ELECTRICAL COMMUNICATIONS

A Study of the History, Development, and Use of the Telegraph, Telephone, Radio, and Related Devices

A Thesis Presented for the Degree of Master of Arts

by

Clayton M. Strider, B.S. in Ed.

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Approved by:

[Signature]
Adviser
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ACKNOWLEDGMENTS

It is my desire here to gratefully acknowledge the contributions of all who have helped in the completion of this thesis. A complete and accurate listing of all contributors would be impossible. Appendix B contains a list of those to whom I am particularly grateful for much of the information appearing in Chapters III, IV, V and VI.

Dr. William E. Warner, my adviser, helped in the planning of the study, and read the manuscript, making many valuable suggestions.

The highest tribute of all I reserve for Rutheva K. Strider, my wife, without whose understanding, encouragement, and help, this work could not have been undertaken nor completed.

Clayton M. Strider
Chapter I
THE PROBLEM

The writer as a graduate student at the Ohio State University during the past year, has gained certain concepts which have helped in forming a philosophy for the teaching of Industrial Arts. These concepts have resulted from classwork, readings, seminars, forums, and informal discussions, and are stated as follows:

1. Bennett and many others show that the Profession has a rich historical heritage, reaching back through the centuries into the Middle Ages.

2. The Terminological Investigation (63, p.19)¹ by the Western Arts Association reveals that many terms have been used, such as Applied Arts, Manual Arts, Vocational Arts, and Industrial Arts.

3. Industrial Arts objectives as derived by Warner (62, p.44) from the reactions of 421 leaders and teachers, to a large number of possible objectives are:

a. Guidance or orientation
b. Recreational opportunities
c. Vocational preparation
d. Consumer's knowledge and appreciation
e. Formation of desirable personal and social habits
f. Development of a degree of skill with tools and in tool or machine processes commensurate with the ability of the pupil and incidental to a project or activity which seems to have "educational" value

¹The numbers shown indicate the number of the reference in the bibliography and the number of the page respectively. All references will be used in this manner.
4. The extreme technological nature of present-day society is revealed by Dewhurst and others in the Twentieth Century Fund Survey. The following statements were paraphrased from appendix 38 of the above report:

a. Human beings and animals produced 94.2% of the total energy output in the United States in 1850.

b. Human beings and animals at the present time produce less than 8.6% of the total energy output.

c. The estimate for 1960 is that this figure will drop to 3.7%.

This means that by 1960, close to 96.3% of the total energy output in the United States will be provided through technology.

5. The American Industrial Arts Association (p, p.1) has recognized the implications of this trend in the presentation of the New Industrial Arts Curriculum, which is designed to reflect the Technology through the following five divisions:

a. Communications
b. Power
c. Transportation
d. Construction
e. Manufacturing

All five of the above-listed concepts are involved in the writer's philosophy as a teacher, but the work presented in this thesis is concerned mainly with the New Industrial Arts Curriculum, and more specifically with the Communications division.

Selecting the Problem. Research into the possibilities of the new curriculum is at present being carried on for the American Industrial Arts Association, under the leadership of
Dr. William E. Warner, professor of education at the Ohio State University. This research is now in its early stages, dealing primarily with the content embraced within each of the five divisions.

Personal interest stemming from service in naval communications and an appreciation of the importance of communications in providing a world-community characteristic of present-day civilization, have led the writer to attempt a contribution to this particular phase of the general problem.

Developing the Problem. A preliminary statement of the problem was made as follows: A study of communications, including the instruments involved, the services rendered, and the procedures carried out in performing these services. Further speculation, however, recalled a definition of communications which had been accepted by a class of graduate students, viz.: Communication has taken place when an idea has been formulated, transmitted, received, and understood. This means that the transfer of any intelligence is communication. It may involve two people or it may include millions. It may take place over a distance of inches or it may travel around the world. It may go in the form of a spoken word carried through the air, over wires or radio waves, or it may be written in notes, letters, books, and newspapers. Through the use of codes and ciphers, either spoken or written, its meaning may be lost to all who handle it except the originator and the addressee.

It soon became apparent that a study of the type contemplated, would not adequately present all phases of commun-
ications. It was therefore decided to limit the scope to the extent that only forms of communication involving the use of electricity, would be considered. This was further limited to include only the telegraph, telephone, and radio, including their related devices.

The final statement of the problem then would be: To make a study of the history, development, and modern applications of the telegraph, telephone, and radio together with their related devices in a search for content for the communications division of the new Industrial Arts curriculum.

Value of the Study. It is believed that this study will be of value in two ways:

1. It will help the individual Industrial Arts, Physics, or General Science teacher in preparing his course of study.

2. It will be of aid to the individual who undertakes to make a curriculum study in either Communications or Power (electrical).

Philosophy. Keeping in mind the objectives of Industrial Arts,\(^1\) it was thought that a review of some of the aims of general education would provide additional clues as to the type of material to be included in the main body of the study.

Dewey (16, p.144) lists the following comprehensive or general aims:

1. Development according to nature.
2. Social efficiency.
3. Culture or personal mental enrichment.

\(^1\) See p.1
He explains that these general aims may be used as viewpoints, from which can be examined the more specific problems of education. Development according to nature then can be transposed into such specific activities as attention to state of health, utilization of the adolescent tendency toward physical activity, providing activity which recognizes the individual differences among students, and recognizing the budding of an interest or its waning. Social efficiency resolves into such constituent concepts as learning a means of earning a living, education in the use of the products of industry, the futility of collecting wealth for the purpose of display, good citizenship including a sense of civic responsibility, an understanding of what men have in common, and the ability to make intelligent choices and decisions. Culture or mental enrichment means the provision of rich experiences, the various implications of which will be assimilated to become a part of the individual's personality. It also means encouragement to free and full communication with other personalities.

It is interesting, in the light of the above paragraph, to note Bonser's (11, p.12) list of goals or principles:

1. Freedom to develop naturally
2. Interest as a motivating influence
3. Guidance and leadership as a function of the teacher
4. Intelligent study of pupil development
5. Attention to health and physical growth
6. Close cooperation of school and home for meeting the pupils' needs

The similarity between the two lists is to be noted, because, considering the stature of the two writers, it
provides no small measure of validity for these objectives.

Bonser (11, 83) in discussing criteria for desirable activities in Industrial Arts has the following to say:

If studies for the industrial and household arts groups are made up largely of scientific and geographical principles and problems in direct relationship to shop and laboratory work; of the historic settings and relationships of the industries as they have developed; of the larger economic and social values of industries; of the thoughts and feelings enkindled by man's reflection upon and emotional interpretation of the meanings and higher significance of his work as expressed in his literature, music and art -- if the laboratory studies are all shot through and through with these human values, then will the work be truly educational and cultural.

It is observed here that he would have the activities in the Laboratory designed to interpret the whole industry involved including its history and development. It is recognized that an individual without a knowledge of, and an appreciation for the background of the work in which he is engaged, is lacking in an important phase of his cultural development.

Again quoting from Dewey (16, p. 7)

... it may be said, without exaggeration, that the measure of the worth of any social institution, economic, domestic, political, legal, religious, is its effect in enlarging and improving experiences ...

One's attention is immediately focused upon the word "experiences". The question arises: What experiences are provided in a formal type of class recitation? Although there may be some, it is presumed that the average reader of this thesis will not require that this question be answered here.
As formal teaching and training grow in extent, there is the danger of creating an undesirable split between the experience gained in more direct associations and what is acquired in school. This danger was never greater than at the present time, on account of the rapid growth in the last few centuries of knowledge and technical modes of skill.

Since these lines were written (1916) the activities of man have become even more technical. This would seem to call for renewed efforts on the part of educators to bring into the school, true experiences of life as the student will find it when he graduates.

Techniques Employed. This study was then carried out, with all the foregoing concepts in mind, by examining available books and other literature; through correspondence with leading companies of the Communications Industry; by visits to various business establishments and organizations making wide use of electrical communications and by talking to personnel in charge of these facilities; and by talking to school administrators, teachers, amateur radio men, telephone and telegraph officials, and program directors of radio broadcasting stations.

The results of these efforts as shown in the pages that follow, include:

1. A history of electricity as well as of electrical communications, since the two are so closely associated.

2. A study of the way electrical communications devices are used.

3. An account of certain statistics and information on the Communications industry itself.
4. Present practices in training and education in electrical communications.

5. A final chapter which contains the writer's conclusions regarding the study together with possible applications, and suggestions for further study.
Chapter II

A BRIEF HISTORY OF ELECTRICITY

Since the achievements of man in modern electrical communication would have been impossible without a knowledge of the phenomenon of electricity, it seems logical, in a study of electrical communications, to give some attention to the history of electricity. Such is the purpose of this chapter. The subject will be treated briefly under the following headings: (1) The Beginning, (2) The Dark Ages, (3) The Renaissance, (4) Early Work in Static Electricity, (5) Early Work in Current Electricity, (6) Developments in Electromagnetism, and (7) The Beginning of Electronics.

The Beginning. It is known, through the writings of Aristotle (384-322 B.C.), that Thales, a Greek wiseman about the year 600 B.C., knew that amber, when rubbed with cloth, would attract light objects such as bits of straw and feathers. This phenomenon must have been the source of great wonderment to Thales and his ancient contemporaries. Little did they dream that their contemplations would form the origin of such a vast and complicated science as electricity is today. It is presumed that the people of their time used this translucent yellow substance, which is known today to be the resin from a species of pine tree now extinct, as ornaments. Still (57, p.7) relates that the women of Syria used it for hair ornaments, and that they called it harnaga, which means "attracting with great force". He goes on to say that the Persians called it karuba, meaning "capable of
attracting straw", and that the Greek name for it was
*elektron*, while the Latin was *electrum*.

**The Dark Ages.** The culture of Greece was suppressed
with the rise of the Roman Empire. This state of intellectual
dormancy continued on into the Christian Era, and through
the period known today as the Dark Ages. The turmoil result-
ing from invasions by the Saracens, Magyars, and Northmen,
precluded the possibility of any advance in philosophy or
science. Another suppressing factor for many centuries was
an authoritarian Church, whose dogmatic teachings discouraged
progress in any form. In spite of turmoil and suppression
however, there were pioneering individuals who pressed for-
ward as leaders. These men were to be found in all walks of
life. There were traders, explorers, and scholars, all press-
ing their individual boundaries. One such individual was
Roger Bacon (1214-1294), who at Oxford carried on scientific
research in the fields of physics and alchemy. He invented
the magnifying glass, developed a saltpeter explosive, and
worked out a new scientific method which revolutionized the
science of his day. It has been said of Bacon, that he lived
several hundred years ahead of his time. Because of his severe
criticism of the clergy, he was removed to Paris in 1287, and
kept from pursuing his work for eight years. During his
subsequent period of freedom he wrote his *Opus Majus*, an
encyclopedia of science, and other works. His activity led
to his imprisonment by the Pope in 1287, where he remained
for ten years. Upon his release, he returned to Oxford and
resumed his efforts for the Church. Later he discovered an error in the then-existing calendar.

The work of Roger Bacon is mentioned here because it points toward the dawn of a new era, a period marked by exploration of the then-unknown parts of the world, by trading activity resulting in knowledges of new cultures, and by a diligent search for truth by the scholars of the day.

The Renaissance. This new era, however did not come about in any sudden manner, although in relation to earth history, it may be thought of as happening quickly. The transition period took place during the 14th, 15th, and 16th centuries, and marked the end of the medieval, and the beginning of the modern -- two radically different civilizations. No doubt the greatest factor in bringing about this transition, was the rapid growth of commerce, industry, wealth and city life. There was more material wealth and consequently more leisure time for people to build up a culture, and to pursue certain studies of their choice. Many of the rigid class lines of the Middle or Dark Ages were broken down, resulting in a more homogenous society. It has been said (fl, Vol. 8, p.419) that "the Middle Ages had been an age of societies; the Renaissance was an age of society".

Thus the stage was set for the search for truth. The curiosity of the ancient Greek philosophers was to be revived in men living in a newer, freer world. Some 2000 years after the time of Thales the study of the strange attractive powers of amber was resumed; this time by an Englishman named William Gilbert, who was England's most noted scientist during the
reign of Queen Elizabeth (1558-1603).

**Early Work in Static Electricity.** Miller (37, p.3) credits Gilbert with laying the foundation of the present-day science of magnetism in his De Magnete, published in 1600. He showed that many substances, such as resin, sulphur, glass, rock crystal, diamond and sapphire were capable of behaving in the same manner as amber. All substances which exhibited this power Gilbert termed *electrics*, and those which did not he called non-electrics. It seems that the first man to use the term electricity was Sir Thomas Browne in his *Pseudodoxia Epidemica: Enquiries into many commonly received Tenets and commonly presumed Truths*, published in 1646. Hence a rapid progress in the new science is indicated.

The earliest form of an electroscope was devised by Gilbert (37, p.6). This instrument was called a "versorium", and consisted of a light rod or needle mounted on a pivot. It would be deflected when a charged body was brought near it.

The idea of conductors and non-conductors was developed in 1729 by an Englishman named Stephen Gray. He showed that when a charged body was insulated it would hold its charge, and that if such insulated and charged body were connected to the ground by a wire, it would lose its charge immediately.

The first machine designed to generate an electric charge seems to have been constructed by Otto von Guericke, of Magdeburg, Germany about 1665. With his machine, which consisted of a sulphur sphere mounted on an iron crank in a wooden frame, he could, by turning the sphere and allowing it to rub against his bare hand, build up a charge on the surface
of the sulphur. With his machine he performed experiments leading to an understanding of the phenomena of repulsion, conduction, and induction.

Still (56, p.43) tells how, in the year 1730, Stephen Gray, with the cooperation of his friend Granville Wheeler succeeded in transmitting electricity a distance of 886 feet through a packthread suspended by silk loops.

Charles Francois Du Fay, a Frenchman, in 1733 showed that there are two kinds of electricity. Only bodies charged with opposite kinds would attract each other. A glass rod, for instance, rubbed with silk takes on what Du Fay called vitreous electricity, while substances such as amber, sulphur, resin, sealing-wax and hard rubber take on a charge of resinous electricity, when rubbed with flannel or fur. (Later, Benjamin Franklin termed these two kinds of electricity positive and negative respectively.) Du Fay also improved upon the conduction experiments of Gray and Wheeler by wetting the packthread. Later it was found that metal wires were the most efficient conductors of electricity.

In August 1748, Dr. William Watson, an Englishman, and his co-workers performed a notable experiment. They discharged a Leyden jar through 12,276 feet of wire and concluded that the time required for the passage of the electricity was "so short as to be imperceptible" (56, p.44). This discovery would seem to indicate the possibility of a rapid means of communication over long distances, but apparently that idea had not yet occurred to any of these early electricians.
The Leydon jar, mentioned in the above paragraph, was so-named by the Abbe Nollet of France, after it had been discovered accidentally in 1746 by a Dutch physicist named Pieter van Musschenbroek of the University of Leyden, Holland. Musschenbroek and one of his students were trying to collect the electric "fluid" in a wide-mouthed flask half filled with water. Cunaeus, the pupil, held the flask in his hand, and passed a wire running from the water in the flask through the cork, to an electrostatic machine. After the bottle was charged, he attempted to disconnect the wire from the machine and received a severe shock. Miller (37, p.26) describes a demonstration of the power of the Leyden jar, which took place at the Convent in Paris. Seven hundred monks were formed in a line 900 feet long. Iron wires were used to connect every two persons. When the jar was discharged through this line, every monk felt the shock. Many such demonstrations were held. The discharge was passed through the water in rivers and lakes; it was used to melt wires, and it was shown that it could kill birds and other animals. The reader is no doubt familiar with the present form of the Leyden jar, but it is of interest to note here, that in 1837 Michael Faraday, whose work will be discussed later, named the non-conducting medium across which electric influence takes place, (glass in the case of the Leyden jar) a dielectric. He also measured the effectiveness of several non-conductors used in this way, and termed this characteristic specific inductive capacity. The terms farad, micro-farad, or micro-micro-farad are used in modern electricity and electronics to
indicate the value of capacitors (condensers).

Greenwood (p71, p.75) states that Benjamin Franklin's attention was first directed to electrical studies in 1745 by a letter from Peter Collinson, a Fellow of the Royal Society of London, to the Literary Society of Philadelphia, but there seems to be no record of his famous experiments before 1752. In October of that year Franklin described his kite experiment, in a letter presumably written to Collinson. That portion of his letter describing the experiment is quoted by Greenwood (p71, p.76) as follows:

Make a small cross of two light strips of cedar, the arms so long as to reach to the four corners of a large thin silk handkerchief when extended. Tie the corners of the handkerchief to the extremities of the cross, so you have the body of a kite which, being properly accommodated with a tail, loop and string, will rise in the air like those made of paper; but, this being made of silk, is fitted to bear the wet and wind of a thunder-gust without tearing. To the top of the upright stick of the cross is to be fixed a very sharp-pointed wire, rising a foot or more above the wood. On the end of the twine, next to the hand, is to be held a silk ribbon, and where the silk and twine join a key may be fastened. This kite is to be raised when a thunder-gust appears to be coming on, and the person who holds the string must stand within a door, window, or under some cover, so that the silk ribbon may not be wet, and care must be taken that the twine does not touch the frame of the door or window. As soon as any of the thunder clouds come over the kite, the pointed wire will draw the electric fire from them, and the kite with all the twine will be electrified and the loose filaments of the twine will stand out every way and be attracted by an approaching finger. And when the rain has wetted the kite so that it can conduct the electric fire freely, you will find it stream out plentifully from the key on the approach of your knuckle. At this key, the phial (Leyden jar) may be charged, and from electric fire thus obtained spirits may be kindled, and all the other electric experiments be performed which are usually done by the help of a rubber, glass globe, or tube, and thereby the sameness of the electric matter with that of lightning completely demonstrated.
These lines serve to identify Franklin as a true scientist, who attempts to satisfy his curiosity by actual experiment, and then records the experiment and the observations made. Many other notable observations, experiments, and discoveries were made by this remarkable man, but these will not be reviewed here.

The preceding pages have carried a brief account of that part of the history of electricity dealing with static or frictional electricity. Much had been learned through laborious and oftentimes dangerous experiments. Perhaps the greatest problem in the minds of these early scientists was that of finding a way to control and utilize this strange "substance". They could make it flow through certain materials which they had learned to identify as "conductors", but this flow could not be made to take place over a period of time. If a steady flow could be obtained, perhaps they could find some way to use it. The discovery of a type of electricity which would flow, then becomes the next subject for consideration.

Early Work in Current Electricity. Soon after the kite experiment of Franklin, an Italian, Luigi Galvani, quite accidentally it seems, made a discovery that paved the way for far-reaching developments. In 1780 he noticed strange jerkings taking place in the body of a frog. Further investigation revealed that these convulsions were synchronized with the spark of an electrostatic machine nearby, with which some of his friends were amusing themselves. Hawks (29, p.28) tells how Galvani carried on his observations by erecting a lightning
rod on the roof of his laboratory, and running a connection from these rods to the nerves in the legs of frogs and other animals. He found that the legs were convulsed with every flash of lightning.

A few years passed and in 1786 Galvani's nephew, Camillo, working with his uncle had prepared some frogs for experiments and hung them by copper hooks to an iron balcony outside the window. He noticed that when the hanging legs touched the iron, they were convulsed as they had been by the electric current from the friction machine and the lightning a few years before. Experimenting further, Galvani discovered that stronger movements could be produced by combinations of different metals. He believed that the movement in the frogs' legs was caused by the union of one kind of charge in the nerve and the opposite charge in the muscle. He was wrong in his assumption, of course, and it remained for another man to show that they were caused by an electric current generated by the two unlike metals.

Alessandro Volta, another Italian, was born in 1745. As a boy he was brilliant and versatile, and at an early age had decided to become a poet. However at the age of eighteen he began to study electricity. After carrying on experiments of his own extending over a number of years, and utilizing the discoveries of other scientists of his day, he was able in 1796 to construct his "voltaic pile" consisting of disks of copper and zinc piled alternately one on top of the other but separated by pieces of moist cloth. He found that from this "pile" he could draw small charges of electricity. As
the supply of this charge was available in a continuous flow, it became known as current electricity. The exact source of this current, however was a matter for much argument among the scientists of the day, for some time following Volta's discovery. The conclusion was finally reached that it was due to chemical action, and the science of electrochemistry was born. Later the voltaic pile was replaced by the voltaic cell, well-known to all students of science today. With this source of electricity providing a steady flow for their experiments, the electricians of the day were able to push forward rapidly.

Hans Christian Oersted, a Swedish philosopher and scientist, began experimenting with magnetism at the turn of the 19th century. In the fall of 1819 while lecturing to a group of students in Copenhagen, he discovered that a wire carrying a current of electricity from a voltaic cell, would deflect a compass needle if the two were brought in close proximity. It is doubtful if he realized the importance of his discovery, but from the vantage point of the present it is not difficult to see just how far-reaching were his observations. A new field of research had been opened -- the field of electromagnetism.

Developments in Electromagnetism. Immediately after the publication of Oersted's discovery, a Frenchman, Andre Marie Ampere (1775-1836) began to work and experiment on the idea. He thought that if a current-carrying wire would exert a force upon a magnet, then two such current-carrying wires should exert a force upon each other. He devised several pieces of equipment for his investigations, and in a relatively short time announced
his laws of electrodynamics. Being a mathematician, he stated those laws in the form of algebraic equations.

Using the knowledge gained through the discoveries of Oersted and Ampere, William Sturgeon in 1825 constructed what is believed to have been the first electromagnet. According to Still (56, p.76) it consisted of a soft-iron rod about \( \frac{1}{2} \) inch in diameter, bent into the shape of a horseshoe, and wound with several turns of copper wire connected to a single voltaic cell using large plates of copper and zinc.

It seems that Johann E. C. Schweigger (1779-1857), a chemist of Hallo, Germany, should be mentioned here in connection with the first instrument designed to measure the flow of electricity. Schweigger showed that the deflection produced by the outward current from a battery, flowing through a wire over a compass needle, was the same as the deflection caused by the return current under the needle. He went further to point out that by causing the wire to proceed from and to the battery above and beneath the compass, a double effect could be obtained. By giving the wire another turn about the needle the amount of deviation was again doubled. Three turns produced six times the effect; four turns, eight times; and so on, the increase in deflection being in direct proportion to the increase in the number of turns of wire.

With this instrument then, known as the galvanometer, minute currents of electricity could be detected, a means of comparison being available in the amount of deflection of the needle.

In England, the work of Oersted and Ampere had claimed the attention of Michael Faraday (1791-1867) destined to
become the father of modern electricity. Faraday believed that if Oersted could make a current-carrying wire affect a magnet, it might be possible to reverse the process and make a magnet produce an electric current. He constructed a cylindrical coil of wire and attached the two ends of the wire to a galvanometer. He then discovered that if a bar magnet were thrust in and out of the coil, the needle of the galvanometer would be deflected twice -- when the magnet entered the coil and when it was withdrawn. He also showed how an alternating current could be produced by making and breaking a direct current. In other words, he demonstrated the principle of electro-magnetic induction and incidentally the transformer, and dynamo. In a supplement to The Bell System Technical Journal, October 1931, entitled The Faraday Centenary, the work of this great man of research is duly recognized. Greetings from all the major scientific societies of the United States were sent to the Faraday Exhibition being held in London, and the page from Faraday's diary wherein he recorded the above-mentioned experiment on electro-magnetic induction, was reproduced in facsimile and accompanied by a transcript. These are shown in Fig. 1 page 21.

Joseph Henry (1797-1878), an American, was a contemporary of Faraday, being only six years younger. Although the latter is rightly credited with the discovery of electro-magnetic induction, it is believed by some students of history that Henry anticipated him and had arrived at certain conclusions regarding induction independently of the discoveries made by Faraday. Throughout his lifetime Henry always referred
Figure 1.

EXERT FROM FARADAY'S DIARY

Facsimile and Transcript of the page recording the Discovery of Electro-magnetic Induction

Aug. 29th, 1831.

1. Experiments on the production of Electricity from Magnetism etc, etc.

2. Have had an iron ring made (soft iron), iron round and 7/8 inches thick and ring 6 inches in external diameter. Wound many coils of copper wire round, one half the coils being separated by twine and calico -- there were 3 lengths of wire each about 24 feet long and they could be connected as one length or used as separate lengths. By trial with a trough each was insulated from the other. Will call this side of the ring A. On the other side but separated by an interval was wound wire in two pieces together amounting to about 60 feet in length, the direction being as with the former coils; this side call B.

3. Charged a batter of 10 pr. plates 4 inches square. Made the coil on B side one coil and connected its extremities by a copper wire passing to a distance and just over a magnetic needle (3 feet from iron ring). Then connected the ends of one of the pieces on A side with battery; immediately a sensible effect on needle. It oscillated and settled at last in original position. On breaking connection of A side with Battery, again a disturbance of the needle.

4. Made all the wires on A side one coil and sent current from battery through the whole. Effect on needle much stronger than before.

5. The effect on the needle then but a very small part of that which the wire communicating directly with the battery could produce.

(Courtesy Bell Telephone System)
Aug. 29th 1831

Hubs on the produce of electricity from Magneto-electricity.

There is an iron ring (with iron), iron and copper coils of iron 6 inches or more diameters. Bound around the coils lies horse feathers by horse feathers there come 3 lengths of wire each about 2 1/2 feet long and they could be unrolled as one length or used as separate lengths. By touch each wire unrolled from the other. Will roll them out of like way "A" on the other wire but separately by an iron wire, now wind wire in two turns together, remount to about 26 feet or less the wire lie on bars with the frame into this side call "B".

Change a batter of 1/2 foot plate, brush copper. Make the coil on B side and cool and immersed its extremity by a 1/2 foot piece of red lead and put upon a copper wire (1/2 foot from wire ring) then immersed in one of the frames on a side with battery immediately a small effect in much it will after of mixture at least no apparent fixture. On few inches of a side with battery gives a disturbance of the mouth.

Make all the wires or a side one cool and mount current from battery through the whole effect on mouth much stronger than before.

The effect of the mouth then had a very small font of that which the wire unrolled directly with the battery could produce.
to the Englishman as the discoverer of electro-magnetic induction. However his work in connecting coils (as well as voltaic cells) in series and in parallel led him to make the following claim quoted by Still (56, p.74):

I was the first to prove by actual experiment that in order to develop magnetic power at a distance, a galvanic battery of "intensity" must be employed to project the current through the long conductor, and that a magnet surrounded by many turns of one long wire must be used to receive this current.

It should be noted here that this discovery contributed much to the practical operation of long-distance telegraph lines.

Georg Simon Ohm (1787-1854) was another important pioneer in the field of electricity. He was a Bavarian, who for many years was a teacher of mathematics. After several years in minor positions and often unemployed, he was appointed professor of mathematics at the Jesuit College in Cologne. Here he had the time and equipment to enable him to experiment upon his many theories and in ten years he published the book which embodies his well-known "law". His superiors in the educational world of that time refused to recognize his efforts and being a sensitive person, Ohm lost heart in his work. Finally through a petition to the king of Bavaria, he was granted a professorship at the Polytechnic School of Nuremberg. Eight years later he was granted recognition, but not by his own country. The Royal Society of London awarded him the Copley medal, pointing out that he had been the first to demonstrate the laws of the electric circuit. He had demonstrated both by theory and by experiment, that the action in
an electric circuit was equal to the sum of the electro-
motive forces divided by the sum of the resistances, and
that the effects remain the same so long as this quotient
remains unchanged. Still (52, p.170) quotes Tyndall on the
subject of Ohm's law as follows:

Ohm assumed the passage of the electric fluid from
one section to another of the connecting wire to be due
solely to the difference of electric tension between the
two sections; he further assumed the quantity of elec-
tricity transmitted to be proportional to this difference
in tension, and from these fundamental assumptions he
deduced the laws of the voltaic circuit. These laws
may be briefly stated thus:

1. The strength of the current is directly propor-
tional to the electromotive force.
2. The strength of the current is inversely propor-
tional to the resistance.

Still goes ahead to point out that Ohm's law as set
forth in his book was not expressed "in quite the same form,
nor in such simple terms as used today", but that "we must
bear in mind that there were at that time no definite stand-
ards of electromotive force, current, and resistance". Ohm's
name was given to the unit of electrical resistance, at the
Paris International Congress of 1881, and his law forms the
basis of the complicated science of electrical mathematics
today.

In 1839 A. E. Becquerel (1820-1891) found that if he
coated two silver plates with silver chloride, immersed them
in water, and closed the circuit through a galvanometer, he
could cause a current to flow by shining a light on one of
the plates. Later on it was found that light would cause a neg-
atively charged zinc plate to discharge rapidly, while a
similar plate positively charged was not so affected. This
formed the basis of the photoelectric-cell or "electric-eye" which is able to convert variations of light intensity into variations in electrical current.

In summing up these early beginnings of the science known today as electrical engineering, the following quotation from Still (57, p.235) is cited:

The beginnings of electrical engineering were not with the rubbed amber of Thales, nor with the Leyden jar, nor even with the electric currents of Galvani and Volta. Dynamoelectric machinery — both generators and motors — and the alternating current transformer are the bases of our electrical era, and they owe their existence to the discoveries in electromagnetism made by Faraday, Henry, Davy, and their contemporaries.

This does not mean that the work of the earlier experimenters is to be disregarded. It does, however, serve to put the spotlight upon that part of electrical history marking the real beginning of modern electricity.

The Beginning of Electronics. Electronics is treated here under a special heading because of the tremendously important place it holds in our complex civilization today. Actually it cannot be separated from the general field of electricity, at least in the historical sense. The ordinary electronic devices of today consist of transformers, resistors, induction coils, and condensers together with the vacuum tube. All of these except the last were developed in their early stages by one or more of the men whose works have been examined in the preceding pages.

The experimenters and discoverers, with few exceptions up to this time, had been men without any great knowledge of mathematics. However the science had progressed to the
stage where it was becoming necessary to express their various discoveries in the form of mathematical equations. Faraday, for instance, was a skillful worker, with a high degree of scientific intuition, but possessed very little ability to reason mathematically. His aversion to mathematics is shown in a letter written to Clerk Maxwell (one of the greatest mathematicians) in 1857. McNicol (36, p.91) quotes a portion of the letter as follows:

"... there is one thing I would like to ask you: when a mathematician engaged in investigating physical actions and results has arrived at his conclusions, may they not be expressed in common language as fully, clearly and definitely as in mathematical formulae? If so would it not be a great boon to such as I to express them so — translating them out of their hieroglyphics, that we also might work upon them by experiment?"

McNicol makes the added observation that many a present-day youth has asked this same question, or at least has had it in mind.

It has been said that at one time Faraday entertained the theory that surrounding a wire carrying an electric current, was an electromagnetic field, which he believed might be conducted through the "ether" surrounding the earth. It remained for Clerk Maxwell, the Scotch mathematician, however to develop these theories in the form of mathematical equations. Through the medium of his figures he expressed the belief that electrical discharges produced effects in the atmosphere in the form of electromagnetic waves, which were of the same character, and travelled with the same speed
as light. His Treatise on Electricity and Magnetism, in which he set forth his theories, was published in the year 1873.

The knowledge of electricity had grown by leaps and bounds in seventy-five years between Volta and Maxwell. A storage battery had been constructed by a French physicist named Gaston Plante in 1859. This device constructed much the same as our lead storage batteries of today gave the workers in electricity a much more satisfactory source of electrical current, than they had had in the voltaic cell. Much had been learned about electromagnetism, and it had been shown mathematically that current disturbances in a wire produced electromagnetic disturbances in the air about the wire, and that these disturbances in the air took the form of waves which travelled with the speed of light.

Prior to, and during the time of the work of Maxwell, several scientists were studying the spark resulting from an electrical discharge. Some of these men constructed complicated pieces of apparatus, consisting of mirrors and cranks, with which to view the spark. One investigator even employed photography in pursuing his study of the discharge. It had been known for some time that the spark was not a sudden rush in one direction, but that it was of an oscillatory nature. That is to say it jumped back and forth many times before reaching a state of equilibrium.

The next contribution of great importance was made by the German scientist Heinrich Rudolf Hertz (1857-1894), who proved experimentally the mathematical predictions of Maxwell.
Hertz in 1887 used an induction coil to produce a spark by electrical discharge, and picked up this spark in a circle of copper wire containing a small spark gap, and held at a distance from the discharge. Being a mathematician, himself he studied the equations of Maxwell long and carefully before setting up his experiment. In order to receive the spark in the circle of wire, he constructed it so that, theoretically, it would be in resonance with the part of the apparatus at the spark discharge. That is, it would have the same period of oscillation -- it would be in tune. He named his receiving device a resonator, and with it he was able to measure the lengths and directions of the waves produced by his oscillator. Toward the end of the century Hertz carried on many experiments with his new-found waves. He found that the waves could be reflected by metal sheets and sometimes by the walls of his laboratory. By using parabolic mirrors he was able to bring the waves to a focus, like rays of visible light. Building a huge prism of pitch, he even succeeded in showing that the waves could be refracted in the same way as light. By the time he had completed his experiments, he had concluded that Hertzian waves, as they were called, were actually waves of *light*, invisible to the human eye because of their long wave-length -- in other words, their low frequency.

The subject which naturally follows the discovery of Hertzian waves is that of wireless telegraphy, but it is not the purpose of this chapter to deal with communications as such. Therefore the next discovery, which although used
widely in wireless communication, has other applications. This next development was that of the vacuum tube.

It had long been known that air in the immediate vicinity of white hot bodies would act as a conductor of electricity. In 1883, Thomas Edison in experimenting with his incandescent lamp, ran a wire in through the top of the bulb, terminating in a metal plate near the filament, but not touching it. He then found that if he connected the positive terminal of a battery to the plate, a current would flow across the gap between the plate and the hot filament. However if he connected the negative terminal of the battery to the plate, no current would pass. This is known as the "Edison effect". Edison could see no practical application for it at the time, but it is the basis of current rectifiers and the great array of electronic tubes available today.

Professor J. A. Fleming (1849-1945), an English physicist, in 1904 applied Edison's discovery to the Fleming valve which he used as a detector of Hertzian waves. His tube contained two elements, and he was granted a patent on it that same year.

Two years after Fleming patented his valve, Lee de Forest, an American added a third element in the form of a wire gridiron type of structure placed between the filament and the plate. This "grid", as it was called, could be electrically charged by an outside source, providing a way of controlling the flow of current between the filament and the plate. This new tube was called the "audion". It seems that its original purpose was that of amplifying speech currents,
but it was soon found that it would also act as a oscillator. This was especially important, because about this time it was found that it was not necessary to produce a spark in order to generate electromagnetic waves, but that the oscillations of a current in a wire would produce the same thing with the added advantage that they could be controlled more easily. It is known today, that De Forest's three-element tube or triode, was the real beginning, not only of radio but of the whole science of electronics.

Summary. An attempt has been made in this chapter to present that part of the history of electricity which leads directly into the field of modern electrical communications. Consequently much has been omitted that would ordinarily be included in a history of electricity. However it is felt that the material presented gives a fairly-well-integrated account of the development of the knowledge of electrical science, from the rubbed amber of Thales to the vacuum electron tube of Lee de Forest.
Chapter III
HISTORY OF ELECTRICAL COMMUNICATIONS

The purpose of this chapter is to present, chronologically, the story of the development of electrical communications, from the primitive devices using static or frictional electricity, to the complex instruments of today. This history will be set down under the following headings: (1) Pithball Telegraphs, (2) Electrochemical Telegraphs, (3) Early Electromagnetic Telegraphs, (4) Morse's Telegraph, (5) The Telephone, (6) Wireless Telegraphy, (7) Radio, (8) Television, and (9) Radar.

Pithball Telegraphs. Although a history of communications would reach back to prehistoric times, when the subject is limited to communication by the use of electricity, developments will naturally begin sometime after the discovery of this phenomenon. For purposes of orientation, this "discovery" will be considered as occurring with the work of William Gilbert\(^1\) at the beginning of the 17th century.

Several visual systems or semaphores were in use, just prior to the use of electricity. They were often called aerial telegraphs. The most notable of these systems, a kind of semaphore using mechanical arms, was invented by a Frenchman named Claude Chappe (1763-1805). After a time Chappe was able to interest the French government in his device. He was given permission to set up a "line" between Paris and Lille, which

\(^1\) See p. 12
proved to be a success. This line consisted of a number of towers spaced between the two cities, so as to be visible one to the other. Atop each tower was a set of mechanical arms which could be operated by a system of levers and pulleys by an operator stationed in the tower. By placing the arms in various positions, and through the use of a code, it was possible to relay a message from tower to tower. Since the towers were quite some distance apart (the operators having to use a telescope) it provided a fairly rapid means of transmitting messages. The system was used quite extensively throughout Europe.

It may readily be seen that the whole story of electrical communication is a recent one when it is recalled that as late as the middle of the 18th century, the scientists were just learning to send an electric charge over long conductors. It seems that the earliest proposals for the transmission of intelligence through the use of electricity, appear in a letter to The Scots' Magazine published at Edinburgh. This letter was written in February 1753 and was signed with the initials C. M., whose identity has never been fully established. Some writers say it was a Charles Marshall while others (56, p.45) support a man named Charles Morrison. At any rate, C. M. proposed stringing between sending and receiving ends, as many wires as there are letters in the alphabet. Each wire at the receiving end was to terminate in a small pithball just below which was to be placed a small piece of paper marked with a letter of the alphabet. When a wire was electrified at the sending end by a frictional machine, the pithball at the
receiving end would attract its letter, and in this way a message could be sent. There is no record of this particular device ever having been constructed however, and indeed its impractical nature may readily be seen.

Another idea requiring only two wires between sender and receiver was suggested by an Italian Jesuit named Joseph Bozolus. He merely suggested that a Leyden jar could be used at the sending end to produce a spark at the receiving end, and by the use of a suitable alphabet of these sparks, intelligence might be transmitted.

It seems that Georges-Louis Le Sage, of Geneva, Switzerland wrote a letter to a friend in June 1782, in which he described a telegraph he had constructed, or was considering. The transmission line was a tube made of a ceramic product, and pierced with 24 holes, through which were to be run 24 brass wires. At the receiving end, each wire terminated near a piece of gold leaf or other light body containing a letter of the alphabet. When the respective wires were electrified at the sending station the corresponding letters were attracted at the other end.

The name of Claude Chappe\(^1\) appears again. This time as the inventor of a type of electric telegraph using a clock at each end of the line. The faces of the clocks were divided into 10 equal divisions, and marked from 0 to 9. At the beginning of transmission the second hands (supposedly a sweep type) were synchronized so as to be at the same place at the

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\(^1\) See p. 31
same instant of time. As the second hands swept around the face of the clock, discharges from a Leyden Jar at the transmitting end appeared as sparks or activated an electroscope at the receiving end. At this instant the numeral would be read under the second hand. By use of a suitable code the numbers could be used to transmit letters, words, or even phrases and sentences. Still (56, p.47)\(^1\) records here that Chappe encountered the same difficulty experienced by all these early experimenters. It was impossible to provide adequate insulation. The erratic static electricity would run off and be gone in an instant.

The following article under the heading "Telegraph", appears in the Supplement to the sixth edition of the Encyclopedia Britannica (20, p.648) published in 1854:

> It has been supposed that electricity might be the means of conveying intelligence by passing given numbers of sparks through an insulated wire in given spaces of time. A gentleman of the name of Ronalds has written a small treatise on the subject, and several persons on the Continent and in England have made experiments on Galvanic or Voltaic telegraphs, by passing the stream at the two extremities or stations through phials of water; but there is reason to think that, ingenious as the experiments are, they are not likely ever to become practically useful.

This article is interesting, if for no other reason, to show the constant barrier of skepticism, and oftentimes

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\(^1\) For much of the information on the invention of these early telegraphs, the writer has drawn heavily from Still, who in turn has taken much of his material from J. J. Fahie's *A History of Electric Telegraphy to 1837* and A. Bonel's *Histoire de la Telegraphie*
downright hostility confronting pioneers in science — and in any other fields for that matter. Still (56, p.49) points out the "gentleman of the name of Ronalds" later became Sir Francis Ronalds, "a distinguished pioneer in the field of telegraphy", and that the "small treatise" on the subject of electricity as a means of conveying intelligence is the now scarce and valuable book *Descriptions of an Electrical Telegraph, and of some other Electrical Apparatus*, London, 1823.

The experiments of Ronalds seem to be important enough to be treated in some detail. Although his telegraph was first constructed in 1816, it was not until 1822 that he published his book describing it. On his lawn he strung up eight miles of wire, which he insulated by hanging it on silk strings attached to trees and other wooden structures. He also included, for experimental purposes, a section 595 feet long placed underground. This was done by placing the wire (a single wire) in glass tubes, laying them in wooden troughs, and covering them with pitch. He connected pitchball electrosopes to each end of the wire, which was kept charged constantly by a friction machine. This would mean that the pitchballs at both ends of the line, stood apart until the wire had been grounded, and this was precisely the manner in which the signals were sent. At each end of the wire Ronalds placed a clock-like mechanism capable of being synchronized one with the other. Each clock consisted of a rotating disk divided into twenty equal divisions. Each of these divisions was marked with a numeral and a letter, (letters F, Q, U, W, X, and Z were omitted) while each alternate division
also carried a word or phrase such as "prepare", "ready", or "finished". Covering this disk was a solid brass plate with a window the size of one of the divisions on the rotating disk. As the disk rotated, one at a time the twenty divisions with their letter, numerals, and words, would appear at the window. When the operator at either end wished to send a message, he would ground the transmission wire, sending a preliminary signal. At this signal both operators would synchronize their disks according to a pre-arranged plan. The message was then sent by grounding the wire, causing the pithballs to fall together when the desired character appeared at the window. Ronalds did not spell out words a letter at a time; that would have been much too slow. Instead he worked out a clever dictionary, by which a word or even a whole phrase or sentence could be transmitted with one signal.

It is to be noted here that perhaps the progress of this type of communication would have been much more rapid, had the various governments been more alert to its possibilities. Ronalds spent most of his life trying to get the British government to accept his invention. When he was seventy-two years old he was knighted by his Queen, in a belated acknowledgement of his work in telegraphy. During the last three years of his life he was known as Sir Francis Ronalds. Today, in the reading rooms of the Institution of Electrical Engineers in London, may be found the Ronalds Library. The Library consists of a valuable collection of books on electricity, collected by Ronalds in the early years of his life as he travelled throughout Europe and Asia.
The impossibility of providing the necessary insulation required when working with static electricity, has already been pointed out. Therefore the invention of the voltaic cell\(^1\) whereby a steady current could be produced, gave new impetus to the search for a means of transmitting intelligence by the use of electricity.

**Electrochemical Telegraphs.** The next development worthy of note was contained in the work of Anthony Carlisle (1789-1840), an English surgeon, and William Nicholson, who edited a magazine called *Nicholson's Journal*. These two men, using a fairly large voltaic pile, succeeded in breaking down a small amount of water into hydrogen and oxygen. They found that by putting the two electrodes in a container of water thus closing the circuit through the water, they were able to produce hydrogen coming off one of the electrodes in the form of bubbles. When they used platinum electrodes, bubbles of hydrogen appeared on one, and bubbles of oxygen on the other. Still (57, p.60) notes that this was the beginning of the science of electrochemistry.

Samuel Thomas von Sommering (1755-1830), a German physiologist, using the discoveries of Carlisle and Nicholson, in 1809, suggested an apparatus for communication. It seems that the receiving end of Sommering's proposed device consisted of a long wooden trough of water in which were placed thirty-five gold electrodes, (one for each letter of the German alphabet, plus ten numerals). Leading out from these electrodes were

\(^1\) See p. 17
thirty-five wires all of which made up the transmission "line". The transmitting end of this telegraph, found each of the wires terminating in a brass plate. The sending operator, using a voltaic pile as a source of current, would touch the negative wire from his battery to the plate representing the desired letter or numeral in the trough at the receiving end. The positive wire could be touched to any other plate. The receiving operator, knowing that hydrogen (from the negative electrode) formed twice as fast as oxygen, was able to pick out the letter being sent, by noting where the bubbles were formed.

The above ideas should be sufficient to show the impracticability of sending intelligence by causing electricity to decompose water, and it was about this time that the work of Oersted\(^1\) was leading the experimenters into new channels.

**Early Electromagnetic Telegraphs.** Albert (1, p.18) credits two Germans, Johann K. F. Gauss (1777-1855) and Wilhelm R. Weber (1804-1891) with the first electromagnetic telegraph of any real note. In 1833 these two men used a single circuit of over 7000 feet of copper wire. The receiver consisted of a large bar magnet mounted horizontally, and pivoted on a vertical rod. Surrounding the bar magnet was a large rectangular coil of wire with the leads running out to become the transmission line mentioned above. A small mirror was mounted on the bar magnet at its point of pivot. Across the room from the magnet was placed a telescope, right above

\(^1\) See p. 18
which was a small divided scale something like a foot-ruler. By looking through the telescope at the mirror on the magnet, the operator could see the reflected small divisions on the divided scale. When a current was applied at the transmitting end of the line causing the large magnet to swing (movement would be slight), the amount of deflection could be ascertained by watching the reflected scale. Obviously the operation would be slow and cumbersome.

A few years later Dr. Karl A. Steinheil improved upon the apparatus of Gauss and Weber. For his indicator he used two small pivoted magnets surrounded by many turns of small wire. These were so arranged that when they were deflected they could be made to either strike a bell or make marks on a moving strip of paper. Steinheil also made the discovery that one of the two wires could be eliminated, the earth being used instead. For his source of current he used a magnetoelectric generator, which had been developed since the discoveries of Faraday, making the observation that a voltaic pile was not suitable for long distance transmission because of its high internal resistance.

Morse's Telegraph. The invention of Samuel Finley Breese Morse (1791-1872) was of such far-reaching importance as to warrant a brief biographical sketch here.

The son of highly educated and cultured parents, Morse was graduated from Yale College in 1810 at the age of nineteen. Almost immediately he went to England to continue his studies in art, where he gained a measure of fame by winning the gold medal of the Adelphi Society for his sculpture, "The Dying
Hercules. Later he returned to America and became professor of art at the University of New York, where he painted several portraits of distinguished public men. After a time however there was less demand for his work. In 1829 Morse again visited Europe, where he remained for three years practicing his art. The story goes that while on board ship as he returned to America he conceived the idea of his recording telegraph. Being of an intense nature, he spent many years working on and developing his idea. His funds ran low and he was poverty-stricken for a time, but a sum of money was raised by his fellow artists, and presented to him as a token of their appreciation for his work. Unlike many inventors who passed on before him, Morse lived to see his telegraph accepted and used widely throughout the world.

Morse was using cast type in 1833 which through the action of an electromagnet would produce dots and dashes on a moving strip of paper. A few years later he had placed a fountain pen on the armature of his magnet, and a zig-zag line was made on the moving paper. In 1838 he was using a receiver employing a style to emboss dots and dashes on the moving paper tape, and on February 21st of that year Morse demonstrated his telegraph before the president of the United States. It was five years, however, before Congress passed a bill appropriating $30,000, with which a line was constructed from Washington to Baltimore. On the morning of May 24, 1844, the historic message, "What hath God wrought" was sent, thus opening a new era of rapid communications.
Greenwood (27, p.183) notes that, following the successful demonstration of his instrument, Morse tried to sell it to the government for $100,000. Failing in this, he obtained private capital and in the same year (1844) a telegraph company was formed to erect a system connecting New York, Baltimore, and Washington. By 1851, fifty companies, using Morse patents, were in operation in the United States and by 1861 Morse patents were being used in Europe.

The story of the laying of the Atlantic cable is a classic in perseverance, and is of such importance as to have a definite place in the history of the telegraph. Much of the following material on the subject is taken from Darrow (14, p.79).

A submarine cable was operating successfully across the English Channel in 1856 which fact attracted the attention of a New York businessman named Cyrus W. Field (1819-1892). In 1856, Field and two English partners, John W. Brett and Charles T. Bright, both of whom had had a part in laying the Channel cable, formed the Atlantic Telegraph Company. An appeal to the United States and British governments resulted in a naval vessel from each country being sent out to make soundings from Newfoundland to the Irish coast. Their report was favorable and the first attempt to lay the cable began in 1857. The United States lent the USS Niagara while the British assigned the HMS Agamemnon to the job. In August of that year these two ships with attending vessels began laying the cable westward from Valencia, Ireland. The
cable itself was made up of seven copper wires insulated with gutta-percha (gum from a Malay pine tree), and covered with tarred hemp. After about 380 miles had been laid by the Niagara the cable broke and could not be recovered. The ships returned to England and a second attempt was made the following June. This time, on the suggestion of Charles Bright, the ships met in mid-ocean, spliced the cable and started in opposite directions. Twice, at distances of three and fifty miles, the cable broke, and each time they returned to the starting point, spliced the cable and started over. After 400 miles had been laid the cable parted once again, and could not be recovered. The expedition returned to England, but in July of the same year the ships met again in mid-Atlantic for a third start. This time Newfoundland and Ireland were connected. Appropriate ceremonies were held and President Buchanan exchanged greetings with Queen Victoria. After only a month of operation, however, the cable ceased to function. In July 1865, Field and his company acquired the Great Eastern, a mammoth vessel for its day, and a new attempt was made, again starting from the Irish coast. Two-thirds of the way across, the ship's machinery broke down, and she was tossed about so violently that the cable again broke. A year later, on July 12, 1866, the Great Eastern began her second attempt. The job was completed in two weeks, and trans-Atlantic communications have not been broken since.

Many improvements and refinements were made in the telegraph during the latter half of the 19th century.
These improvements, however, are still in use today and will be treated in chapter four.

The Telephone. It may be of interest here to note some of the earliest attempts to transmit the human voice electrically, as recorded by Hawks (23, p.124) and Still (56, p.120). It seems that in 1837 at Salem, Massachusetts, a Dr. C. G. Page had constructed a device designed to transmit sound in the form of tones. This apparatus consisted of a vibrating diaphragm provided with a device to make and break an electrical circuit with vibrations set up in the diaphragm. At the receiving end, a thin iron rod wrapped with a coil of insulated wire, emitted sounds or tones which were used to cause the diaphragm at the sending end to vibrate. This was an ingenious set-up, but quite incapable of transmitting speech. In 1854, Charles Bourseul, a Frenchman, made a definite attempt to send the sound of a human voice over a wire. His transmitter was similar to that of Page, but at the receiving end he used a second diaphragm acted upon by an electromagnet to reproduce the sounds made on the transmitter diaphragm. But although this device would reproduce sound quite well, it did not have the necessary flexibility to transmit the spoken word.

Johann Philipp Reis, a German school teacher, succeeded in 1861 in building an apparatus which according to some writers was able to transmit speech. It is known that Reis experienced great difficulty in obtaining any sort of recognition for his work. However, when one views his efforts from the vantage point of the present, the fact that he was an
unusual and brilliant man is clearly evident. His receiving device consisted of a steel knitting needle passing through a coil of wire. As the current in the wire varied, the needle vibrated near the sounding board of violin. A key device on the side provided a simple telegraph arrangement to act as a "crutch" in telephonic communication. The work of Johann Reis is certainly important, at least from the historical angle, but like so many pioneers with new and imaginative ideas he died a disappointed man.

The first really successful telephone was invented by Alexander Graham Bell in the year 1876. Bell was born in Edinburgh, Scotland in 1847, just 100 years ago. He was the son and grandson of men who had distinguished themselves as teachers of speech. According to Greenwood (??, p.185) Graham Bell's father produced a system of alphabetics known as "visible speech". On this subject Greenwood quotes a writer named Catherine Mackenzie:

In Visible Speech, Melville Bell reduced to a series of printed symbols the anatomical positions which the speaking organs take in uttering sounds. These symbols were so drawn as to indicate the shapes taken by the lips, the positions of the tongue and so on, and once a sound was written in its proper symbols, the initiate had only to reproduce the physical position with his own organs of speech to reproduce the sound. There was, for instance, a symbol indicating 'closed lips, voice passed through the nose'. When the lips are closed and a nasal sound is made, the result is the same whether the language is English or Choctaw.

There were only ten basic symbols, and these in various combinations covered the whole range of vocal sound in any tongue.

Mackenzie goes ahead to point out that the possibilities
of this system for teaching language were very great, and that the idea brought Melville Bell quite a large measure of fame during his lifetime. She also says that this was perhaps the most important link in that chain of inheritance which brought about the invention of the speaking telephone. It is well-known that the diction of Eliza Doolittle, in George Bernard Shaw's "Pygmalion", was completely changed by Bell's Visible Speech so that the little cockney maiden was able to pass as a duchess at the King's party.

Alexander Graham Bell was well fortified then, for the work which was to make him famous. He came to America with his father in 1870 and was subsequently appointed Professor of Vocal Physiology at Boston University. Later he established his own school, using his father's system of visible speech.

The first efforts of Bell in working with speech and electricity were directed toward an attempt to make speech visible. His idea was to use a vibrating needle in place of a speaker to cut a sound trace on suitable surface. In this way speech could be made visible, and the system would be especially valuable to the deaf. As he worked with this apparatus other ideas began to crowd in upon Bell. As a speech teacher, he knew well the mechanics of the human ear. One of the many experiments he performed involved the use of a deaf man. The story goes that Bell placed one end of a straw against the deaf man's eardrum; the other end resting against a piece of smoked glass. Bell then shouted into the
man's ear, and the eardrum in vibrating, caused the straw to make a trace on the smoked glass. The struggling inventor realized that if he could construct a diaphragm which would vary the electrical current in a wire leading to a second diaphragm, he might be able to reproduce any sound originating near the transmitting diaphragm.

Bell worked steadily on the telephone idea for a number of years with the aid of his assistant, Thomas A. Watson. Hawks (25, p.127) tells the following incident which, although accidental in nature, marks the actual birth of the telephone:

On a hot and oppressive afternoon in June 1875 Bell and Watson were toiling away as usual, testing some new arrangement of their apparatus. Watson, who was working in a room by himself, had charge of the transmitter, and was experiencing trouble with one of the springs of the instrument, which stopped vibrating. He plucked repeatedly at the spring to start it vibrating again when suddenly he heard a shout from Bell in the next room, who rushed into the room, demanding: "What did you do then? Don't change anything. Let me see!"

The spring which had stuck was a vibrator spring operated by an electromagnet and fitted with make-and-break points. The points had become welded together and the spring would no longer vibrate. However, the current was still flowing in its electromagnet. When Watson plucked the steel spring so near the pole of the magnet it, being magnetic itself caused the magnetic field about the magnet to vary which in turn changed the character of the current flowing in the magnet and of course this produced a varying current in the receiver at Bell's end of the line. It was purely an electronic effect,
although Bell had no knowledge of this at the time. Even so he was clever enough to realize what had happened. Accordingly, he and Watson went to work with renewed effort. In less than a year they had produced the first telephone.

Bell's job now was to sell a reticent public on the idea of his telephone. He was given a small amount of space in one corner of the Educational Building at the Centennial Exhibition at Philadelphia in 1876, where he set up his apparatus. As the story goes, the exhibition went on for several weeks, with the telephone receiving very little attention. One day, Dom Pedro, the young Emperor of Brazil, visited the Educational Building with a number of dignitaries. He recognized Bell immediately, having visited his school in Boston with the idea of founding a similar school in Rio de Janeiro. Bell showed the Emperor his telephone, and he was so impressed and displayed so much enthusiasm that the attention of the judges of that exhibit was attracted, although they had previously refused to pay any attention to Bell. They were astonished at the invention and promptly gave it a more prominent place for showing. Lord Kelvin, a famous English scientist, also saw the telephone at the Exhibition and was so impressed that he later became its faithful champion in an England that was at times actually hostile to the new device.

Bell was granted his first patent in August 1877. By that time there were already 778 telephones in use and The Bell Telephone Association had been formed. Bell, Watson and two friends were the shareholders. They possessed little
capital and progress was extremely slow. A few small exchanges had been set up in New York, New Haven, Bridgeport, and Philadelphia before a Wall Street concern decided to replace their telegraphs with telephones. From then on the growth of the telephone industry was fast and continuous.

The telephones of 1876 were far from perfect, as may well be imagined. Improvements came almost immediately. In 1877 Thomas Edison made a great contribution in producing his carbon-block transmitter, which permitted messages to be sent over much longer distances. The term 'microphone' was first used by Wheatstone in 1837 to describe an instrument designed to increase the loudness of minute sounds, but it remained for Professor David E. Hughes (1831-1900) to produce the first electrical microphone in 1878. Still (56, p.130) says that the microphone produced by Hughes was so sensitive that the footfalls of an insect running across the sounding board, could be heard. That same year Runnings invented his carbon granule transmitter, which today is the most familiar type of telephone transmitter. The year 1878 also saw the first commercial switchboard being installed in New Haven, Connecticut. This switchboard served 8 lines and 21 subscribers.

The greatest problem confronting the early telephone engineers at this time was that of gaining more distance. Edison, in 1878, solved this problem by taking the transmitters out of the line circuit and connecting them to it through transformers. This resulted in the fairly strong currents of the microphone circuit inducing lighter currents of higher voltage in the line circuit. The higher voltage in the line
circuit carried the smaller current for greater distances. Developments from this point were very rapid. In 1892, toll lines had been extended from New York to Chicago. Then followed a period when lines were growing throughout the eastern half of the United States. In 1911 the long distance lines had reached Denver, and in 1915 Boston talked to San Francisco. It seems logical to mention here that these long distance lines of telephone communications were made possible by the invention of the vacuum electron tube by Fleming and De Forest.¹

The foregoing pages have given an account of the development of communication over wires, first in the form of signals, and then by actually sending the sound of the human voice. Attention is now turned to the efforts of men to communicate by electricity through space.

Wireless Telegraphy. It will be recalled that electrical knowledge had progressed to the place where electromagnetic waves could be generated, sent through space (over a limited distance), and detected; this having been accomplished by Hertz.² Hawks (29, p.180) relates that "the discovery of the Hertzian waves had scarcely been announced when Huber, a civil engineer of Munich, suggested to Hertz that they might be used as a means of communicating without wires." Hertz, however, thought of the telephone with its low frequency, and decided immediately that his high-frequency waves could not be used for this purpose. Many scientists repeated the experiments of Hertz, in the years immediately following his

¹ See p. 28
² See p. 26
discovery, most of them seeking a means of using the newly-found waves for wireless communication. In this connection Still (56, p.148) quotes the words of Sir William Crookes (1832-1919) as they appeared in the Fortnightly Review, 1892:

Here is unfolded to us a new and astonishing world, one which it is hard to conceive should contain no possibilities of transmitting and receiving intelligence. . . . At the present time experimenters are able to generate electrical waves of any desired length from a few feet upwards, and to keep up a succession of such waves radiating into space in all directions . . . I assume that the progress of discovery would give instruments capable of adjustment by turning a screw or altering the length of a wire, so as to become receptive of wave-lengths of any particular length.

This is an amazing bit of literature considering when it was written. It clearly predicts the future of wireless communication.

It was apparent to the scientists of the day, that before this type of communication could become a reality some device much more delicate that the spark-gap resonator of Hertz, would have to be developed to detect the electromagnetic waves. This turned out to be the coherer of Professor Edouard Branly. An experimenter named Calzecchi Onesti had found that copper filings (ordinarily a poor conductor when heaped together) became conductive when subjected to the discharge from an induction coil, their resistance dropping very low. Branly used this principle in constructing his coherer. In 1894, at the Royal Institution, London, Sir Oliver Lodge produced Hertzian waves and used a Branly coherer to detect them at a distance of 150 yards. He used a telegraph key to start and stop the waves, and in the receiver with the
coherer he used a galvanometer, which, of course would indicate when a current was flowing. By depressing the key of his transmitter to make the dots and dashes of the Morse code, he showed that the code could be read on the galvanometer, at his receiver. Lodge also used a little tapper on the coherer to keep the filings shaken down when a wave was not passing. Wireless telegraphy was within his grasp, but apparently he did not realize that fact, for he failed to pursue it further.

It is well known that Guglielmo Marconi (1874–1937) was the first man to realize and develop the practical application of Hertzian waves. As a student in physics at the University of Bologna, Marconi became interested in the work of Hertz. He read all the literature he could find on the subject and repeated all the published experiments of Hertz and others. In 1896 he set up his apparatus on his father's farm and succeeded in sending signals a distance of 1200 feet. That same year he went to London where he continued his experiments. After improving the coherer of Branly he was able to extend his distance of transmission to 13 miles. He also confirmed the earlier assertion of Hertz, that the waves would penetrate walls and other solid structures. In July 1897 Marconi was granted a patent on his device, by the British government. His instrument as described in an abstract of the patent specifications (56, p.150) seems to be the same as that used by Sir Oliver Lodge, three years earlier. However, Marconi worked tirelessly and made one improvement after another. The British Navy became interested and by 1899 had several sets operating
aboard ships, sending and receiving messages up to distances of 100 miles. As the number of sets in operation increased, trouble was experienced due to the fact that they were all on the same frequency, there being no way provided to tune the instruments. After a time Marconi placed a tuning coil in his transmitter. This was actually the primary coil of a transformer, the secondary being in series with the antenna and ground. Oscillations in the primary coil from the induction coil spark gap induced sympathetic oscillations in the antenna. These then were radiated into space in the form of electromagnetic waves. A similar set-up was incorporated into the receivers. Apparently each receiver was tuned for a specific transmitter.

Marconi’s crowning achievement came in December 1901, when he succeeded in sending the letter “S” across the Atlantic. By the end of the next year a transatlantic station had been set up at Cape Cod, Massachusetts. Commercial telegraph service across the Atlantic began about 1903, and communication through space became an accomplished fact.

Radio. It is interesting to note that even before the discovery of Hertz, Thomas A. Edison and his assistants, while working in their laboratory, noticed sparks in a metallic system near a vibrating armature which was making and breaking a circuit. The sparks occurring at the contact points were generating electromagnetic waves which were being picked up by the near-by metal apparatus, but of course this was not known to either Edison or his helpers. However Edison carried out
a study of the matter extending over a period of time, but was unable to explain the phenomenon. McNicol (36, p.49) quotes the following article, written for the Scientific American, January 22, 1878, by a Dr. G. M. Beard, who had seen some of Edison's experiments on the subject:

At the present time the weight of evidence in my mind is in favor of the theory that this is a radiant force, somewhere between light and heat on the one hand and magnetism and electricity on the other, with some of the features of all these forces . . . . The more I experiment in this department, and the more closely I reflect on the results of experiments, the further I seem to be driven from the electrical toward the radiant theory of this force; and there would appear to be no ready escape from the conclusion that we have here something radically different from what has before been observed by science.

This discerning observation is presented here because it seems to anticipate name "Radio", which soon replaced the term "Wireless".

The quest for more suitable detectors during the first decade of the 20th century led to the discovery and use of the mineral crystal. It was found that this device would rectify the incoming alternating antenna current into pulsating direct current, which was what the coherer had done in a less convenient manner. McNicol notes (36, p.131) that the crystal detector "being an inexpensive device, enabled a host of amateur experimenters in America and other countries to set up small stations", and that from them "came many suggestions for improvements in detail and much experimental data of immediate use to watching scientists engaged in solving the larger problems of radio signaling".
Kennelly in the United States and Heaviside in England, in an effort to explain the traveling of radio waves over the surface of the earth, simultaneously but apparently independently, advanced the theory that the electromagnetic waves were kept from passing off into space by a reflecting area of rarefied atmosphere some 50 miles above the earth's surface. This theoretical area became known as the Kennelly-Heaviside layer.

Edwin H. Armstrong, just graduated from Columbia University in 1914, showed how the de Forest three-element tube could be used to amplify radio waves. Using the tube in this way in his receiver he was able to detect radio signals at much greater distances than had ever been realized up to that time. Still (56, p.164) notes that "perhaps Armstrong's greatest contribution to radio broadcasting was his discovery that, with certain changes (this tube) could be used to generate high-frequency currents". That is to say it could be used as an oscillator to generate a radio wave of a frequency to be determined by the circuits in the transmitter.

The next step was toward radio telephony, in "modulating" this "carrier" wave by impressing upon it, by means of the telephone microphone, the sound of the human voice. This was accomplished almost immediately following Armstrong's discovery, and in 1915 speech was transmitted across the Atlantic. In the next few years and immediately following the end of World War I, much research was carried on in an effort to improve still further, radio transmission and reception. Many individuals built their own sets, both transmitters and receivers.
One of these early "amateurs" was Dr. Frank Conrad, who upon returning from the War, set up some apparatus in his garage, and experimented with broadcasting. He played music and read news over the air, and in 1920 he broadcast the election returns in which Harding and Coolidge defeated James Cox and Franklin D. Roosevelt. This station of Conrad's later became the Westinghouse station KDKA, which claims to be the first broadcasting station in the United States. This claim however is contested by WWJ in Detroit. At any rate the fad of radio was becoming an industry. Hubbell (30, p.127) notes that in 1922 there were 400,000 sets in use in the United States, and that 20 years later there were 80,000,000.

The next development in electrical communications was a natural one. It was now possible to talk personally to a friend on the other side of the earth as easily as if he were right beside you, the only difference being that you couldn't see him. But inquiring minds of electrical engineers and other scientists had been looking toward the possibility of making even this possible.

**Television.** Hubbell (30, p.59) describes a system proposed by an American, G. R. Carey of Boston, in 1875. Carey's idea was to pass the light from the object through a lens which threw the image onto a mosaic of selenium (photo-electric)\(^1\) cells. Each cell was to be wired to a light bulb in a similar mosaic (of light bulbs) at the receiving end. The theory was that the image on the selenium cell mosaic would be reproduced on the bank of light bulbs. That is to say the

\(^1\) See p. 24
whole image would be taken from the transmitting mosaic and transferred through the wires to the bank of light bulbs and reproduced. This idea, ingenious though it was, failed in practice because the selenium cells were not capable of strong enough currents, and the vacuum tubes later used as amplifiers had not yet been produced.

In 1880 a Frenchman named Leblanc conceived of the idea of "scanning" the image. This means breaking the image up into small bits and sending each small portion separately, one after another. This was the practice used with considerable success later on. The revolving, or scanning disk was suggested by Paul Nipkow in 1884. In the revolving disk was a spiral of holes, while behind the disk was a source of light. As the disk turned, the light shining through the holes illuminated the object a small bit at a time. These variations were to be caught by a photoelectric cell and transmitted to the receiver. Another idea for scanning the object was suggested by a man named Weiller in 1889. His proposal was to use a rotating drum on which there were many tiny mirrors. With the object illuminated, the mirrors on the rotating drum would pick up small portions at a time and these reflections in turn would be picked up by a photoelectric cell and transmitted.

It became apparent after several years of research, that it would not be possible to produce a mechanical means of scanning that would be swift enough to be effective. But an electronic device could, and did, solve this problem. The
first one was produced by V. K. Zworykin of the Radio Corporation of America. This tube is called the "iconoscope." It consists of a lens for throwing the image of the object being transmitted onto a mosaic of many tiny photoelectric cells, all placed closely together but insulated from each other.

Another, more sensitive tube was later developed by P. T. Farnsworth. The construction and operation of these devices will be treated in chapter four.

Radar. Perhaps this new development in the use of radio waves, may not be considered by some to be a communications device. However during World War II it was always used in conjunction with communications. Also through its application to the identification of friendly planes and ships, it was almost a pure communication instrument.

The word "radar" is an abbreviation for the phrase "radio detecting and ranging." A brochure published by the Department of Information, Radio Corporation of America tells the story of the development of radar in the United States and The National Encyclopedia Yearbook 1946 relates a parallel development in England. Germany was not far, if any, behind. As early as 1934, RCA in cooperation with the Army Signal Corps set up a microwave apparatus on the New Jersey coast near Sandy Hook. From the transmitter of this device a radio beam of ultra-high frequency was projected out over the channel leading into the harbor. When a ship came through, the beam was reflected back to a receiver, where it produced a tone, indicating to the operator the presence of an object
in the channel. This beam was in the form of a continuous modulated wave and as such could not be made to measure the distance. Work was then begun on an improved apparatus which transmitted waves in trains of short pulses enabling distance, as well as direction to be determined. By 1937 it was possible to measure short distances with a fair degree of accuracy, and to obtain reflections of distant objects. At this time the Navy requested that future work be secret. Early in the same year RCA provided experimental apparatus, with which the Army Signal Corps conducted aircraft location tests. A little later the Army had in its possession the type of radar equipment used at Pearl Harbor in December 1941. Prior to 1939 the Navy had developed a set of radar equipment in its own Naval Research Laboratory, and in that year awarded RCA a contract for the building of these sets, which were designed for aircraft detection. Rapid advancement in research and a stepped-up program of production during the war resulted in thousands of sets of various kinds being used by the Allies at the war's end.

**Summary.** Some of the more important events making up the history of electrical communications have been recorded in this chapter. The early devices of Le Sage, Chappe, Ronalds and others may seem unimportant in the light of present-day equipment, but they serve to form a definite historical background to modern means of communication. They were the stepping stones of progress.

It should be noted that the progress in communication by means of electricity was extremely rapid, only 100 years
being needed to advance from the telegraph of Morse to the television tube of Zworykin. Since it is hardly likely that engineering research will fail to develop new devices in the years to come, the world of tomorrow will surely be a wondrous place.
Chapter IV
MODERN APPLICATIONS OF ELECTRICAL COMMUNICATIONS

A study of the various ways in which electrical communications are used will be presented in this chapter. It is believed that in this way, can be shown its present-day importance; and that there may be applications which will lend themselves readily to the Industrial Arts Curriculum. Applications of electrical communications are shown for each of the following: Transportation, Business, Newspapers, Law Enforcement, War, Disaster, The Home, The School and Church, and A Hobby.

Transportation. Transportation today is made up of many large and complex industries all of which use every possible form of electrical communication. Therefore it is not the intent here to treat the subject in detail, but rather to point out in a more or less general manner, how the different communication devices are used by certain agencies of transportation in each of the three areas -- land, air, and water.

The Railroads.

A letter from the Superintendent of Communications of the New York Central Railroad System reveals that the Communication department has supplanted the Telegraph department. This seems to be significant because it shows that the term "communications" has been accepted. It also shows that railroad communications have become much too complex to be included under the single heading "telegraph". It was
pointed out that many railroads today are using carrier equipment which basically utilizes frequencies above the voice range for creating additional talking channels superimposed over the voice frequency telephone wires.

Between division offices, railroads utilize telegraph services along with the telephone. The use of the telegraph may include either printer service, or Morse code. A speech-plus-duplex system utilizes a small portion of the voice band to transmit code without disturbing the voice transmission.

Some systems utilize a high-frequency radio for communications between engine and caboose, and between caboose and station. This type of communications is used in freight switching. Radiotelephone service for passengers is at present in the early stages of development.

Highway Transportation.

Beside the usual net of telephone and teletype connections found in the offices of all large bus and trucking companies, some organizations are using very-high-frequency radio for two-way communication. Figure 2 shows a driver getting instructions over such a system. When he is called, a bell rings briefly and the call light on the control unit comes on. Note the call number on the control unit.

Commercial Airlines.

Much of the information presented here has been drawn from Roberts (46, ch. 9). The material on airport traffic control, however, is the result of several hours of observation by the writer, in the control tower at the Columbus Municipal Airport.
Figure 2.

Two-way radiotelephone installed in the cab of a delivery truck.

(Courtesy Bell Telephone System)
A driver gets delivery instructions over a Bell System mobile radiotelephone while at the wheel of his truck.

The control unit of a Bell System mobile telephone. When a call is received a bell rings briefly and the "call" lamp lights.
In order to control the great volume of air traffic today the Federal Government operates some 30 airway traffic control centers, each with an assigned geographical area. These centers are connected with several hundred radio stations scattered throughout the country. In addition these traffic control centers have direct telephone lines to all the major airport control towers in their respective areas. Practically all communications carried on between these ground stations are over telegraph, telephone, and teletype land lines. This means a great network of Federally operated lines, used for controlling air traffic and disseminating weather information.

Two-way communications in aviation provide the following basic functions: point-to-point communications linking ground stations, point-to-ship communications between ground stations and aircraft, and ship-to-ship communications between craft in the air, which takes place infrequently in the commercial airlines.

The point-to-point communication facilities of the airline companies themselves is even more extensive than those just described operated by the Government. Each individual airline maintains its own network of telegraph, telephone, and teletype linking the various cities which it serves. A typical teletype room is shown in Fig. 3, with its battery of teletypewriters linking that station with the airlines major airports. This type of equipment is used in carrying on all routine administrative traffic. Direct operational
Figure 2

Typical teletype room of a commercial airline company
(Courtesy United Airlines)
communications are provided by the telephone and the radiotelephone where the operations are within the country. Transoceanic lines, however, use the radiotelegraph in point-to-point communications over the great distances involved, with the radiotelephone being used for shorter distances, during approaches and landings.

The modern point-to-point and point-to-ship transmitters used by most airlines today operate with a power output of 5000 watts, while the power of the transmitters aboard the planes themselves is 100 watts. These transmitters provide a reserve of power which makes for highly satisfactory communications at normal distances. A large company will have hundreds of radiotelephone operators who keep in contact with the ships flying its routes.

One of the most impressive demonstrations of the application of radiotelephone communication to the control of air transportation is to be seen in the control tower of a busy airport. At the Columbus tower the writer found three young men quietly and efficiently handling a continuous stream of navy, commercial, and private planes, coming in and taking off from the field. These operators are civil service employees under the Civil Aeronautics Administration and the Department of Commerce. All of them were pilots with several hundred hours in the air. This does not mean however, that all control tower operators are fliers, although it is true that in competing for a job they have a distinct advantage.

It was found in the tower, that four different kinds of electrical communications devices were being used: (1) The
radiotelephone, used in communication with the aircraft; (2) The telephone, for communication with other offices in the station, and for continuous contact with Air Traffic Control Center\(^1\) in Cincinnati; (3) an automatic recording machine for each circuit which records all conversation on that circuit; and (4) an electric signalling gun which is used to flash signals to the few aircraft which do not have radio receivers.

The radiotelephone operator controls the aircraft, both in the air and on the ground. Commercial planes, called "air carriers" are required to report in to the tower as they enter the control zone of that station. This is from 10 to 12 miles out. The control tower then may give landing information (runway number and direction and velocity of wind) with permission to come on in and land, or he may tell the plane to report in again at 3 miles, delaying his instructions until that time. If traffic is unusually heavy the plane may be instructed to circle the field once or twice. Radiotelephone communications with air carriers may be carried on in one of two frequencies -- a medium high frequency of 3117.5 kilocycles or VHF 118.5 megacycles. Army and Navy planes are on 126 megacycles, 6510 kilocycles, and 4495 kilocycles, while private planes may be on 182.5 megacycles, 7105 kilocycles, or the 6210 kc. channel mentioned above. These various channels require that the operator have a device for selecting the frequency needed. The transmitters used are

\(^1\) See p. 60
not located at the tower and are therefore operated by remote control.

The main job of the second operator is to handle telephone communications to and from the Air Traffic Control Center in Cincinnati. From them he gets clearance and flight instructions for the air carriers, or for any other plane making a cross-country flight. This information is written on a sheet of paper in standardized form as it is received. The radiotelephone operator then relays it to the plane which is about to take off. After the plane indicates its readiness to take off, however, the actual take-off instructions are given by the radiotelephone operator. Once the ship is in the air and out of the tower’s control zone it is no longer contacted by the tower except in case of emergency.

The third man in the tower is more-or-less a relief to the other two. Where a number of small private planes are in the air there may be several without radio receivers and even more with receivers but without transmitters. Therefore he helps in the spotting and handling of these craft, utilizing the electric signalling gun when necessary.

The electric recording devices mentioned above are placed, one in each communication channel. They are electronic instruments which produce a grooved sound-track on an endless plastic belt. These belts are then filed according to date and provide a means of checking back at any later date on the voice transmissions over any one of the various circuits or channels.
Waterways. Large shipping concerns, like any other industry, utilize all forms of electrical communications in carrying on their business—telephone, telegraph, teletype, tickers, inter-office communications, radio including both radiotelephone and radiotelegraph, and, as a post-war development, Radar\(^1\). Because of the nature of water transportation its dependence upon radio, and now radar, is very great. Therefore this section will be devoted entirely to ship-to-shore contact through these devices, most of the information being drawn from the writer's own experiences.

Great ocean shipping companies with freighters plying the high-seas maintain large radio transmitting stations in order to keep in contact with their ships. As in the case of the transoceanic air transportation, the radiotelegraph is used for long distance communications. In the case of small and medium-sized vessels there may be only one radio operator aboard. This makes a 24-hour radio watch impossible. However, by scheduling the routine broadcasts, he is only required to stand watch at certain periods during the day. All ships at sea must maintain a continuous watch on 500 kilocycles which is designated as the distress frequency. These ships with only one operator keep a receiver on this frequency, which is equipped with an "auto-alarm". When the operator is going to be out of the radio "shack" he sets this alarm, so that when a signal comes through on 500 kcs. it operates a relay which sets off the bell-alarm. One of these bells is located in

\(^1\) See p. 56
the radioman’s stateroom, and others may be located elsewhere such as in the mess-hall. The bell continues to ring until a switch is thrown on the receiver.

Radiotelegraph communications on the high seas are standardized by the International Signal Book. This publication contains rules and regulations and lays down the form to be followed by radio operators in transmitting radiotelegraph messages. This contributes to the ease of handling traffic throughout the world.

As the ship nears port it utilizes the radiotelephone to contact the Port Director, who sends out a pilot to bring the ship into its proper berth.

Since the early days of radio, large ocean passenger liners have been associated with long telegraph companies in providing radiogram service to passengers. This enables a passenger, while in mid-ocean, to send a message to almost any civilized part of the world. This type of service has been expanded, so that today it is possible to make telephone calls from ships at sea, the American Telephone and Telegraph Company providing the link in the United States.

The latest boon to waterway transportation has been in the development of radar.¹ Used only on war vessels during the War, it is now being made available to all shipping, both salt-water and fresh-water. This device operates on the principle originally discovered by Hertz² that radio waves could be reflected. A rotating antenna on the ship’s radar mast throws

¹ See p. 56
² See p. 26
out a narrow radio beam composed of ultra-high-frequency waves. Down in the pilot house of the ship, this rotating beam may be seen in the P. P. I. (plan-position indicator) scope, where an electron beam sweeping steadily around the face of the scope shows the position of the antenna beam as it sweeps around the horizon. Around the edge of the scope is a scale graduated in degrees with zero being at the top, which represents dead-ahead of the ship. If the rotating radio beam strikes an object it is reflected, picked up by the antennas, and down at the P. P. I. scope a blob of light is produced momentarily by the sweeping electron beam. This momentary light on the scope shows four things about the object "seen" by the antenna beam: (1) Its relative bearing from the ship, (2) A rough estimate of the distance from the ship, (3) The relative size of the object, and (4) Something of the material nature of the object, since metal objects produce clear-cut images while less solid materials appear fuzzy. Another scope is used to give the distance in yards or miles, while still a third scope connected with the ship’s gyro-compass permits the operator to read the true bearing of the object, for navigatin purposes.

Figure 4 shows an actual picture of a P. P. I. scope. Arrows leading from it to an official navigation chart, show how landmarks can be identified by the pilot of a radar-equipped ship. The scenes shown cover a 1½ mile section of the Detroit River.

Communications in Business. A quick review of almost any business or industrial establishment will serve to give some
Figure 4

Photograph of Radar PPI scope with navigation chart of area shown.

(Courtesy Radio Corporation of America)
idea of the extent to which electrical communication equipment is used. The telephone of course easily holds first place in importance. However the telegraph through the TWX (tele-
typewriter exchange) is used quite extensively by large com-
panies with branches in distant cities. In some cases private lines are provided, giving a company its own teletypewriter network.

Another electrical communications device used widely in business and industry is the well-known public address system. At the present time (5) there seems to be a growing practice in industry to use this type of equipment in providing "planned music" at certain periods during the day. With proper organi-
zation and administration the same equipment can also be used for paging.

Inter-communications equipment was found to be used extensively by almost all large offices. The master station on the executive's desk gives him two-way communication with all his immediate subordinate.

The system at the F. & R. Lazarus department store was examined, in connection with the study of the use of commun-
ications in business. This store normally employs between 2500 to 3000 people, and the main buildings consisting of six stories cover approximately three-fourths of a city block. There is a large annex on an adjoining block and a warehouse three blocks away. It was presumed that the communications system of such an establishment would be representative of business as a whole.
The following types of electrical communications were found:

1. Telephones. The switchboard shown in Figure 5 serves 450 telephones throughout the store, in making connections for some 5000 to 6000 incoming and outgoing calls daily. Calls within the store are handled by the automatic dial system, and there is a regular directory listing all the telephones of the system. In addition to the 450 telephones mentioned above, many of the offices and departments have extensions which may be connected by a secretary.

2. Intra-Department System. In each department is a master station with a number of speakers providing two-way communication to the various areas of the department. In this system there is no provision for inter-department communication since that is taken care of by the dial phones mentioned above. An examination of the plan of this intra-department system revealed that altogether there are 175 two-way speakers being used.

3. Auto-Call System. This is a system for calling executives and key employees when they are out in the store. The system consists of small bells, so spaced that they can be heard from any point. The operators at the switchboard have keys by which they tap these bells with the code-call of the individual being paged. Upon hearing this he picks up the nearest phone and the connection is completed.

Newspapers. A half-day was spent at the Columbus Dispatch, a large daily newspaper, in order to find out how electrical communications are used by the Press. The Dispatch
Figure 5

Eight-place telephone switchboard of a large department store.

(Picture by writer, courtesy F. & R. Lazarus & Co. Columbus, Ohio)
is served by seven wire channels leased from Western Union and The American Telephone and Telegraph Company: (1) A main trunk wire which carries items of prime interest, and serves the whole United States between the hours of 2:00 AM and 6:00 AM. The rest of the time, it is divided into an eastern section and a western section. (2) A regional wire which goes as far west as Kansas City and carries news of secondary interest. (3) Finance News wire which provides a network from New York City to Omaha, Nebraska, and on which is carried news of purely financial interest. (4) A ticker-tape wire which supplies stock market quotations. (5) A State line which connects all the major cities of the state (Ohio). (6) A wire for smaller newspapers providing them with non-local news, and allowing them to send out news of prime interest which may occur in their respective communities. (7) The Associated Press wire-photo line, which provides fast news photos all over the United States.

All of these lines with the exception of the last are supplied with teletypewriters (the ticker being a form of teletype). The Associated Press wire-photo room shown in Figure 6 was a point of special interest. This is one of sixty such stations scattered over the entire country. Each one of these stations acts as a "central" in providing AP wire-photo service to the nation. The speaker mounted on a bracket near the top of the control panel is hooked in to the wire and supplies instantaneous two-way conversation for the sixty stations, with the station controlling the circuit being in New York. The instruments in the foreground along the
Figure 6

Associated Press wirephoto room

(Courtesy Columbus Dispatch, Columbus, Ohio)
window are transmitters while the receiver is just to the left of the control panel. The cylinder on the receiver is actually an aluminum can inside of which is a photographic film. When the station has a picture considered to be of prime interest the operator places it on the cylinder of the transmitter and calls New York over the speaker system informing the controlling station of the nature of the item. The priority is decided and he will either be told to go ahead or to wait. When he is told to go ahead and transmit he holds down a master switch and a 2400-cycle tone is heard over the wire, which has a carrier frequency oscillating at this frequency. When they hear this tone, operators all over the country -- 59 others in the main stations plus hundreds of others who have receivers only -- will hold down the starting switch on their receivers. When the transmitting operator releases his switch the cylinder on his machine starts turning. At a certain point on the first revolution an arrangement on the cylinder cuts a light beam to a photoelectric cell which automatically interrupts the tone and starts the receivers all over the country. The receiver operators may then release their switches and the process of reproducing the picture continues. The usual size of the picture transmitted is 8 by 10 inches. The transmitter cylinder turns at the rate of 100 r. p. m. under a beam of light 1/100 of a square inch in area. The reflections from the picture as it passes under this tiny beam of light are passed into a photoelectric cell which sends the varying impulses through an amplifier and out through the wire to the distant receivers, where it causes corresponding variations in
a 1/100-square inch light beam playing on the photographic film where the cylinder is also turning at 100 r.p.m. Through a worm-gear arrangement, the light source and photocell in the transmitter and the light beam in the receivers are made to move horizontally along the picture at the rate of 1/10 inch with each revolution of the cylinders. When the picture is completed the transmitter automatically stops the machines, whereupon the receiving operators remove their cylindrical cans containing the exposed film into an adjoining photographic dark room where the film is developed and printed.

Another wire-photo device of interest in a study of electrical communications is a portable transmitter which operates either from a storage battery or from a regular electrical outlet. This instrument provides a means of transmitting pictures from near the scene of an incident of news-interest, the only requirement being a long-distance telephone line to one of the sixty main stations, where a switch permits the picture to be put directly into the nation-wide wire-photo network. For instance this portable transmitter operating in the home of some farmer near the scene of a train wreck may send a picture of the wreck directly to all wire-photo receivers in the United States.

Communications for Law Enforcement. A study was made of the communications system of the Ohio State Highway Patrol in order to find out how law enforcement agencies use electrical communications. It is believed that this system is representative of those used by similar organizations throughout the United States.
An examination of Figure 7 will reveal the extent to which the state is covered by the Highway Patrol communications network. Columbus acts as a controlling hub for the whole system, while each of the four division headquarters is a sub-administrative center for its own particular area. The communications center for the entire system is housed in the transmitter building located about a mile northwest of the Ohio State University in Columbus. This small building consists of three rooms not counting the attached garage. For convenience in referring to them these rooms will be designated as "A", "B", and "C". In room "A" is found the dispatcher, a radiotelephone man, and a teletype operator. Figure 8 shows the radiotelephone operator at his station, with the teletypewriter in the background. This teletypewriter is on a direct wire to the Highway Department about five miles away in the center of the city, and provides a fast means of checking on drivers' and motor licenses. The dispatcher's desk is off to the radiotelephone operator's left. Here is kept a log of all incoming and outgoing traffic. The transmitters and radiotelegraph operator are in room "B". These medium-high-frequency radiotelegraph transmitters have a power output of 1000 watts. Practically all the traffic handled by the operator in this room is either coming from, or going to the South and West, as is shown on the map by the dotted lines leaving the state to these areas. There are no teletype lines extending beyond the borders of the state in either of these directions. Because of the great number of stations involved, CW traffic is handled over seven different channels or frequencies.
Figure 7

Map showing Communications System of the Ohio State Highway Patrol.

(Courtesy Ohio State Highway Patrol)
OHIO
STATE HIGHWAY PATROL
AND
POLICE
COMMUNICATION SYSTEM
Figure 8
Radiotelephone room of the Columbus transmitting station, Ohio State Highway Patrol.
(Courtesy Ohio State Highway Patrol)

Figure 9
A portion of the teletype room at the Columbus transmitting station, Ohio State Highway Patrol.
(Courtesy Ohio State Highway Patrol)
This means that before the operator, is a bank of seven receivers. When he receives a call, he notes the receiver over which it is coming and through a push-button switching system connects his "bug" (high-speed sending key) to the transmitter on that frequency. He is then ready for two-way radiotelegraphic communication. After giving the distant operator a brief signal which means: "Send your message", he waits at his typewriter for the transmission to begin. He wears a set of headphones to facilitate reading the signal. When the message is completed he sends another signal as a receipt, switches off his transmitter and takes the dispatch to the dispatcher who logs it. If it is to relayed on to the East, it is assigned a teletype serial number and taken to the teletype room which is room "C".

In this room is a teletype operator with a battery of teletype machines providing this type of communication to the following points:

1. Pittsburgh, Pa. and all northeastern states
2. Delaware, O. office of State Highway Department
3. Newark, O. " " " " "
4. Lancaster, O. " " " " "
5. Central Office of State Highway Department in State Office Building, Columbus, O.
6. General Headquarters of the State Highway Patrol East Broad St., Columbus, O.
7. Findlay, O., Highway Patrol Headquarters for District A.
8. Massillon, O., " " " " " " B.
9. Wilmington, O., " " " " " C.
10. Cambridge, O., " " " " " D.
11. The Ohio State University Testing Laboratory
All of these machines with the exception of 2, 3, 4, and 11 are equipped with reperforating and automatic sending devices. Figure 9 shows a portion of room "C", and on either side of the machine in the left background are the two devices mentioned above. On the right (with cover removed) is the reperforator, while the automatic sending apparatus is shown at the left. The machine being discussed happens to be the one to Findlay (see 7 above). In the foreground of the same picture is the General Headquarters (6 above) machine flanked by automatic senders. This teletypewriter, through the use of the switchbox in the left foreground, may also be used to send to any one or all of the above stations except No. 11.

The use of the reperforator and the automatic sender may be shown by the following illustration. Suppose a bank is robbed in the Findlay area and a description of the bandits and their car is obtained. This description is sent out over the teletype to the Findlay machine shown in the picture. Two copies of the message are received. One is in the usual typewritten form as taken from the teletypewriter. The other comes from the reperforator (shown with cover off) in the form of a perforated tape. For each character the machine punches five holes across the tape, the different letters being produced by varying the position of the five holes with respect to the edges of the tape and to each other. When the message is completed, the tape is torn off and fed into the automatic sender in the foreground by the switchbox. All the switches are thrown on with the exception of the one to Findlay, which of course has the message, and presumably has already transmitted it to
the other stations in that area. As the automatic sender feeds the tape through, sending the message to the nine other stations, an interesting thing is happening at the three other district headquarters, one of which -- the one at Cambridge -- is shown in Figure 10. All the district headquarters have teletype communications with a number of points in their respective localities. A switchboard arrangement (shown to right of teletypewriter) permits them to send to all these sub-stations at the same time. Consequently when the message being described, comes in, a tape will be produced by the reperforator shown to the right of the switchboard, and the tape will be led across the front of the teletypewriter and fed into the automatic sender barely visible behind the teletype operator. Thus there is a minimum of delay in relaying the message to all of the smaller sub-stations; and also a minimum of work, since the only operator to actually type out the message was the original operator in Findlay. The above illustration serves to show the operation of the reperforator and the automatic tape sender, as time and labor-saving devices.

Approximately 200 patrol cars and 100 motorcycles are scattered over the State, based at the various district headquarters and their surrounding posts. The patrol cars are equipped with one transmitter and two receivers. The transmitter is FM at 39.78 megacycles, which permits communication to the nearest post or headquarters, possibly a distance up to 20 miles. The two receivers in the cars, are on 1730 kcs. and 38.1 mgs with the latter being FM. It will be noted then that the cars cannot communicate with each other except
Figure 10
Communications room of Division D Headquarters Ohio State Highway Patrol, Cambridge, Ohio.
(Courtesy Ohio State Highway Patrol)
through a radiotelephone station. The 1730 kcs. channel is a State net for general alarm, and the motorcycles mentioned above are equipped with receivers on this frequency. They do not carry transmitters of any kind.

A portable Radio Post (Figure 11) is used whenever the Patrol is required to handle large volumes of traffic over a sustained period of time, such as at county fairs.

It may be seen then that this communications system performs two general functions: (1) It knits the State together, providing quick, efficient handling of information and orders pertaining to law enforcement within the State; and (2) it acts as a relay between the West, South and East.

Wartime Communications. Anyone who was connected with Army G-3 or Higher Operations during the War, will readily recognize the importance placed on electrical communications by the Armed Forces. The work of the Army Signal Corps in setting up communications in all areas is well known. Mechanized units, pushing into enemy territory often relied solely upon their VHF radio for contact with the rear areas. Each island in the Pacific, as it was taken from the enemy, was soon a network of telephone wires. Exchanges were set up, with portable switchboards, and mimeographed directories were gotten out. An island radio station was connected to offices of various units on the island by teletype, and thereby furnished a link from these offices to other islands and back to the "States".

It is doubtful if any other organization has developed all phases of communications to the point that has been
Figure 11

Mobile radio post

(Courtesy Ohio State Highway Patrol)
achieved by the U. S. Navy. This, no doubt, is a logical circumstance, due to the fact that naval vessels may be scattered to all parts of the world, with their locations changing from day to day. Because of enemy radio detecting devices, vessels at sea during the War were required to maintain "radio silence"; i.e. they could receive but could not transmit except in emergencies or when ordered to do so. Naval vessels were reached by an intercept method known as the "fox" method. Messages sent to merchant ships by the same method were called BAMS (Broadcasts to Allied Merchant Ships). By this system a message to a certain ship would be sent by teletype or radio transmission to the transmitting station nearest to the known position of the ship. At the proper transmitting station it would be put on the appropriate schedule, depending whether the addressee was navy or merchant marine, and broadcast with the proper call sign in the heading. Since all ships were required to copy their respective schedules, the message would reach its destination. On all schedules the messages were numbered serially so an operator would know if he missed a heading.

It should be noted in considering naval communications alone that maximum use was, and is, made of every form of communications. In electrical communications these are the telegraph, telephone, and radio and radar. The ultimate in electrical communications, especially radio and radar, may be found in use on a major war vessel such as the aircraft carrier shown in Figure 12. Devices not indicated in the picture would
Figure 12
Superstructure of U. S. Navy aircraft carrier showing communications antenna lay-out.

(Courtesy Bell Telephone System)
The extensive use of electronics in World War II is reflected in this complex array of antennas atop the "island" on a modern giant of our aircraft carrier fleet. In this view, at least 28 radar and radio antennas of different shapes and sizes are outlined against the sky. These may be identified by the corresponding number listed below. Circled in the picture of an Essex class carrier at the bottom of the page may be seen the identical area shown in the upper photograph.
be those providing communication within the ship itself, such as the telephone system, the ship's public address system, the "tele Talks" in individual departments, and the sound-powered "battle-phones". These sound-powered phones are especially important as a means of linking the various battle stations, because they require no source of electrical current, thus precluding the possibility of a hit at such a power source cutting out the whole system. Utilizing all these various communication devices, a large ship becomes an efficient, integrated unit, well equipped to carry out the functions for which it was designed.

Disaster. Disaster has become an all-too-common thing in the fast-moving complex world of today. The uses of the telephone, radio, and telegraph, in helping to relieve human suffering when disasters occur, are too well-known to be reviewed here. However it seems that it would not be amiss to mention the amateur radio operators in this connection. In some areas they are specially organized and equipped for emergencies. In case of flood, where areas have been marooned, amateurs have gone on the air and directed rescue operations. They have picked up distress calls from ships at sea, and using the telephone to call the proper authority have been instrumental in sending help to the stricken vessel. Recently a navy pilot crashed on a small island of the Hawaiian group and was badly injured. An amateur radio operator on the island put out a call for help and succeeded in contacting another "ham" in the state of New Jersey, who carried out the following action: (1) Called a nearby doctor who came in and gave direc-
tions over the radio to the amateur near the scene of the crash in Hawaii; and (2) called the Navy which sent a message to Pearl Harbor where a rescue plane was dispatched to return the injured man to the Naval Hospital.

There are many incidents of this type on record, all testifying to the value of electrical communications in time of crisis.

The Home. Still (55, p.12), in discussing the place of the radio in American Life states that approximately 98% of the homes in the United States today own radios, and that 41% own telephones. At the present time, the proportion of homes in the urban areas that own telephones is much greater than that for those in the rural areas. Something of the significance of the telephone in the city home is shown by the following statement by the American Telephone and Telegraph Company (3, p.58):

In the 170 largest U. S. cities served by the Bell System, the average number of telephones the customer can reach by a local call has increased from 30,000 in 1920 to 90,000 today, and the monthly cost to the residence customer measured by each 1,000 telephones he can reach by a local call has declined 60 per cent.

This means then that from the average city home, with a telephone, an individual may, in a few seconds time, contact any one of 90,000 different people.

In this same connection, in regard to the use of the radio, a few simple calculations will serve to show that the individual in his home today, in theory at least, could be a part of an audience numbering over 100 million people. This
speculation bears out a statement by Mumford (41, p.241) who recalls that:

Plato defined the limits of a city as the number of people who could hear the voice of a single orator.

and adds:

Today those limits do not define city, but a civilization.

The implications for mass impression through the use of the telephone and radio then seem to be very great. The reader is referred to the findings of the President's Research Committee (48, p.153) for a list of 150 effects of the radio-telegraph and telephone, and of radio broadcasting.

As a further indication of the prominent place of radio and telephone in the home today, it is to be noted that many new homes being built include provisions for built-in television receivers. Also will be found built-in telephone wires with phone-jack type of outlets in various parts of the house. Individuals with a flair for invention have installed two-way radios in their cars for communication with their homes, where telephone connections can be made. This type of service eventually will be made available to everyone who wants it.

The School and Church. The writer, through talks with administrators, visits to school plants, and personal experience, has found that in addition to the telephone used for outside communications, many schools today are making use of one or all of the following electrical communications devices: (1) radio receivers; (2) two-way, permanently installed public address systems; and (3) Recording machines, which are of two
general types -- those that use a disk, providing a means of filing the recording for future use; and the magnetic-wire recorders, most of which provide only a temporary record, which may be "erased" and the wire used again and again.

Schools possessing radio receivers use them in making available to the students, selected radio programs which may be useful to some particular course of study. It is used quite extensively by teachers of music appreciation, dramatics, languages, home economics and journalism.

More and more schools today are installing the two-way public address system. This consists of a central station with the controlling equipment and the microphone, and a number of speakers placed in the various classrooms. On the control panel at the central station are switches which permit communication with any one classroom without disturbing the others. The administrator may "listen in" on any class without either the teacher or the pupils knowing it. However, many teachers resent this practice and few administrators follow it. The great value of the system is realized in two ways: (1) It provides a means of making routine announcements, as well as emergency calls, with the least possible confusion; and (2) It allows the school to carry out a program of radio broadcasting by the students themselves. This latter function comes under the heading of communication education and will be discussed in chapter six.

The Industrial Arts laboratory at Napoleon (Ohio) High School is equipped with a two-way communications system of the type described above. A master station on the instructor's
desk is provided with a selector switch so that the various areas of the laboratory can be contacted individually or all at once for general announcements. It was learned that the system reduces confusion, makes for better discipline and add a business-like atmosphere to the shop which is reflected in the industry of the students.

In checking the six Columbus high schools in regard to their utilization of electrical communication devices it was found that although only one (South) has a public address system of the type described above, all six possess a recording machine. These machines are used in the following manner: (1) By public speaking classes as a means of improving diction, voice tone, and sentence structure; (2) As a means of filing outstanding student reports, and assembly programs for future use; and (3) By various groups sponsoring programs, who wish to know how the program sounds before they present it.

Churches also use electrical communications devices. Probably the most common is the public address system. Large churches provide speakers in various areas of the building, which take care of over-flow crowds. One of the most unique uses, and certainly a laudable one, is in providing hearing aids. The microphone and amplifier are used quite widely in this manner even by very small churches. Certain pews are equipped with phone jacks with leads to the amplifier. Any person who has difficulty hearing the sermon, procures one of the available sets of headphones and plugs it into one of these jacks. The voice of the minister speaking into a microphone then, is brought directly to him.
A **Hobby.** Following the early work of Marconi, a few individuals began to tinker with the new idea. It has already been shown that one of these "tinkerers" started commercial broadcasting in the United States. Since that time the number of amateurs has increased steadily until today there are some 100,000 licensed "Hams" in the United States alone, with probably another 900,000 in the rest of the world. Both sexes and all ages make up this group of hobbyists, and many of them enjoy world-wide contacts. Their activities on the air are controlled by the Federal Communications Commission, which also assigns certain frequencies in which they may operate. These frequencies are assigned in ranges which they may operate. These frequencies are assigned in ranges which are called "bands". At the present time the "hams" may "work" certain areas of any of the following bands, depending upon the type of license held:

- **80 meter band** - 3500 kc to 4000 kc
- **40 meter band** - 7000 kc to 7300 kc
- **20 meter band** - 14000 kc to 14400 kc
- **10 meter band** - 28000 kc to 30000 kc
- **6 meter band** - 46000 kc to 50000 kc
- **2 meter band** - 144.4 mc to 147.4 mc
- **1 meter band** - 294 mc to 300 mc
- **¾ meter band** - 400 mc to 401 mc

The true "ham" usually builds his equipment. Oftentimes he becomes interested while still in the elementary grades, and possibly builds a simple receiver. Later he builds a low-power
Figure 13

A typical "ham radio" station

(Picture by writer courtesy Mr. N. E. Farrar, 556 Waverly St. Columbus, Ohio)
Figure 14. Three-element, rotatable beam antenna of the set shown in Figure 13. (Picture by writer courtesy Mr. N. E. Farrar, 556 Waverly St., Columbus, Ohio.)
CW (uses telegraph key) transmitter, and then gradually works his equipment up to higher power, usually adding a microphone, getting into the 'phone group.' The 'ham' whose set is shown in Figures 13 and 14, built all the equipment shown except the receiver, and many amateurs today who have progressed beyond the novice stage find it more practicable to buy commercial receivers than to build their own, because most of them lack adequate testing equipment. The transmitter shown has a power output of 100 watts and is usually operated on the '10 meter band.' The antenna (p. 96) is a 3-element unidirectional rotary array equipped with Selsen motors enabling the operator to direct his beam to any point of the compass, by turning the dial shown on top of the receiver to the desired degree. For instance, to point his beam due north he would turn the dial to 0; to point it due east the dial would be turned to 90, due south to 180 and due west to 270. By throwing a beam rather than radiating in all directions, the power of the set is concentrated.

Summary. The applications of electrical communications shown in this chapter admittedly are only representative of the total picture. It is believed, however, that this representative group, clearly shows the extent to which electrical devices are used for communications. It is thought also that the detail contained herein may be of value in building projects and activities for this unit in Industrial Arts.
Chapter V
THE COMMUNICATIONS INDUSTRY

A study of the communications industry itself may be helpful at this point, in determining the magnitude, rate of growth, activities performed, and social and economic changes being brought about chiefly because of its influence. The statistics shown in the tables in this Chapter have been taken from Statistics of the Communications Industry, put out by the Federal Communications Commission on December 31, 1944. In carrying out the above purpose, each of the following will be examined in turn: (1) The Federal Communications Commission, (2) The Telephone, (3) The Telegraph, and (4) The Radio.

The Federal Communications Commission. This government agency, set up by the Communications Act of 1934, consists of a six-man board, one of which is appointed chairman. Section 1 of the Act is quoted to show generally why it was created:

Section 1. For the purpose of regulating interstate and foreign commerce in communication by wire and radio so as to make available, so far as possible, to all the people of the United States a rapid, efficient, Nation-wide, and world-wide wire and radio communication service with adequate facilities at reasonable charges, for the purpose of the national defense, for the purpose of promoting safety of life and property through the use of wire and radio communication, and for the purpose of securing a more effective execution of this policy by centralizing authority heretofore granted by law to several agencies and by granting additional authority with respect to interstate and foreign commerce in wire and radio communication, there is hereby created a Commission to be known as the Federal Communications
Commission," which shall be constituted as hereinafter provided and which shall execute and enforce the provisions of this act.

Section 301 of the Act states, in part:

It is the purpose of this Act . . . . to maintain the control of the United States over all the channels of interstate and foreign radio transmission; and to provide for the use of such channels, but not the ownership thereof, by persons for limited periods of time, under licenses granted by Federal authority, and no such license shall be construed to create any right, beyond the terms, condition, and periods of the license. No person shall use or operate any apparatus for the transmission of energy or communications or signals by radio . . . . except under and in accordance with this Act and with a license in that behalf granted under the provisions of this Act.

A further examination of the Act reveals the following rules and regulations pertinent to the purpose of this study:

1. The Commission has the authority to prescribe the qualifications of station operators, to classify them according to the duties to be performed, to fix the forms of such licenses, and to issue them to such citizens of the United States as the Commission finds qualified.

2. The Commission has the authority to suspend the license of any operator upon proof sufficient to satisfy the Commission that the licensee has --
   a. Violated any provision of any act, treaty, or convention binding on the United States which the Commission is authorized to administer.
   b. Failed to carry out a lawful order of the person in charge of the equipment he is operating.
   c. Willfully damaged or permitted radio apparatus or installations to be damaged.
   d. Transmitted superfluous radio communications or signals or communications containing profane or obscene words, language, or meaning, or who has knowingly transmitted false or deceptive signals or communications, or a call signal or letter which has not been assigned by proper authority to the station he is operating.
e. Willfully or maliciously interfered with any other radio communications or signals
f. Obtained or attempted to obtain, or assisted another to obtain, an operator's license by fraudulent means.

3. The Commission shall make such rules and regulations, and prescribe such restrictions and conditions, not inconsistent with law, as may be necessary to carry out the provisions of this Act, or any international radio or wire communications treaty or convention, or regulations annexed thereto.

4. The actual operation of all transmitting apparatus in any radio station for which a station license is required by this Act shall be carried on only by a person holding an operator's license issued thereunder, and no person shall operate any such apparatus in such station except under and in accordance with an operator's license issued to him by the Commission.

5. Nothing in the Act gives the power of censorship to the Commission, and likewise the Commission shall not interfere with the right of free speech.

6. The Commission has jurisdiction over the common carriers (telephone, telegraph, radio) engaged in interstate or foreign communications. This jurisdiction includes the controlling companies of such carriers, also standard broadcast stations and networks.

7. All common carriers subject to the Act are required to file annual reports with the Commission.

8. Monthly reports of revenues and expenses are filed by telephone carriers having annual operating revenues exceeding $250,000 and by wire-telegraph, ocean-cable, and radiotelegraph carriers having annual operating revenues exceeding $50,000.

This then is a brief view of the government agency with the responsibility and power for controlling and regulating the communications industry which, as may be seen in the following pages, is taking on vast proportions.

The Telephone. The telephone organizations in the United States are called "carriers" and are classed as follows:

Class A: Carriers having average annual operating revenues exceeding $100,000.
Class B: Carriers having average annual operating revenues exceeding $50,000, but not more than $100,000.

Class C: Carriers having average annual operating revenues exceeding $25,000, but not more than $50,000.

Class D: Carriers having average annual operating revenues not exceeding $25,000.

An examination of the list of carriers reporting to the Federal Communications Commission for the year ending December 31, 1944, shows 136 Class A, 10 Class B, 13 Class C, and 28 Class D carriers.

Since by far the majority of the companies are Class A carriers, the table on page 102 gives a pretty good idea of the present magnitude of the industry. The table on page 103 serves to give an indication of the growth of the telephone industry from the year of the invention of the instrument to the end of the year 1944, while Figure 15 shows graphically the present extent of the industry in the United States.

An inquiry by the writer at the Bell Telephone in Columbus, Ohio, a city of 306,000 people, produced the following information: At the end of January 1947 there were 141,295 telephones in operation in Columbus. This number represents the number of phones actually owned by the Company. Many business concerns own and operate their own intraplant systems but these are not considered as being a part of the telephone industry as defined here.
SELECTED DATA SHOWING THE DEVELOPMENT THROUGH THE YEARS 1926 TO 1944, INCLUSIVE OF CLASS A TELEPHONE CARRIERS FILING ANNUAL REPORTS WITH THE COMMISSION.

<table>
<thead>
<tr>
<th>Year</th>
<th>Operating Revenues</th>
<th>Operating Expenses</th>
<th>Cable</th>
<th>Aerial</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1926</td>
<td>$381,632,995</td>
<td>$590,712,296</td>
<td>49,574,545</td>
<td>4,966,265</td>
<td>54,540,910</td>
</tr>
<tr>
<td>1927</td>
<td>950,464,436</td>
<td>638,717,381</td>
<td>55,403,941</td>
<td>5,112,254</td>
<td>60,521,195</td>
</tr>
<tr>
<td>1928</td>
<td>1,034,540,172</td>
<td>692,574,245</td>
<td>60,651,892</td>
<td>5,290,898</td>
<td>65,943,790</td>
</tr>
<tr>
<td>1929</td>
<td>1,135,320,375</td>
<td>767,686,189</td>
<td>63,076,381</td>
<td>5,698,776</td>
<td>73,775,157</td>
</tr>
<tr>
<td>1930</td>
<td>1,169,149,686</td>
<td>805,606,596</td>
<td>74,788,560</td>
<td>5,871,684</td>
<td>80,660,244</td>
</tr>
<tr>
<td>1931</td>
<td>1,131,113,896</td>
<td>769,896,145</td>
<td>78,761,741</td>
<td>5,669,803</td>
<td>84,431,044</td>
</tr>
<tr>
<td>1932</td>
<td>1,013,001,605</td>
<td>691,486,571</td>
<td>80,598,220</td>
<td>5,415,197</td>
<td>88,013,417</td>
</tr>
<tr>
<td>1933</td>
<td>935,051,338</td>
<td>667,948,613</td>
<td>77,826,930</td>
<td>4,522,444</td>
<td>82,349,774</td>
</tr>
<tr>
<td>1934</td>
<td>946,477,468</td>
<td>666,711,450</td>
<td>77,773,321</td>
<td>4,450,559</td>
<td>82,227,880</td>
</tr>
<tr>
<td>1935</td>
<td>998,957,182</td>
<td>702,622,989</td>
<td>78,312,068</td>
<td>4,366,119</td>
<td>82,578,187</td>
</tr>
<tr>
<td>1936</td>
<td>1,076,451,150</td>
<td>722,276,290</td>
<td>79,025,699</td>
<td>4,327,869</td>
<td>83,344,668</td>
</tr>
<tr>
<td>1937</td>
<td>1,140,095,991</td>
<td>775,926,688</td>
<td>81,261,051</td>
<td>4,581,305</td>
<td>85,612,356</td>
</tr>
<tr>
<td>1938</td>
<td>1,142,797,784</td>
<td>796,041,781</td>
<td>82,251,884</td>
<td>4,321,644</td>
<td>87,572,528</td>
</tr>
<tr>
<td>1939</td>
<td>1,200,531,903</td>
<td>803,540,027</td>
<td>85,451,764</td>
<td>4,294,922</td>
<td>89,746,678</td>
</tr>
<tr>
<td>1940</td>
<td>1,272,664,572</td>
<td>841,637,817</td>
<td>89,351,848</td>
<td>4,326,120</td>
<td>92,687,968</td>
</tr>
<tr>
<td>1941</td>
<td>1,406,882,519</td>
<td>917,456,856</td>
<td>95,327,759</td>
<td>4,452,599</td>
<td>99,780,358</td>
</tr>
<tr>
<td>1942</td>
<td>1,535,283,072</td>
<td>1,020,299,707</td>
<td>97,856,293</td>
<td>4,500,692</td>
<td>102,357,085</td>
</tr>
<tr>
<td>1943</td>
<td>1,778,118,317</td>
<td>1,142,477,308</td>
<td>97,578,380</td>
<td>4,486,885</td>
<td>102,664,645</td>
</tr>
<tr>
<td>1944</td>
<td>1,903,385,027</td>
<td>1,223,745,808</td>
<td>98,254,439</td>
<td>4,495,287</td>
<td>102,747,726</td>
</tr>
</tbody>
</table>

*This decrease is due mainly to the fact that prior to 1933 the total of wire jointly owned with other companies was included, whereas from then on only the respondent's portion of jointly owned wire was included.*
<table>
<thead>
<tr>
<th>Year</th>
<th>Number</th>
<th>Year</th>
<th>Number</th>
<th>Year</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>1876</td>
<td>2,600</td>
<td>1899</td>
<td>1,004,700</td>
<td>1922</td>
<td>14,747,395</td>
</tr>
<tr>
<td>1877</td>
<td>9,300</td>
<td>1900</td>
<td>1,355,900</td>
<td>1923</td>
<td>15,369,500</td>
</tr>
<tr>
<td>1878</td>
<td>26,300</td>
<td>1901</td>
<td>1,001,100</td>
<td>1924</td>
<td>16,208,900</td>
</tr>
<tr>
<td>1879</td>
<td>30,900</td>
<td>1902</td>
<td>2,371,044</td>
<td>1925</td>
<td>16,925,900</td>
</tr>
<tr>
<td>1880</td>
<td>47,900</td>
<td>1903</td>
<td>2,808,900</td>
<td>1926</td>
<td>17,746,200</td>
</tr>
<tr>
<td>1881</td>
<td>71,400</td>
<td>1904</td>
<td>3,353,200</td>
<td>1927</td>
<td>18,522,767</td>
</tr>
<tr>
<td>1882</td>
<td>97,700</td>
<td>1905</td>
<td>4,126,900</td>
<td>1928</td>
<td>19,741,300</td>
</tr>
<tr>
<td>1883</td>
<td>122,600</td>
<td>1906</td>
<td>4,932,800</td>
<td>1929</td>
<td>20,272,000</td>
</tr>
<tr>
<td>1884</td>
<td>147,700</td>
<td>1907</td>
<td>6,116,578</td>
<td>1930</td>
<td>20,201,600</td>
</tr>
<tr>
<td>1885</td>
<td>155,800</td>
<td>1908</td>
<td>6,486,600</td>
<td>1931</td>
<td>19,707,600</td>
</tr>
<tr>
<td>1886</td>
<td>167,100</td>
<td>1909</td>
<td>6,995,700</td>
<td>1932</td>
<td>19,424,406</td>
</tr>
<tr>
<td>1887</td>
<td>160,700</td>
<td>1910</td>
<td>7,635,400</td>
<td>1933</td>
<td>16,710,900</td>
</tr>
<tr>
<td>1888</td>
<td>185,000</td>
<td>1911</td>
<td>8,348,700</td>
<td>1934</td>
<td>16,983,800</td>
</tr>
<tr>
<td>1889</td>
<td>211,500</td>
<td>1912</td>
<td>8,729,592</td>
<td>1935</td>
<td>17,424,000</td>
</tr>
<tr>
<td>1890</td>
<td>227,900</td>
<td>1913</td>
<td>9,542,500</td>
<td>1936</td>
<td>18,422,000</td>
</tr>
<tr>
<td>1891</td>
<td>279,300</td>
<td>1914</td>
<td>10,046,400</td>
<td>1937</td>
<td>19,453,401</td>
</tr>
<tr>
<td>1892</td>
<td>260,800</td>
<td>1915</td>
<td>10,523,500</td>
<td>1938</td>
<td>19,953,000</td>
</tr>
<tr>
<td>1893</td>
<td>266,400</td>
<td>1916</td>
<td>11,241,400</td>
<td>1939</td>
<td>20,831,000</td>
</tr>
<tr>
<td>1894</td>
<td>285,400</td>
<td>1917</td>
<td>11,716,520</td>
<td>1940</td>
<td>21,928,000</td>
</tr>
<tr>
<td>1895</td>
<td>339,500</td>
<td>1918</td>
<td>12,077,600</td>
<td>1941</td>
<td>22,581,000</td>
</tr>
<tr>
<td>1896</td>
<td>404,300</td>
<td>1919</td>
<td>12,668,500</td>
<td>1942</td>
<td>24,919,000</td>
</tr>
<tr>
<td>1897</td>
<td>515,200</td>
<td>1920</td>
<td>13,411,400</td>
<td>1943</td>
<td>26,381,000</td>
</tr>
<tr>
<td>1898</td>
<td>680,800</td>
<td>1921</td>
<td>13,875,200</td>
<td>1944</td>
<td>28,859,000</td>
</tr>
</tbody>
</table>

*Figures taken from U.S. Census of Telephones; other data are estimated and from unofficial sources.*
Figure 15
Map of the United States showing Bell Telephone toll lines
(Courtesy Bell Telephone System)
There were 1854 people being employed by the Bell Company, and the average number of long distance calls being handled per day was 895,093. The calls within the city and immediate surrounding areas were handled by automatic equipment.

By far the largest organization in the telephone industry is the Bell System. The controlling organ of this system is the American Telephone and Telegraph Company. There are three other major divisions of the system -- the Bell Telephone Laboratories, The Western Electric Company, and a group of telephone companies scattered over the United States, each serving its own particular territory but acting as associates of the Bell System.

The American Telephone and Telegraph Company, or A. T. & T. as it is called, owns most of the stock of the operating companies mentioned above, and with the Western Electric Company, shares ownership of the Bell Telephone Laboratories. Its Long Line Department performs a number of functions, some of which are: 1. Providing and operating long distance lines and switchboards which make world-wide telephone service possible; 2. Leasing wires to radio broadcasting networks in order to provide the well-known coast-to-coast hook-up; 3. Operating the radiotelephone circuits to points overseas; 4. Laying and maintaining the coaxial cable network which will bring television to all parts of the country; 5. Leasing wires to press associations for the dissemination of news; 6. Working with the regional operating companies in providing teletypewriter service to business concerns, commercial airlines and government agencies; 7. Operating the TWX, or teletypewriter
exchange service, which permits the interconnection through switchboards of any subscriber's machine with any one of more than 17,300 others making up the nation-wide system for the interchange of typewritten messages.

The Bell Telephone Laboratories are located in New York City, Murray Hill, New Jersey, and at various other field locations. In the laboratories a continuous program of research is carried on. Just prior to and during the War, the scientists, engineers, and technicians bent their efforts toward the development of communications equipment for use in war. Their research in radar, in conjunction with the Army and Navy was invaluable. Their coaxial cable is only 1\(\frac{1}{4}\) inches in diameter but it will transmit as many telephone conversations as were carried by eight 90-foot poles with 25 cross-arms, in 1880. The work of the Bell Telephone Laboratories (2, p.32) is of four broad types: (1) Research investigations of a fundamental character, not only in electricity but also in mathematics, physics and chemistry. (2) Apparatus Development is responsible for the design and proper functioning of the individual mechanisms in the telephone plant. In particular, it scrutinizes the new facts turned up by research, to see if they can be used to improve existing devices or to help create new ones. (3) Transmission Development is concerned with improvements in the talking quality of the completed circuit. It considers such things as loudness, intelligibility, naturalness and the various factors that make or mar them. (4) Switching Development joins wires and apparatus into complete systems, so that telephone connections
can be made quickly, accurately and economically.

The Western Electric Company, which, as stated above, is another unit in the Bell System, is the largest maker of communications equipment (3, p.39) in the United States. In addition to the manufacturing of equipment this company carries on the following functions for the System: 1. It buys for the associated operating telephone companies large quantities of supplies which it does not itself produce. 2. It operates distributing warehouses where stocks are maintained to speed delivery to the telephone companies, of the right equipment and materials at the right time. 3. It provides specially trained Western Electric forces to install most of the complicated central office equipment required to interconnect all parts of the telephone system.

Following, are some of the highlights (3, p.60) in the future plans of the Bell System:

1. Provision of circuits and switching equipment so that individual lines again can be made available to all who want them.

2. Installation of modern handset telephones for everybody, and, for all who have need of them, new and improved intercommunicating devices with switching keys built into the base of the telephone.

3. Further extension of dial service both in cities and in rural areas, and the introduction of methods and equipment which will enable long distance operators to dial calls directly through to the called telephone even though it is on the opposite side of the continent.
4. Extension of telephone service to an additional million farm homes and general improvement of rural service to make it as nearly like city telephone service as possible. The completion of this program in three to five years will require the expenditure of more than $100,000,000.

5. Installation of a coast-to-coast network of coaxial cable which will provide channels for the transmission of hundreds of telephone conversations simultaneously, and also transmit television programs.

6. Introduction of radio relay systems which may be used in conjunction with the cable network to transmit telephone messages, AM or FM sound broadcasting programs, or television programs.

7. Development of mobile telephone service to provide two-way radiotelephone communication to and from motor vehicles, trains and other mobile units operating within metropolitan areas and over intercity routes with any one of the millions of regular telephones.

The telephone has become so common as to be a part of daily routine. Providing instant conversation between distant parties, it has reduced the postal traffic immeasurably. Perhaps its greatest social influence has been in the way it has knit communities together. The place of the telephone in daily life is indicated in the following lines from the report of the President's Research Committee (48, p.199):

These figures testify to the permeation of the nation by the new agency, and indicate its acceptance, not as a luxury or a desirable convenience, but as a necessity. The disadvantages of not having the telephone
close at hand are so great that it is installed even where the total number of calls may be relatively few. The telephone directory has assumed importance as a city directory, and is useful in establishing contact. To be without a telephone or a telephone listing is to suffer a curious social isolation in a telephonic age.

It may be said that the telephone represents a vast industry, and as an agency of rapid communications has become one of the most important social and economic influences of modern times.

The Telegraph. The telegraph has both commercial and personal uses, with the former probably being the more stable. The average individual sends and receives very few telegrams, but it finds great utilization in business, and although it represents a great industry, its growth as a separate industry has not paralleled that of the telephone.

Following is a list of wire-telegraph, ocean-cable and radiotelegraph carriers reporting to the Federal Communications Commission (23) for the year ended December 31, 1944. This list probably gives a pretty good picture of the telegraph industry as pertains to the companies involved;

<table>
<thead>
<tr>
<th>Name of Carrier</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>All America Cables &amp; Radio, Inc.</td>
<td>Ocean cable (P)</td>
</tr>
<tr>
<td>Canadian Pacific Railway Co.</td>
<td>Wire-telegraph (S)</td>
</tr>
<tr>
<td>Colorado &amp; Wyoming Telegraph Co.</td>
<td>Ocean-cable (P)</td>
</tr>
<tr>
<td>Commercial Cable Co.</td>
<td></td>
</tr>
<tr>
<td>Commercial Pacific Cable Co.</td>
<td>Wire-telegraph (S)</td>
</tr>
<tr>
<td>Continental Telegraph Co.</td>
<td>Ocean-cable (S)</td>
</tr>
<tr>
<td>Cuban All America Cables Inc.</td>
<td>Wire-telegraph (S)</td>
</tr>
<tr>
<td>Great Northwestern Telegraph Co. of Canada</td>
<td>Radiotelegraph (P)</td>
</tr>
<tr>
<td>Interstate Telephone &amp; Telegraph Co.</td>
<td></td>
</tr>
<tr>
<td>Mackay Radio &amp; Telegraph Co.</td>
<td>Radiotelegraph (S)</td>
</tr>
<tr>
<td>Mayor and City Council of Baltimore, Md.</td>
<td></td>
</tr>
</tbody>
</table>
Mexican Telegraph Co.  Ocean-cable (P)
Michigan Wireless Telegraph Co.  Radiotelegraph (S)
Minnesota & Manitoba R. R.  Wire-telegraph (S)
Mountain Telegraph Co.  Wire-telegraph (P)
Northern Telegraph Co.  Radiotelegraph (P)
Olympic Radio Co.  Radiotelegraph (P)
Pere Marquette Radio Corp.  Radiotelegraph (P)
Press Wireless, Inc.  Radiotelegraph (P)
R. C. A. Communications, Inc.  Radiotelegraph (S)
Radiomarine Corporation of America  Radiotelegraph (P)
South Porto Rico Sugar Co. (of Puerto Rico)  Radiotelegraph (P)
Tropical Radio Telegraph Co.  Radiotelegraph (S)
Norman B. Underwood (Marine Communications Co.)  Radiotelegraph (S)
United States-Liberia Radio Corp.  Radiotelegraph (P)
Wabash Radio Corp.  Radiotelegraph (S)
Western Union Telegraph Co.  Wire-telegraph &
Yellowstone Park Co.  Ocean-cable (P)

Note: (P) indicates principal carriers having average annual operating revenues exceeding $50,000.
(S) indicates small carriers with average annual operating revenues not exceeding $50,000.

Further information on the extent of the industry may be obtained by examining the table on page 111.

The Western Union Telegraph Company is easily the largest and best-known organization in the telegraph industry. Most of the following information was supplied to the writer directly, by Western Union. The following data serve to give an idea of the size of the Company: (figures as of Jan. 1, 1945)

236,590 miles of pole line
30,345 miles of ocean cable (nautical miles)
5,278 miles of landline cable
29,740 telegraph offices and agency stations
64,570 employees, including messengers
12,000 messengers
3,000 quotation tickers
100,000 time service units synchronized in 2,000 cities
2,100 baseball tickers in season
28,891 stockholders

The principal domestic services performed by Western Union are as follows (65, p.10):
DATA SHOWING DEVELOPMENT BY TWO-YEAR PERIODS
FROM 1926 TO 1944 INCLUSIVE, OF PRINCIPAL WIRE-TELEGRAPH, AND OCEAN-CABLE CARRIERS.

<table>
<thead>
<tr>
<th>Year</th>
<th>Miles of wire</th>
<th>Aerial</th>
<th>Revenue messages transmitted</th>
<th>Employees at close of June</th>
</tr>
</thead>
<tbody>
<tr>
<td>1926</td>
<td>364,866</td>
<td>1,731,763</td>
<td>230,824,284</td>
<td>86,383</td>
</tr>
<tr>
<td>1928</td>
<td>407,698</td>
<td>1,919,979</td>
<td>229,381,297</td>
<td>84,520</td>
</tr>
<tr>
<td>1930</td>
<td>482,340</td>
<td>1,933,603</td>
<td>226,459,997</td>
<td>92,148</td>
</tr>
<tr>
<td>1932</td>
<td>517,001</td>
<td>1,834,982</td>
<td>154,388,303</td>
<td>66,707</td>
</tr>
<tr>
<td>1934</td>
<td>525,261</td>
<td>1,834,299</td>
<td>167,853,876</td>
<td>68,383</td>
</tr>
<tr>
<td>1936</td>
<td>557,280</td>
<td>1,829,341</td>
<td>191,259,116</td>
<td>69,776</td>
</tr>
<tr>
<td>1938</td>
<td>558,350</td>
<td>1,823,375</td>
<td>185,240,059</td>
<td>63,210</td>
</tr>
<tr>
<td>1940</td>
<td>560,697</td>
<td>1,828,023</td>
<td>189,864,165</td>
<td>63,036</td>
</tr>
<tr>
<td>1942</td>
<td>573,660</td>
<td>1,833,860</td>
<td>221,672,324</td>
<td>70,120</td>
</tr>
<tr>
<td>1944</td>
<td>586,862</td>
<td>1,801,157</td>
<td>220,897,022</td>
<td>66,872</td>
</tr>
</tbody>
</table>
1. **Telegram.** The fastest service, with full-rate charge.

2. **Serial.** A service to provide for intermittent correspondence with one firm or person during the course of a day.

3. **Day Letter.** Messages which do not have to be handled at once. Reduced rate.

4. **Night Letter.** An inexpensive overnight service designed for longer messages which can be delivered the following morning.

5. **Telemeter.** Provides direct connection between customer's main offices and branches or correspondents.

6. **Telegraph Money Order.** Provides a quick, safe method of transferring money from one place to another.

7. **Correct Time Service.** Western Union clocks throughout the nation are automatically wound, and synchronized hourly with Naval Observatory Time. (Fig. 16)

8. **Commercial News.** Reports of trading volume, and quotations on twenty principal security and commodity exchanges.

9. **Teleregister.** Teleregister boards in broker's offices receive quotations over telegraph wires from a central operator. These quotations are set up on the board automatically.

10. **Cablegram and Radiogram.** A full-rate fast service, for either plain-language or cipher messages, to most of the civilized areas of the world.

11. **Cable Money Order.** A way of sending money to points in many foreign countries.

12. **Ship Radiogram.** Provides communication of ships at sea in all parts of the world, in association with connecting radio-telegraph companies.

It is interesting to note in conclusion that this company has become such an integral part of everyday life, especially in the business world, that the term "Western Union" has almost become synonymous with "telegram." Its provision of rapid communication for stock quotations, trading information and news, has made it a definite agency in influencing social
Figure 16

Master clock of the nation-wide time system provided by Western Union.

(Courtesy Western Union Company)
and economic development.

The Radio. Although it is the purpose here to give most attention to the radio broadcasting industry, it seems desirable at the outset to give some idea of the magnitude of the total industry including the manufacturing and use of radio sets. Much of this information is taken from the 1946 Yearbook of the Encyclopedia Britannica.

The total number of receiving sets in use in 1945 was approximately 56,000,000, with 6,000,000 of these being used in automobiles. The number of homes with radios was in the neighborhood of 34,000,000. In 1945 there were only about 500,000 sets manufactured because of the demands of war, (there had been 13,000,000 manufactured in 1941). At the beginning of 1946 the American people had approximately $350,000,000 invested in the radio manufacturing industry, with the annual gross revenue being about $3,000,000,000. The average number of employees for the year 1945, retained by 1200 manufacturers was 350,000 with an annual payroll of $570,000,000. In 1944 during the peak of war production, there were 530,000 employees in the industry with an annual payroll of $1,200,000,000.

Radio distributors, dealers and other retail establishments represented on January 1, 1946, a total investment of $280,000,000 with the annual gross income exceeding $200,000,000. These establishments were employing some 100,000 workers who were drawing an annual payroll of $150,000,000.

At the beginning of the same year there were 940 standard broadcasting stations in operation with 64 more
under construction. As the year 1945 ended the Federal Communications Commission had granted licenses to approximately 250 new FM (frequency modulation) stations in all sections of the country.

There are four coast-to-coast radio broadcasting networks in the United States, together with a number of smaller regional networks. These networks enable radio to bring incidents of nation-wide interest directly into the home.

The Radio Corporation of America (42, p.28) is the largest radio organization in the United States. It is engaged in every phase of radio: research, engineering, design and development, manufacturing, communications, broadcasting, and technical training. One of the major divisions of RCA is the National Broadcasting Company (NBC). The engineering force of NBC (42, p.65) is composed of a large group of studio, field, maintenance, and recording engineers, in addition to a smaller central staff group divided into four units:

1. The Audio Facilities group is responsible for the design and installation of all broadcast technical equipment as well as other mechanical features such as lighting and air-conditioning, in all NBC plants.

2. The Radio Facilities group functions in the same manner in the case of all broadcast transmitting apparatus used by the company. This includes short wave equipment to transmission to foreign countries.

3. The Development group works in research, where the engineers experiment with new methods of improving service, in addition to conducting continuous experiments on present equipment.

4. The Technical Services group supplies a general costing, drafting, and stock-room service to other engineering groups, and in addition is responsible for the architectural design of all new studio plants and alteration layouts.
The Press Department of NBC carries on the following functions:

1. Provides information and publicity to the press on the various programs and on other NBC activities in which there may be a public interest.

2. Acts as liaison between network and press -- explaining policies, arranging interviews etc.

3. Issues Advanced Program Service, containing details of all NBC programs, which is sent three weeks in advance to 1275 daily and weekly newspapers.

4. Mails NBC education programs to the leading educational journals of the country.

Thus it is seen that this company which is representative of all the network companies, carries on a number of activities, in connection with providing nation-wide hookups.

The Radio Corporation of America has produced many of the latest developments in radio. The first successful television camera tube was produced in their laboratories. This electronic device is known as the iconoscope, and although it is used widely in black and white television today, it is being replaced by the Image Orthicon. (Fig. 17)

This television "eye", as it is called, registers the image on a photosensitive surface. The image then is carried electronically to a target and scanned. No matter how faint the light (and consequently the electronic image), the electron beam scanning the target can pick up the image. The diagram shown below the tube shows the electron beam returning from the target is made to toss out secondary electrons from a small metal disk at the back of the tube. These electrons pass through multipliers, like tiny steam-turbine wheels, and
Figure 17
Image Orthicon tube, used in Television cameras.
(Courtesy Radio Corporation of America)
are stepped up in each stage from three to five times. Thus the signal is amplified as it leaves the tube and enters the transmitter. Thus the great advantage of this tube is that it can be used in ordinary light, being of practically the same sensibility as the human eye.

Black and white television then has passed the laboratory stage and will be available all over the United States as soon as a means for long distance has been provided. It is a well-known fact that the micro-waves used in television do not follow the curvature of the earth as do the ordinary radio waves. Any one of three methods may be used for long-distance transmission of these micro-waves of television, or they may supplement each other. Automatic radio relay stations may be located on high points of land, each station receiving the wave and passing it on to the next automatically. Stratovision may be used wherein a plane or a number of planes flying at high altitudes pick up the wave from ground transmitters and rebroadcast it to an assigned geographical area. The third method is in the use of coaxial cable. This method is being used rather widely at the present time, since the cable has already been laid on the eastern seaboard, and as far west as Cleveland in the North and all the way across the United States in the South.

RCA maintains and operates a mobile television unit (Fig. 18) which provides a means of bringing news incidents to the television "listener". In the New York area this mobile

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1 See p. 108
Figure 18

Mobile Television Studio

(Courtesy Radio Corporation of America)
unit transmits the scene to the NBC-RCA station atop the Empire State Building, where it is relayed to the television audience.

A growing demand for television receivers has resulted in a number of radio manufacturers altering a certain proportion of their receivers accordingly. Figure 19 shows General Electric's newest development in radio-television receivers. This receiver also embodies frequency modulation.

Color television was accomplished, until 1946, by means of a system of filters rotating by mechanical means, which had not proven entirely satisfactory, but on October 30, 1946 RCA demonstrated all-electronic color television. A cut-away drawing of the camera responsible for this advancement is shown in Figure 20. The light beam from a cathode-ray tube is projected upward through a kodachrome slide and through a series of color filters which separate respectively the red, blue and green portions of the image. Each color is then reflected into photocells which change the light values into electrical signals for transmission to the receiver. At the bottom of the page an RCA scientist adjusts the all-electronic color camera. The receiver is shown diagrammatically by cut-away drawing in Figure 22. The unit in the bottom of the cabinet, consisting of three kinescopes, is called the trinescope. Each kinescope draws its image from one of the phototubes (Fig. 20) of the camera. The three images coming from the trinescope then carry the colors of the object being viewed -- in this case, the kodachrome slide. These images are caught by the mirror, blended and reflected to the trans-
Figure 19
Modern radio receiver, incorporating television, frequency modulation, automatic record changer, and album storage.
(Courtesy General Electric Supply Corp., Columbus, Ohio)
Figure 20
Cut-away drawing of RCA all-electronic color television camera.
(Courtesy Radio Corporation of America)

Figure 21
RCA all-electronic color television camera
(Courtesy Radio Corporation of America)
Figure 22
Cut-away drawing of RCA all-electronic color television receiver showing trinoscope producing image in three colors.
(Courtesy Radio Corp. of America)

Figure 23
Rear-view photograph of RCA all-electronic color television receiver
(Courtesy Radio Corporation of America)
lucent viewing screen. Figure 21 is an actual rear-view photograph of the all-electronic color television receiver, showing the trinoscope, comprising the three cathode-ray kinescopes which project the red, blue, and green images on the mirror and viewing screen.

A close-up view of certain phases of the operation of a radio broadcasting station was obtained by a visit to WCOL in Columbus. A new modern building houses the reception offices, executive offices, audition and broadcasting studios, control rooms, engineers' laboratory, teletype and ticker room, and a dark room for photography. Figure 24 shows an engineer seated at a control panel and facing one of the smaller studios shown through the sound-proof window. On the engineer's right is a similar window looking into the larger studio (Fig. 25) which can accommodate an audience of approximately 160 people. This is studio "A" and will be used for television when that development eventuates in Columbus. Note the structures on the walls for scientifically controlling sound.

The teletype room mentioned above provides a terminal for the A. T. & T.-leased wires of the Associated Press and the International News Service; the latter with two wires -- a day wire and a night wire. Also in this room is a Western Union sports ticker, which permits the station to report the latest in sports news, and a direct loud-speaker line to the main station of the Columbus Fire Department.

An inquiry as to the future plans of the station revealed that engineers were in the process of installing frequency modulation equipment which would be in operation in October.
Figure 24

Studio Engineer's control panel with studio visible through sound-proof plate-glass window.

(Courtesy WCOL Columbus, Ohio)
Figure 25

A broadcasting studio, showing wall construction for sound control. This studio will later be used for television broadcasting

(Courtesy WCOL Columbus, Ohio)
on an assigned frequency of 92.3 megacycles. In addition to the actual transmitter, the installation process involves placing a thirty-foot extension on top of the present antenna tower, similar to that shown in Figure 26.

The tower shown here (one on the right) is that of WELD another Columbus broadcasting station, which was also visited. This is the first station in the state to broadcast FM. At the present it goes on the air at 1:00 PM and broadcasts until 11:15 PM on an assigned frequency of 97.1 megacycles and with a power of 35,000 watts which is soon to be advanced to 60,000. This station also carries out a limited program of radio-facsimile broadcasting. Their transmitting equipment for this is shown in Figure 27. Radio facsimile involves sending printed matter including pictures over the air. With a facsimile receiver in his home, an individual at breakfast may have a digest of the latest news printed by his own radio during the night. Note the master copy about the cylinder of the transmitter. A photoelectric cell scans this copy and the transmitter sends it out in the form of radio waves, which are taken in by the receiver where a light source, varying according to the impulses from the above-mentioned photoelectric, plays on special sensitized paper to produce the image without further development.

**Summary.** Something of the magnitude of the electrical communications industry has been shown in this chapter. It is also possible from the information presented here to gain a conception of the rapidity with which this industry has developed, the whole thing growing up almost within the space
Figure 26.
Radio broadcasting antenna tower showing extension used for Frequency Modulation transmission.

(Picture by writer courtesy WELD Columbus, Ohio)
Figure 27

Radio facsimile transmitting equipment.

(Courtesy WELD, Columbus, Ohio)
VACUUM FACSIMILE SCANNER AND TRANSMITTER
of a life-time. Reflection on the activities and services performed by the telephone, telegraph, and the radio, as described in the preceding pages will serve to show the far-reaching influence of the industry. In providing point-to-point communication it has extended the radius of man's contacts, and the radio especially, as an agency of mass impression has, to a degree, stimulated the individual to think and act like millions of his fellows. And finally it is seen that engineering research within the industry is constantly producing new devices contributing to the increasing comfort, convenience, and pleasure of mankind.
Chapter VI
EDUCATION IN ELECTRICAL COMMUNICATIONS

A further search for content leads to an examination of what is already being done.

Attention will be given in this chapter to the type of education or training being carried on in secondary schools, colleges and universities, industry, the armed forces, and to the educational films available on the subject of electrical communications. The information presented has been gathered from various sources, -- references as shown, talks to school administrators, visits to school plants, contacts with Army and Navy recruiting offices, and the writer's military, as well as, civilian experience.

A. Secondary Schools

Actual communication involving the use of electrical devices seems to be very spotty. The work that is being done, in varying degrees of intensity, can be put into three categories: (1) That involving the use of radio receivers, to bring in standard broadcasts; (2) The use of a built-in public address system; and (3) Technical work in constructing devices -- mainly radio.

Schmidt (49), at the Ohio State University School, has developed a course in Communications, in which Radio, Press, Movies, and Books are studied as communication devices. The radio receiver is used and field trips are taken as extra work in interpreting these various means of communicating thought.

\[1\text{ See p. 92}\]
She suggests the possibility of dropping the term "English teachers" and using "Communications teachers." It was found that many schools have radio receivers, but that for the most part they are looked upon merely as a producer of programs, which are brought in for their intrinsic value only, and not to illustrate principles of communication.

It has been found that most of the schools that have been fortunate enough to get a permanently installed public address system, or Broadcast System, as it is sometimes called, are utilizing its possibilities to an extent increasing as experience is gained. Columbus South High School provides a good example. Here the "studio" consists of two rooms: A larger room for a class or audience, and a smaller room in which is placed the microphone, and which may be viewed through a large glass window from the larger room. This physical set-up enables the school to offer a strong program in radio speaking. The class forms the radio audience but they can also see the performers. From this microphone-room also originate programs, skits, and announcements which may be broadcast to the whole school over the speakers in the various rooms. At South they have found that this type of communication education has the following values:

1. It improves the use of English because students are more conscious of errors when they are made over the radio.

2. Diction and tone quality as well as sentence structure are improved.

3. Students are unwittingly getting character education by preparing scripts and giving broadcasts on subjects such as cheating, good citizenship, and safety education.

4. Experience in the use of the microphone may be of value in later life.
To these the writer would add that students also gain a broader conception of the use of the radio as a means of mass-communication, whereby the thoughts and ideas of the few may be impressed upon the minds of the many.

There seem to be wide gaps in the technical area of communications education in schools at the secondary level. That which is offered seems to be entirely in the field of radio. This is done in physics departments where instruction is confined mostly to history and theory, in vocational courses in electricity, and in the radio areas of Industrial Arts laboratories, where the type of instruction and the available equipment varies widely with individual schools. The radio section of the Industrial Arts Department in the High School at Napoleon, Ohio, is shown in Figure 28. This lay-out is a part of an exemplary laboratory, and provides a much richer offering of radio than will be found in most schools. An examination of the syllabus for the department reveals the following, under the heading of radio:

10th Grade
1. Radio terms
2. How to read radio circuits
3. Construction of a crystal set
4. Construction of two-tube set
5. Study various stages of radio, such as audio, amplifying, detector, etc.
6. Learn code
Figure 28
Radio area of an Industrial Arts Laboratory
(Courtesy Napoleon High School, Napoleon, Ohio)
11th Grade
1. Construct three tube set
2. Use of channels
3. Operation of amplifier
4. Recording
5. Construction of T.R.F. or superhet set

12th Grade
1. Learn Code
2. Work on radio repair
3. Work on superhetronies
4. Study transmitting

It will be noted that all the work is entirely within the field of radio communications, and is mostly of a technical nature.

Electronics magazine, in the summer of 1942, carried out a survey of the electrical engineering departments of colleges offering accredited courses in Engineering leading to a degree, in order to determine what was being offered in the fields of electronics and communications. Although this survey was made at the beginning of the War, and consequently some of these courses may have since been discontinued, it is to be presumed that due to recent advances in electronics and communications, most of them will have been retained and developed. In searching for electrical communications content for the Industrial Arts curriculum it seems that an examination of the findings of a survey of this nature, may be of value. It is reproduced here by permission of the copyright owners (See Appendix B).
Generalizations evolved from the study were: 1. The majority of the engineering colleges are increasing their instruction in electronics and communication subjects, or have already done so. 2. Some forty or more colleges are offering communication courses under the program of engineering, mostly given in the evening without college credit.
3. A considerable program of research is being carried on in electronics and communications.

Following is a selected list of the schools replying to the questionnaire together with a brief account of each school:

University of Akron - Basic communication and radio technician course as recommended by NAB (National Association of Broadcasters.)

University of Arizona - A three-unit course largely devoted to the theory of telephony.

University of Arkansas - 1. 3-hour course in Elements of Communications Engineering; 2. A 3-hour course plus a 2-hour Laboratory period in Communications Engineering.


Brown University - Course in Basic Radio Communications

University of California - A full program of communications courses.

Carnegie Institute of Technology - Communication Circuits 2nd term of Senior year.

University of Cincinnati - 1. Electrical Communications Lectures and Laboratory work; 2. Electromagnetic radiation and wave Propagation; 3. Microwave technique.

Cornell University - Course of 12 weeks in Communications to holders of Liberal Arts Degrees. Purpose being to give sufficient background in communications to prepare graduates for those positions where highly trained engineers are now used but are not necessarily needed
Georgia School of Technology - Regular schedule in Communications Engineering.

Harvard University - Introductory course of electricity and magnetism, then a regular series of Communications courses.

University of Idaho - Communications courses include one each on vacuum tubes, elements of telephony, and radio engineering.


State University of Iowa - Courses designed to meet needs of war training.

Kansas State College of Agriculture and Applied Science - Courses in wire communication covering communication circuits, and in Radio Communication dealing with radio and electronics.

University of Kansas - Courses in Communication circuits and in Radio Communication.

University of Louisville - Two courses in Communication Engineering and one on Television.

University of Maryland - A required 6-Semester-hour course in Radio

Massachusetts Institute of Technology - Communication majors take a course in Engineering Electronics along with regular electrical engineering students, plus an engineering course in electronics from Physicist's point of view, and one and one-half years in Communications theory with an additional one year in the Communications Laboratory. Courses at the graduate level include: 1. Advanced Network theory; 2. Advanced Communications Laboratory, designed to meet the needs and interests of individual students; 3. Study of Sound; 4. Advanced Electrical Communications; 5. Radio lines antennas and wave propagation; 6. A study of the patent application of electrical communications in the United States.

Michigan College of Mining and Technology - Vacuum tubes as apply to radio receivers.
Michigan State - Communication networks and Radio

University of Michigan - Have courses in five broad classifications: 1. Basic courses required of all undergraduate electrical engineering students; 2. Advanced undergraduate and graduate elective courses covering fundamentals in electromagnetic field theory; 3. Advanced undergraduate and graduate elective courses for students specializing in communications; 4. Advanced undergraduate and graduate electives for students in Electronics; 5. Communication courses for students from other departments, which include Elementary Radio and the Elements of Electrical Communications. Under (3) above students may take a. Advanced theory of electrical circuits; b. UHF technique; c. Radio Communications; d. Television; e. Heaviside operators.

University of Minnesota - In Junior year majors in Communications take a full year of Electrical Communications. In their Senior year Communications students are required to take a 2-hour course in Radio, and a 2-hour course in Electrical Communications. Elective courses offered are: radio transmission, problems in receiver design, UHF, and sound and acoustics.


New York University - New courses added were: Communication Engineering No. 1, Communications Engineering Laboratory, and Radio Engineering.

University of Oklahoma - A new course in UHF and several communications courses for persons desiring radio training for entry into Armed Forces or into Industry.

Oregon State College - New courses were added to the Physics Department: 1. A one-term course in Elements of Radio for students who want some knowledge of Radio but do not wish to follow it professionally. 2. A course for juniors in the Preparation in Fundamentals of Communication Engineering preceding their professional work.

Pratt Institute - 1. Electronics; 2. Elementary Engineering Laboratory in vacuum tubes, gas tubes and rectifiers.

South Dakota State College - 1. 3-hour course in Communication Circuits; 2. 3-hour course in vacuum tubes. With amount of time spent in communications and vacuum tube laboratory being doubled.

Swarthmore College - Electronics and communications have been separated. Each will form a separate course.


Texas Technical College - 1. Elementary Radio open to any student; 2. Advanced Radio open to senior electricity students; 3. 1-semester course in Communications required of all electricity students.

University of Texas - Communication Engineering subjects covering voice, frequency, telephony and radio communication systems required of Communication Engineering majors. Graduate courses include: 1. Advanced Communications network analysis; 2. Radio transmitters and receivers; 3. Television Engineering; 4. Antennas and Wave propagation.

Tulane - Courses in wire communication systems require about 1/3 the time of electrical engineering students in the senior year.

Virginia Polytechnic Institute - Specialists in Communication take courses in Communication and Radio Engineering. All courses include laboratory work. Material used in teaching UHF to Naval personnel to be retained for regular communication engineering students.


University of Washington; Accent is on electronics. No mention of communications in particular. 95% of all Electrical Engineering students taking all the Electronic courses.
Yale - New courses in Communications include: 1. Electrical Communications and elements of Radio for non-electrical students; 2. VHF for regular Engineering students.

An account of the communications courses offered by the Electrical Engineering Department of the Ohio State University is paraphrased here in order to show the extreme technical nature of the work involved.

1. Communication Engineering - 3 classes, 2 laboratory, and 1 calculation period each week.

2. Electron Devices and Circuits - 3 classes, 3 Labs. each week. Designed for non-electrical engineering students who find a knowledge of electronic devices necessary in their work.

3. Communication Engineering (advanced) - 3 classes, 3 Labs. An advanced study of medium and high frequency alternating current circuits. Radiation fields and their measurement.

4. Applied Electromagnetic Wave Theory - 3 classes, 3 Labs. Elementary magnetic field theory as applied to antenna systems, wave guides, cavities and electromagnetic horns.

5. High Frequency Measurements - 3 classes. Measurements of current, power, impedance and field strength. Antenna pattern measurements; special measurements.

6. Ultra High Frequency Engineering - 3 classes, 3 Labs. The generation and detection of UHF oscillations at wave-lengths of only a few centimeters. Their transmission by conductor lines and wave guides; their control in time and space and the recording of their behavior. A study of the use of velocity modulating tubes, magnetrons, electromagnetic field theory, wave guides, transient phenomena, electromagnetic field horns, antennas, wide band amplifiers and multiple detection receivers as used in application of UHF modulation.

7. Fundamentals of electromagnetic theory. 3 classes. Vector analysis, electrostatics, magnetostatics, Maxwell's equations, fundamental theorems, plane waves, polarization.
8. Travelling waves on Transmission lines. 4 classes. Theory of wave propagation on single and multi-wire lines; reflection and refraction of waves. Impulse character of insulation, and insulation coordination.


10. Vacuum tube networks. 3 classes. Selection of tubes in terms of derived-merit figure, such as gain band, power-band, signal-to-noise merit.

11. Wave Guides and Resonators. 3 classes. Various types of wave guides.


13. Research in Electrical Engineering. A problem may be selected by the student with approval of his advisor.

It is to be noted that all these courses, with the possible exception of the second one listed, are designed for the specialist in communications -- the engineer.

Industry. Correspondence with officials of the telegraph, telephone, and radio industries reveals that most of the training is of a highly specialized type, usually taking place on the job, under experienced supervision. It is quite common for a company to provide classes in theory to supplement the practical work. The program of the National Broadcasting Company (42, p.110) is believed to be typical of most large organizations of this type. This company follows the policy of having their supervisors and foremen watch for promising young men and women, who upon discovery are placed in various departments to learn the jobs in that department. There are also apprenticeship groups such as in the Engineering Department,
where each apprentice is trained for a specific job under a designated engineer. Later he may be assigned to Studio, Maintenance, Field, Recording, or Transmitter Engineering, depending upon his field of specialization. Courses given by the company in after-working hours include: Announcing, Sound Effects, Production Script Writing, Television Engineering, and General Discussion groups. These are considered workshop courses and meet weekly. The students hear lectures and take actual part in production, presentations, and discussions.

Figure 29 shows a training class in the Bell System. The men are learning the problems involved in installing a telephone in a subscriber's home. There are mock-ups of buildings constructed of different types of materials such as wood, stucco, and brick. The man on the pole is talking over a portable telephone set at a cable terminal box while tests are being made on some of the wires in the cable attached to the pole. This duplicates the procedure as carried out, when out on the job. The men at the table are working on problems involving the apparatus itself.

The Armed Forces Communications Training. In certain fields of communications, such as aviation radio (50, p.495) the best type of instruction, both from the material and the operational standpoints, is to be found in the Armed Forces. Both the Signal Corps of the Army and the Bureau of Naval Personnel maintain schools where technicians as well as operators are trained. Figure 30 shows a class of the Army Signal Corps learning the fundamentals of radio as used in the field. At the bottom of the page (Fig. 31) a class of navy radio operators
Figure 29

A training class in the telephone industry (see p. 142)

(Courtesy Bell Telephone System)
Figure 30
U. S. Army Signal Corps class in radio fundamentals
(Courtesy U. S. Army Signal Corps)

Figure 31
U. S. Navy radio operators learning the elements of circuit design
(Courtesy U. S. Navy)
Courtesy U. S. Army Signal Corps
for aircraft are learning the elements of circuit design.

Note the equipment available for instruction, and the size of the classes.

Radio operators and communication yeomen in the Navy, especially aboard ship and in base communications offices, are in a position to learn all phases of communications. They learn the proper forms to be used, how the message is logged, released and transmitted over the necessary channels to insure its reaching the addressee. This may involve the use of inter-office communication, telephone, radiotelephone, radiotelegraph, telegraph, and teletype. The responsibility placed upon personnel in communications as elsewhere, is in proportion to their rate. That is to say, in a radio-room where there are four sailors on watch, the one with the highest rate takes over. If he leaves, the one with the next highest rate will be in charge and so on. Men obtain their rates by "striking" for them. For example, suppose a seaman second class (no rate) has been working on deck in one of the deck divisions, and decides that he wants to become a radioman. His wish is made known through the proper channels and comes to the attention of the Division Officer, if it hasn't been discouraged by a Chief Petty Officer someplace along the line. The man's abilities are then examined and if found satisfactory, the Division Officers concerned will recommend to the Executive Officer that the man be transferred to the "C" (communications) Division as a radioman "striker". The rate he is trying for is Radioman Third Class. He has an instruction manual for this rate and is given periodic and
standardized tests. He studies message form, sending and receiving code, and radio circuits. There is a workshop and material available so that he can build simple sets which become more complex as he progresses. It is the duty of the Chief Radioman to supervise his instruction. When the course book has been completed, and all the tests satisfactorily passed, and if his division petty officer feels that his sending and receiving warrant a rate, the recommendation will go through the channels to the Commanding Officer, who will rate the man Radioman Third Class, subject, however, to the approval of the Bureau of Naval Personnel.

The advancement to Second Class, First Class, and Chief take place in the same manner, with the work increasing in complexity and time-in-rate being longer. By the time he becomes Chief Radioman, he has no doubt served at land bases as well as aboard ship and knows the naval communications system thoroughly. In addition he is a qualified radio repairman able to keep both transmitters and receivers in operating condition. He knows correct voice procedure for radiotelephone, and can carry on radiotelegraph communication at the rate of forty to sixty words per minute. He can send a message to naval units any place in the world, and be reasonably sure it will reach its destination, because it was started on the correct path.

Roberts (50, p.496) points out that the best way to learn radio navigation is to take a course in a Link Trainer. Since radio navigation is dependent in a large measure upon communications with the ground, this device will be briefly
presented here. The general layout of the equipment is shown in Figure 32. The trainer is especially valuable because it simulates actual flight. There is little to be left to the imagination of the student as he sits in the enclosed fuselage with the machine in operation. With this microphone and headset he is in constant communication with the instructor seated at the control desk, and who is on the "ground" to the student. Figure 33 shows the instructor's desk opened revealing the control panel in the center drawer, by which he produces the conditions of actual flight. The power unit may be seen in the lower left drawer and the electronic controller on the right.

**Educational Films in Electrical Communications.**

Following is a list of films which are available at the indicated sources. These films are interpretive in nature, designed to tell the story of communications, rather than to give technical details of the various electrical devices involved:

<table>
<thead>
<tr>
<th>Name of film</th>
<th>For information, contact:</th>
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<tbody>
<tr>
<td>1. Communication Signalling</td>
<td>Encyclopedia Britannica Films</td>
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<tr>
<td></td>
<td>N. Wacker Dr.</td>
</tr>
<tr>
<td></td>
<td>Chicago 6, Ill.</td>
</tr>
<tr>
<td>2. Studies about Communications</td>
<td>Robert M. Purinton</td>
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<tr>
<td></td>
<td>4404 42nd St.</td>
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<tr>
<td></td>
<td>San Diego, Calif.</td>
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<tr>
<td>3. Laying the Atlantic Cable</td>
<td>Knowledge Builders</td>
</tr>
<tr>
<td></td>
<td>625 Madison Ave.</td>
</tr>
<tr>
<td></td>
<td>New York 22, N.Y.</td>
</tr>
<tr>
<td>4. Remote Control</td>
<td>General Motors Corp.</td>
</tr>
<tr>
<td></td>
<td>Broadway at 57th St.</td>
</tr>
<tr>
<td></td>
<td>New York 19, N.Y.</td>
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</table>
Figure 32.

Link Trainer lay-out. A-fuselage; B-revolving octagon; C-base; D-turning motor; E-Instructor's desk; F-automatic recorder; G-remote instrument box; H-microphone and headset.

(Courtesy Link Aviation Devices, Inc.)
Figure 23

Instructor's desk of the Link Trainer.

The power unit is shown on the left, control panel in the center, and electronic apparatus on the right.

(Courtesy Link Aviation Devices, Inc.)
<table>
<thead>
<tr>
<th>No.</th>
<th>Title</th>
<th>Address</th>
</tr>
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<tbody>
<tr>
<td>5.</td>
<td>Airwaves - Radio Broadcasting</td>
<td>Bell &amp; Howell Co., 20 Rockefeller Plaza</td>
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<tr>
<td></td>
<td></td>
<td>New York 20, N.Y.</td>
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<td>6.</td>
<td>Attack Signal</td>
<td>King Cole's Sound Service</td>
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<tr>
<td></td>
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<td>540 3rd Ave.</td>
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<td>New York 10, N.Y.</td>
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<td>7.</td>
<td>Modern Alladin's Lamp</td>
<td>Western Electric Co.</td>
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<td>195 Broadway</td>
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<td></td>
<td>New York, N.Y.</td>
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<td></td>
<td></td>
<td>Des Moines 10, Iowa</td>
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<td>9.</td>
<td>Radio at War</td>
<td>William J. Ganz Co.</td>
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<tr>
<td></td>
<td></td>
<td>40 E, 49th St.</td>
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<td></td>
<td></td>
<td>New York, N.Y.</td>
</tr>
<tr>
<td>10.</td>
<td>Radio Operator</td>
<td>Office of War Information</td>
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<td></td>
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<td>Bureau of Motion Pictures</td>
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<tr>
<td></td>
<td></td>
<td>Washington 25, D.C.</td>
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<tr>
<td>11.</td>
<td>Sending Radio Messages</td>
<td>Encyclopedia Britannica Films</td>
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<tr>
<td></td>
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<td>N. Wacker Dr.</td>
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<td>13.</td>
<td>Case of the Missing Telephone</td>
<td>Southern Bell Tel. &amp; Tel.</td>
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<td>18.</td>
<td>Air Transportation</td>
<td>Carl F. Mahnke Prod.</td>
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<td>Communications and Our Town</td>
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<td>Radio Operator Training</td>
<td>Castle Films (see No. 19 above)</td>
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<td>Clear Track Ahead</td>
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<td>23.</td>
<td>How to use the Telephone</td>
<td>Teaching Films Inc. (see No. 20 above)</td>
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<td>24.</td>
<td>Railroad Signalling</td>
<td>New York Central System Motion Picture Bureau</td>
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<td>New York 17, N. Y.</td>
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<td>25.</td>
<td>Telephone &amp; Telegraph</td>
<td>Carl F. Mahnke Prod. (see No. 8 above)</td>
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<td>26.</td>
<td>Dial comes to Town</td>
<td>American Tel. &amp; Tel. (see local Bell office)</td>
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<td>29.</td>
<td>The Big Day (Telephone)</td>
<td>American Tel. &amp; Tel. (see local Bell office)</td>
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These films were selected from a number listed in The Educational Film Guide, published by the H. W. Wilson Co., New York. They are for the most part, dramatizations of the utilization of various types of electrical communications, and are believed to be of value in helping to interpret the Communications Industry.
Summary. The information presented in this chapter should serve to give some conception of the type of training and education that is being carried on in the field of electrical communications. It is to be noted that with few exceptions, the instruction is of a highly technical nature. Many companies within the communications industry provide apprenticeship training to cover various narrow phases of work, while some schools at the secondary level are utilizing the built-in public address system in providing certain phases of communications education.

A number of films are available, which may be helpful in teaching the cultural side of communications, rather than the technical side.
Chapter VII

CONCLUSIONS, APPLICATIONS, AND SUGGESTIONS FOR FURTHER STUDY

The purpose of this chapter is to state certain conclusions and observations that may be drawn after several months of work in compiling the information presented in the preceding chapters. Also it is proposed here to set down ways in which the study may be applied, and to make a number of suggestions for further investigations.

Conclusions. Electrical communications today make up a vast and important industry. The telephone, telegraph, radio, and their related devices provide the "nerves" which control business and industry, and bring news and entertainment into the home of the common man. Most people however, use these instruments at work and in their homes with neither understanding nor appreciation. It is believed that a carefully planned communications unit in the Industrial Arts curriculum will contribute much toward an appreciation of the broad function of electrical communications as well as toward general education for life in an increasingly technical world. The following observations drawn from this study should give some indication of the possibilities for the Communications division of the New Curriculum for Industrial Arts:

1. Back of the electrical communication marvels of today is a long history, rich in human endeavor and initiative.

2. Successful communication by electricity is a new development, being only one hundred years old.
3. Modern electrical communications equipment is extremely technical in nature.

4. Basic devices are the electromagnet and the vacuum electronic tube.

5. The field of amateur radio provides interesting possibilities for a hobby.

6. In its short history the Industry has grown to vast proportions, with world-wide facilities.

7. There is liaison between telephone, telegraph, and radio companies, enabling an individual in his home to send a message to a friend on a ship at sea.

8. There are hundreds of different jobs in the Industry, ranging from highly trained Communication and Electrical Engineers to day laborers.

9. Air and water navigation have been revolutionized through the use of radar and radio navigation devices.

10. Black and white television broadcasting will soon cover the United States, with color television following in five to ten years.

11. Most of the communications courses in colleges and universities are designed to meet the needs of the prospective Communications Engineer.

12. Very little is being done toward any phase of electrical communications in secondary schools.

13. Many companies provide motion pictures which tell the story of their use of electrical communications.

14. It is possible to get excellent training in both operation and maintenance of electrical communications equipment in the United States Armed Forces.
15. Many of the early experiments and devices may be reproduced in the Industrial Arts laboratory, not only to teach appreciation of the work already done, but also to provide a better understanding of equipment and procedures used today.

16. There seems to be no justification for limiting communications activities in the Industrial Arts laboratory to radio alone.

17. There are many facts about the communications industry that are not commonly known.

18. The Press uses all phases of electrical communications in bringing news to the people of the world.

19. Electrical communications are invaluable in law enforcement, thus contributing to the greater safety and freedom of society.

20. Devices used in electrical communications were developed rapidly during the World War II.

Applications. It is believed that the above conclusions together with the more detailed information found in the study may be applied to the following purposes:

1. Before building a communications unit in the Industrial Arts curriculum, it should be apparent that a knowledge of what is contained in the subject is needed. It is therefore believed that this thesis will provide a certain portion of the content for that phase of the communications program involving the telephone, telegraph, and radio.

2. Teachers of Industrial Arts, General Science, and Physics should be able to use much of the information pre-
sented, in building their respective courses of study. It seems that the following would be especially helpful:

a. The history of electricity, and development of electrical communications, integrated from the standpoint of communications.

b. Rapid growth and present extent of the Industry as shown by statistics.

c. Ways in which business establishments, institutions, and special agencies utilize electrical communications.

d. Information as to type of instruction to be found in many colleges and universities as well as secondary schools, and the Armed Forces.

e. Films that are available for visual teaching aids.

f. Types of projects which may be constructed in the communications laboratory of the secondary school.

**Suggestions for Further Study.** It is believed that the above material can be used to build a rich offering in the study of electrical communications. However, it is also realized that there is much left to be done. Therefore, as a conclusion to this study, the following are offered as possible subjects for further investigation:

1. A curriculum study for the entire field of communications.

2. A survey of a number of representative colleges and universities to find out the nature of instruction being offered in communications to the non-technical student.
3. Further content studies of a more technical nature on the telephone, telegraph, or radio.
5. A study of teaching aids in electrical communications.
6. Development of the physical lay-out for the communications area in the Industrial Arts laboratory.
7. A biographical study of some of the pioneers in electrical communications.
8. The development of a communications workbook and teachers' manual for high school seniors.
9. A suggested program for integrating the Speech, Science, and Industrial Arts departments in providing a rich program in communications.
10. A study of Naval Communications with suggested adaptations to the Industrial Arts curriculum.
APPENDIX A

POSSIBLE PROJECTS

1. Portable radio by Popular Science.
5. Phone and CW radio transmitter by Samuel L. Marshall and Peter Greenleaf.
PORTABLE RADIO

The advanced student in radio will enjoy building this fine portable radio. Two 1S4 pentodes are wired in parallel in the output stage and matched to a light permanent-magnet speaker. The tubes feed into a universal output transformer that has several taps on the voice-coil (secondary) winding. A transformer with an input capable of matching load impedances up to 4000 ohms is desirable since that is the theoretical resistance of two 1S4's in parallel. In the original receiver the 2000 ohm tap was used because it produced the most pleasing tone. The transformer matches this tube impedance to the voice-coil impedance of the speaker which, in this case is 4 to 6 ohms. The speaker itself is one of the lightest 5-inch units that can now be purchased; its alnico magnet is about as large as a thimble. Weight, of course, is correspondingly small. The chassis consists of a $3 \frac{1}{2}$ inch by 11-inch strip of brass approximately one sixteenth inch thick. This piece has no sides but a 2-inch flange is formed in front to support the dial assembly. By keeping chassis dimensions to a minimum and eliminating the sides, weight is reduced, and wiring is made easier. Before cutting the chassis, measure the inside dimensions of the carrying case you intend to use.

Eight tuned circuits are used. Tuning is accomplished by means of a midget two-gang tuning condenser.
The plates of the oscillator tracking section are considerably smaller than those of the antenna section. This is because the oscillator automatically tunes to a beat frequency of 456 kcs higher than the antenna. As usual, all the IF transformers are adjusted to this fixed 456 kcs intermediate frequency. Incoming signals go directly to the 1R5 which acts both as first detector and local oscillator.

A pair of 1T4's is utilized for IF amplifiers. Ground return leads of both the inter-stage and output IF transformers (L4 and L5) are wired into the automatic volume control circuit. Manual control of volume is obtained through a 1-meg. variable resistor (R11) in series with the control grid of the 1S5. Detection, or more correctly rectification, is performed by the diode plate within the envelope of the 1S5. The pentode section of the tube acts as the first audio amplifier and is coupled to the detector through R11 and C12. Resistance and condenser coupling is also employed between the first and second audio stages. The latter consists of the pair of 1S4 power pentodes which, in combination, boost the audio signal to the high output level that makes the set so satisfactory.

The case should measure about 4 3/4 inches by 8 3/4 inches by 11 3/4 inches outside; a smaller one is not advisable. Before cutting the case, make cardboard templates of the chassis, speaker, and batteries, and decide on the best position for each of them. Mark the
positions of the volume control and tuning shafts and the openings for the speaker and dial on the outside of the case. Score the leather with a sharp knife, drill the shaft holes, and cut or saw the circular speaker and dial apertures. The edges of the cuts can be concealed by a escutcheon plate.

Most overnight bags are fitted with mirrors, and if yours has one it should be removed and the loop antenna slipped under the cover lining. Instead of being mounted rigidly inside the case, the chassis is sprung to absorb jolts and shocks. Two soldering lugs are screwed to the top of the case and another two lugs are bolted to the edge of the chassis. Between the anchor points thus formed, small tension springs are installed to support the rear edge. The front is held only by the shafts, which project through the face of the bag and are gripped by the knobs on the outside.

In order to keep battery drain to a minimum, no pilot light was used in this circuit. This makes it all the more important that you remember to turn off the switch when the set is not in use. If you can't trust your memory, insert a 1.5 volt .06 amp pilot light behind the dial and wire it in parallel with the tube filaments.

A list of part appears on the following page, and pages 162 and 163 show pictures and wiring diagram.
List of parts:

(All resistors 1/2 watt carbon unless otherwise noted)

R1: 100,000 ohms
R2: 2 meg.
R3: 10,000 ohms
R4: 2,000 ohms
R5: 5,000 ohms
R6: 5 meg.
R7: 15,000 ohms
R8: 1,000 ohms
R9: 5 meg.
R10: 3 meg.
R11: 1 meg. with switch pot.
R12: 10 meg.
R13: 1 meg.
R14: 1 meg.
R15: 180 ohms, 1 watt
C1: Two-gang condenser
C2, C11: .1 mfd., 450 volt paper tubular cond.
C3, C13: .0001 mfd. mica.
C4, C5, C6, C7, C8, C9, C10, C12, C15: .05 mfd.,
450 volt paper tubular condensers
C14: .0002 mfd. mica
C16: .005 mfd., 450 volt paper tubular cond.
L1: Loop antenna
L2: Iron-core oscillator coil
L3, L4, L5: input, interstage, and output trans.
T1: Midget universal output trans.
S1: D.P.S.T. switch on R11
Speaker, tubes, case, tube sockets, shields, batteries, hardware.
A piece of flat brass, cut to fit snugly across the upper part of the case, is used as a chassis. The lower portion of the cabinet is given over to the speaker and batteries. One 1.5 volt A and two 45-volt B batteries supply the set with power. The loop antenna slips under the lid of the case.

Here's part of the spring-suspension system that helps protect this set from the jolts and bumps that shorten the life of most portables. Anchored between soldering lugs on the chassis and case, two tension springs provide a "floating" or shock-absorbing support for one edge of the chassis.
BED RADIO

The bed radio shown on pages 166 and 167 makes an interesting project for the radio student. It uses two tubes. The 12B8GT contains an RF pentode and high-mu triode, which are used for the RF and detector stages respectively. The 25A7GT contains the pentode output amplifier and the half-wave rectifier.

Instead of these tube types, the reader may use the newer low-drain models, the 25B8GT and the 70L7GT. If these tubes are used, the line cord resistor will have to be changed to one having a built-in resistance of 135 ohms instead of 220 ohms. Also the connections to the 70L7GT tube differ slightly. Connections to the 25B8GT are similar to those of the 12B8GT. No other changes are necessary in the circuit.

The antenna coil is shielded and is mounted right next to the 12B8GT tube. The RF coil, though shielded, is mounted in an unconventional way--upside down. However, it is still thoroughly shielded and in this new position makes wiring of the set easier. The small screw on top of the can, which holds the coil in place, is unscrewed and passed through a hole in the chassis to anchor the shielding can and coil securely in place.

Volume is controlled in the conventional manner, by varying the grid bias on the RF tube, using a 50,000 ohm potentiometer between the antenna and cathode of the RF pentode. A 300 ohm, 1/2 watt fixed resistor in series...
with the potentiometer keeps the tube always slightly biased. Ganged with the 50,000 ohm volume control is the S.P.S.T. on-and-off switch. To provide greater stability in the RF stage, the screen of the pentode (12B8GT) is decoupled by means of the 5000 ohm, 1/2 watt resistor and the .05 mfd. tubular by-pass condenser.

The cabinet is constructed of pine, with the sides 3/8 inch thick and the front about 5/16 inch. A round hole of 3 5/8 inch diameter is cut in front for the speaker and decorated with a round escutcheon from a tuning dial. The escutcheon may be purchased separately at any large radio store. Aluminum 1/16 inch thick is used for the back. To it, two brass strips 3/4 inch wide, previously bent in a vise, are attached, each with two 6/32 machine screws and hex nuts. The angles shown will do for most beds. A large ventilating hole should be placed on the bottom of the cabinet.

A list of parts appears on page 167.
The pictorial diagram above makes it easy to follow the wiring connections.

View below shows the cabinet and speaker, with chassis ready to be installed. Right angle view of the finished set and brackets.
**LIST OF PARTS**

- Two-gang tuning condenser, 90036 mfd.
- Antenna coil, unshielded.
- RF coil, shielded.
- Filter choke, 10 henry.
- Line cord, 220 ohm (see text).
- 2B6GT tube (see text).
- 2A7GT tube (see text).
- Permanent magnet speaker, 4".
- Output transformer.
- Potentiometer, carbon, 50,000 ohm.
- S.P. S.T. switch.
- Octal wafer sockets (two).
- Carbon resistor, 150 ohm, 1 watt.
- Carbon resistor, 500 ohm, 50 watts.
- Carbon resistor, 1,000 ohm, 1/2 watt.
- Carbon resistor, 150,000 ohm, 5 watts.
- Carbon resistor, 500,000 ohm, 6 watts.
- Carbon resistor, 2 mfd., 25 volt.
- Electrolytic condenser, tubular, 10 mfd., 25 volt.
- Electrolytic condenser, tubular, 16 mfd., 150 volt.
- Electrolytic condenser, tubular, 3 mfd., 1250 volt.
- Tubular condenser, 1 mfd., 100 volt.
- Tubular condenser, .05 mfd., 500 volt.
- Tubular condenser, .02 mfd., 40 volt.
- Tubular condenser, .01 mfd., 10 volt.
- Film condenser, .0015 mfd.
- Film condenser, .0002 mfd.
SINGLE BUTTON LAPEL MICROPHONE

The case from an old dollar watch makes an ideal shell for this lapel "mike". Replace the crystal with the solid back from a similar watch.

Turn out two concentric wood rings which will fit snugly one inside the other, and just go into the watch case. Fasten the inner ring to the case with short screws.

Cut out the carbon cup from an old dry cell electrode and glue felt to the rim, to act as a buffer for the diaphragm. Bolt the cup to the case.

Cut a ribbon 1/4 inch wide, of length equal to the diameter of the outer ring, from thin copper foil. Fasten a small piece of detecting crystal to the middle of the strip with fine thread-like copper wire.

Cut a disc the diameter of the larger wood ring from a sheet of unwrinkled cellophane, and make two short cross slits in the center. Push the crystal through the hole. Fill the carbon cup 3/4 full of silver or bronze filings. Metal filings tend to eliminate the annoying "hiss" of carbon granules.

Place the cellophane diaphragm, with crystal in the filings cup, over the inner ring. Press the outer ring down carefully until the cellophane is well stretched.

Fasten one lead to the ribbon with a washer and screw, the other to the case. Drill about five half-inch holes in the front cover to allow sound to reach the diaphragm, and the "mike" is complete.

See page 169 for illustration.
Tiny lapel "mike" works well on low power phone transmitter or public address system. Connect to a 3-volt battery in series with single button "mike" transformer.
TELEPHONE SET

These telephones work on the same principle as the standard instrument, with receiver, transmitter, signal bell, push button, receiver hook or switch lever and induction coil. Without the last, a fairly satisfactory instrument can be made, but as the coil makes the transmission of voice so much more clear it is well worth while to include it. Over-all dimensions of this phone are given on the illustration at the bottom of page. Study the illustration just above this before starting construction. Then begin with the box.

Use 3/4 inch material for the back and on this build the cabinet of 1/4 inch plywood. The location of various parts on the inside depends upon the equipment selected. It is well to install the bell first, then locate the wood block "A" just under it and about 1 1/4 inches from the left side. Next, make the receiver hook "B" from a strip of fairly heavy sheet brass. From the same material, cut three contact strips, "C", "D", and "E", and locate them so that when the hook is up it will contact "C" and "D", and when the receiver is on the hook the latter will contact "E". A light coil tension spring "F" keeps the hook up against "C" and "D" when the receiver is in use. Bend a spring latch "G" from another strip of brass and install as shown. The cover of the box is made of 3/8 inch plywood and carries the transmitter and push button. The push button however, may be located at any convenient place on the cabinet.
The transmitter is made up of a transmitter button and a diaphragm. The buttons can be purchased from radio or electrical supply houses. A cross section of the transmitter assembly is shown in detail in Fig. 4, page.

Note that there is a hub on the button which is set in a hole drilled in the cabinet door. This should be a snug fit so that the button is held rigidly. A spring brass fork is bolted to the plywood door in such a manner that it exerts a slight outward pressure on the small knob, thus holding it against the diaphragm. Some transmitter buttons are equipped with a nut in place of the rounded knob. In that case, drill a hole in the center of the diaphragm, instead, insert the screw and put the nut back again. Such assembly requires an electrical connection on the edge of the diaphragm, but in the original, the spring fork completes the electrical circuit. If a standard diaphragm such as used in a telephone transmitter is not available, you can cut one from a photographer's thin ferrotype plate. Care should be taken not to dent it, for efficiency is impaired if it is not perfectly flat. It should be 2 1/2 inches in diameter. Lacquer should be scraped away at the connections if the diaphragm is used to complete the electrical circuit instead of a spring fork. The diaphragm is held between a wooden ring "M" and a cover disk "N". Note that the thickness of "M" should be slightly less than the height of the knob, so that they will always be in contact. In Fig. 4 shows the
method of turning the cover disk "N" on a lathe faceplate. White pine is recommended because this soft wood is close-grained and not likely to split. By drilling a small pilot hole in the wood when first put on the lathe it is possible to center the job properly when it is turned over for turning the other side. The hole in the cover disk "N" should correspond to the small end of the mouthpiece used.

If the induction coil is used, a three-point switch will be required. In the original job, a neat push button was installed just below the transmitter on the door of the box, and the contacts arranged as shown, but it may be found easier to build up a button switch on the side of the box. The importance of an induction coil has been noted, and if you are able to purchase a pair from an electrical supply house, by all means do so as it is a considerable job to wind one neatly. The primary coils are not so hard, but the fine wire of the secondary is like trying to wind a spool of thread. If you are obliged to do the job, however, insert the ends of a bundle of stovepipe wire, 1/4 inch by 3 1/2 inches in blocks of wood 1 inch square as in Fig. 3, page 174. Wrap a sheet of paper around about four times and give it a coat of shellac. When dry start winding the primary coil, leaving one end project through a hole in the wood block. This coil should be two layers of No. 20 copper wire, with a sheet of paper around each layer, and shellacked.
The secondary is No. 34 silk-covered wire and is wound just like the primary except that it has twelve layers. Ends of the wires should be drawn through holes in the blocks, as shown. Cover the finished coil with two or three wrappings of paper and shellac to protect the wires.

Wiring plans are shown in detail in Figs. 5 and 6 on page 176.
"Sure Sounds Like Bill"
Play Telephone for the Junior Electrician
In turning wood disk "N" for transmitter, fasten pine disk to faceplate with screws near edges. Drill pilot hole in center and turn shaded portions as in X. Then reverse on faceplate and complete job "Y."

If induction-coil system is used, a three-point switch will be required.
Object:

To construct a phone and CW transmitter using an R.F. section consisting of a 6L6G crystal controlled oscillator and a 6L6G R.F. amplifier; a modulator section consisting of a 6C8G twin triode resistance coupled amplifier and 2 6L6G tubes wired in push pull; and a power supply containing a 5Z3 rectifier tube.

The Heising system of high level plate modulation is used. "High-level" modulation is modulation that takes place in the plate circuit of the final amplifier. Modulation in any other previous stage is referred to as "low-level" modulation.

Theory:

The circuit of Fig. 1 is that of transmitter designed for C.W. and phone on the 10, 20, 40, 80, and 160 meter bands. Its output on C.W. is approximately 15 watts. This is obtained by means of a crystal oscillator feeding into an R.F. amplifier, both stages using 6L6G tubes.

Bias on the oscillator tube is obtained by means of R1. RFC1 is an R.F. choke designed to prevent R.F. currents from flowing in the grid bias circuit. Pl is a pilot lamp inserted in series with the crystal to indicate crystal current.

K2 is a key jack with two switches mounted on it so that when the key is inserted in the jack, Sl opens,
C.W. AND PHONE TRANSMITTER
permitting cathode current to flow through the key, and S2 closes, short-circuiting the secondary of the modulation transformer, so that no audio currents affect the CW output.

The crystal tank circuit consists of C4, 100 mmfd. variable condenser, and L1. RFC3 prevents any of the R.F. from entering the "B" supply. The screen grid voltage is series fed through the capacity-resistor filter C2, R2, and C6.

The R.F. from the crystal tank circuit is coupled to the 6L6G R.F. amplifier through C3. "C" bias to this tube is obtained by means of R4, RFC4 preventing any R.F. from entering this circuit.

The tank circuit of this tube, C10 and L2 is in series with a milliammeter "A", which indicates resonance when an adjustment of C10 results in a minimum reading in this meter. The screen grid voltage is series fed through the filter C8, R5, and C9. It will be observed that the "B" voltage is obtained through the secondary of the modulation transformer, L4, when the transmitter is phone operated.

The R.F. energy from the tank circuit is transferred to the antenna terminals by means of the coupling transformer L2. Condensers C11 and C12 tune the antenna into resonance with L2 thereby effecting a maximum energy transfer.

The middle section of this transmitter is the audio amplifier or modulator which is coupled to the final
CRYSTAL OSCILLATORS

The crystal-controlled oscillator is one of the simplest, most stable, and most efficient. To understand clearly the operation of this circuit it is essential that the crystal be considered an equivalent inductance, capacitance and resistance, $L_1$, $C_1$, and $R_1$, all connected in series as shown in fig. 2. $C_8$ represents the capacity of the electrodes across the crystal faces with the crystal itself as the dielectric. $C_9$ represents the series capacity effect of these electrodes and is to be taken into consideration when they are not in intimate contact with the crystal face. Variable air-gap crystal holders result in $C_9$ being a factor to be considered.

It becomes obvious, therefore, that the crystal is an equivalent series resonant circuit containing a series and a parallel capacitor all of which affect the resonant frequency at which the crystal will oscillate.

Inserting a crystal in the circuit shown in fig. 3 results in a generation of R.F. the frequency of which will be determined by the crystal itself. The tank circuit $C_8$ and $L_9$ will develop a maximum R.F. voltage across its terminals when it is tuned to the crystal frequency. Feedback takes place due to the grid to plate capacitance of the tube.
R.F. stage through the modulation transformer L4. This method of coupling is called the Keising system of modulation, and is most universally used in transmitter design.

The microphone is inserted in the jack K1 which contains a switch S3, short-circuiting R6 when the microphone is not in use. The two triodes are contained in a single tube, a 6C8G. Resistance coupled amplification is used up to the final stage. Here push-pull transformer amplification is used. This method of audio amplification is explained on page 182. The output audio signal is finally transferred to the modulation transformer L4 which is in series with the R.F. tank circuit. The power supply is a conventional condenser-input circuit type.

If wired carefully, this transmitter will render excellent results.

Procedure:

1. Lay out, mount and wire all component parts on an 8 inch by 16 inch chassis and an 8 inch by 18 inch panel, using the layouts suggested on page 183.

2. Connect a dummy antenna across terminals T1 and T2.

3. Make a resistance analysis.

4. Turn on the power switch S3 and the line switch S4.

5. Insert the key and fasten down the key knob.

6. Neutralize the 6L6G R.F. amplifier, using con-
A push-pull amplifier is designed to eliminate the distortion due to the operation of a tube at points beyond the straight line limits of its characteristic curve. This operation may occur because of a large signal input or other conditions.

A distorted wave, such as the one shown in fig. 2a, results. This wave can be broken up into two components: the original fundamental corresponding to the undistorted signal input, and a second wave twice the frequency of the fundamental, called the "second harmonic".

By means of a push-pull amplifier, such as the one shown in fig. 1, we eliminate the second harmonic. The analysis is as follows: First it will be observed that the signal input at the grid of tube A is opposite in polarity to the signal input at tube B. This will make the plates of tube A positive and tube B negative. The signals in the split transformer sections in the plate circuit will then be in series and as a result add to each other, so that the magnetic field linking the secondary is a result of the cumulative effect of both voltages.

The 2nd harmonics which are developed in the tubes get started at the same instant so that waves rise and fall at the same time. The result is that the voltages they produce in the split primary of the output transformer are opposite in direction to each other so that the net effect is a cancellation of the 2nd harmonic component. This is shown clearly in fig. 1.
FIG. 2
SUGGESTED CHASSIS LAYOUT

FIG. 2
SUGGESTED PANEL LAYOUT
denser C7 for this purpose. See Figs. 1 and 2
page 186.

7. Tune condensers C4 and C10 to resonance which will
correspond to the lowest reading in the milli-
ameter "A".

8. Make an analysis as outlined on page 188.

9. Remove the key and connect a microphone in jack K2.

10. Adjust R10 so that at the greatest audio input sig-
nal at the microphone, the transmitter is modulat-
ed slightly less than 100%. There are many methods
of checking this condition, one of which is to in-
sert a thermo-ammeter in series with the dummy an-
tenna. For 100% modulation the increase in antenna
current will be 22 1/2 percent. If a thermo-am-
meter is not available the signal can be checked
with a receiver in the immediate vicinity. If all
circuits are functioning properly, that is, if the
signal comes in clearly with the volume control
adjusted for low audio output, overmodulation will
result in distortion.

Neutralization:

Due to the grid to plate capacitance of a tube,
oscillations are produced which tend to unbalance the nor-
mal circuit operation. In a triode this effect is consid-
erable, whereas in a screen grid tube it is almost en-
tirely eliminated. However, inasmuch as every trace of
this sort of feedback must be eliminated in a transmitter,
it is necessary, even with a screen grid tube, to resort
to a method called "neutralization". By this procedure
we neutralize the voltage from the plate circuit, that is
fed back into the grid circuit by means of the grid to
place capacity.

The object is to introduce a voltage in the plate
circuit exactly opposite in direction to the voltage due
to feedback. This is done by connecting a condenser C7
(Fig. 1, page 186) between the grid and the plate re-
turn of the tube. What takes place will be understood
as we perform the neutralization process step by step:
(1) Remove the "B" voltage from the final R.F. stage only.
(2) A signal from the crystal oscillator will now appear
across C10 and L2 if they are tuned into resonance with
this frequency. This R.F. signal $E_s$ is due to the coupl-
ing that exists between the grid and plate because of cgp.
It direction is indicated by the arrow as shown in Fig. 1.
At the same time it will be observed that a portion of
this R.F. signal passes through the neutralizing condenser C7.

This voltage $E_n$ will depend on the value of the cap-
acity C7. Since the direction of this voltage is opposite
to $E_s$ in L2, a cancellation will take place if $E_n$ equals
$E_s$. The setting of C7 which will make $E_n$ equal $E_s$ is the
correct point of neutralization.

If a milliammeter is inserted in series with the grid
circuit as in Fig. 1, and the tank circuit condenser C10
is rotated through resonance, a change in grid current as
observed by the grid current meter A2 will result. The
Fig. 1

Principles of Neutralization

Fig. 2

Cross Neutralization
nearer we approach neutralization, the smaller this current change will be. Therefore, the procedure is to adjust C7, then rotate C10, observing the amount of change in A2. Further adjustments on C7 are made until rotation of C10 through resonance results in no further deflection in the grid circuit ammeter. The circuit is then neutralized.

Other neutralizing indicators are neon tubes, fluorescent lamps and pilot bulbs connected in series with a few turns of wire. Bringing these devices close to the tank circuit will cause them to glow if R.F. is present in this circuit. The procedure, using these devices is to adjust the neutralizing condenser until the glow disappears.

Many transmitter circuits use push-pull R.F. stages. The method of neutralization for this type of circuit is identical with the procedure outlined for a single stage, except that in this case one tube at a time is neutralized. The name given to this method is "cross-neutralization".

It is important that the tank circuit in the crystal stage be adjusted to resonance when neutralizing the final stage of this transmitter, otherwise there will not be enough excitation to effect an indication in either the grid circuit milliammeter method, also referred to as the grid-dip method, or in the plate circuit methods of R.F. indication.
Transmitter analysis:

Measure the tube terminal voltage, current and resistance values for conditions of resonance and off-resonance, and tabulate these results in the following form:

<table>
<thead>
<tr>
<th></th>
<th>Plate</th>
<th>Screen</th>
<th>Control</th>
<th>Filament</th>
<th>Dummy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Off resonant voltage</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Off resonant current</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Resonant voltage</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Resonant current</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Resistance to ground</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Power</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1. Measure the resistance of all tube contacts to ground with the line switch in the "off" position.

2. Turn on the line switch, allowing the tubes to heat up for about 5 minutes, and measure the required voltages and currents.

3. Measure the antenna power by both the direct and indirect methods. The direct method of measurement is to insert a thermo-ammeter in the antenna circuit. The power is then equal to the current squared times the resistance. The indirect method of measurement is to take the product of the plate current, the plate voltage, and the plate efficiency of the final amplifier. For the value of plate efficiency in this case use 80%. 

### Materials and equipment required:

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Item</th>
</tr>
</thead>
<tbody>
<tr>
<td>CR</td>
<td>10, 20, 40, 80, 160 meter crystals</td>
</tr>
<tr>
<td>K1, S1, S2</td>
<td>Closed circuit filament jack</td>
</tr>
<tr>
<td>K2, S3</td>
<td>Closed circuit jack</td>
</tr>
<tr>
<td>R.F.C. 1, 2, 3, 4</td>
<td>215 mh. 150 ma. R.F. chokes</td>
</tr>
<tr>
<td>A</td>
<td>0-200 ma. meter D.C.</td>
</tr>
<tr>
<td>P1</td>
<td>60 ma. pilot light</td>
</tr>
<tr>
<td>S4, S5</td>
<td>S.P.S.T. toggle switches</td>
</tr>
<tr>
<td>R1</td>
<td>50,000 ohm carbon 1 watt resistor</td>
</tr>
<tr>
<td>R2, R4</td>
<td>10,000 ohm carbon 2 watt resistors</td>
</tr>
<tr>
<td>R3, R5</td>
<td>10,000 ohm 10 watt resistors</td>
</tr>
<tr>
<td>R6</td>
<td>5 meg. 1/2 watt resistor</td>
</tr>
<tr>
<td>R7, R11</td>
<td>1500 ohm carbon 1 watt resistors</td>
</tr>
<tr>
<td>R8</td>
<td>50,000 ohm carbon 2 watt resistor</td>
</tr>
<tr>
<td>R9, R12</td>
<td>5,000 ohm 5 watt resistors</td>
</tr>
<tr>
<td>R10</td>
<td>1/2 meg. volume control</td>
</tr>
<tr>
<td>R13</td>
<td>200 ohm 10 watt resistor</td>
</tr>
<tr>
<td>R14</td>
<td>25,000 ohm 10 watt resistor</td>
</tr>
<tr>
<td>C1</td>
<td>.0001 mfd. 1000 volt mica condenser</td>
</tr>
<tr>
<td>C2, C3, C6, C8, C16</td>
<td>.01 mfd. 600 volt paper condensers</td>
</tr>
<tr>
<td>C4, C10</td>
<td>100 mfd. 600 volt variable condensers</td>
</tr>
<tr>
<td>C5</td>
<td>.00005 mfd. 1000 volt mica condenser</td>
</tr>
<tr>
<td>C7</td>
<td>Neutralizing condenser</td>
</tr>
<tr>
<td>C11, C12</td>
<td>50 mfd. variable condensers</td>
</tr>
<tr>
<td>C14, C17</td>
<td>10 mfd. 25 volt elect. condensers</td>
</tr>
<tr>
<td>C15, C18</td>
<td>.1 mfd. 400 volt paper condensers</td>
</tr>
<tr>
<td>C19, C20</td>
<td>16 mfd. 450 volt elect. condensers</td>
</tr>
<tr>
<td>L1, L2</td>
<td>Matched set of 10, 20, 40, 80, and 160 RF coils</td>
</tr>
<tr>
<td>L3</td>
<td>Push-pull input transformer</td>
</tr>
<tr>
<td>L4</td>
<td>Modulation transformer</td>
</tr>
<tr>
<td>L5</td>
<td>Power transformer, high voltage secondary 400-0-400 volts, low voltage windings 5v. 2 amps., 6.3v.-6 amps. 30 h. 250 ma. choke, low D.C. resistance</td>
</tr>
<tr>
<td>L6</td>
<td>Antenna binding posts mounted on isolantite insulators</td>
</tr>
<tr>
<td>T1, T2</td>
<td>3 Octal sockets, isolantite</td>
</tr>
<tr>
<td></td>
<td>4 Octal sockets, bakelite</td>
</tr>
<tr>
<td></td>
<td>3 GL6G tubes</td>
</tr>
<tr>
<td>1</td>
<td>523 tube</td>
</tr>
<tr>
<td>1</td>
<td>608G tube</td>
</tr>
<tr>
<td>1</td>
<td>Pilot light socket</td>
</tr>
<tr>
<td>1</td>
<td>Line cord and plug</td>
</tr>
<tr>
<td>1</td>
<td>Transmitter key</td>
</tr>
<tr>
<td>1</td>
<td>Dummy antenna</td>
</tr>
<tr>
<td>1</td>
<td>4-prong crystal socket, isolantite</td>
</tr>
<tr>
<td>1</td>
<td>Metal panel and chassis combinations approximately 8 inches by 18 inches and 8 inches by 18 inches</td>
</tr>
<tr>
<td>1</td>
<td>Microphone</td>
</tr>
<tr>
<td>2</td>
<td>Tuning dials and knobs to match Wire, solder, hardware and tools</td>
</tr>
</tbody>
</table>
APPENDIX B

CONTRIBUTORS
INDIVIDUALS AND COMPANIES
WHO MADE MATERIAL CONTRIBUTIONS

Albinger, Al, Program Director WCOL, Columbus, O. Pertinent information on radio broadcasting.

Beighley, Warren; Sweet, Robert S.; and Worthington, Roland, Control tower operators, Columbus Municipal Airport. Demonstrated use of electrical communications in handling air traffic at a large airport.

Brillhart, C. D., Superintendent of Schools, Napoleon, O. Course of study in radio as shown in Chapter VI.

Easterly, E. E. Jr., Associated Press room, Columbus Dispatch. Information on the use of electrical communications by the Press.

Farrar, Neil H. 566 Waverly St., Columbus, O. Material on amateur radio.

Gittings, T. B. Vice President of Western Union. Contributed a large amount of literature on telegraphy.

Hegele, Sgt. M. G. Ohio State Highway Patrol. Provided information and material concerning the communications system of the Ohio State Highway Patrol.

Hughel, P. S. Superintendent of Communications New York Central Railroad System. Personal letter describing certain phases of railroad communications, with a list of sources for more detailed information.

McGraw-Hill Publishing Co. (Electronics) Albany 1, N.Y. Gave permission to use the survey appearing in Chapter VI.

Radio Corporation of America. Provided many publications showing the latest developments in radio, television, and radar.

Replogle, L. K. Assistant Superintendent of Columbus Public Schools. Information on communication instruction in the Columbus school system.

Richey, J. L. Demonstrations Engineer Bell Telephone System. Contributed much information on the telephone industry, including reports on wartime research.

Shook, Paul, F. & R. Lazarus and Co., Columbus, O. Electrical communications in a large department store.

Yerian, James, Radio Station WELD, Columbus, O. Radio facsimile broadcasting and frequency modulation.
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