large-scale Spectra 70/60 batch processor designed to handle credit and reservations systems, automate production control, and serve data banks. The following year, RCA introduced a new series of small- to medium-class computers—the RCA 2, 3, 6, and 7. Two of these new processors also had virtual memory.

Progress was also made in electronic composition systems. The speed of the RCA Videocomp was increased tenfold in 1968, making it possible to set the text of a novel the size of *War and Peace* in less than an hour. Two later developments further enhanced its capabilities: the ability to set complex line drawings and then position the drawings on a page together with text and the development of a program that enables the system to produce halftone photographs composed of small ideographic characters.

Consumer electronics
Solid-state components were incorporated in RCA color tv sets for the first time in 1968. By the end of 1971, these components replaced tubes, other than the kinescope, in a large number of RCA color sets.

The company also produced Stereo 8 tape decks for car owners in the United States. Four-channel sound in an eight-track cartridge configuration was introduced in 1970, providing a new dimension in musical realism.

Electronic components and solid-state devices
RCA designed, produced, and marketed thousands of different types of electronic building blocks for uses that ranged from color tv to manned spacecraft. These were also years of technological change in the electronics industry. The receiving tube, on of the Corporation's oldest component lines, was slowly being replaced by products of the new solid-state technology. To coordinate activity in this field, RCA, in 1970, consolidated semiconductor activities into a Solid State Division. A new Solid State Technology Center was established at Somerville, N.J., as a focal point for semiconductor developments throughout RCA.

Commercial and industrial products
In 1968, the company introduced the TK-44A camera, which can take acceptable color pictures at only 15 footcandles, a light level too low for reading.

In 1969, the Corporation introduced a 30-kW UHF transmitter that improved the technical quality of tv transmissions by a margin of two to one.

Space and defense
When astronaut Neil Armstrong stepped from the Apollo 11 Lunar Module onto the magnificent desolation of the moon, his RCA-produced man-pack radio was his electronic link to home. It carried his historic first words across 225,000 miles of space to the world and on to posterity.

The radio was only one of the important RCA contributions to the Apollo program during the five-year period. In 1968, a tiny tv camera designed and built by the company for the Apollo 7 mission sent back the first live pictures of astronauts aboard a U.S. spacecraft. Another RCA camera flew on Apollo 8, man's first voyage to the vicinity of the moon. On the later Apollo missions, RCA was responsible for the rendezvous and landing radars that helped guide the astronauts in the LM to and from the lunar surface, as well as the attitude and engine control assemblies that aided them in making pinpoint landings on the moon. The RCA LM communications system enabled the astronauts to maintain continuous voice contact with earth, and the VHF communications/ranging system kept the LM in constant touch with the Command Module when the two spacecraft were separated in flight. Two RCA countdown computers at Cape Kennedy provided critical ground support for the moon mission, monitoring 3000 functions of the Saturn 5 rockets prior to launch.

In 1972, RCA announced its new Precision In-Line color tv tube system designed for lower cost solid-state portables. The system incorporated an advanced-design electron gun, a factory-positioned yoke, and line-screen picture tube.

In 1974, the Precision In-Line concept was expanded to include large-screen sizes with 110-degree deflection, thus offering savings to European tv set manufacturers in circuitry and labor costs while maintaining excellent picture quality.

The Picture Tube Division introduced, as part of RCA's new ColorTrak receiver, a new high-contrast phosphor picture tube that provided a contrast ratio improvement of approximately 25 percent over conventional phosphor tubes, and reduced reflections under high-ambient light conditions. For the international marketplace, 110-degree PIE engineering improvements included development of a quick heat gun and a new tube geometry system which resulted in improved color purity and white uniformity from turn-on through the warm-up cycle.

In 1976, the Picture Tube Division entered into a long-term technology transfer contract with the UNITRA agency of the People's Republic of Poland. This contract included the installation of complete color tube manufacturing facilities capable of producing up to 600,000 picture tubes per year. The 21-inch 110-degree PIE tube type was designated as the type to be produced in this new facility.

1976 also saw the introduction into the European Market of the 21-inch (diagonal) 110-degree Precision In-Line, self-converging tube.

Solid state devices
In the early 1970s, RCA introduced a new digital technology—COS/MOS. In 1974, the Solid State Division produced the industry's first combination of MOS and bipolar semiconductor technologies on a single chip, as well as introducing the first linear COS/MOS circuits for higher performance in control functions. By late 1975, with the announcement of 40 new integrated circuits of its CD4000 series, the Solid State Division had more than 180 standard commerical circuits in the COS/MOS series, plus more than 100 custom circuits, the widest line in the industry of such low-power devices for computers, communications equipment, and industrial controls.

In 1975, Solid State introduced COSMAC, the industry's first COS/MOS microprocessor, the central processing unit of microcircuits. In 1976 a single-chip version and support circuits were announced. These units are capable of operating over extreme ranges of temperature, and in hostile industrial, consumer, and automotive environments. They are highly resistant to electrical interference, and highly tolerant to a wide power supply voltage range.

Another 1975 innovation was the introduction of the industry's first integrated circuits with hermetic performance in a low-cost plastic package compared with the more expensive hermetic ceramic or metal packages.

As a consequence of the realignment of RCA Electronic Components in 1975, the Industrial Tube Division became part of the Solid State Division under the new name of Electro-Optics and Devices.

In 1972, the Electro-Optics Group within the former industrial Tube Division entered the rapidly growing CCTV (closed-circuit television) market with television cameras and associated equipment designed not only around the conventional vidicon but also with the silicon vidicon, and with the SIT (silicon intensifier target) tube for very low light level tv surveillance.

Three years later, in 1975, Electro-Optics and Devices demonstrated two all-solid-state, tubeless black-and-white tv cameras.

The heart of the camera was the world's highest resolution and largest charged-coupled device (CCD) television image sensor. Subsequently, fully standard U.S. 525-line compatible video was demonstrated in both black-and-white and color CCD tv cameras.

In another era, Electro-Optics continued to lead in the development of photomultiplier tubes, particularly for such medical applications as the Gamma camera and CAT scanners. Solid-state lasers and detectors were developed and marketed for military and commerical fiber-optic communications.

Receiving tubes
The steady shift to solid-state devices in nearly all electronic products, and the consequent steady decline in the receiving tube business resulted in RCA closing its receiving tube plant at Harrison, N.J., in April 1976.

Global and domestic communications
In 1971, RCA Global Communications Inc. was the only RCA subsidiary operating in the telecommunications field. Six years later there were two more—RCA Alascom to operate Alaska's long-lines telecommunications and RCA Americom to own and operate a domestic satellite communications system.

The RCA Satcom System, initially employing leased capacity in a Canadian satellite, was the first to provide commercial domestic space communications services in the United States, beginning December 1973. These services were switched to RCA Satcoms I and II after their launches in 1975 and 1976, respectively. Subsequently, the Satcom System carried the first regularly scheduled pay-tv program service in 1976. RCA American Communications, Inc., was created as a separate subsidiary of RCA Corporation to operate the domestic satellite communications satellite system.

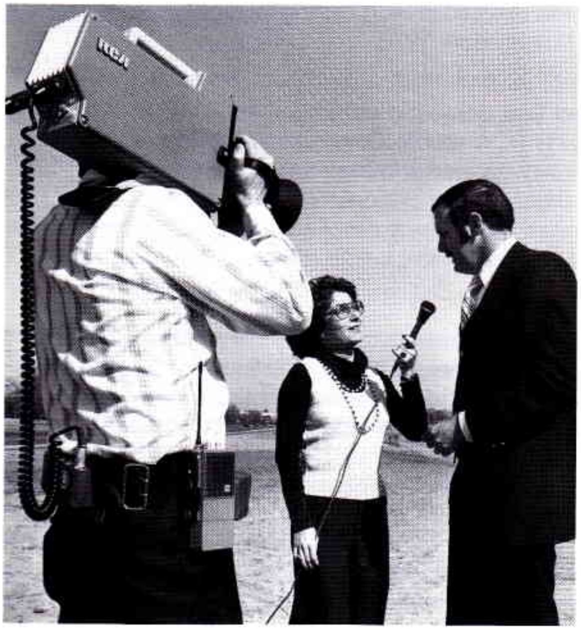
By the end of 1976, major RCA Americom earth stations were situtated near seven key U.S. cities: New York, Philadelphia, San Francisco, Los Angeles, Chicago, Houston, and Atlanta, with the last three stations joining the network in 1976. In all, including government and specialized users, more than 115 earth stations were transmitting and/or receiving space communications via RCA satellite. During the year, RCA Americon also began providing dedicated earth stations carrying high-speed data and television transmission for NASA in support of its Viking Explorer mission on Mars and the Space Shuttle program.

Commerical communications
RCA shared in the late 1960s boom in broadcast equipment sales, resulting from the conversion of tv stations to color and the launching of new stations.

One product was the TCR-100 Video Tape Cartridge Recorder/ Player. First placed in service in 1971, the system ushered in a major change in television broadcast operations. It made possible the automatic on-air showings of pre-programmed commercials, program promotions, and other 30-second to 3-minute tape segments.

In 1974, RCA introduced the TR-600 Video Tape Recorder which took advantage of the increasing emphasis on cost effectiveness by incorporation into its design capabilities formerly offered as accessories.

The most noteworthy accomplishments in 1975 was the TK-76, the first self-contained high-quality portable color television camera for electronic journalism. This lightweight camera, housing three imaging tubes and all required electronics, provides a new order of flexibility combined with high-quality performance.



Other advances during the period included the development of portable color camera, the TKP-45, that matched the TK-45 studio color camera in high-quality pictures; the introduction of the TK-28, a tv film system which greatly improved the reproduction of color film on television and quickly became the standard of the industry; and announcement of a circularly polarized tv antenna designed to reduce reflections and ghosts caused by tall buildings and other obstructions in urban areas.

Space and defense
By the close of 1976, 24 RCA-built weather satellites had been successfully orbited and had returned some three-million photographs of the Earth's weather for use in weather forecasting. RCA was selected by NASA in 1975 to develop the Tiros-N, a third generation weather satellite, and to build, integrate, and test eight of the polar-orbiting spacecraft for launch beginning in 1978. At 1400 pounds, Tiros-N nearly doubled the weight of current weather satellites and carries four times the payload. New sensors enable the satellites to obtain high-quality atmospheric temperature and water vapor soundings, day and night worldwide cloud cover pictures, and radiometric information for sea-surface temperature mapping.

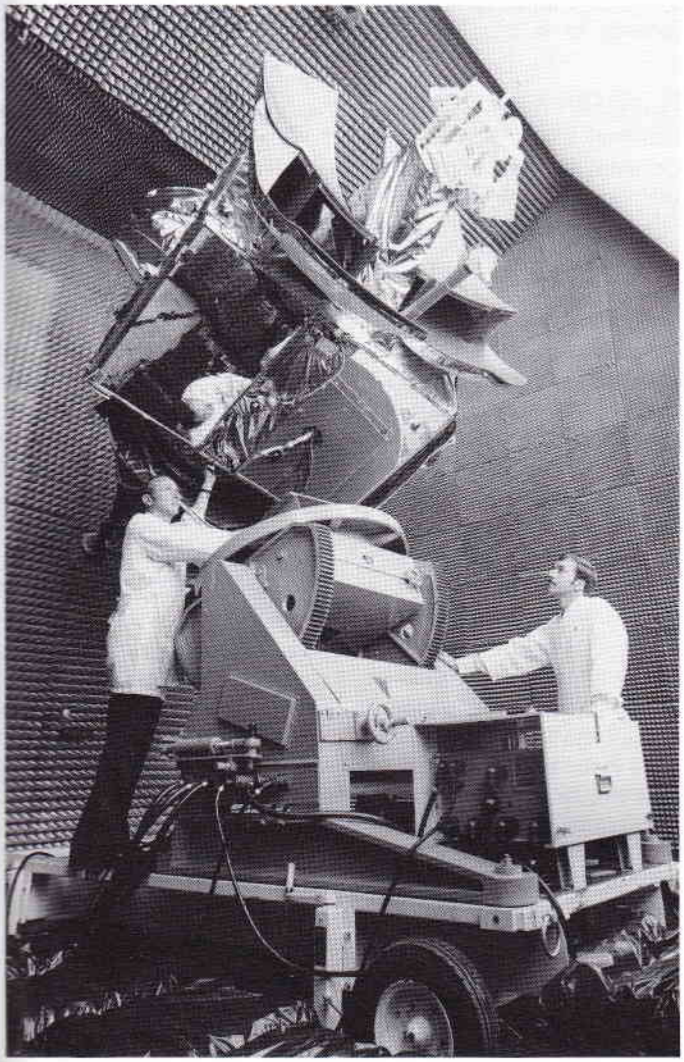
In 1972, an RCA Return Beam Vidicon Camera flew for the first time on the Earth Resources Technology Satellite and produced high-resolution multispectral pictures of excellent scientific value. The same year saw the successful orbiting of NOAA-2, first of series of RCA-built environmental satellites to provide worldwide weather and ocean information never before available.

In 1973, and RCA-build Atmosphere Explorer satellite was orbited to make a continuing and systematic study of the earth's upper atmosphere. The first Explorer was followed into orbit by two others, launched in 1975.

RCA communications equipment was successfully used in two space probes, one to the Moon and the other to Mars. During the Apollo 15 manned lunar expedition in 1971, an RCA tv space camera produced the clearest color pictures made to date of the lunar surface. The camera was part of RCA's Ground Commanded Television Assembly (GCTA), a system which permitted controllers at Houston to operate the camera remotely from earth. The GCTA was mounted on the astronauts' lunar roving vehicle along with a briefcase-size RCA communications set for direct two-way contact between the Moon and Earth. Apollo 16 and 17 astronauts used similar RCA systems as well as an RCA-built laser altimeter for accurate mapping of the lunar surface.

During 1976 RCA-built communications equipment was a vital part of the Viking missions that undertook scientific probes of Mars and a search there for life. The RCA equipment was dormant during the 11-month voyage but shortly after the Viking Lander touched down it began to transmit color pictures and telemetry to Earth over a 250-million mile link. The pictures were generally regarded as remarkable for their clarity and color definition.

The RCA Satcom I and II communications satellites, delivered to RCA Globcom for launch in 1975 and 1976, respectively, made ingenious use of cross-polarized signals to incorporate 24 channels in a frequency band that formerly accommodated only 12. The 24 channels each can carry one color-tv transmission, or 600 two-way voice circuits, or 64 million bits of data per second.



RCA SATCOM in testing chamber.

AEGIS, a key Government Systems development of the 1970s became the first Navy defensive system with the ability to automatically search, detect, and track multiple targets and to fire missiles. The system's heart is the AN/SPY-1 phased-array radar, which performs the simultaneous detection and tracking of multiple targets, and also provides designation data for target illuminators. RCA was chosen as the AEGIS prime contractor in 1969. Since then, AEGIS has become the nucleus of a total combat system, providing target-coordinate data to other weapons aboard ship and controlling their use through its integral computer subsystems. Installed aboard the *USS Norton Sound*, the system detected, tracked, and destroyed its first target drone in May 1974. Since that initial success, the AEGIS weapons system has had a near perfect intercept record of missile and aircraft targets.

AEGIS entered its second phase in 1976 with the award of a new $159.2 million Navy contract calling for RCA to provide a combat system engineering development (CSED) prototype at Moorestown. Centered on AEGIS, it includes additional radars, electronic warfare, and surface and undersea weapons to form a complete combat system.

In 1974 and 1975, RCA delivered to the U.S. Air Force four low-cost mobile instrumentation radars controlled by a minicomputer and capable of one-man operation and maintenance. Officially designated the AN/TPQ-39(V), the system is intended for mini-ranges and temporary missions, and is lightweight, relatively small, quickly set up, and highly accurate. It is capable of a variety of tracking applications, including range safety, scoring, vehicle performance evaluation, and determination of discrete mission events.

In military communications, Government Systems' development of a family of transportable satellite terminals led to a $37 million U.S. Army contract to build 31 such stations. Readily transportable, the terminals can be put in use within 20 minutes and will permit tactical and strategic communications on a worldwide basis.

RCA was named in 1975 to complete the prototype and subsequent production of a modern communications center, or Integrated Radio Room, for America's Trident-class submarines. The system makes it possible to control all ship-to-ship and ship-to-shore communications from a single console.

In 1975, the Armed Forces began testing the RCA-developed EQUATE (electronic Quality Assurance Test Equipment), a system capable of testing virtually all types of military equipment. A computer-based third-generation system, EQUATE performs diagnostic, fault isolation, and performance testing.

During the early 1970s, RCA developed for the U.S. Army an automotive test system that performs more than 50 types of tests and maintenance checks on a wide range of engines and accessory systems. The system, known as Simplified Test Equipment for Internal Combustion Engines (STE/ICE), is capable of testing 15 different types of vehicles, including armored personnel carriers, trucks, jeeps, self-propelled howitzers, tanks, and recovery vehicles. The system produces a substantial reduction in maintenance time while significantly improving the accuracy of vehicle diagnosis.

A notable 1974 development was a hand-held laser system that accurately determines the range of a military target in one second. The GVS-5 system is about the size of field binoculars, which it resembles, and weighs only five pounds. The rangefinder's successful design resulted in contracts for several large production quantities.

In 1973, RCA Laboratories developed a solid-state image sensor containing more than 120,000 electronic elements on a silicon sensor chip the size of a nickel. This was the forerunner of the CCD cameras that RCA Electro-Optics and Devices demonstrated and made commercially available in 1975.

In 1975, the RCA Solid State Division announced the commercial availability of the industry's first COS/MOS microprocessor. The Solid State Technology Center of RCA Laboratories was responsible not only for the concept and development of the device but also for the research and engineering that turned the experimental device into a commercial product. The same year, the Solid State Division also began offering silicon-on-sapphire (SOS) circuits to the electronics industry on a sampling basis. These low-power, high-speed devices are expected to take over an increasing share of the electronic watch business, as well as to play an important role in electronic data processing.

During 1975, the Laboratories also made significant progress with the research program on automotive electronics concerned with monitoring and controlling engine performance and pollution.

In 1976, Laboratories researchers developed high-speed logic circuits that process five billion bits of information per second under test conditions, functioning about ten times faster than logic circuits used in conventional information processing.

In cooperation with the Alaska Office of Telecommunications, RCA scientists developed frequency-modulation techniques to permit the transmission of satellite-borne tv signals requiring minimum power and bandwidth to small earth stations in the Alaskan bush. A related project resulted in the development of technologies that permit the simultaneous transmission of two tv channels by a single-satellite transponder, thus doubling the transmission capacity for tv programs from the lower 48 states to Alaska.

During 1971-1976, RCA Laboratories made good progress in new research areas. For example, in 1971, Laboratories scientists developed a new semiconductor laser with an optical capacity that doubled the output efficiency of previous deveces, thus speeding the eventual use of such lasers in closed-circuit television and in commerical and military communications systems.

In 1974, a major development was an electro-optic modulator that could permit as many as 5,000 persons to talk simultaneously over a single-laser beam, high-grade telephone circuit. The experimental device was the first electro-optic modulator compatible with integrated circuits and capable of aiming or switching the direction of a laser beam. In another phase of electro-optic research, the Laboratories demonstrated a document reader employing a semiconductor laser that can provide high-quality electronic reproductions of text, sketches, and photographs suitable for long-distance facsimile transmission.

In 1975, RCA Laboratories demonstrated a solid-state laser that produces visible light. This continuous-wave device, which operates at room temperature, is expected to enhance and speed the use of optical communications in many applications.

Telephone Communications in the Delaware Valley

One day in 1877, a Philadelphia electrician named Thomas E. Cornish returned from a business trip to Boston with a new invention in his valise. It was Alexander Graham Bell's telephone, and Cornish was convinced that it would give him—and the business world—a golden future.

Commercially, however, the telephone got off to a slow and painful start. The public was apathetic and unresponsive. Cornish, nonetheless, was resolute.

He obtained rights to promote the telephone in Philadelphia and vicinity and formed a company which he called "The Telephone Company of Philadelphia", later to be expanded to include the name of the inventor. The first two telephones in the state were installed in his home and Chestnut Street appliance shop.

In the summer of 1877, he employed two former telegraph company men to install the first Philadelphia switchboard from which he ran iron wire lines to customers whose financial backing was critical to the success of his infant enterpraise: E. T. Stotesbury, an important financier; Colonel Thomas A. Scott, president of the powerful Pennsylvania Railroad; James E. Kingsley, proprietor of the city's leading hotel and destined to become the company's second president.

Alexander Graham Bell and a group of patent owners had, in July of that year, begun the leasing of telephones, and granting licenses to authorized agents throughout the country.

Initial efforts to expand the infant telephone business, records show, were filled with hardship and adventure. The telegraph company, wealthy and powerful, considered the building of a telephone plant an infringement of its prerogatives, and persuaded city officials to refuse Cornish permission to string his wires. His workmen were arrested. He was warned to quit or be driven out. Capitalists refused him money.

Cornish persisted. Soon after, he founded the first Philadelphia exchange. In 1878, the first telephone directory, consisting of four cards printed on two sides, made its appearance, listing 23 subscribers.

On September 18, 1879, they were granted incorporation as "The Bell Telephone Company of Philadelphia". Cornish was elected president at a salary of $1,000 a year. At that time, the telephone directory contained the names of 420 subscribers.

Meanwhile, the telephone was also being introduced in Harrisburg, Pittsburgh, and other Pennsylvania cities. In most places the telephone got its start from men associated with the telegraph business.

Harrisburg's telephone industry began on March 18, 1878, when Western Union Superintendent Horace A. Clute placed gray private line telephones in service, primarily in state departments and business concerns. Later he added some Bell telephones. Those were the beginnings of the Western Union and Capitol Hill Telephone Company.

In 1880, Clute was licensed by the American Bell Telephone Company as its agent for eight nearby counties. He immediately quit Western Union to concentrate full time on the development of the telephone, which then had 75 subscribers.

A charter was issued in 1882 for "The Southern Pennsylvania Telephone Company". By then, parts of New Jersey had been added to Clute's original territory.

The late 1800s and early 1900s were years of rapid expansion through consolidations. The Bell company established financial ties with a number of other telephone firms. By 1910 it served not only Pennsylvania, but was involved in operations in other states—Delaware, New York, New Jersey, Maryland, Virginia and West Virginia and the District of Columbia. Eventually, the company relinquished all of its holdings outside of Pennsylvania.

The climax to a series of mergers occurred in 1907, when the Bell Telephone Company of Pennsylvania was formed. The Pennsylvania Telephone Company serving most of today's Central Area, joined with the Bell Telephone Company of Philadelphia and the Delaware and Atlantic Telegraph and Telephone Company of Pennsylvania; (actually three companies serving different areas) to give the corporate name in use today.

The Lehigh Telephone Company, with headquarters in Allentown, consolidated under the Bell banner in 1930.

The last direct competing telephone system in the country, the Keystone Telephone Company, joined Bell in September, 1945. That ended the customer irritant of having two or more competing telephone companies serving the same city or town.

It was a Theodore N. Vail precept that if AT&T remained a well-run business, it could afford to invest in experiementation that would lead to new discoveries. Those discoveries, in turn, could be afforded by the operating Bell companies if they, too, were well managed businesses.

Pennsylvania has been such a company. To this day it continues to forge ahead, pioneering new ideas from Bell Telephone Laboratories and sharing the resulting service and cost benefits for its customers.

What has kept Pennsylvania on the system's technological frontier? Engineers cite three factors: management with a mental set conducive to innovation; an organization willing to risk unproven developments; and very importantly, regulators who have allowed the earnings that prudent investments in progress require.

Bell of Pennsylvania began recording technological breakthroughs in Pittsburgh in 1881. Though the achievment seems almost prehistoric in the light of today's advances, the placement of the first underground cable, using a wooden box for conduit, is recorded as a major event in telephone history.

Two years before the legendary blizzard of '88, the first toll lines linking Philadelphia to New York opened. Three years later Pittsburghers could call Philadelphia, but not without effort. In those days long distance callers had to trek to the telephone office to place their calls because only nearby telephones were within the reach of their own sets.

It was the invention of the repeater—an amplifying device to boost voice signals —that made the spanning of increasingly greater distances by telephone possible. Repeaters were first used commercially in the Bell System on a toll line near Pittsburgh in 1904.

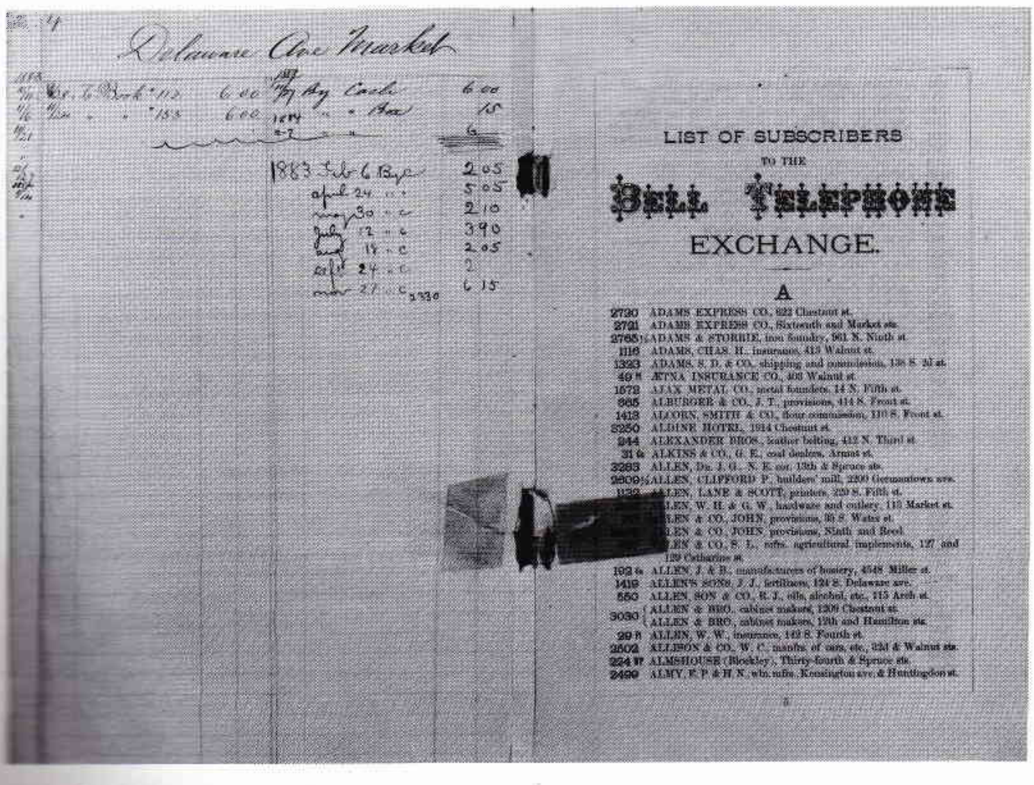
A special supplement to the February 15, 1915 edition of Bell's employee publication—The Telephone News—heralded a technological milestone: the opening of transcontinental service with the completion of the first call between Philadelphia and San Francisco.

The creation of Bell Telephone Laboratories in 1925 as the research and development resource for Bell companies was, in later years, to trigger a string of technological firsts for Bell of Pennsylvania and provide the fast-growing company with improved ways of working and serving its customers.

Though history records that independent telephone companies in Hazelton and Allentown had introduced a primitive form of customer dialing in 1906, it was the addition of the dial to candlestick sets in the '20s that spawned a communications revolution.

Machine switching panel units, designed to serve big cities, were installed initially in 1923 in Philadelphia's Sherwood office.

In 1948, Media, near Philadelphia, was chosen as the pioneer location of the Bell System's most advanced switching machine, the No. 5 Crossbar. It was also the first equipped with Automatic Message Accounting (AMA).



Early phone books had the space to lead two lives. This one doubled as a ledger.

On February 11, 1915, Bell of Pennsylvania launched one of the first transcontinental long distance services.

Five years earlier in 1943, the company scored another network first when it cutover the newly developed No. 4 toll switching machine in the Race building in Philadelphia. Pittsburgh and Scranton got 4As after World War II.

A big telephone jump across the Atlantic took place in 1966 when a Long Lines executive made the first Direct Dialed Long Distance call from Philadelphia to Geneva, Switzerland.

An Automatic Call Distributor went into service for the first time anywhere at West Chester in 1956.

The Conshohocken Accounting office, from 1958 through 1962,served as the proving ground for the use of large-scale computers for billing and maintaining customer records. The first Electronic Data Processing (EDP) bills were mailed to customers in 1960. Lessons learned in Conshohocken paved the way for similar advances across the Bell System.

Not all of Pennsylvania's experimental efforts resulted in instant success. The Bell System's 1967 trial of the Centralized Records Business Office (CRBO) in Upper Darby and the first commercial exchange offering of Picturephones see-as-you-talk service, in Pittsburgh in 1970 were two ideas whose time was yet to come.

In the '60s, the most costly research and development project ever undertaken by Bell Laboratories-electronic switching—began to bear fruit. Again Bell of Pennsylvania was early and single-minded in its commitment to this new technology that promised undreamed of service and expense savings possibilities.

The company launched its move into the electronic age in 1967 with the cutover of the first No. 1 Electronic Switching System (ESS) in Philadelphia's Germantown office. Since then, Pennsylvania has achieved one of the Bell System's fastest phase-outs of panel equipment, eliminating it completely in 1978.

Also the Pennsylvania portion of the switched network was tremendously strengthened by the installation of the No. 4 ESS, a solid-state super switcher with an hourly call processing capability of 550,000 calls. The company's first 4E installations took place in Wayne and Pittsburgh in 1977 as joint Bell-Long Lines operations.

Operator service, too, has been revolutionized by electronic technology. The pioneer Traffic Service Position (TSP) office opened in Philadelphia in the summer of '65. It made operator service calls dialable by customers, and replaced the switchboards of yesteryear with the pushbutton operator consoles of tomorrow.

The 1970 Philadelphia debut of the Traffic Service Position System was first of many TSPS conversions across the state. They have streamlined the handling of operator-assisted calls and made possible the centralization of operator services in fewer, more efficient locations.

It has been said that Bell created the telephone and Vail created the telephone business. Certainly the personality and personnel policies of Theodore N. Vail helped to build the telephone company's reputation as "a good place to work."

Reported one biographer, "Mr. Vail required courtesy and efficiency of Bell employees, in return he provided for their comfort and happiness. These matters lay very close to his heart."

Bell of Pennsylvania, one of the System's oldest associated companies, lived up to Vail's dual goals: organization and humanity.

Development of Microwave Radio Relay Systems

Donald S. Bond (F '74)

The pioneer development of the microwave radio relay system by RCA was started at RCA in Camden, NJ, in 1943. It was the first in the world to employ microwave frequencies in multi-hop service. It used the new techniques and components developed for 10 cm radar. The circuits operated originally at 3 GHz but were later shifted to 4 GHz. A 100 mW Western Electric reflex klystron was used as the transmitter and was cavity stabilized. Antennas for transmission and reception were 1-meter diameter parabolic dishes. A double FM modulation method was used to provide multiplexed voice audio program, and teleprinter channels within a base bandwidth of 150 kKz.

Forestry-type towers, about 35 meters high and spaced 50 to 60 km, were used at the relay stations at Bordentown, Ten Mile Run and Woodbridge, New jersey. The terminals were at Building 8 of RCA in Camden and at the Western Union Telegraph Company, 60 Hudson Street, in New York City. The Camden terminal was later moved to a Western Union location on the Merchants National Bank Building at City Hall Square in Philadelphia. This New York to Philadelphia circuit was made part of the New York - Washington route of Western Union and handled commercial traffic on an experimental basis for extended periods, beginning in 1945.

After the commercial success of this radio relay system was demonstrated to the great satisfaction of Western Union, RCA took a contract from the latter and built equipment for a triangular route of 23 relay stations with terminals at New York City, Pittsburgh, and Washington, D.C. This project extended from 1946 to 1948. The equipment was used commercially and continuously by Western Union for over 20 years. Some of the RCA apparatus was donated by Western Union to the Smithsonian Museum after its retirement from service. It is historically significant as the first microwave radio relay equipment in a commercial system in the world.

Many other systems of lengths up to 5,000 km were built by RCA to this same or improved designs. The worldwide use of microwave relaying for wide-band services has followed this pioneer work by RCA.

Further Contributions to Microwave Communication

B.E. Wheeler (LS '79)

etween 1944 and 1948 RCA in Camden, NJ had completed the evelopment, field test and evaluation, and the final installation of n 850 mile triangular microwave system route for Western Union elegraph Co. connecting New York, Philadelphia, Wasington C. and Pittsburgh. This 4,000 MHz system utilized FDM/FM/FM requency Division Multiplex on an FM sub-carrier Frequency odulating the final RF carrier). The system of about 30 line-of-ght propagation paths represented a major achievement outside the Bell System's development of its TD-2 microwave relay stem.

nis pioneering work had been done under the leadership of onald S. Bond (IEEE Fellow, F '74) and later under Gerald G. erlach (IEEE Senior Member). Leland E. Thompson (F '57) was key engineer in the planning and design of this system and his ntribution resulted in the IRE Fellow Award.

oking toward further applications of multichannel microwave mmunications, RCA conducted an exhaustive analytical and perimental investigation of modulation and multiplex methods artly funded by the US Army Signal Corps) during 1947 and 48. Vernon D. Landon (F '51) of RCA Laboratories, Princeton, d L.E. Thompson were the principle investigators for this study.

cause of the limited demand for common carrier systems such that developed for Western Union, RCA and other communica-n equipment producers surveyed other potential markets for lti-channel point-to-point microwave relay systems. RCA's dy, completed in 1949 concluded that the then existing federal gulations tended to limit applications to two other classes of ers: first, by State and Municipal governments for interconnec-n of mobile radio base stations, where the need was for low pacity (2 to 6 voice channels) short-haul (20 to 400 mile) sys-ns, and secondly for right-of- way companies such as utilities d pipeline operators, whose need was for medium capacity (6 24 channels) long-haul (200 to 2,000 miles) systems.

nciple contenders for this business in these post-World War II ars were ITT Federal, Motorola, Philco, and RCA — the latter located in the Philadelphia area. ITT chose to develop a 2,000 lz system using PPM/AM (Pulse Position Modulation on an AM rier), Motorola a 6,000 MHz system using FDM/FM (Fre-ency Division Multiplex on an FM carrier) with remodulating eaters, and Philco a 6,000 MHz system utilizing PAM/FM lse Amplitude Modulation on FM carrier). RCA had investi-ed all three modulation techniques, had conducted propaga-tion studies in the three available frequency bands and, while the WU installation was being completed, started development of a low-capacity short-haul system operating with FDM/FM in the 890-960 MHz frequency band.

A few short links of RCA's CW-5A 960 MHz equipment were installed early in 1950, followed by the long system placed along the extended Pennsylvania Turnpike when it opened in November 1950 from the Ohio border to King of Prussia, PA. [This was a four channel system with channel drops at mobile base stations, toll booths, maintenance depots, and the Turnpike offices along the 325 mile right-of-way.] The success of this system resulted in a similar one along the New Jersey Turnpike which went into operation at its opening in November 1951, and later at other toll roads across the US.

The CW-5A used a remodulating repeater, i.e., Receiver and Transmitter connected back-to-back, and a crystal controlled phase modulator multiplied up tc the output frequency. Except for a diode receiver mixer, the units used vacuum tubes throughout. Conservative design provided surprisingly good reliability in the unattended repeater equipment.

RCA's next microwave communication project was the development of a system to meet the long-haul market needs. First production of the CW-20A system, operating in the 1850-1990 MHz band, was begun in October 1950 and continued throughout the 1950's. The initial design was subsequently extended to cover frequency bands from 1,700 to 2,700 MHz for other applications. This microwave system was the first non-Bell System equipment to utilize the heterodyne repreater, which avoids modulator and demodulator non-linearities which degrade the intermodulation performance of FDM/FM system repeaters. An ingenious AFC system applied to a modulated shift frequency oscillator provided the ability to drop and add voice channels at a repeater. This had not been previously realized but was a necessity for the market use.

Initially designed for 24 standard single-sideband suppressed carrier multiplex channels, the CW-20 design was later modified by RCA-Victor Ltd., Montreal, for 120 channel applications. The total vacuum tube equipment used a cost effective but reliable design which proved highly dependable (for its day) in unattended field performance. The 2C39 triode power output stage provided two watts output. The 30 MHz IF receiver with 5 MHz bandwidth provided an equivalent noise input of -123 dBW. The repeater

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frequency shift was 40 MHz. RF duplexing filters allowed use of a single antenna for transmission and reception.

Early systems using the CW-20A equipments were installed for the United Gas Transmission Co. in Mississippi and Louisana and for the Union Electric Co. in Missouri. The development and early application of the CW-5A and CW-20A microwave relay equipment and systems was conducted by a team, led by B.F. Wheeler, and consisting of the following engineers.

N.C. Colby, (M55)	R.L. Rocamora (M48)
H.R. Mathwich (M55)	M.G. Staton (M47)
C.E. Peterson (M58)	L.E. Thompson (F57)

Philco Corporation

David B. Smith (LF '77)

The Early Years

"Philco" was one of the first electrical manufacturing companies. Starting in 1892 as the Helios Electric Company, it manufactured arc street lights to meet the needs of the then "new-fangled" electric street lighting. The early years were a struggle. After a decade of touch and go, Helios Electric Company finally abandoned the street lighting business and in 1906 reorganized itself as the Philadelphia Storage Battery Company to manufacture large storage batteries for electrically propelled cars, trucks, launches and mine locomotives in its plant at C and Ontario Streets, Philadelphia, Pa. In 1911 the invention of the electric starter created a demand for SLI (starting-lighting-ignition) batteries. Philco had a profitable business in the large industrial and naval market but was unable to break into the original equipment automotive market. In 1919 it adopted an aggressive marketing strategy to capture the SLI after-market under the trade-mark "Philco" (from the cable address) Diamond Batteries. This strategy involved a strong adverstising campaign plus the development of an extensive network of distributors and automotive dealers and garages who supplied and serviced the Philco after-market SLI batteries. The technical advantage was that the battery could be shipped dry and the electrolyte added at the point of sale.

World War I brought with it the first wireless communications and in 1920 Westinghouse changed wireless from a commerical tool to a means of mass communication with the opening of KDKA and the broadcast of the Harding-Cox Elections. Home radio was born.

At that time radio receivers required direct current power supplies. The SLI battery was a natural for the "A" battery and Philco developed a self-charging, electrolytic power supply or "B" Eliminator for "V" or plate supply. This business was a bonanza for Philco and fit beautifully with its marketing strategy and distribution organization. But this prosperity was short-lived. In 1927 RCA announced the alternating current radio tube and the bottom dropped out of the market for both the SLI battery for radio use and the "B" Eliminator.

Faced with this dramatic loss of business in a few short months, the management of Philco decided it would have to go into the home radio business. And it did so with a vengeance. In 1928 Philco brought out its first receiver, the Philco Neutrodyne-Plus, a conservative receiver design with a built-in power supply. After an initial successful market test, Philco decided to go all out. It developed a line of quality products and made the decision to install mass production conveyer belt systems in a new plant at C and Tioga Streets. It acquired the Timmons Radio Products Corporation, a manufacturer of electrodynamic speakers. The existing distributor network was just right for the distribution of these quality receivers and Philco's market share quickly rose. But all this took a lot of money; so, shortly after the stock market crash of 1929 Philco went to the Philadelphia Banks and borrowed seven million dollars, an enormous sum for a small company at that time. In 1930 Philco rounded out its line by introducing a inexpensive new table model, the "Baby" Grand, sometimes referred to as the Tombstone or "Cathedral" model. Its distinctive shape is frequently seen in old movies.

It was a quality product yet profitably priced well below the market. The combination of mass-produced, quality products and a superb dealer-distribution system gave Philco a commanding market share. By 1930 Philco had become the largest radio manufacturer in the world, out-selling its nearest rival RCA Victor by two to one, a position it retained for the next thirty years. It had also become the largest manufacturer in terms of employment in Philadelphia and had paid back its bank loans. During this same year Philco acquired the Automobile Radio Corporation and established a new subsidiary, the Transitone Automobile Corporation, with product development and marketing facilities in Detroit but production in Philadelphia.

As soon as viability in the home radio field was established, Philco also looked at electronic television. Initially it acquired a part interest in the Farnsworth Laboratories of Philco Farnsworth, one of the pioneers in electronic TV. However, relations between the two companies were not satisfactory and Philco decided to establish its own TV Reseach and Development facilities. In 1932 it acquired a license for W3XE, the second license for an experimental station for electronic TV in the country. The transmitter, initially, was located at the C and Tioga streets plant. During the later part of the '30s Philco took an active Part in the work of the National Television Systems Committee in the development of the NTSC black and white TV standards and, with the authorization of commercial TV broadcasting in 1940, received the second commercial TV license in the USA for WPTZ- Channel 3, Philadelphia. Initial receiver sales began in May 1939. To improve the coverage the transmitter was moved to high ground at Wyndmoor just outside the city limits.

WPTZ was Particularly interested in news and sports broadcasts. A popular feature of its programs was live broadcasts of the University of Pennsylvania football games from Franklin Field.

Model 20B, 1930.

With the development of the fluorocarbon refrigerants and the hermetically sealed motor-compressor units in the mid-thirties, electric household refrigerators and room air conditioners became practical and Philco entered both businesses as a manufacturer and as a marketeer utilizing its successful distributor-dealer network as its outlet. In June of 1938 it entered into an agreement with the York Ice Machinery Company, York, PA., to provide it with room air conditioners. In November it acquired the entire refrigeration division of Fairbanks-Morse Company, including its refrigeration engineering department which was moved to Philadelphia. This became the Philco Refrigeration Company, a subsidiary.

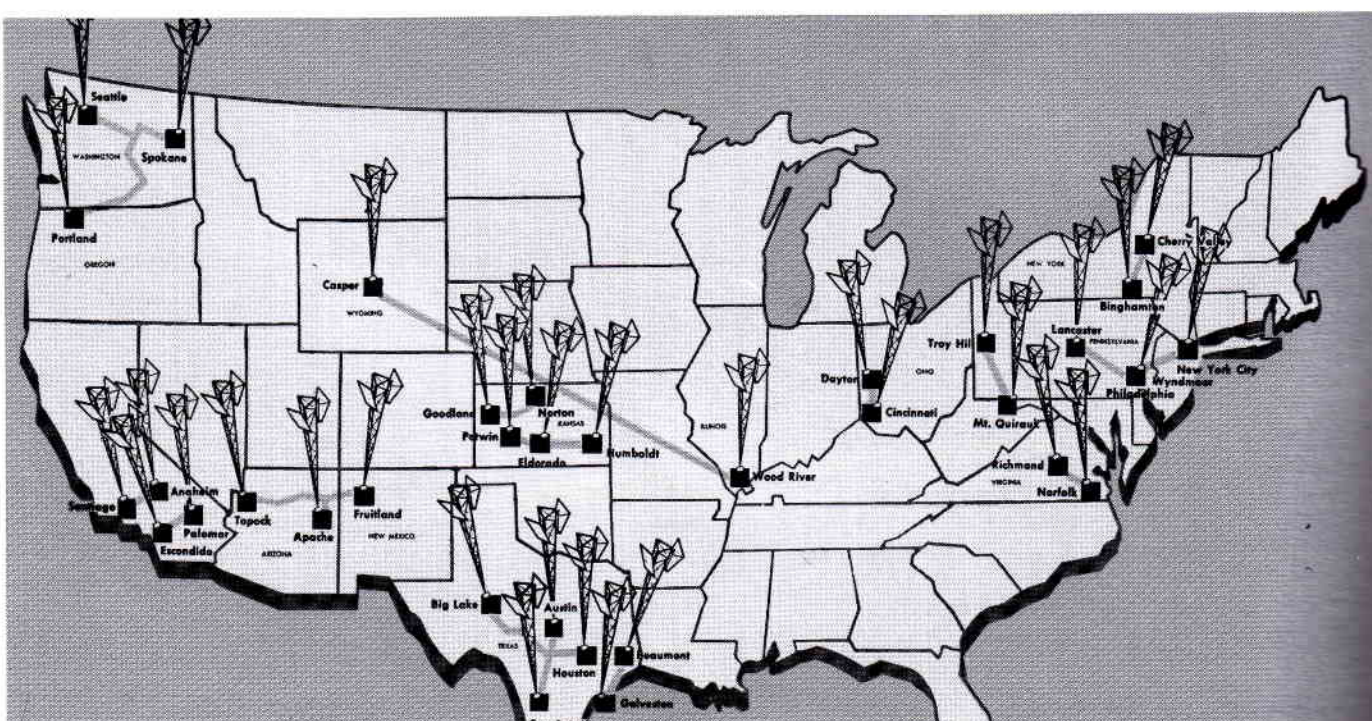
In the early thirties Philco established arrangements with both Sylvania and Hygrade, later Hygrade-Sylvania and then Sylvania, to manufacture radio tubes under the Philco name. In the later part of the thirties Philco entered into a further agreement with National Union to establish a production facility at Lansdale, PA., for radio and cathode ray tubes.

In the early thirties, largely for patent reasons, the company was divided into two completely separate companies, the original Philadelphia Storage Battery Company, the manufacturing company, and Philco Radio and Television Corporation, the engineering and marketing company. In 1940, after the conclusion of a long and bitter legal controversy with RCA, which Philco won, the two Philco companies were joined together and became Philco Corporation. At the same time the company, which heretofore had been privately owned, went public and was listed on the N.Y. Stock Exchange under the name Philco.

The War Years

The advent of World War II caused an abrupt halt in Philco's consumer business and Philco scrambled to become part of the war effort. The production lines in Philadelphia were covered over for the duration and the R&D and other management groups were charged with finding ways to use their talents in the war effort. Philco's decade of TV R&D was a major advantage. A first break came as a consequence of the Pearl Harbor attack. One of the problems was that it was not possible to distinguish between friendly and enemy aircraft. A UHF instrument (IFF-Identification Friend or Foe) equipment had been developed, to the prototype stage by the Air Force, which was most anxious to get it into production. Philco found out about it shortly after December 7th and promised two samples by New Years Day and production in eight weeks. Philco got the contract and on New Years Eve, not two but twenty-four samples were on their way to Wright Field, Ohio, in a baggage car fitted up as a laboratory in which the final tests were made on the way to Wright Field. Production began seven weeks later.

An excellent working relationship was developed with the Radiation Laboratory at M.I.T. and Philco became the engineering and manufacturing facility for many military products originating there. The first of these was the first microwave radar built in the U.S. It



Microwave Relays

was an S-band system with PPI display and a British magnetron transmitting tube. Production began in the fall of 1942 for the Navy. This was known as the George radar (ASG) and in Navy parlance Dog One and provided yeoman service in the Pacific and in submarine surveillance in the Atlantic. This was followed by the X-band Mickey and its successors. Philco quickly became the largest manufacturer of airborne radar in the world. It also developed and manufactured "VT Proximity" fuses, LORAN and other navigation equipment and a variety of mobile communications equipments, "walkie-talkies", etc.

At the start of the war Philco had a well organized corporate service and training program for its dealer service men. This was expanded and converted into the Philco Technical Representative Field organization. Hundreds of Philco dealer service men were enlisted in this effort. Soon Philco Tech. Reps. were to be found in all major military bases assisting and supervising the field service and maintenance of military equipment and providing field training to Government personnel. One objective was to maintain and support the dealer service organizations for the duration. For similar reasons, the Philco marketing department made an all-out effort during the war to find available products for Philco dealers to sell, in the hope of maintaining the Philco distribution system intact. The commercial TV broadcasting station, WPTZ, continued to provide limited service during the war.

The Postwar Years

With the termination of hostilities, Philco found itself with a greatly expanded Research and Development organization quite competent in the military field and with continuing R&D type projects but with the prospective loss of some significant military production contracts. The electronics and communication technology had vastly grown during the war and a host of new products and services had come into being. Likewise, there was an expanding population and major demand for all kinds of home appliances. Philco then decided, first, to get back into the home appliance field and broaden its base there and, second, to continue to develop and expand its military and government business and extend it into the commercial field.

Based upon its war experience Philco quickly developed a wide-band, FM microwave inter-city relay system to interconnect WPTZ in Philadelphia with WNBT at the Empire State Building in New York City. This was the first commercial inter-city microwave relay system and clearly superior to the then coaxial cable of ATT. With this as a starter, Philco then established a significant commercial business for private wide-band microwave relay systems for railroads, pipe lines, foreign governments and the like and similar two-way tropospheric scatter military and government systems. A new higher transmitting tower was built for WPTZ at Wyndmoor.

The atomic bomb had introduced a major new element in warfare and the need for large scale early warning systems. The first of these was the SAGE (semi-automatic ground environment) system which was assigned to the Lincoln Laboratory at MIT to develop. This was the first of a series of very large Command and Control Systems which the nation would require. Through its continuing relation with MIT, Philco was involved in this effort from the very beginning. Philco's research on microwave diodes positioned it to move quickly into the transistor field when that development was announced by Bell Labs. In 1947 Philco acquired a vacuum tube manufacturing facility and the engineering talents of Rodger Wise & Company at Lansdale and terminated its relations with National Union, acquiring the engineering and production facility division.

In the consumer field business was booming. The advent of frozen foods had added a new dimension to appliances and in a few years the appliance business was comparable to the radio-TV business. Electromaster of Mt. Clemens, Michigan, a manufacturer of electric ranges, was acquired. Black and white TV was rapidly expanding and WPTZ was now a full fledged commercial station. In this period Philco also substantially expanded its production facilities particularly in the appliances area and sold off its storage battery business to Gould. By 1950 Philco was still the number one manufacturer of radio and phonographs.

In the early 50's, Philco announced a technical break-through in the transistor field, the Surface Barrier high frequency transistor, which could be made on fast automatic equipment. This had a major impact on the communication and computer field since it made possible, for the first time, high speed, transistorized computers with very low power requirements and high frequency transistorized military and domestic communications equipment. The first uses of these were in airborne military computers and in the large computers required by the giant military command and control systems. This got Philco into the design and manufacture of large scale, high speed transistorized computers initially for military and then for civilian use. A new plant was constructed in Willow Grove, PA., to manufacture the Philco "Transac" computer, the first transistorized computer.

In a related development in the early fifties, Philco was asked to develop the Sidewinder missile, invented by Dr. McLean at the Naval Test Station at China Lake, California. Philco not only developed and produced this in large quantities but also the critical special infrared cell required for its operation. This activity led the company into a variety of "smart" missiles.

On the consumer side, early in the 50's, TV station WPTZ was sold to Westinghouse and became KYW-TV-Channel 3, thus terminating Philco's broadcasting business. But Philco continued to expand its consumer goods manufacturing facilities and also acquired the Bendix Home Appliance business and the Bendix line of washers.

The controversy between mechanical and electronic color TV broke out shortly after the end of the war after black and white TV had been underway for several years and a few million receivers had been sold to the public.

Philco played an active role in the organizing and managing of the Second National Television Systems Committee which finally developed a set of compatible color standards based largely on earlier work by RCA but including significant contributions from Philco and Hazeltine. These standards were, with a few notable exceptions, adopted world wide.

In the later part of the 50's, the United States entered the space age. Philco "Surface Barrier" transistors were on board the initial project, the Vanguard scientific satellite, and Philco built the first communication satellite, the Courier. To better serve this and the expanding Command and Control System market, a portion of the Research Laboratory was moved to Palo Alto, Calif., and established as the Western Development Laboratory (WDL).

One of WDL's larger projects was the NASA Mission Control Center at Houston, Texas, for which WDL was the prime contractor for the actual system. This system included the world's largest wide band (20 MHz) high resolution (945 lines) closed circuit TV displays used by flight controllers and personnel in support areas. Hundreds of communication circuits brought in telemetry, communications, tracking data and other signals from the space station, tracking stations and support operations. Several hundred precision monitors, large scale displays, etc., were required for use by station personnel. The two video switching units, each including about twenty-five relay racks, were fully assembled, bolted together as a unit and shipped fully assembled on air suspension trucks to Houston. At the site, one side wall was left open and incomplete so that the units could be lifted by a crane into their final position. Philco provided similar services to the NORAD Command & Contral center in Colorado, and other major Command & Control centers.

Mission Control Center Johnson Manned Spacecraft Center Houston, Texas.

During the fifties, the market for radios and TVs and home appliances continued to expand. But the mass merchandisers, like Sears and the discount houses, moved in. As a consequence Philco's home appliance business suffered severe financial losses which the quite successful, high technology government and industrial business could not overcome. A major reorganization and streamlining of the consumer side of the company was put into effect in the late fifties, but to no avail. The future outlook became quite grim.

The Philco-Ford Years

Ford, at that time, had a small group, known as Ford Aeronutronics, located at Newport Beach, Calif. It was about the size of, and in general, in the same kinds of business as, Philco's WDL. After about a year of intensive investigation by Ford and several trips to the Department of Justice, Ford made a formal offer to acquire all Philco stock in a stock exchange. This offer was accepted by the Philco Board of Directors, approved by the Philco stockholders and the exchange took place in December, 1961. Philco then became a subsidiary of Ford and later the name was changed to Philco-Ford. Ford Aeronutronic was later merged into Philco's Government and Industrial Division. As might be expected, this change was accompanied by major management changes and restructuring of the company, including the withdrawal of Philco-Ford from several business areas such as computers, etc.

In the following decade, foreign competition, in the radio and TV business continued. The mass merchandisers established decisive control of the appliance goods business. In 1969 Philco-Ford withdrew from the laundry, range and dishwasher business. In 1971 it withdrew from the semi-conductor field and sold the entire business to General Instrument Corporation. In 1973 the cathode ray North American tube plant in Lansdale was sold to former arch rival Zenith. In the following year Philco-Ford withdrew from the air conditioning business. The balance of the consumer business including the trade mark Philco was sold to GTE-Sylvania, who in turn sold the remnants of the radio and TV business to GTE-Phillips. Ford retained the balance of the Government and Industrial business and Technical Representative business which has prospered and is now conducted under the name Ford Aerospace & Communications. It also has retained the in-house capability to manufacture auto radios, auto air conditioners and auto electronic controls. But the once proud name of Philco is now only a memory.

Broadcast Communications

A. C. Luther (F '74)

Television and radio broadcasting is so much a part of the present-day scene in the United States that one could easily overlook that it is still developing and growing. Major changes in techniques and services provided have occurred and still more changes are visible in the near future.

Using cameras, recorders, and switching or mixing equipment, programs are put together from live input material. In most cases today, this process is done ahead of time and the total program is recorded on tape or film. The process of preparing recorded program material is called production or teleproduction (for television). Most broadcasters do some of this, but many organizations do only teleproduction — they are not broadcasters. Teleproduction operations may be in business to produce total program packages or they may just offer technical services to others who provide the program content material.

Every broadcaster performs the second function of broadcasting. Called a continuity operation, it is the process of assembling program material from various sources into a continuous stream that feeds a transmitter. These two functions combine in a typical United States television broadcasting environment, including our network system. News is a completely separate operation at both the network and local levels. News is a specialized teleproduction and continuity operation that should be explained further.

Broadcasters compete actively to be first with a news break and so want to minimize the time delay from shooting pictures at a news scene until finished material is available for airing. Recently, however, there has been a trend to doing news "electronically", using television cameras and video tape recorders. Called "electronic news gathering" or "electronic journalism", it is growing because it provides greater immediacy, better quality on-air, and lower cost of operation than film systems. Electronic journalism is leading to a special category of equipment optimized for portability, flexibility, ease of operation, and reasonable performance. RCA's electronic journalism camera, the TK-76, has been very successful.

Live program material from either studio or location shooting is recorded on video tape. Then the material goes through the "post-production" processes, where it is corrected, adjusted, mixed, and assembled into the finished program sequence. In these processes, where artistic factors dominate, it is essential to have the greatest possible flexibility for manipulating the recorded materials. This has led to extremely sophisticated systems for controlling the video recorders and special peripheral equipment such as RCA's microprocessor based AE-600 time-code editing system for editing the recorded material.

Production version of TK-76 was coming off the assembly line only twelve months after the advanced development model was shown.

From Kovacs to Cable

Joanne Calabria
Janet Levine

Philadelpahia's Channel 3 (KYW-TV), celebrating its 50th anniversary in 1982, was first granted permission to operate as experimental station W3XE in 1932, but actually had begun experimenting with the new medium as far back as 1928. Since then, Channel 3 — Philadelphia's first television station and NBC's first and largest affiliate — has continued to be an innovator in news and entertainment.

As an experimental station in 1932, Channel 3, then operating out of the Philco company plant at C & Tioga Streets, lived up to its label. Founded by the Philco Corporation, the station first broadcast into the homes of 100 of the company's employees, mostly engineers. As the Philco engineers tinkered with the new technology, the station aired employee talent shows and travelogues to enable them to check the quality of the broadcast signal.

But it wasn't long before the staff began toying with the station programming as well. In 1939, W3XE telecast the first college night football game, Temple University versus Kansas, and the following year started regular telecasts of the University of Pennsylvania home games which it continued until 1951. That same year, the station became NBC's first affiliate, broadcasting network shows into an estimated 150 homes. Channel 3 continued to break new ground into the 1940s by broadcasting 60 hours of the 1940 National Republican Convention, the first major coverage of a national political conclave and the first "remote" telecast locally. The signal was sent to the station's tower, then located in Wyndmoor, Pennsylvania to Princeton, New Jersey, and on to the Empire State Building in New York City from which NBC broadcast it nationally.

In 1941, the station gained commercial status under the call letters WPTZ-TV, the first commercial television station to be licensed in Pennsylvania by the Federal Communications Commission and the second in the country.

Throughout the 1940s, Channel 3 continued to break new ground in developing both its station and the medium. In 1941, the station brought viewers the first telecast of Philadelphia's annual Mummers' Parade and in 1942 produced and broadcast the first soap opera nationally, LAST YEAR'S NEST. The six-part serial, which dealt with the trials and tribulations of a young German immigrant boy, starred Channel 3 actor/director Leonard Valenta.

In 1946, Channel 3 got its first commercial sponsor, ARCO (then Atlantic Refining Company) which sponsored broadcasting of Pennsylvania football. But it was Gimbel Brothers that became the station's first "full-show" sponsor that same year with ALL EYES ON GIMBELS. Local actress Jane King hosted the first half of the show, demonstrating the department store's products and presenting tips from Gimbel's beauty salon. In the second half, Uncle Wip, probably the first kiddie show host locally, introduced a company of talented youngsters who sang and danced.

But it wasn't until the early 1950s, when the television set started to become a fixture in many homes, that television programming really took off locally. Channel 3 was in the forefront then too, giving TV its first celebrity, Ernie Kovacs. Kovacs' early programs for NBC, IT'S TIME FOR ERNIE in 1951, followed by ERNIE IN KOVACSLAND and KOVACS ON THE CORNER originated from WPTZ-TV's Philadelphia studios.

The 50's also saw significant pioneering in children's programming. Australian Lee Dexter made his BERTIE THE BUNYIP character an enchanting and popular fixture in children's TV along with characters Sir Guy, the Wily Fox, and Fussy and Gussy.

In June, 1953, WPTZ-TV was sold to Group W (then known as Westinghouse Radio Station, Inc.) which stepped up the station's tradition of television firsts. On December 18, 1953, less than 24 hours after the FCC had approved compatible color, WPTZ-TV became the first local station to televise a commerical television program, clips from the Walt Disney technicolor productions "Living Desert" and "Ben and Me".

In January, 1956, Channel 3 became an NBC owned and operated station. NBC acquired the station through an exchange of broadcast properties with Group W, and, in February, changed WPTZ-TV's call letters to WRCV-TV.

In June, 1965, Channel 3 took on the call letters KYW-TV as Group W once again assumed ownership of the Philidelphia station. Until that time, KYW-TV had been operating in Cleveland, and with its move to Philadelphia, the popular station took with it THE MIKE DOUGLAS SHOW, the first live syndicated program to originate from Philadelphia.

Channel 3's EVENING MAGAZINE continues to do the same today through a syndicated cooperative with over 100 television stations nationwide. The show, which debuted in 1977, was the first local weeknight magazine shown revolutionizing programming for the prime access period.

But all of Channel 3's innovation hasn't been in entertainment. In 1968, KYW-TV pioneered the EYEWITNESS NEWS format which is now used throughout the country. This concept allowed reporters to deliver their own stories, a revolutionary development since, in those days, all stories were prepared by the station anchormen.

The revolution goes on today as Channel 3's news anchors break new ground in the cable industry — operating as both commercial station anchors and regional anchors for Satellite News Channels, Group W's cable news service.

Today, Channel 3, located on historic Independence Mall, can reach into more than five million homes, a figure that would have been incomprehensible to the Philco engineers tinkering with 100 sets in their living rooms. And although employee talent shows are gone forever, W3XE's great experiment continues every day as its grandchild, KYW-TV, goes on breaking new ground in broadcasting.

POWER AND INDUSTRIAL APPLICATIONS

The Philadelphia Electric Company

From the earliest days of the Brush Electric and the Edison Electric Light Company through to 1902 there were a great many local electric companies formed. From 1881 to 1895, more than twenty such companies sprang up in Philadelphia alone, bearing such names as Germantown, Columbia, Wissahickon, Diamond, West End, Kensington and Southern. These companies operated at a number of different frequencies and voltages, some direct current, some alternating current, some supplying Brush systems, some incandescent light. This period was marked by political, financial and legal in-fighting and the struggle for franchise territories. Out of all this disarray the Philadelphia Electric Company emerged in 1902, with control of all the small electric companies and with the right to operate in the whole city of Philadelphia. J. B. McCall was the president of the company. His wisdom, vision and understanding led to the successful consolidation of the many companies.

Not the least of the problems that confronted the consolidated company was that of unifying the officers, foremen and workmen of the individual companies into one operating body. Each group was accustomed to doing things in its own way and operating different types of electric systems.

A later president of the company said, "I give McCall credit for having weathered not one financial storm but a multitude of them... having dealt with various franchises and all that went into the deals in those days, he ultimately succeeded in combining the various companies... into one composite group that... set the stage for what we today know as the Philadelphia Electric Company."

Joseph B. McCall became chairman of the board in 1924, with Walter H. Johnson succeeding him as present and H. P. Liversidge becoming vice president and general manager.

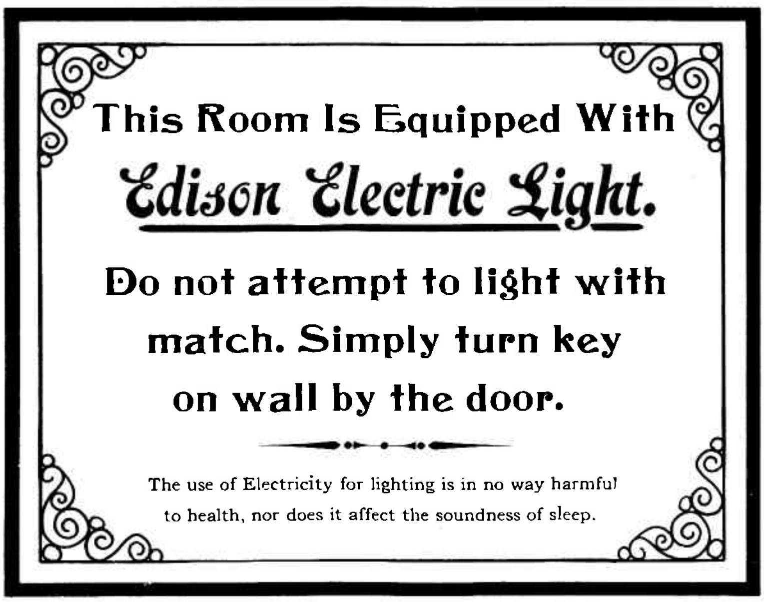
The company has many firsts to its credit. Four of these are described in the following articles taken from "Milestones Philadelphia Electric Co., 1881-1981":

'TWAS EVER THUS

In this period of consolidation and growth, the newspapers were printing vehement objections to stringing wires which "might kill people." The fact that oil lamps, oil stoves and candles were the major causes of fires was ignored. History shows every new and improved technology has begun by being frightening to some people, most frequently those who were the least informed. Nevertheless, the adverse publicity encouraged public figures to find other faults with the company.

In February, 1906, the president of the Trades League discussing Philadelphia Electric concluded: "1. No one will claim that the consolidation of the electric companies has inured to the benefit of the city or its citizens; 2. Its citizens have been enormously taxed as the result of this consolidation; 3. The city has been compelled to pay an immensely high rate for its lighting, nearly 100 per cent higher than any other city of equal importance."

McCall appeared before the League in April, 1906, to speak on behalf of the company's record. After hearing what he had to say, the League decided: "The consolidation has resulted in cheaper rates and better service, and to this extent has been a benefit to the citizens of Philadelphia; it is undoubtedly true that since the consolidation there has been a substantial decrease in the cost of public lighting and in the rates charged private consumers; and further that the Philadelphia rates compare favorably with those prevailing in other cities of the first class."


This Room Is Equipped With

Edison Electric Light.

Do not attempt to light with match. Simply turn key on wall by the door.

The use of Electricity for lighting is in no way harmful to health, nor does it affect the soundness of sleep.

Conowingo Dam

W.S. Lacey, PE

As early as 1884, serious thought was given to harnessing the power of the Susquehanna River which was described as "sometimes a raging torrent, sometimes a tired and shallow trickle", at Conowingo, Maryland. In 1921, PECO began a study of the project and its base load concept.

The undertaking was a giant one. Philadelphia Electric Company proposed to create a hydro-electric development second in size only to Niagara. The Conowingo project, however, was basically different from that of Niagara where the source of power, the endless rush of water from the greatest reservoir in the world, was constant. The flow of the Susquehanna was erratic, now heavy, now light. It could be used for hydro-electric purposes only in conjunction with a highly developed center for electricity which also had steam plants capable of taking care of the area demands. With Baltimore already receiving hydro-electric power from Holtwood, Philadelphia was the only center within practical transmission range of Conowingo that had these requisites. When the Susquehanna was running strongly, the energy it generated would carry Philadelphia's base load, the steam plants furnishing the peak demands. At other times, when the river was low, the steam plant would supply the base load, and Conowingo would be sparingly used to handle the peak loads.

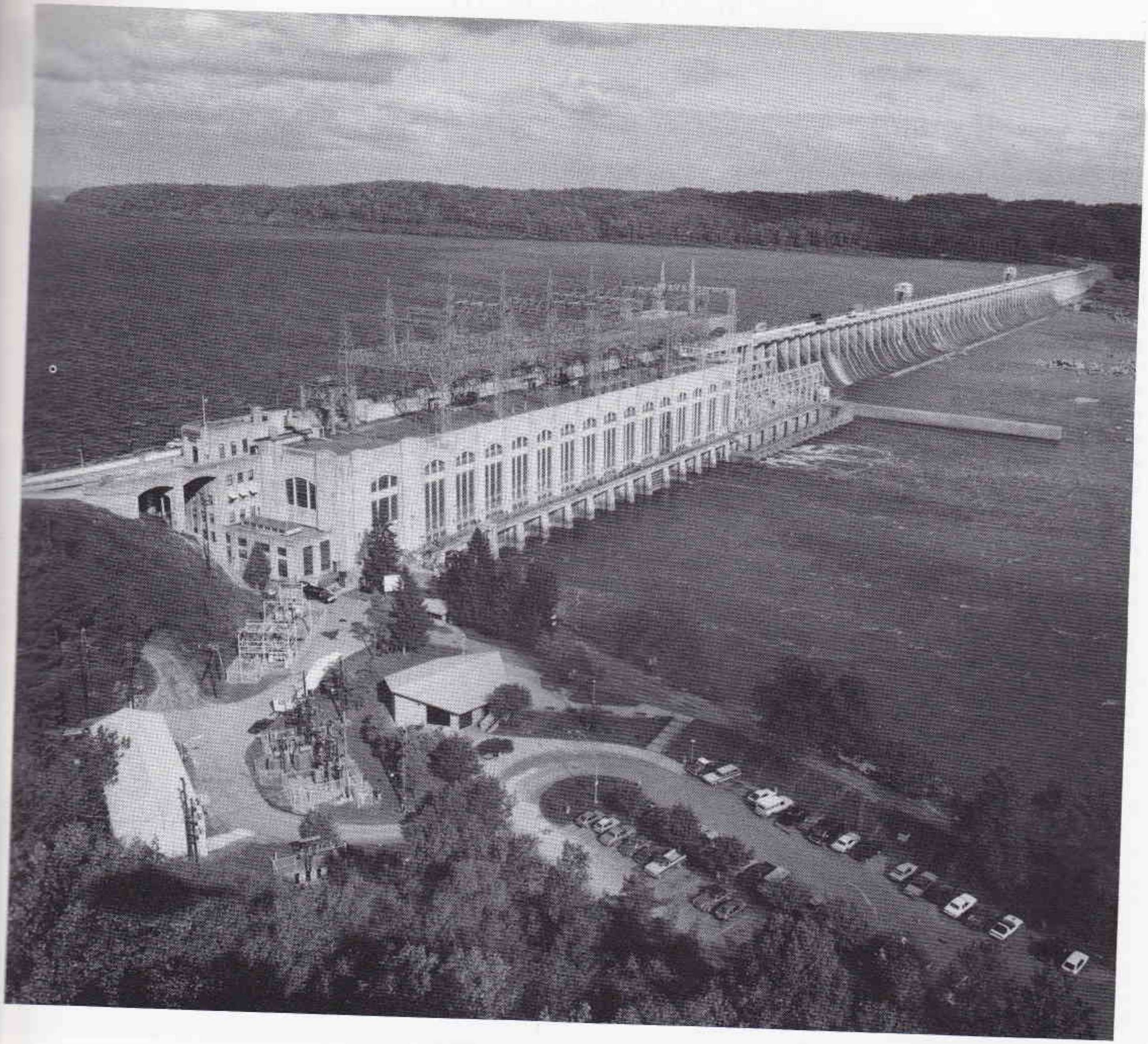
In March 1926, the project got under way. The plans for the powerhouse and dam were designed by Stone & Webster who supervised the construction and themselves built the powerhouse and a section of the dam, the powerhouse being on the west side of the river near the main channel. The Arundel Corporation of Baltimore constructed the main part of the solid concrete dam which, in its entirety, is 4,648 feet in length and rests on solid rock approximately 96 feet below the surface of the lake it forms.

At this time, PECO was working on a plan for interconnection with Pennsylvania Power and Light and Public Service Electric and Gas of New Jersey which proposed bringing two 230 kV transmission lines into substation in PECO's service area. Several sites for the substation had been reviewed and eventually it was decided to combine the interconnection and Conowingo transmission in one substation at Plymouth Meeting. Two 230 kV transmission lines were installed between Conowingo and Plymouth Meeting Substation, a distance of approximately 60 miles.

Early in 1928, the monumental Conowingo project was completed. Backed up behind its mighty dam was a lake 14 square miles in area and 14 miles long, in which were impounded 150,000,000,000 gallons of water. In place and ready to operate were seven huge water wheels, each driving generators rated at 36,000 kW. Standing by, in reserve, were foundation provisions for four additional units should their installation ever be required. The requisite machinery to generate a capacity of 252,000 kW was in place. On March 1, 1928, power from Conowingo was transmitted to Plymouth Meeting.

Additions to the project have been made since then and the present generating capacity now available is 512,000 kW or 3.3% of system summer rating.

Editor's note: Upon completion, the Plymouth Meeting Substation became the largest transmission substation in the world. In the early 1980s the generating capacity was increased to 5.12 mw or 2.3% of system capability with the installation of four 60 mw generatos.



Conowingo Dam

Eddystone Station

W. S. Lacey, PE, (M '77)

During the early 1950's economies in the production of electricity had been achieved by technological improvements involving gradual increasing of operating pressures and temperatures to 2,400 pounds per square inch and 1100 degrees Fahrenheit, with units of 150,000 kW capacity and larger becoming both practicable and desirable.

Eddystone Station, as it evolved through changing plans, contains two generating units each rated at 325,000 kW. Both operate in the supercritical range although at different temperatures and pressures. Number 1 turbine, built by Westinghouse, was the one designed for main steam conditions of 5,000 pounds per square inch and 1,200 degrees Fahrenheit. The steam generator of the Sultzer Monotube type was built by Combusion Engineering, Inc. No. 2 unit is a more conventional machine, designed for 3,500 pounds per square inch and a temperature of 1,050 degrees.

There were no large supercritical generators in operation when Philadelphia Electric Company decided to build Eddystone. Consequently, the adoption of the supercritical principal was of benefit to the electric industry because it tested the promise held out by that concept. By way of explanation, "critical point" is that pressure and temperature of a substance at which the densities and other physical properties of the liquid and gaseous stages are identical. Under these conditions, steam has the density of water. At supercritical pressures, water does not come to a boil. Instead, it passes directly into the supercritical state of steam with density equivalent to that of water. In so doing. it contains far more heat energy than ordinary steam, and produces more kilowatt-hours for each unit of fuel than was possible before. In fact, the No. 1 unit at Eddystone was designed to be 158 times more efficient than Cromby, the company's most economical station before Eddystone went on the lines. Its fuel rate was to be about 0.60 pounds of coal per kilowatt-hour.

Unusual problems encountered in placing so large and advanced a station in operation slowed the construction timetable. No. 1 unit was placed in commercial operation on February 5, 1960 and, after a period of tests and corrective measures, was brought up to its rated capacity early in June. On October 7, unit No. 2 was declared in commercial use. Within a few weeks, it was producing its rated capacity and had handled loads up to 360,000 kilowatts. Thus, after six years of designing and building, Eddystone, the largest plant in the Philadelphia Electric Company system, came into its own at a cost of $162,000,000. Eddystone required the rebuilding of the transmission system; new substations and more than one hundred miles of transmission lines, costing $30,465,000, were erected.

Editor's note: In a supercritical system, the high pressure and temperatures result in identical physical properties for water in liquid or gas storages. The water does not boil but instead passes drectly into a gaseous supercritical (steam) state. The steam contains more heat than ordinary steam resulting in more kilowatt-hours per unit of fuel.

Eddystone Station

Pennsylvania-New Jersey-Maryland Interconnection - PJM

Wilmer S. Kleinbach

At the dawn of the electric utility industry, throughout the country an unbelievable number of isolated systems were organized, first to supply lighting for streets, offices, and commercial and industrial buildings, and later, light for residences and power for business and industry. Proceeding in parallel with the merger of the numerous systems into the still very large number of utilities that exist today was the interconnection of generating stations within each system. Although the first objective was to improve service reliability, which was as strong a desire then as it continues to be today, it was soon learned that the benefits of interconnecting stations were appreciable, even at the relatively low voltages by today's standards. Savings due to load diversity, forced outage diversity, reserve diversity allowed for a lowering of the needed installed capacity and operating reserve capacity. Economic dispatch of operating capacity and energy added considerably to the savings.

With this knowledge, the pioneers in power pooling realized that service reliability and savings could be increased by interconnecting systems, an expansion on interconnecting generating stations. With this foresight, in the mid-1920's three companies in central and eastern Pennsylvania and northern New Jersey launched a study to evaluate the costs and benefits of interconnecting the three systems. Even at that time, the proponents of a "super grid" or a "national grid" system provided additional incentive to a power pool.

The three-system study showed justification for pooling and, by an agreement dated September 26, 1927, the Pennsylvania-New Jersey Interconnection was formed. It included Public Service Electric and Gas Company, Philadelphia Electric Company, and Pennsylvania Power & Light Company with a combined load of approximately 1,500 megawatts. Two hundred and ten miles of new transmission was installed and operated at 230 kv. This provided a strong ring with two lines terminating on each of the three systems. All of the savings the three systems realized by interconnecting first their own generating stations were expanded under the one-system operating concept. Under this concept, the systems were operated as though they were under one management and the resulting savings were equitably divided by accounting procedures in proportion to each system's contribution to the savings. Generation was manually dispatched on all units regardless of ownership, to meet the total pool load. Lower installed capacity requirements alone more than offset the cost of the new transmission.

The three member pool was operated with adjacent systems and more remote systems throughout most of the Mid-Atlantic Region of the United States for a period close to thirty years.

In 1956, it was time to expand the three member pool into a five member pool. The PJM Agreement was signed on September 27, 1956, and added to the original three members the Baltimore Gas and Electric Company and the then four operating subsidiaries of the General Public Utilities Corporation (GPU): Pennsylvania Electric Company, Metropolitan Edison Company, New Jersey Power & Light Company, and Jersey Central Power & Light Company. Although all are signatories to the PJM Agreement, the four GPU utilities are operated in PJM as a single system.

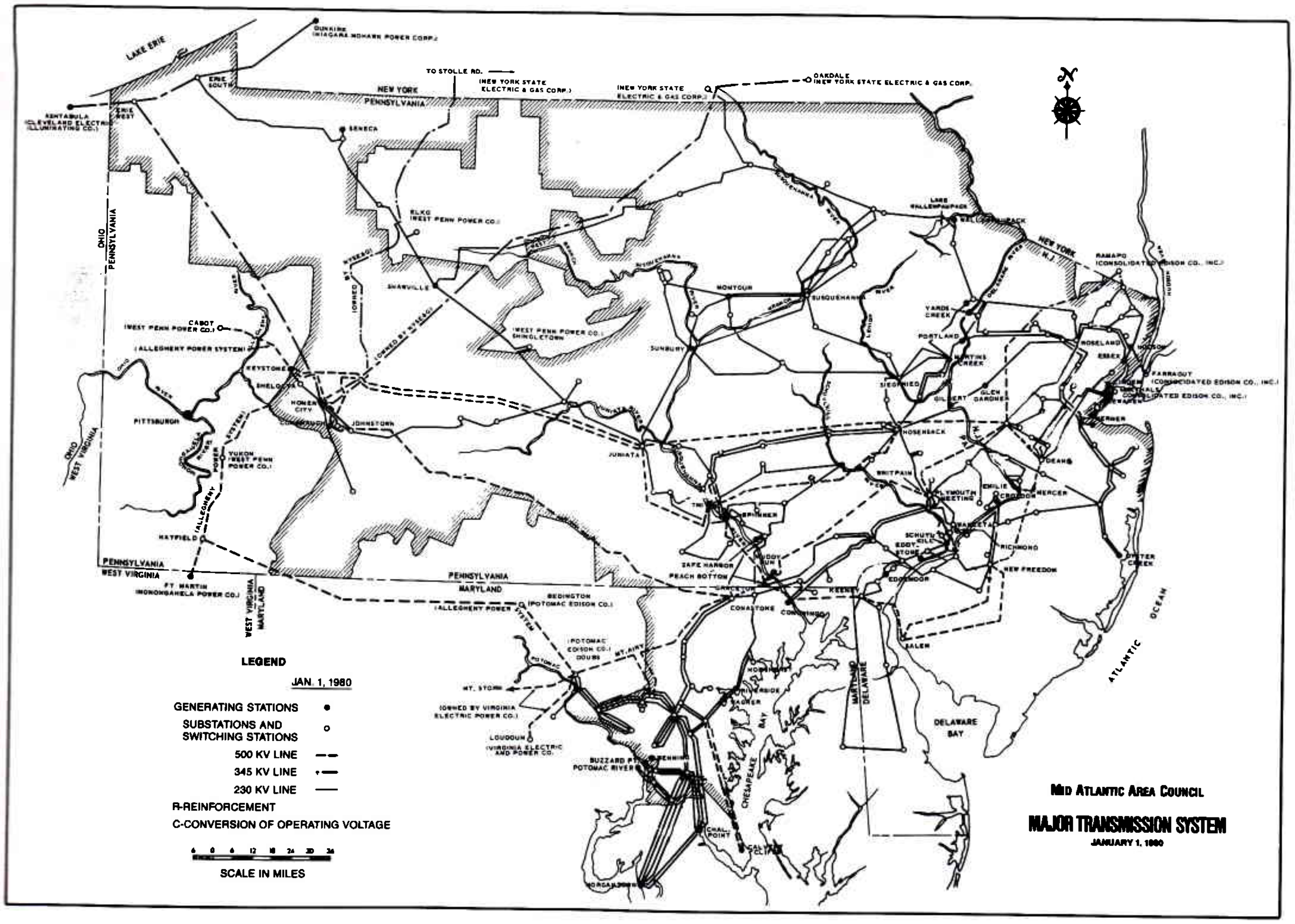
In 1962, giant steps were taken in PJM's interconnected operations. In April, PJM's interconnections to the north were closed on a permanent basis thereby interconnecting PJM with the Canada United States Eastern (CASUSE) Interconnection. In October, PJM installed its first automatic generation control analogue computer, having operated under manual dispatch of generation until that time. On November 1, 1962, seven ties were closed to the west that interconnected PJM with the Interconnected Systems Group (ISG); thereby interconnecting the United States and Ontario Hydro in Canada from the Atlantic Ocean to the Rocky Mountains, excluding the major portion of Texas, which operated as a separate interconnected system.

In the early and mid-1960's, changes took place that had a major affect on the operations. Limited sites near metropolitan load centers for new generating plants, higher fossil fuel costs, and the beginning of environmental restrictions all lead to construction of mine-mouth plants and EHV transmission in PJM. Transferring greater amounts of power over longer distances required the stricter monitoring of the transmission system while still striving for the most economic operation. Subsequent major power system interruptions placed even greater emphasis on reliability and the need for strengthening the operation. The extensive use of large scale digital computers became a necessity in the operations and were initially applied on PJM in the late 1960's and early 1970's.

Potomac Electric Power Company, which initially operated as an Associate, became a signatory and full member of PJM in 1965 forming a six system power pool. Also in 1965, interconnections were made to the west of PJM with the Cleveland Electric Illuminating Company and to the south of PJM with Virginia Electric and Power Company.

Recently, on June 1, 1981, PJM became an eight member pool when Atlantic City Electric Company and Delmarva Power & Light Company became signatories and full members. Prior to this date, both systems were operated for many years as Associates in PJM. Luzerne Electric and Gas Division, UGI, is operated as an Associate in PJM through a bilateral agreement with Pennsylvania Power & Light Company.

So today, PJM includes in its fully coordinated operations eleven investor-owned electric utility systems which serve all or parts of Pennsylvania, New Jersey, Maryland, Delaware, Virginia, and the District of Columbia. These systems serve over 7.5 million customers, a population in excess of 21 million. The facilities required represent an investment in plant of over $31.5 billion. The present installed capability exceeds 45,000 megawatts. Included in this capability are generating units of several municipal systems and industrial systems which, through separate agreements with certain PJM member systems, are operated as a part of PJM. Since its beginning, PJM operated as a single control area, and today is the largest control area in North America.

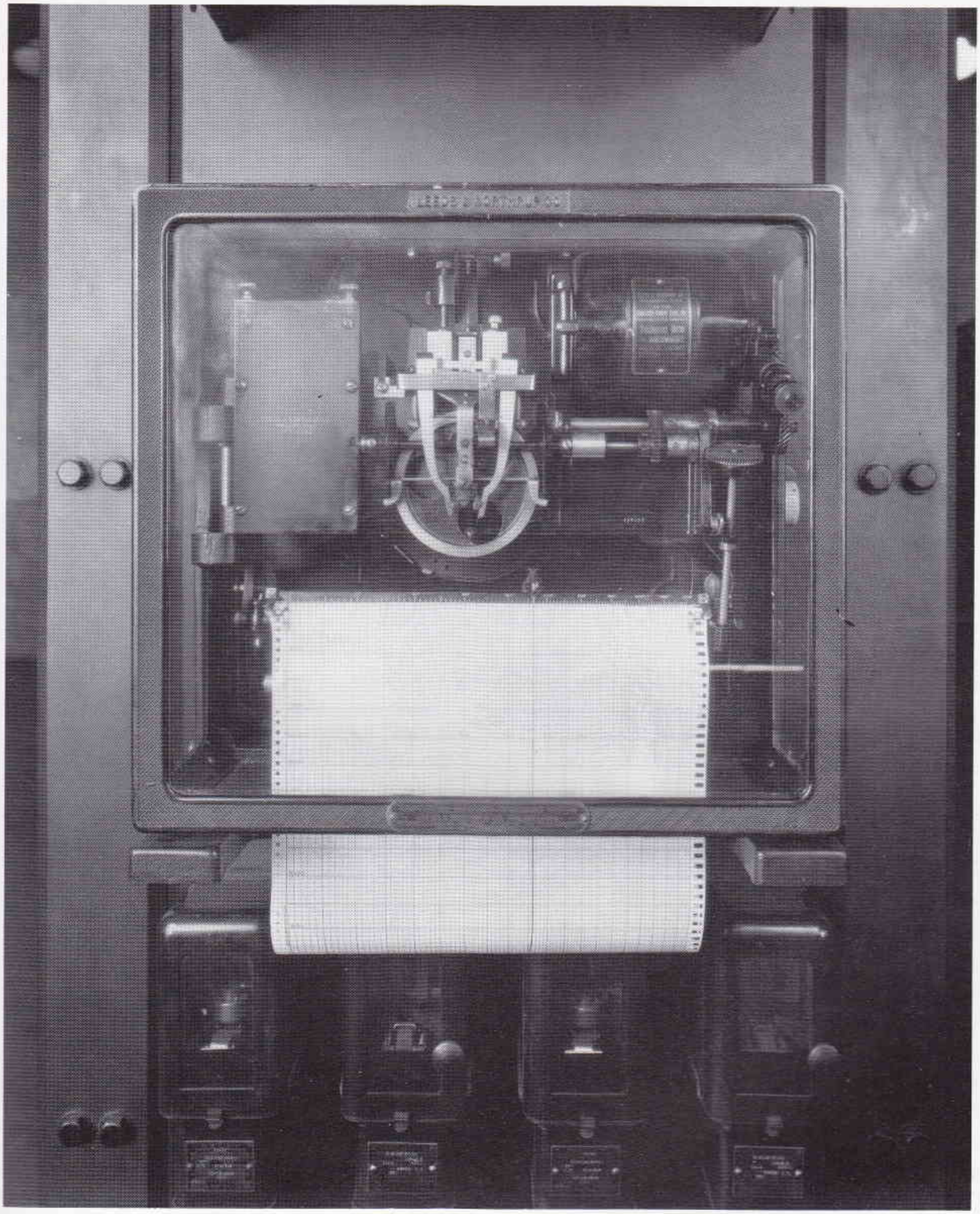


Leeds & Northrup Company

Morris E. Leeds began building precision laboratory-type
l measuring instruments to compete with German im-
1903, the Leeds & Northrup Company was incorporated.
, L&N introduced the world's first successful, automati-
lanced industrial recorder. Service to industry rapidly ex-
, spurred by a growing array of "firsts" and other technolo-
e world's first high-speed electronic recorder (1932), the
tralized load-dispatching system for power plants (1942),
incremental cost computer for an electric utility (1954), the
" expendable immersion thermocouple for measuring
metal temperatures (1958), the first combination pH elec-
esigned for accuracy and reliability in lab or plant (1977),
erization of pH signal to match process titration curve for
proportions control (1979), MAX 1 unit process control
first self-tuning, automatic proportioning controllers, Elec-
V (1981) and the first domestic optical electrical highway
L&N's 150-acre complex at North Wales, PA, is world
arters. The Administration Building Technical Center and
cturing Plant provide almost 800,000 sq. ft. of facilities for
00 people at this location. Additional instrument manufac-
acilities in the United States and a dozen foreign countries
e measuring and controlling devices for many industries.

On September 19, 1978, Leeds & Northrup merged with General Signal Corporation of Stamford, CT. General Signal Corporation is a leader in instrumentation and control technology for industrial automation, conservation and management of electric energy, rail transportation, telecommunications and semi-conductor processing.

Lord Kelvin, famed British scientist, once said, "If you can measure what you are talking about, and express it in numbers, you can know something about it." Today, man's expanding knowledge in science and industry depends on numbers, incredibly large, infinitesimally small, precise, reproducible numbers – gathered swiftly, from all parts of a complex process. Numbers precisely recorded, categorized, calculated, and sorted for later retrieval. L&N has evolved as a leader in industrial process control instrumentation which allows cost reduction, improves product quality and optimizes yield. Since the first days of electric power production, Leeds and Northrup expertise and equipment have played a major role in the evolution of control applications for electric power systems throughout the world.



Leeds' Mechnanical Null Balance Recorder.

The Evolution of Real Time Control Application to Power Systems

Nathan Cohn (F)

(Digest of paper presented at the International Federation of Automatic Control Symposium on Real Time Digital Control Applications, Guadalajara, Mexico, January 15, 1983.)

Throughout the history of the power industry, dependable, real time automatic control for safe, reliable, responsive operation has been a necessary element of power system installations. That was true a hundred years ago at Thomas Edison's first central generating station at the Pearl Street Station in New York. It was placed into operation on Sept. 4, 1882, and generally regarded as marking the founding of the electric power industry. Each of the station's six 100 kW generators was equipped with speed governors.

The first attempts to run two generators in parallel resulted in chaos. One engine would stop, and the other would speed up to 1,000 revolutions per minute. Then they see-sawed. The governors, effective for single unit operation, were not initially designed to permit parallel operation. After modification and adjustments the problem was overcome.

As in the very beginning, speed governors are still required. Such governors throughout the system, together with the frequency coefficient of connected customer load and the variation of system stored energy as a function of frequency, serve as the basic self-regulating forces throughout the system. Supplementary area controls are required, however, to reallocate generation changes in order to satisfy individual interconnected area responsibilities and objectives, which include programmed bulk power transfers to other areas and economic and secure operation within generator location area.

In the late 1920's the U.S. generating capability was about 25,000 MW. Thomas Edison and Nikola Tesla, the giants of the electric power field, were still working. The Edison dc and Tesla ac battle between their respective technologies had been resolved in favor of ac, though many metropolitan areas continued distributing dc power. No one could have visualized then that dc would one day be back, as the preferred medium for long distance, extra high voltage transmission lines and for asynchronous interconnections.

In the 20's, transmission voltages were lower, transmission distances shorter, and generating units smaller. In the context of present day plant and system coordination, we can note that most fossil fueled power plants were divided into three separate parts: a boiler room, a turbine-generator room, and an electrical switchboard room each operated with little central control.

Supplementary automatic control was indeed in its infancy. Voltage control was regularly used. Boiler feed water control was customary and boiler combustion control was relatively new. System control depended primarily on generator speed governors, supplemented by manual control.

By 1927, the potential operating and economic benefits of interconnections between adjacent areas, had been recognized and the practice started.

The Pennsylvania-New Jersey Pool, later to be the Pennsylvania-New Jersey-Maryland Pool, was within a few months of being established.

Two of the major parameters involved in power systems control are system frequency and magawatt load, the latter applying either to generators or transmission tie lines, or both. Apparatus for making such measurements prior to 1924 was of limited flexibility or precision, or of inadequate applicability to control systems, or far too costly.

Three developments, one initially unrelated to power systems activities and two that occurred virtually simultaneously but totally independently of each other, filled the measurement voids for power systems applications and were major factors in stimulating the early work in power systems real time control. These developments were:

1. The self balancing potentiometer high torque servo recorder, invented by Leeds (1912).
2. The adaptation of the Leeds self-balancing recorder to a self-balancing ac Wien bridge frequency recorder by F Wunsch of Leeds & Northrup (1925).
3. The Lincoln thermal converter, introduced in 1924 by Lincoln Meter Company of Canada.

The Leeds recorder was originally developed for the automatic measurement of small dc potentials such as those encountered with thermocouples or resistance thermometer circuits. It was a revolutionary development and a great stimulus to scientific and industrial measurement in many applications throughout the world. Its major characteristic was that in measuring very small electrical voltages, it did not draw power or alter the measured voltage. In addition it possessed, from its own energy source, adequate power to drive a pen, without restraint, on a ten inch wide chart, to operate control contacts and to operate a number of retransmitting slidewires in independent circuits in which were

Modern Utility Control Room with L&N Systems Equipment.

reproduced the measured voltage at high levels for analog computation and automatic control use. When the instrument was developed in 1912 no one could have anticipated that it would become the cornerstone of frequency and load measurement and control.

In 1923 N. E. Funk, Chief Engineer of Philadelphia Electric Company, asked Leeds and Northrup if it would be possible to build an open scale recorder for precise frequency measurement. Felix Wunsch adapted a Leeds recorder to serve as a self balancing ac Wien bridge suitable for the precise measurement of system frequency, using a range of 58 to 62 cycles over a ten inch chart. The recorder was installed at Philadelphia Electric in 1924.

The Lincoln thermal converter was invented by Prof. Paul Lincoln of Cornell. It was introduced in 1924 coincidently with the Wunsch frequency recorder with which it was later to have so close and extensive an association.

Conventional practice in power systems operations had been to depend on generator governors to respond to system load changes and to utilize manual adjustment of governor settings on one or more machines to achieve desired distribution of generation between alternative sources. An early central dispatching installation to facilitate such operation was the Philadelphia Electric Company. Recorders showing the generation at each of their four stations, the total system generation and the first Wunsch recorder showing the system frequency were provided at the dispatching center. A transmitting potentiometer slidewire, attached to each station's recorder, transmitted station output by telephone line to a recorder at the central office.

A Warren master clock provided the reference for periodic manual adjustment of the system speed to maintain time within limits considered appropriate.

In 1961, the Pennsylvania-New Jersey-Maryland (PJM) 12-company system planned to establish permanent ties north to the New York, New England, and Canada system and west to the Interconnected Systems Group.

Up to this time, PJM had not used automatic frequency control during its many years of operation as an independent single area system. Operating practice had been to manually notify each of its several operating entities as to the desired incremental cost of power. Each company in turn would adjust the generation sources of their respective systems to operate at this common value, and thereby achieve optimum operating economy for the pool.

From time to time, on instructions from the control center at Philadelphia, manual adjustments would be made to system frequency to keep system time within desired limits.

As a result of additional ties it was necessary to install automatic area controls which would utilize the by then well developed frequency biased technique for inter-area bulk power transfers. In addition, it was desired to supplement such control with a system that would closely emulate, automatically, the previous manually notifying operating companies of incremental power costs.

Data on total generation at each of the companies was available at the control center. An adjustable function generator was preprogrammed to simulate, from available pool data, the relationship between total required generation and approximate the necessary lambda to achieve it.

This initial value of lambda was automatically refined to the precisely requisite value. The computed lambda was continuously broadcast to all participating companies so they could maintain their own respective generation outputs at the broadcast common lambda value.

The system performed well over the years. Though now replaced with digital equipment, it has been retained for standby use at the PJM Valley Forge Control Center.

With the advent of digital technology and digital computers, interest developed in adapting their flexibility and capability to power system control. A first step was to replace the analog desired generation computations with digital computation, and use the results automatically to set analog allocation equipment.

The next step utilizing direct digital control soon followed. There were then great advances in computer design and programming technique. Current comprehensive digital power system monitoring and control installations incorporate extensive new analytical and security functions that contribute to reliability and economy of system operation.

Philadelphia Electric Company's New Power Control Center

H. J. Pantis (M '46) & G. W. Gordon (SM '50)

In 1969 the decision was made to move PECO corporate headquarters to 2301 Market Street, it was also decided that a new power control center would be established at that location.

The existing control center at 10th and Chestnut Streets was a computer directed analog system that essentially controlled the system generation to match system load. At that time most of the PECO substations were automated so that, from several satellite centers, a single operator could control and monitor as many as eight individual substations.

A task force recommended a completely new System Automatic Monitoring and Control (SAMAC) system be designed and installed at 23rd Street to meet the company's needs for at least fifteen years.

North American Rockwell was selected to design and install the system. A triple redundant computer system was proposed to provide automatic monitoring of the power system. The design was to provide a 99.99% system availability. The system would be in use 24 hours a day, 365 days a year. Some military systems that had attained this level of availability but it is believed that this was a first for a commercial application.

This digital system, like the analog system before it, had to keep load and generation in balance automatically, in addition to communicating with the Pennsylvania, New jersey, Maryland Power Pool. The SAMAC system monitored the transmission system and developed a strategy for testing what system overload would result from the loss of the most important transmission line or equipment. The system control room operators immediately are aware of this possibility, and can take steps to readjust line loadings.

This on-line contingency checking was a new tool for power dispatchers and has proven to be a very useful one. It would not have been possible without the use of a high speed digital computer and a relatively large on-line data base.

The man-machine interface provided color cathode ray tubes (CRT's) to the system operators with dynamic graphics and tabular data to make it easy to determine where problems existed and the magnitude of those problems. Multicolor graphic CRT's had never been used for this type of commercial display. In addition, ten CRT's were grouped two tubes high and five tubes wide to depict dynamically the entire PECO transmission system.

Supervisory control of substations was also centralized at the new control center. With more sophisticated computer programs, it is possible for one operator to manage up to 30 moderate size substations during normal operations. Additional operators may be required during storms or any major system disturbance. SAMAC is currently serving the needs of the Philadelphia Electric Company, however, the system is currently under study and a replacement system is scheduled for the late 1980's.

General Electric Company "Switchgear" Achievements in the Philadelphia Area

For more than sixty years, the Philadelphia area has been General Electric Headquarters for the design, manufacture, and marketing of significant products for the protection and control of the world's electric power systems. The businesses were built on a General Electric engineering heritage dating back to the 1890's, involving circuit breaker inventions which utilized air, water, and low-volume oil as the circuit interrupting media. The latter, known as the "H" breakers, went into production just prior to the turn of the century. A few are still in service.

In the mid-1920's, the Company centralized its switchboard and related product activities in new general offices and manufacturing buildings located on a 27-acre complex on Elmwood Avenue in Southwest Philadelphia. The opening of these facilities brought together switchboard and circuit breaker development and manufacturing engineers previously located at the company's Willow Street plant in Philadelphia; its switchboard operation in Baltimore; and its high-ampere circuit breaker manufacturing operations in Schenectady, New York. Today, the Elmwood Avenue facility is only one of the company's locations involved with circuit protective products, but for many years it was the world's largest switchgear plant; its engineers world-renowned for their work in the art and science of power system control and protection.

Of the many achievements and "firsts" in protective relays, switchgear, power circuit breakers, and high power conversion equipment, the following are cited for their impact on power systems expansion and reliability.

Low and Medium Voltage Switchgear Equipment

In the late 1920's and early 1930's, the concept of the switchgear equipment package, including insulation protection and instrumentation, was developed and made practical. Prior to this, customers purchased switchgear components and assembled the equipment at the job site. The factory assembled switchgear equipment led to improved reliability of the distribution power system, and greatly increased safety for operations personnel.

In the late 1930's, the switchgear operations introduced the air magnetic breaker for its medium voltage metalclad switchgear equipment. This design, with its high speed interrupting rating, would set the pace in medium voltage switchgear for many years. During World War II, nearly 34,000 units were installed at military bases and aboard ships.

In the 1940's, General Electric relay engineers developed and introduced the first draw-out type protective relay for switchgear application. Designated the IAC, this highly dependable electromechanical time overcurrent relay set the trend in protective relaying reliability. Its construction features permitted testing without removal of the relay and simplified replacement. Over one million IAC relays are in service around the world, installed on General Electric switchgear and switchboards, as well as on similar equipment manufactured by others.

For industrial and commercial applications, AKD-5 draw-out type switchgear was introduced for 600 volt power systems. This equipment and the IAC relay are generally recognized for their significant contributions to the reliability and expansion of industrial power systems in the 1950's.

High Voltage Power Circuit Breakers

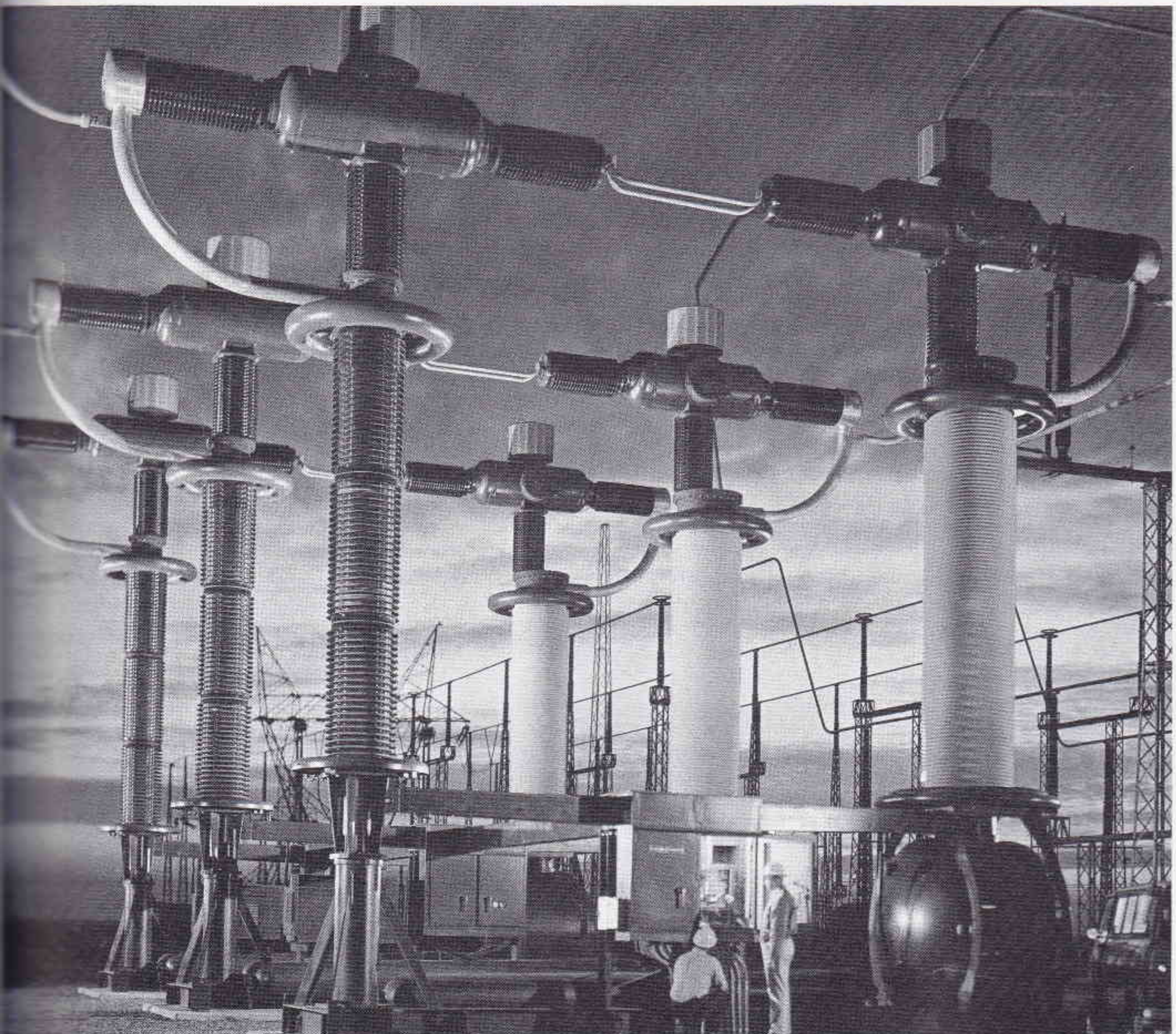
In the 1930's, General Electric Philadelphia engineers designed many of the principles of arc interruption which would assist the development of the nation's long distance high voltage transmission systems. The 287,000 volt impulse oil breaker that set the circuit breaker records at Boulder Dam in the 1930's was among the achievements of the depression years.

Developments in high voltage power circuit breakers accelerated in the 1950's, as industrial production and utility power generation rose to meet the pent-up consumer demand.

To assure new power breaker designs would meet field service requirements, General Electric opened its High Power Testing Laboratory near the Philadelphia International Airport in 1952. Now called the Skeats Laboratory in honor of the prolific inventor who evolved the concept of Compound Circuit Testing, the Laboratory enabled field service simulation evaluations of new products.

As loads grew in the 1950's and 1960's, electric utilities placed increasing emphasis on High Voltage transmission power circuit breakers which could handle ever higher loadings and short circuit currents. To meet the need, General Electric introduced both a line of air-blast circuit breakers and re-designed its transmission type oil circuit breakers. Its 362 kV steel clad oil impulse breaker of the period enabled switching of up to 25 million volt amperes. In 1957, this breaker set the world record for successful interruption of short circuit current.

The nation's first 500 kV power system went into service in May of 1965 — guarded by General Electric 500 kV Air Blast Breakers, also the first power breakers of this rating. Rated for two- cycle



General Electric Air-Blast power circuit breakers.

interruption, this breaker featured the largest nonporcelain insulator columns ever applied. Called GEPOL, the insulator was four feet in diameter, and in excess of fifteen feet in length.

Protective Relays

In a related effort, engineers developed and introduced a line of solid-state relays in the early 1960's for the protection of power transmission lines, which met the need for higher speed relaying and improved stability. Because of the vast improvement in fault clearing time, these relays helped permit more power to be carried on the transmission lines.

During this period, digital technology was first applied to commercial protective relays. General Electric introduced a Digital Frequency relay with more precision and stability than possible with electro-mechanical technology. It was offered to meet the needs of load conservation and the related fast response required during power emergencies.

Supporting Power Generation Needs

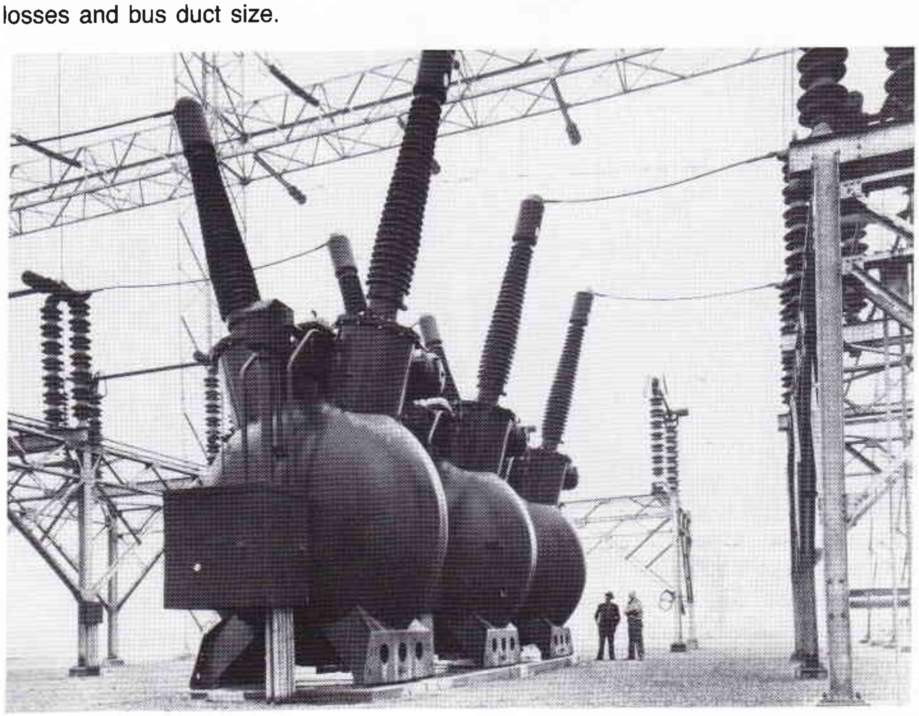
For many years, the General Electric Philadelphia Operations supported utility power generation requirements through advanced relays for protection of the machine and through generator station switchgear. In addition, significant development and manufacturing work on generator bus conductors increased operational reliability while increasing current carrying capabilities. Among the General Electric developments now widely employed were single-insulator support designs called "Mini-Flux", which improved mechanical withstand; and forced air cooled ducts, which reduced heating losses and bus duct size.

An early application of solid-state relaying technology was that developed for generation protection. Called the SGC, this relay provided added sensitivity required to protect large generators from possible damage due to unbalanced currents resulting from prolonged faults or load imbalances.

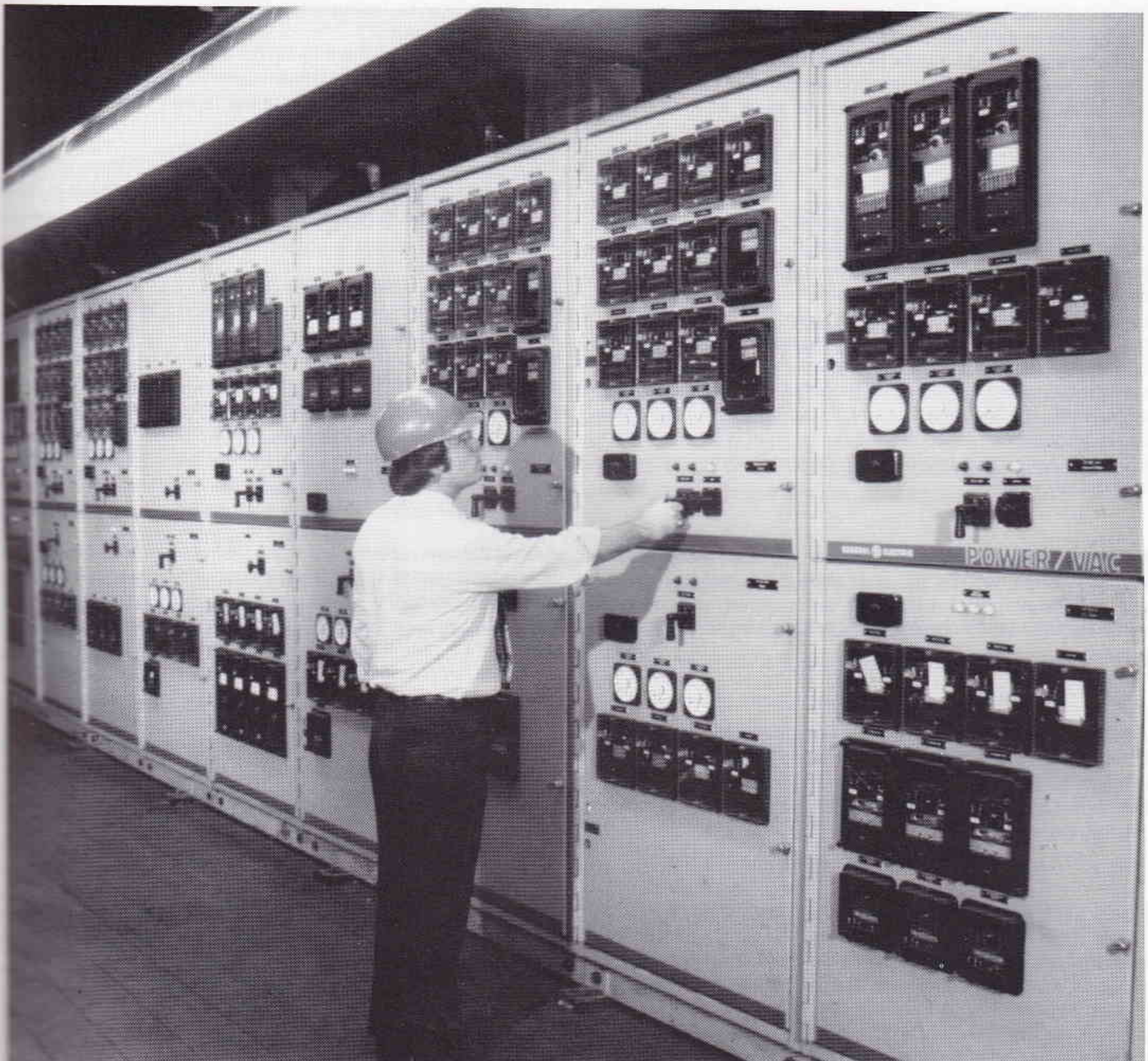
Interrupting Circuits in Vacuum

From the beginning of the power industry, engineers recognized the ideal circuit interrupting means for alternating current would likely be one in which electrical contacts were enclosed in a vacuum. The resulting device would be simple and virtually maintenance-free. Producing a reliable vacuum power circuit breaker, however, would not occur until the early 1960's when General Electric announced its breakthrough of high capacity vacuum interrupters for protection and control of medium voltage power systems. This most significant innovation was the culmination of many years of General Electric research, beginning in the mid-1920's, based on early work at the California Institute of Technology. The ability to interrupt power arcs in vacuum enabled the development of smaller, lighter power breakers, requiring less maintenance.

General Electric introduced the first vacuum power circuit breaker in 1961 for 15kV-27kV distribution systems. In 1971, vacuum metalclad switchgear was introduced for 34,500 volt service. This development, of primary importance for protection of generator station auxiliary equipment, provided significant reduction in maintenance expense over traditional interrupting means and further demonstrated the viability of vacuum interruption.



General Electric Extra High voltage, oil-filled power circuit breaker.



Power/vac metalclad switchgear.

Further developments followed in 1976 with the introduction of Power/Vac(R) metalclad switchgear. The Power/Vac design was the first to fully capitalize on the inherent space and maintenance saving features of vacuum interruption for protection of medium voltage systems. Applicable to power systems of 5 kV through 15 kV, the vacuum switchgear equipment has since been installed on off-shore rigs; in steel mills to handle arc furnace switching; within auxiliary systems to protect power generators, as well as within utility and industrial substations to serve as the primary protection.

Power Conversion Innovations

On a different technological front, engineers and physicists of the company's Philadelphia and Collingdale, Pa. power system operations were working to devolop and advance the ratings of diodes and thyristors (Silicon Controlled Rectifiers) which would be suitable for the high power conversion requirements of industrial and utility power systems. A major advancement was made in 1958 with the introduction of Silicon Controlled Rectifiers (SCRs) with power handling capabilities of 50 amperes at 200 volts. Today, cell capability is 1,800 amperes at 4,500 volts. These innovations have enabled significant equipment developments for power control and for conversion of alternating current to direct current for transmission systems.

One of the earliest equipment advances came in 1965 with the installation of the world's first solid state drive system for steel mills. This development, which was an outgrowth of continuing work in SCRs, would enable vast improvement in control and output of steel mills.

Similarly, the development of solid state static vac equipment utilizing SCRs permitted constant system voltage to be maintained in AC systems, despite large and frequent variations to load, thereby providing improvement in stability of the power transmission system.

In 1968, static power circuit breakers were developed for protection and control of large steel mill induction heating furnaces. This was followed in 1969, with the order for the first solid state high voltage DC converter equipment. This milestone would pave the way to the world's first all solid state DC converter tie installed at Eel River, New Brunswick, Canada in 1972, linking the asynchronous Canadian and U.S. Systems for reliable power interchange.

Subsequently, the company has led the industry with DC installations linking East and West power grids (1976); and in proving practicability of converting AC power to DC at mine-mouth and shipping "coal by wire" some 500 miles over DC transmission lines while reducing land usage one third (1977).

Further, the installation in 1977 of a solid state HVDC and gas insulated substation at Astoria, New York — which involved the Electric Power Research Institute, Consolidated Edison and General Electric — is recognized as a landmark in substation design and technology for metropolitan areas.

The energy crunch of the mid-1970's and today's need to reduce the cost of generation and transmission has accelerated interest in HVDC and its ability to deliver power reliably and economically.

More than 2,000 MW of new GE-HVDC installations will go in service by 1987, including a major new 700 MW installation to link Quebec Province to New England.

Automating the Power System

While development work continues to perfect the traditional electro-mechanical and solid state technologies, increasing engineering emphasis is being placed on developing and manufacturing products which utilize microprocessors. General Electric engineers at the company's Power Systems Management Department in Malvern, Pennsylvania, are engaged in prototype and commercial production of many products and systems involving distributed microprocessors for the monitoring, protection, and control of the power system.

Among the new products are those for FM radio control by utilties of consumer water heater and air-conditioning loads; monitoring and automatic control of industrial substations; and the automation of transmission distribution systems involving interactive terminals which permit centrally located operations personnel to interrogate remote switching points and to re-route power in the event of power faults.

The use of digital technology for protection and control of power systems was first explored in the 1970's in a joint Philadelphia Electric and General Electric project involving fault isolation on a 500 kV line. From this and similar field projects for distribution systems, the requirements of microprocessors for the substation environment were formulated.

ITE

John C. Conte
Director of Communications
Brown Boveri Electric Inc.

The former I-T-E Power Equipment and Gould Electrical Systems Groups are now BROWN BOVERI ELECTRIC, INC. Following a 1976 merger with Gould and a subsequent joint venture in 1978, they became known as Gould-Brown Boveri in 1978. I-T-E was purchased by Brown Boveri & Company in 1980.

Although the name is new, the company is not. As a matter of fact, it's been around for almost 100 years. It was back in 1888 that the Cutter Company was formed in Philadelphia.

The first I-T-E circuit breaker was produced by Cutter in 1890. The letters I-T-E stood for Inverse Time Element (tripping time inversely proportional to magnitudes of fault current) the principle that made the circuit breaker practical and the basis for almost all air circuit breaker development that followed. Through the years, the company expanded its product line to include an extensive offering of circuit breakers and switch-gear.

The I-T-E trademark became so strong that, in 1928, the company name was officially changed to I-T-E Circuit Breaker Company. Over the years many basic improvements to circuit breakers were developed or popularized by I-T-E engineers.

In 1926, the need for greater safety and compactness led I-T-E engineers to create new designs. Instead of individual circuit breakers and enclosures on a slate panel, they designed vertical steel units with compartments for drawout or fixed-mounted circuit breakers and steel enclosed rear bus sections.

In 1934, for the Boulder Dam Powerhouse, the U.S. government specified elimination of the usual cable connections to the generator. Instead, segregated phase metal-enclosed bus duct — a new idea — was ordered. I-T-E won the bid. In 1938, I-T-E announced development of an air break circuit breaker for 2,300 volt service. During World War II, I-T-E was a major supplier of switchgear for the U.S. Navy. One development was the direct acting, dual selective, overcurrent trip device.

In 1947, I-T-E acquired the R&IE Company of Greensburg, PA., leaders in the high voltage disconnect switch business. They presently manufacture the largest SF gas insulated circuit breakers available in the U.S. Since porcelain insulators are vital to the switch and substation business, I-T-E acquired Victor Insulators of New York in 1953. One of the oldest insulator manufacturers in the country, Victor was founded by Frederick Locke, the "father" of the electrical porcelain industry.

In the mid-1950's, I-T-E developed a spring charged mechanism that quickly closed and latched the main contacts — no matter how slowly the operator pulled the closing handle — leading to the 1958 introduction of the K-Line low-voltage power circuit breaker. Also available was an electrically operated model that used a small motor to charge the spring — in just two seconds. I-T-E pioneered SF technology in the U.S. during the 1960's and are still leaders in the gas-insulated equipment field.

Industry Firsts include:

Air Switch to interrupt load current.

"Live front" switchboards for industrial and marine use.

"Shock-proof" circuit breaker for U.S. Navy use.

Single-unit, factory-built switchboard for industry.

Metal enclosed breaker which paved the way for "dead front" switchboards.

Segregated phase metal-enclosed bus developed for Boulder Dam powerhouse.

Isolated-phase, metal-enclosed bus - 15kV, 3,000 amperes.

Automatic high-speed grounding switch.

Coordinated, fused interrupter switch-gear with a single-rated assembly.

500kV, 1800kV BIL vertical break switch.

345kV SF gas-insulated system installed and energized.

345kV SF underground transmission DIP installed and energized.

United Engineers & Construction Inc. History

Thomas M. Dahl, Chmn. and President

"The largest engineering and construction company in this country has been organized in Philadelphia." So opened a press release issued January 17, 1928, announcing the combining of four internationally known firms to form United Engineers & Constructors Inc. The new company was off to an auspicious start with over $100 million in contracts. It had offices in New York, Newark, Chicago, Los Angeles, Atlanta, Houston, Pittsburgh, Montreal, Buenos Aires, and Rio de Janeiro in addition to its Philadelphia headquarters.

The four founding firms were United Gas Improvement Company, Public Service Production Company, Dwight P. Robinson & Company, and Day & Zimmerman Engineering & Construction Company. Together, they provided engineering and construction experience in industrial and commercial facilities, electric power production and transmission, manufactured gas facilities, highways and railroads, irrigation projects, and water and wastewater treatment projects. Dwight P. Robinson was United's first president. An electrical engineer with degrees from Harvard and M.I.T., he was a dynamic businessman who had started his own engineering and construction firm in 1918. The chairman of the board of directors was Arthur W. Thompson, formerly president of the United Gas Improvement Company. This founding firm provided office space in its building at Broad and Arch Streets, where United resided until its six-block move to South 17th Street in 1975.

United expanded further in 1964 when Jackson & Moreland, the Boston-based engineering and construction firm founded in 1897, merged with the company. In 1969 United became a subsidiary of Raytheon Company, a diversified science and technology-based organization with annual sales in excess of $5 billion.

Today United Engineers & Constructors has about 4,500 employees and employs an additional 10,000 craft and contractor personnel at construction sites. In addition to its Philadelphia home office, United maintains offices in Boston, Dallas, Denver, Knoxville, and locally in Valley Forge, PA., and Echelon, NJ. Today, the company has a wide variety of projects in power generation, metals, chemicals, and general manufacturing and industrial fields under way across the United States and overseas.

Philadelphia Landmarks

The Barclay Hotel, 30th Street Railroad Station, Suburban Station and its rail viaduct, the Franklin Institute, the Eastern State Penitentiary at Graterford, numerous buildings at Girard College — these are just some of the Philadelphia-area landmarks that United or its founding firms designed and constructed in the early days. Over the years United has left its mark locally through design and construction of power plants, substations and transmission lines for Philadelphia Electric Company; through design and construction of additions to the University of Pennsylvania Hospital, Abington Memorial Hospital, Chestnut Hill Hospital, and the old Childrens Hospital and through design of research facilities such as General Electric's Valley Forge Space Center.

United has been a global company from the start. Over the years major projects have been completed in every one of the fifty United States and Puerto Rico, and in eight Canadian provinces. Around the world the company has performed work in 25 countries – Argentina, Bolivia, Brazil, Chile, China, Cuba, the Dominican Republic, England, India, Ireland, Italy, Japan, Korea, Lebanon, Mexico, the Netherlands, New Zealand, Peru, Saudi Arabia, Spain, Swaziland, Venezuela, and the United Arab Emirates.

The following projects, old and new, illustrate the company's wide range of experience:

Power Generation — United has been known for the design and construction of utility and industrial power plants since its beginning. The company has built numerous coal, lignite, gas, oil and hydro power facilities; built many substations and transmission facilities; conducted countless studies; and performed many major improvement projects over the years. An early example is design and construction of the $6.8 million Richmond Generating Station for Philadelphia Electric in 1931. Recent examples are design and construction management of a 280-MW coal-fired station for the Sunflower Electric Cooperative in Kansas, a $500 million sulfur dioxide and particulate removal retrofit for Arizona Public Service, and a major oil-to-coal conversion project at Delmarva Power & Light's Eddystone Station near Wilmington, Delaware.

The company also has widely recognized expertise in the design and construction of nuclear power plants. United's first nuclear project was construction of Detroit Edison's 100-MW Fermi Unit 1, which went into operation in 1963. The most current is engineering and construction management of the 2,320-MW Seabrook Station for Public Service of New Hampshire. Thc first unit is scheduled for operation in 1984.

Steel Industry — Engineering and construction of iron ore beneficiation, steelmaking, and other metals facilities has long been a field of expertise for United. Just two of the significant projects completed over the years are the 1948 design and construction of a 57.2 million 30' hot strip mill for Alan Wood Steel of Conshohocken, and major coal chemical facilities for United States Steel at Gary, Ind. in 1952. Currently, the company is providing construction engineering for installation of continuous casters at Bethlehem Steel's plants at Sparrows Point, Md., and Burns Harbor, Ind.

Chemical Industry — Chemical clients over the years have included industry giants such as Allied Chemical, DuPont, America Cyanamd, Monsanto, Tennessee Eastman, Union Carbide, and Merck Sharp & Dohme, Typically, in the early 1950s United designed and constructed a vinyl chloride monomer plant and two phenol plants for Monsanto. Recently, the company has been involved in process design as well. Working jointly with Philadelphia Electric, United developed a new regenerable magnesium oxide flue gas desulfurization process now in operation at PECO's Eddystone and Cromby power stations near Philadelphia.

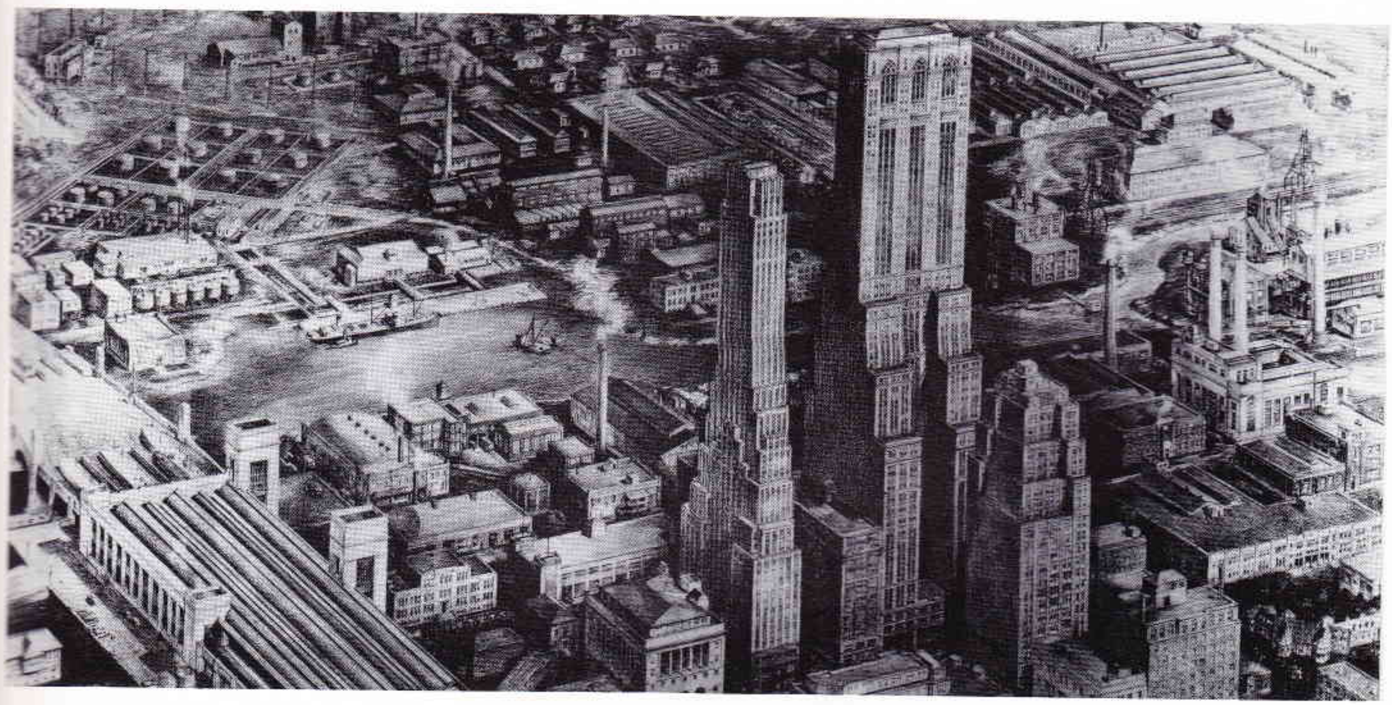
Transportation — The first subway system in Buenos Aires, Argentina, was built in 1930 by United Engineers & Constructors. On a schedule that seems impossible by today's standards, the 4.6-mile downtown section of the LaCroze Subway was constructed in 20 months. United estimated financing, designed the subway structure, built the line, purchased the rolling stock, and organized the operating force.

Currently, for the District of Columbia's Washington Metro, United is designing the complete traction power system. The system for the all-electric Metro converts high-voltage alternating current to usable 700-volt direct current that is fed into a third rail. Computers calculate power loads for the substations and tie breaker stations. Begun in 1969, the Washington Metro has over 40 stations now and a planned total of 86 stations on 101 miles of track.

Manufacturing and Engineering and construction of industrial plants Research Facilities — such as paper mills, rubber factories, textile mills, cement plants, and glassmaking plants have been done by United since its early days. In the Delaware Valley, firms such as Scott Paper, General Electric, Girdler Corporation, Fairmont Machinery, Curtis Publishing, and Ford Motors were early clients. Most recently, United designed a major cogeneration project for a Union Camp paper mill in Georgia.

Over the years, United has become known for the design and construction of sophisticated research facilities. One of the major highlights was the design of NASA's Lunar Landing Research Facility and the associated research vehicle to simulate the first moon landing. Recent projects include the master plan and final design for expansion of General Electric's combustion and fluid mechanics research facility at Niskayuna, New York, and the design, engineering and construction of a laser energetics laboratory at the University of Rochester.

In summary, United Engineers & Constructors has had an illustrious history since its founding in 1928. The number of clients and the variety of their needs has been remarkable. Today the company is involved in major power projects in Italy and Venezuela as well as in the United States, and is extending its skills into developing technologies through contributions to projects such as the Department of Energy's National Waste Terminal Storage Program and the Wind Farms station in California. United looks forward to continuing engineering and construction contributions to the Philadelphia area and the nation.



Artist conception of all United Engineers & Construction project during 1930s - enough to make a city.

Today, the Process Control Division is a major force in industry. Among the key technological breakthroughs it has spawned are:

- The first digital computer specifically designed for process control.
- The first cage-type valve which could be serviced and repaired without removal of the entire valve.
- The first potentiometer suitable for rugged industrial environments.
- A microprocessor-based control system—the TDC 2000—to control processes of any size or complexity.
- A digital control programmer to precisely regulate temperature and humidity in industrial furnaces and environmental chambers.

Headquarters for Honeywell Process Control is located in the suburbs of Fort Washington. An early downtown Philadelphia Honeywell location was consolidated in 1956 into the company's Fort Washington facility.

The division's products and services span practically every conceivable manufacturing market worldwide, from the assembly of aircraft to the production of zinc.

Pioneers in Productivity

Honeywell Process Control Division

Process instrumentation and control are the eyes and hands of today's industrial production line. Stated simply, the goal of process control is improved productivity and/or product quality.

The bulk of instrumentation and control equipment is designed to monitor and regulate the basic and vital elements of the production process—heat, temperature, pressure and flow.

A century ago, process control and instrumentation was, for the most part, in the eyes and hands of the plant manager. The viability of the manufacturing operation relied largely on his experience and intuition. That was when Edward Brown, a young English engineer and patent attorney, established the roots of Honeywell's Process Control Divison by inventing a portable pyrometer for measuring the expansion of iron in industrial furnaces.

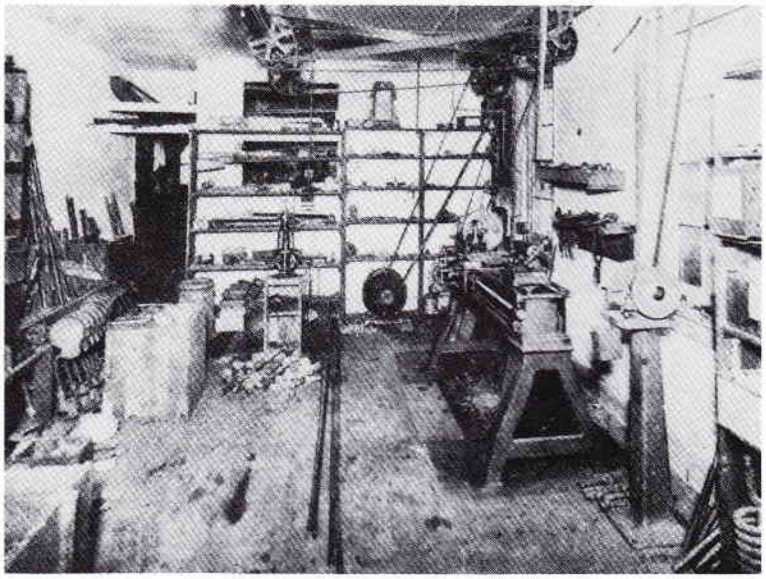
The invention in 1859 gave the infant steel industry the accuracy of control it needed to expand production. It also brought forth the Brown Instrument Company at 311 Walnut street in Philadelphia. There it grew, and in 1911 purchased the Keystone Electrical Instrument Company and moved into Keystone's facilities at Ninth Street and Montgomery Avenue. In 1934, the company consolidated with Honeywell (The Minneapolis Honeywell Regulator Company), then the leading manufacturer of domestic thermostats.

The age of electronics burst upon the industrial scene in the 1940s, creating new demands for greater accuracy, sensitivity and speed in measuring, recording and controlling manufacturing process variables. In response to the need, capabilities expanded, and factories grew. Seven different Honeywell plants were established in the Philadelphia area. In 1965, Brown Instrument Division and the other plants were consolidated in suburban Fort Washington into what was then the world's largest instrumentation and service facility under a single roof.

Subsequently designated the Process Control Division, the 1 million-square-foot plant employs more than 2,500 people from throughout the Delaware Valley and is the operational base for thousands of sales and service personnel throughout the world.

Even more notable than its size, the Fort Washington facility embodies a unique production concept that has created, in effect, factories within a factory. This uncommon structure physically separated the huge plant's extensive manufacturing capabilities into a half-dozen highly manageable product groups. Each "factory" has its own manager, production control, engineering, assembly operation, parts inventory and storeroom.

Brown Portable Electric Pyrometer



Machine shop of The Brown Instrument Company in 1907, located at 311 Walnut Street.