RCA REVIEW

A Quarterly Journal of Radio Progress

Published in July, October, January and April of Each Year by
RCA INSTITUTES TECHNICAL PRESS
A Department of RCA Institutes, Inc.
75 Varick Street, New York, N. Y.

VOLUME VI | October, 1941 | NUMBER 2

CONTENTS

SUBSCRIPTION:

United States, Canada and Postal Union: One Year $2.00, Two Years $3.00, Three Years $4.00
Other Foreign Countries: One Year $2.35, Two Years $3.70, Three Years $5.05
Single Copies: 75¢ each

Entered as second-class matter July 17, 1936, at the Post Office at New York, New York. under the Act of March 3, 1879.

Printed in U.S.A.

A SURVEY OF RESEARCH ACCOMPLISHMENTS WITH THE RCA ELECTRON MICROSCOPE

By

G. A. Morton

Research Laboratories, RCA Manufacturing Company, Inc., Camden, N. J.

Summary—*A number of RCA Electron Microscopes have been in operation for more than a year and have given excellent service. During this period active research in various fields of applications has been carried on in the RCA Laboratories at Camden. These fields include Biology, Metallurgy, and Chemistry.*

An RCA Fellowship, established under the auspices of the National Research Council, has made available the services of a trained biologist as well as the collaboration of some of the ablest scientists in the fields of biology and bacteriology. Important investigations of bacterial morphology and metabolism, viruses, antigen-antibody reactions, and chromosome structure have thus been made possible.

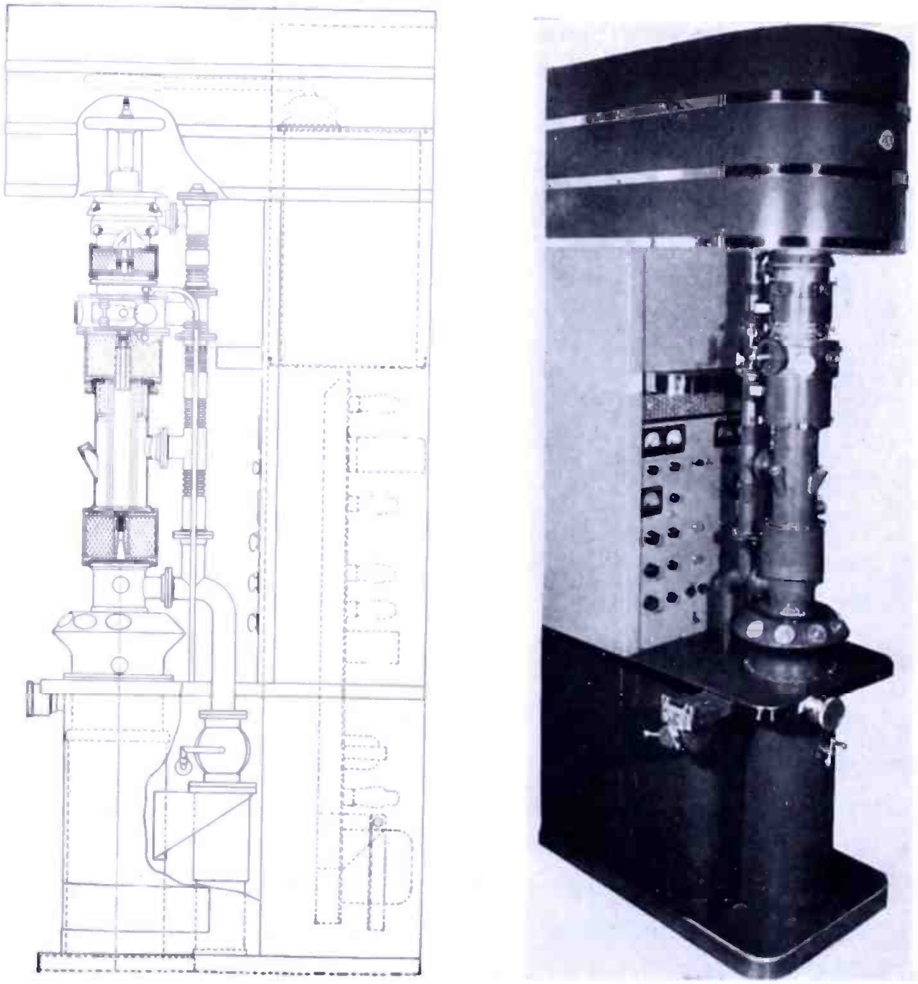
In metallurgy a new replica technique has been developed which permits the study of such bulk material as iron and its alloys, brasses, etc.

The new instrument has wide applications in the field of chemistry, and provides the answers to many industrial and scientific problems. Much work related to chemical research has been carried out, including investigations of particle size and shape, colloids, surface chemistry, thin films, and plastics.

ELECTRON optics is fundamental to the design of many of the tubes used in modern radio and television, and has long been a subject of intensive investigation in the RCA Research Laboratories. An outgrowth of this work in the field of electron optics has been an active interest, extending over the past five years, in electron microscopy. The initial work in this field consisted of a theoretical and experimental study of the electron microscope. A number of preliminary models were built, leading to the construction of an experimental microscope designed for use in scientific and industrial research.[1] This instrument was described in detail in the October, 1940 issue of this journal.

This instrument gave good results as far as resolving power was concerned, but was designed to be strictly an experimental research microscope, rather than a commercial unit suitable for use in general research laboratories. The next step in the development was to produce an instrument for ordinary laboratory use. A new microscope was designed by James Hillier[2] which, while equal or better in resolving power, was sufficiently simple and reliable in its operation to meet the requirements of a practical research tool.

The microscope is illustrated in Figure 1. Figure 1-a is a simplified diagram showing the principal features of its construction. As with the previously described microscope, the electron-optical system consists of an electron gun and three magnetic lenses. The electron gun, together with the first of these lenses (known as the condenser lens), serves to "illuminate" the specimen with electrons. The convergence of the beam of electrons falling on the subject can be controlled by varying the current through the condenser lens, since the focal length of this lens is a function of the current through the lens coil. The second lens coil serves as the objective, and forms an enlarged intermediate image of the specimen under observation. Electrons from the central portion of the intermediate image are re-imaged by the projection lens into the final, highly-magnified image which may be



(a) (b)
Fig. 1—RCA Electron Microscope.

recorded photographically or viewed on a fluorescent screen through observation ports.

The electron-optical path in the microscope must be freed of air to avoid scattering the electrons. A mechanical pump and an oil diffusion pump serve to produce and maintain the requisite vacuum. In order to facilitate changing the specimen, an airlock is provided which gives access to the specimen holder without breaking the vacuum in the main chamber of the microscope. A similar airlock is employed for changing the photographic plate. A second mechanical pump is used to exhaust the airlocks.

The specimens to be examined cannot be mounted on ordinary glass slides as these are, of course, opaque to electrons. Instead the specimen is mounted on a thin film of collodion about 10^{-6} centimeters thick which is, in turn, supported on a fine metal mesh. A more complete description of the methods of mounting specimens will be given below.

Stable electrical supplies, both for the overall voltage and for the current of the lens coils, are essential to the obtaining of high-resolution micrographs. The principles involved in these stabilized power supplies are described in an earlier issue of the RCA REVIEW by A. W.

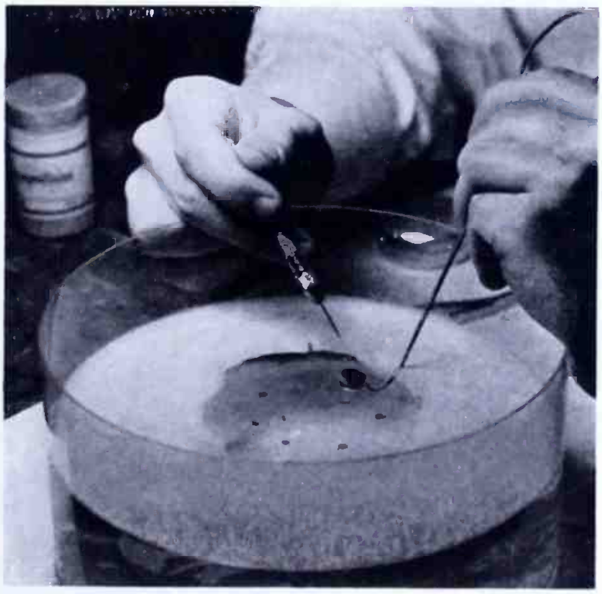


Fig. 2—Mounting collodion film on supporting screen.

Vance[3] in connection with the first microscope. The power supplies for the new instrument were redesigned, improved, and made more compact. Instead of the conventional 60-cycle high-voltage transformer and rectifier, a low loss 20-kilocycle resonant transformer is employed to generate the 60 kilovolts required for the overall voltage. In this way the power consumed is decreased, the filtering problem simplified, and the speed of stabilization greatly increased.

A photograph of the complete instrument is shown in Figure 1-b. The unit consists of the microscope and its associated power supplies which form an integral part of the equipment.

This new instrument has been in service for more than a year and has proved itself excellent under a wide variety of conditions. It is so simple in its operation that a few days experience on the part of a competent laboratory technician is all the training necessary to give him full mastery of the instrument, including alignment, replacing the filament, and changing the objective aperture, as well as the routine

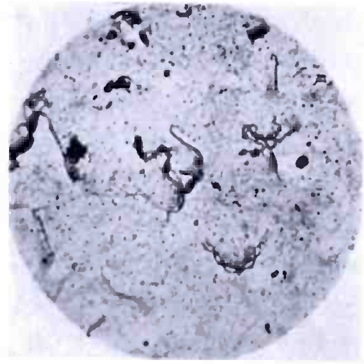
Electron Micrographs

Light Micrographs

Spirochete

Magnification 4,000 diameters

A



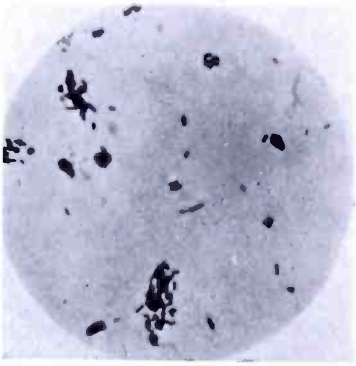
Magnification 540 diameters

B

Subtilis

Magnification 15,000 diameters

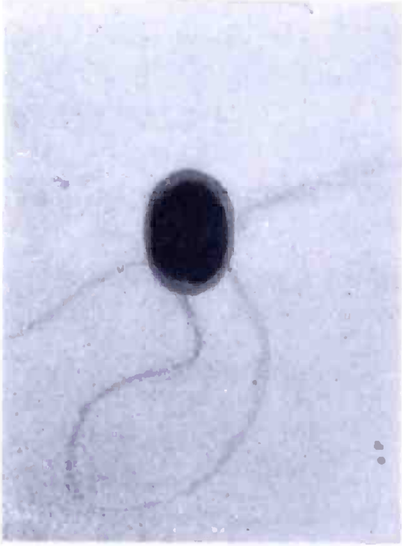
C



Magnification 540 diameters

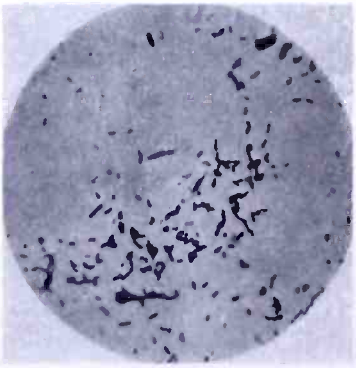
D

Typhoid



Magnification 13,000 diameters

E



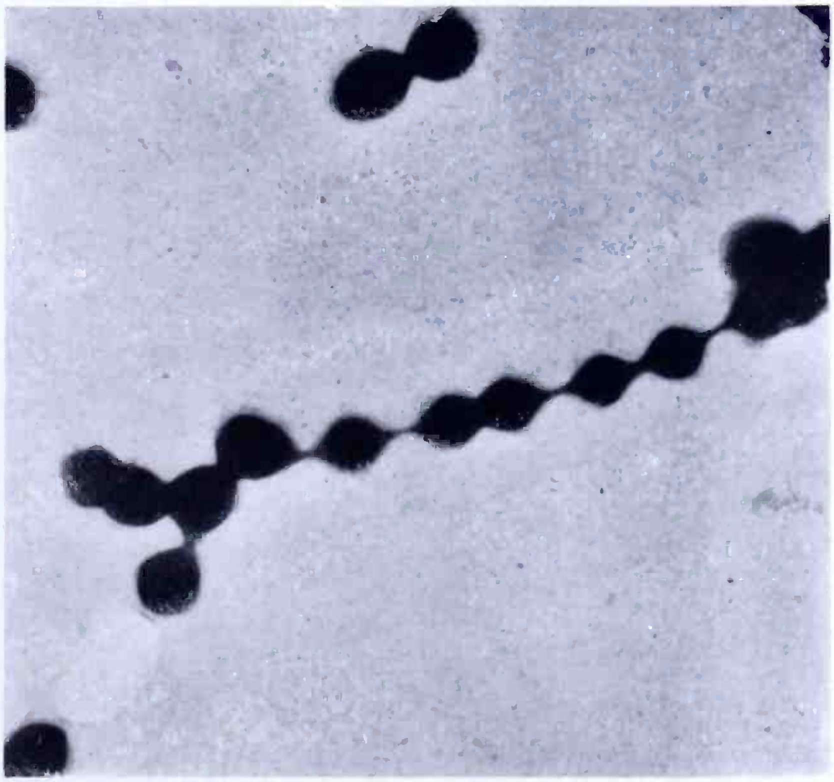
Magnification 540 diameters

F

Fig. 3—Comparisons between light and electron micrographs.

of making micrographs. In other words, it has proved itself to be an instrument well suited to the requirements of a research and industrial laboratory tool.

As soon as the period of development and test was completed, the microscope was turned over to a production group so that it could take its place as a commercial product. The interest shown by research workers in almost all fields of science has been gratifying indeed, and instruments have now been installed in a number of scientific and industrial research laboratories.



Courtesy of *Journal of Bacteriology*

Fig. 4—Streptococcus from a blood agar culture.
(Magnification 15,000 diameters)

Development of the commercial model of the electron microscope terminated the first phase of the investigation in this field. At this point the research was divided into two branches. The first concerned itself with the developing of various new forms of electron microscopes,[11] instruments using the same principles employed in the commercial model, as well as those embodying entirely different principles. The description of this research work is beyond the scope of this paper.

The second line of research is a broad study of the applications of the electron microscope to various scientific problems. This work was undertaken to develop techniques and because of the importance of the work itself. Since much of the work was in fields outside of those normally studied in the RCA Laboratories, it was necessary to obtain the collaboration of specialists from other laboratories. The willingness with which this aid has been given was one of the truly gratifying aspects of this whole program of research.

For convenience, the lines of research undertaken will be divided into three major fields: Biology, Metallurgy, and Chemistry.

Biology

To carry out a program of research in the field of biology and bacteriology, requiring as it does a technique quite foreign to those employed in electronic research, it was necessary to obtain the services of a scientist trained in these fields. Therefore, an RCA Fellowship

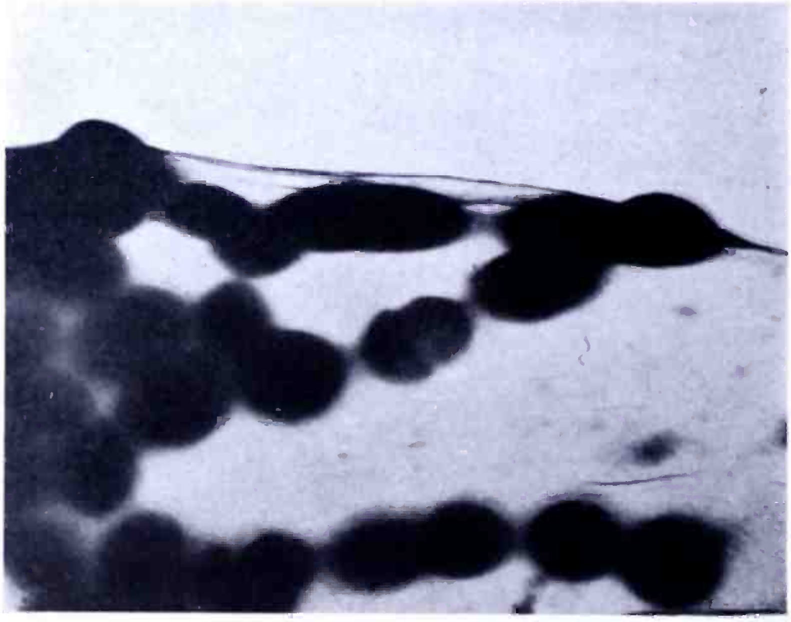


Fig. 5—Streptococcus showing some cells in profile.
(Magnification 16,000 diameters)

for research with the electron microscope was established under the auspices of the National Research Council. A committee was appointed by the Council to handle the Fellowship. This committee is made up of some of the ablest scientists in the various fields of biology and medicine in this country. Its membership is as follows:

Dr. Stuart Mudd, *Chairman*, School of Medicine, University of Pennsylvania, Philadelphia, Pa.

Dr. M. Demerec, Carnegie Institution of Washington, Cold Spring Harbor, Long Island, N. Y.

Dr. Caryl P. Haskins, Union College, Schenectady, N. Y.

Dr. Michael Heidelberger, College of Physicians and Surgeons, Columbia University, New York, N. Y.

Dr. J. H. Kempton, Bureau of Plant Industry, Washington, D. C.

Dr. C. W. Metz, Department of Zoology, University of Pennsylvania, Philadelphia, Pa.

Dr. Katherine A. Polevitzky, School of Dentistry, University of Pennsylvania, Philadelphia, Pa.

Dr. Gordon H. Scott, School of Medicine, Washington University, St. Louis, Mo.

Dr. W. M. Stanley, Rockefeller Institute for Medical Research, Princeton, N. J.

Dr. V. K. Zworykin, Associate Director Research Laboratories, RCA Manufacturing Co., Inc., Camden, N. J.

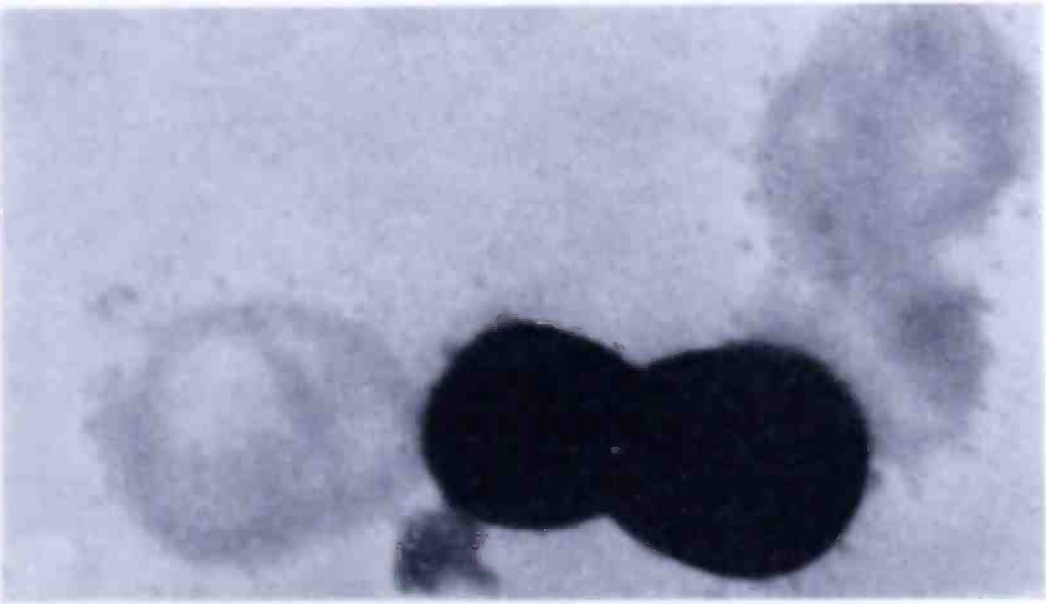


Fig. 6—Streptococcus after sonic vibration.
(Magnification 30,000 diameters)

The first task of this committee was to select from among the applicants for the fellowship the research worker best qualified for the position. The man selected to carry out the research under the direction of, and in collaboration with the Committee is Dr. Thomas F. Anderson of the University of Wisconsin.

The technique of bacteriological research with the electron microscope is different in many respects from that with an optical microscope. One of the important reasons for the difference is that an examination with electrons must be performed in vacuum, with specimens which are transparent to electrons. The latter requirement means that both the specimen and mount must be very thin since the scattering power and absorption of an object is dependent upon density and thickness. Furthermore, due to the effect of the vacuum, the specimens will lose any water which is not firmly bound. The second major difference is the order of size of the objects being examined.

The microscope will resolve detail 50 to 100 times finer than can be resolved with an optical instrument, and, consequently, the objects studied must be very much thinner than those used for optical studies. This means that many of the ordinary techniques for manipulating, sectioning, and mounting specimens cannot be used, and new ones must be worked out to take their places.

The preparation of the specimen and specimen support is very important to the success of making electron micrographs. A rather special technique has been developed for doing this, and is of sufficient general interest to warrant a brief description.

As has already been mentioned, the base material for the film most frequently used is collodion, although other plastics such as

Fig. 7—*C. diphtheriae* on normal blood agar.
(Magnification 12,000 diameters)

cellulose acetate or vinylite may be used. The plastic is dissolved in a suitable solvent to form a dilute solution. In the case of collodion, amyl acetate is used as solvent. A drop of the solution from a medicine dropper is allowed to fall on the surface of clean distilled water. The solution will spread over an area about 20 centimeters in diameter, and harden into a collodion film about 100 Angstrom units in thickness. The metallic supporting meshes cut into disks $\frac{1}{8}$-inch in diameter are placed on the film, as shown in Figure 2. With the aid of a special tool, which can be seen in the photograph, the support with the film adhering to it can be lifted out of the water after the portion of the film on the support has been cut away from the rest. After the film has dried, it is ready for the specimen. Where possible, the specimen is held in a water suspension (or in any other liquid which will not dissolve the supporting film) so that a drop of the suspension can be placed on the support and allowed to dry. This procedure can be used for many biological and bacteriological specimens, as well as for colloidal particles, pigments, and other chemical preparations.

Other forms of mountings may also be used as the occasion demands. These include sealing the specimen between collodion films, embedding the material to be examined in the collodion, and suspending it in a film, for example of gelatine, which, in turn, is supported on a collodion film. Certain types of specimens can be mounted directly on the wire mesh itself.

Fig. 8—*C. diphtheriae* on potassium tellurite chocolate agar.
(Magnification 16,000 diameters)

Work in the field of bacteriology was started at the RCA Laboratories before the fellowship was established. The first step was to build up a small library of electron micrographs of different types of bacteria. Nearly 100 varieties were photographed in this connection—a large part of these specimens being prepared and supplied by Dr. Polevitzky of the University of Pennsylvania Dental School. The collection included a great many of the common pathogenic and benevolent germs. Each one of the photographs made with the electron microscope showed a great deal of structure and detail which are beyond the resolving power of an optical microscope.

Figure 3 shows the comparison between light and electron micrographs for three frequently encountered bacteria.* Figure 3-a is an electron micrograph of the spirochete responsible for infectious jaundice (Weil's disease), while Figure 3-b shows the same organism using optical methods. The difference in information contained in the two micrographs is striking indeed. Much of the structure visible in the electron micrograph has not been seen before and years of study will be necessary before it is fully interpreted. The other micrographs in this figure are of Bacillus subtilis (electron micrograph Figure 3-c, light micrograph Figure 3-d); and of the typhoid organism (electron micrograph Figure 3-e, light micrograph Figure 3-f). In each case the

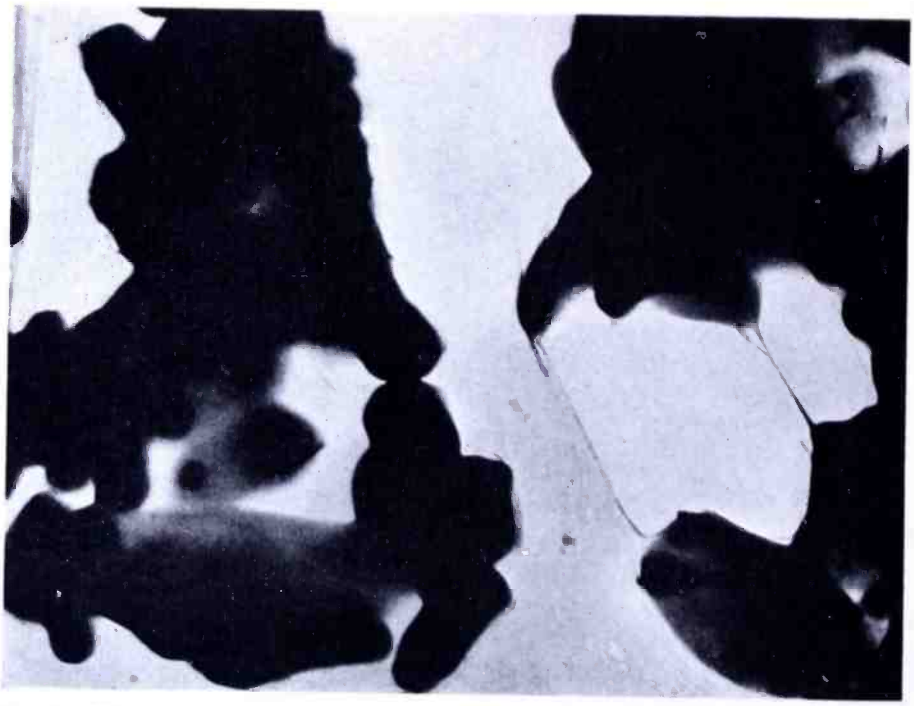


Fig. 9—The same cells as shown in Figure 8, at higher magnification.
(Magnification 29,000 diameters)

picture made with the electron microscope is of much higher magnification than those made with the optical instrument. It would be possible to magnify the optical micrographs further, but since the eye can resolve the finest detail in the image when the magnification is one or two thousand diameters, no additional information is gained by further enlargement. On the other hand, 20,000 to 50,000 diameters magnification is required to make visible all the detail in the electron images.

After this preliminary survey, a number of specific research projects were undertaken, most of them under the auspices of the National Research Council. Space does not permit a detailed account of all of

* The light micrographs courtesy of Dr. H. E. Morton of the University of Pennsylvania.

these, but a few will be included in order to illustrate the scope and importance of this work.

One of the first projects was a study of the structure of Streptococcus Pyogenes,[4] undertaken by Drs. Stuart Mudd, David Lackman, and L. Marton. Figures 4 and 5 show two micrographs taken from this work. The photographs give evidence that the streptococcal cells possess a strong, relatively rigid membrane (cell wall) continuous over a number of cells. This rigid membrane apparently binds groups of cells together and is the reason these bacteria form the chains clearly in evidence in the photographs. The rigidity of the cells can be judged

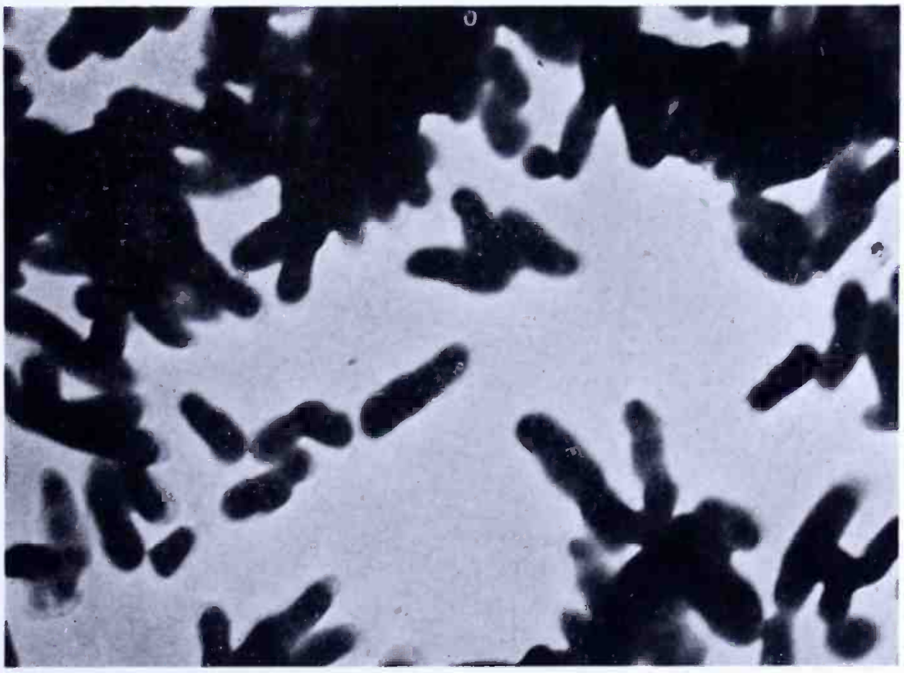


Fig. 10—*C. diphtheriae* grown on potassium tellurite agar after treatment with bromine water.
(Magnification 22,000 diameters)

from the fact that those seen in profile at the fold in the supporting membrane have not been flattened either by the desiccating effect of the vacuum or the action of the electron beam. The effect of subjecting the streptococcus to a short period of sonic vibration is seen in Figure 6. This micrograph shows two cells which are essentially intact, and attached to them, forming part of the chain, are three ghost cells in which the outside membrane has been ruptured, allowing the internal protoplasm to escape. Further sonic treatment would have caused the destruction of all the cells.

This study of the morphology of bacteria is being continued with the investigation of such organisms as Bacillus megatherium, Bacillus anthracis, and Bacillus subtilis. The results have been published recently in a paper[5] by Drs. S. Mudd, K. Polevitzky, T. F. Anderson, and L. A. Chambers.

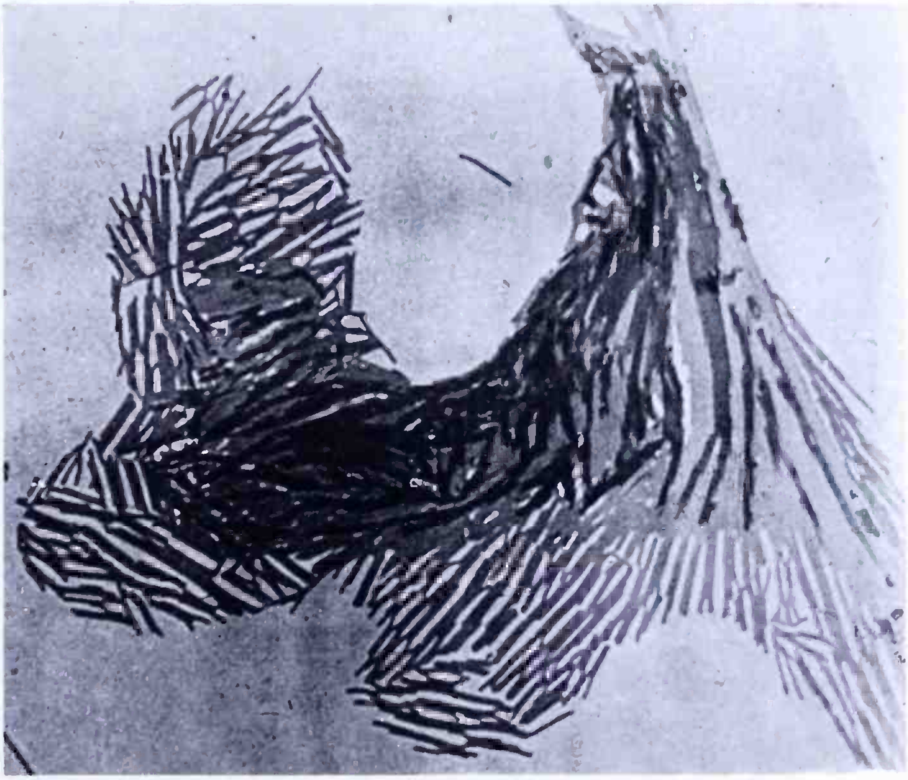
The new microscope makes it possible not only to see details of the surfaces of cells which cannot be resolved in any other way, but also makes clearly visible internal structures. It has long been known to bacteriologists that certain chemical reactions are brought about by bacteria. The reduction of potassium tellurite to metallic tellurium by diphtheria bacilli is such a reaction. An understanding of these reactions, and where they occur, is important in order to gain a more complete knowledge of the functioning of these organisms with a view towards more effective methods of combating them. However, it is not possible with an optical instrument to determine whether such reactions occur exclusively on the surface of the cell, or whether they

Courtesy of *Journal of Biological Chemistry*

Fig. 11—Tobacco mosaic virus.
(Magnification 19,000 diameters)

take place within the organisms. With the electron microscope, the points where reactions of this type occur can be located. A research project to investigate the reduction of potassium tellurite by Cornyebacterium diphtheriae was undertaken[6] by Dr. H. E. Morton in collaboration with the RCA Research Fellow. Micrographs were made of the bacteria obtained from diphtherial colonies grown on pure blood extract agar and on potassium tellurite chocolate agar. Figure 7 shows the appearance of the organisms grown on the control agar. The characteristic polar granules showing as small black circles are in evidence. Figures 8 and 9 show the same type of organism grown on the culture medium containing potassium tellurite. Minute crystals of metallic tellurium are clearly visible inside the organisms. In order to establish that these crystals are tellurium, a suspension of cells which had been grown on the potassium tellurite culture medium were treated with bromine dissolved in water. Such treatment should cause the needle-like crystals to dissolve by forming a soluble tellurium compound. Figure 10 shows the diphtheria bacilli treated in this way. It will be seen that the crystals are no longer present.

The results of this research indicate that the tellurite salt or telluriumion diffuses through the wall of the cells and is reduced to metallic tellurium within the organism. Thus with the new instrument it is possible to see the location within the cell of the sites of certain chemical reactions incident to the metabolism of the organism. These two studies are, of course, only a small part of the research being



Courtesy of *Journal of Biological Chemistry*

Fig. 12—Aggregation of tobacco mosaic virus particles from a concentrated suspension.
(Magnification 21,000 diameters)

carried on in the field of bacteriology in connection with the RCA Fellowship. Others[7], including investigations of immune reactions, staphylococcus and phage, the tubercle bacillus, pneumococcus, etc. are being actively pursued, and have already led to important results.

Another field of immense importance in biology is that relating to viruses. Before the advent of the electron microscope practically all viruses were beyond the range of direct observation. The ability to see and photograph these entities themselves is an enormous advance and should lead to a rapid growth in our knowledge of their nature and of methods of combating them.

Viruses are known to be minute particules constituted of organic chemicals such as nucleoprotein. Whether or not viruses are elementary living particles, or whether they are inanimate organic molecules, or complexes, is not definitely known. It depends in part upon definition. Biologists frequently use the term molecule to designate an individual virus unit. The use of the term in this way is purely a matter of convenience.

Viruses are what is known as obligate parasites, that is, they do not multiply except in the proper living host cell. All attempts to grow cultures of these organisms in artificial media have met with failure. However, viruses are not necessarily destroyed when removed from their host. Thus it is possible to isolate and purify them by suitable

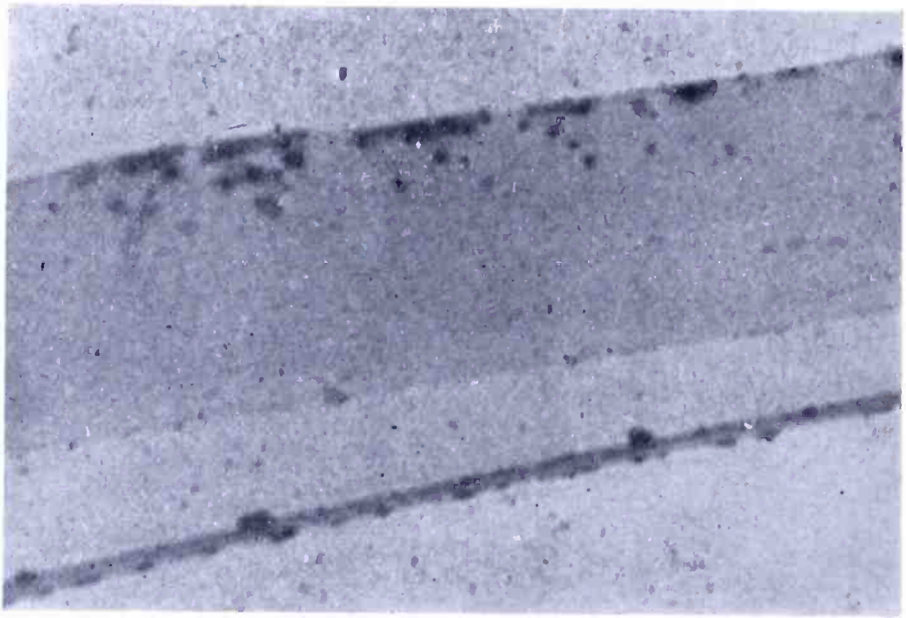


Fig. 13—Tomato bushy stunt virus.
(Magnification 25,000 diameters)

techniques, such as ultrafiltration and centrifuging. The purified strains of virus when reintroduced into a living host will resume their activity.

Prior to research with the electron microscope, various indirect methods had been devised for studying viruses These methods had revealed that the sizes ranged between 250 and 10 millimicrons. Furthermore, it was found that both spherical and asymmetrical viruses exist.

An investigation was undertaken with the electron microscope to study a number of plant viruses. This work was carried out by Dr. W. M. Stanley of the Rockefeller Institute for Medical Research at Princeton, in collaboration with Dr. T. F. Anderson, the RCA Research Fellow.

The first virus to be studied was the tobacco mosaic virus.[8] Suspensions containing the virus purified by differential centrifugation in different concentrations were placed on mounting films for examination with the microscope. When a very dilute suspension was used, the individual particles were clearly discernible as can be seen from Figure 11. These particles are rod-like in form, and have a width of 15 millimicrons, and are 280 millimicrons in length. Measurement of a large number of particles indicates there is some deviation from these dimensions, but that the deviation is small. These values are in agreement with previous determinations within the accuracy of the earlier measurements. When the concentration of virus particles is high, and when the preparation has aged, there is a tendency for an

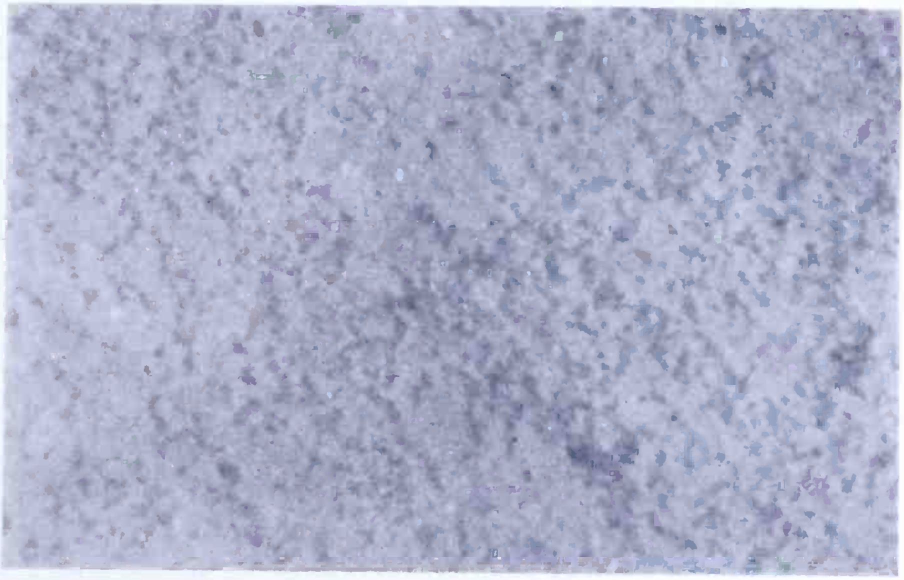


Fig. 14—Tobacco necrosis virus.
(Magnification 27,000 diameters)

end-to-end and side-to-side attachment of the individual particles. At very high concentrations this joining becomes very marked, leading to a partially regular array of the type shown in Figure 12. However, the evidence indicates that the normal form of fresh active virus is as discrete rods.

Cucumber mosaic virus 3 resembles the tobacco mosaic virus in many of its chemico-physical properties. However, it is only active in plants which are members of the Curcurbitaceae. Tobacco mosaic virus, like many other viruses, has a much greater range of hosts. The latter has been transmitted to 46 species of plants representing a number of widely separated families (although not including cucumber plants). When examined under the electron microscope, cucumber mosaic virus 3 was found to have a length of about 300 millimicrons. It seemed to show a somewhat greater tendency to form end-to-end aggregation, but this may be a result of

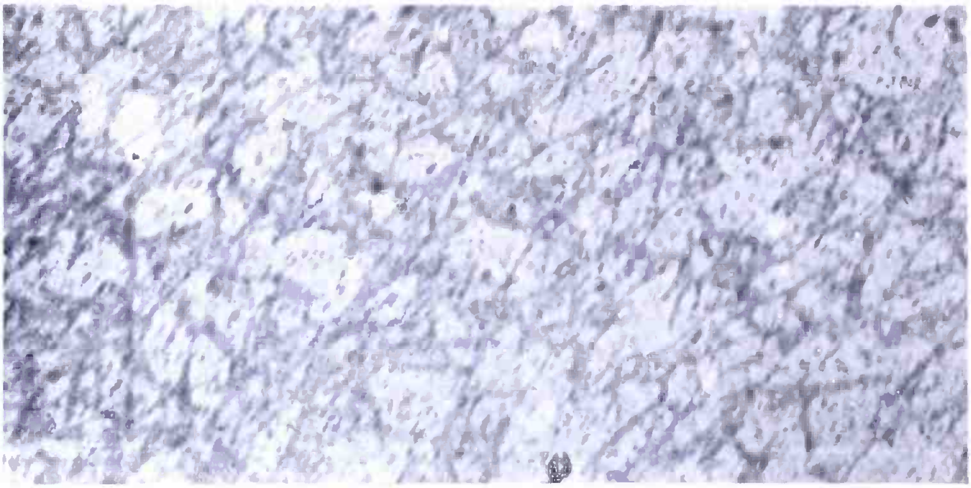


Fig. 15—Partial disintegration of tobacco mosaic virus by dilute ammonia.
(Magnification 20,000 diameters)

preparation rather than an innate property of the virus. This is being investigated.

Cucumber mosaic virus 4 was also investigated. This strain was found to resemble cucumber mosaic virus 3, not only in size and shape, but also in its tendency to form end-to-end aggregations.

Two other viruses were investigated in the course of this research. These were tomato bushy stunt virus and tobacco necrosis virus. Micrographs showed that the elementary particles of these viruses are essentially spherical. Their diameters are 26 millimicrons and 20 millimicrons, respectively. Figures 13 and 14 are micrographs of these viruses.

Viruses can be inactivated in various ways. Chemical agents such as ammonia will cause their destruction. Figure 15 illustrates the effect of a small amount of ammonia on a preparation of tobacco mosaic virus. It will be seen that there is a pronounced disintegration of the

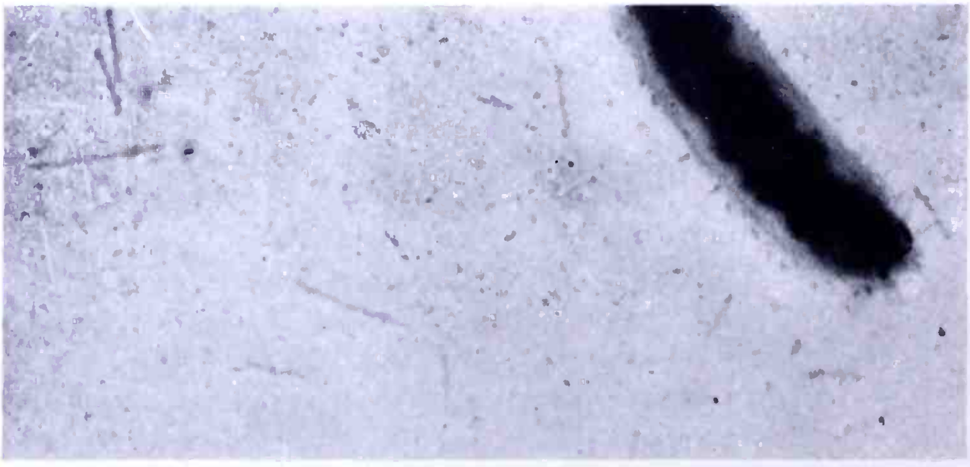


Fig. 16—Tobacco mosaic virus in the presence of normal rabbit serum.
(Magnification 19,000 diameters)

rod-like particles; with higher concentrations, the disintegration is complete. Living animal bodies can inactivate viruses as a protection against disease. For example, if tobacco mosaic virus is injected into the blood stream of a rabbit, after some days a protein substance is generated which inactivates the virus. This de-activating substance or antibody can be isolated by chemical methods. The purified antiserum (i.e., serum containing an antibody), when introduced into a preparation of tobacco mosaic virus will combine with the virus, the antigen-antibody complex aggregating as a precipitate. Another property is its specificity. The antiserum generated in a living body due to the presence of a particular virus, such as the tobacco mosaic virus mentioned above, will not denature another type of virus, as, for instance, bushy stunt virus.

The reaction between viruses and antibodies has been studied with

Fig. 17—Tobacco mosaic virus in the presence of anti-serum.
(Magnification 19,000 diameters)

the aid of the electron microscope[9] by the same two workers who carried out the research described above. Examining a mixture of tobacco mosaic virus and normal rabbit serum (i.e., serum from a rabbit which has not received an injection of the virus), the individual particles are found to be unchanged. This can be clearly seen in the micrograph reproduced in Figure 16. Figure 17 illustrates the effect of the addition of anti-serum to a preparation of tobacco mosaic virus. Three effects of the antibody are immediately apparent. First, the individual particles have been greatly thickened, the diameter of the rods having increased from their normal size of 15 millimicrons to about 60 millimicrons. A second effect is that the boundaries of the particles are no longer sharp, having a fuzzy appearance although the microscope is sharply in focus. Finally, the particles tend to stick together in clumps.

According to the theory which most nearly explains the facts as they are known today, the antibodies are elongated organic molecules

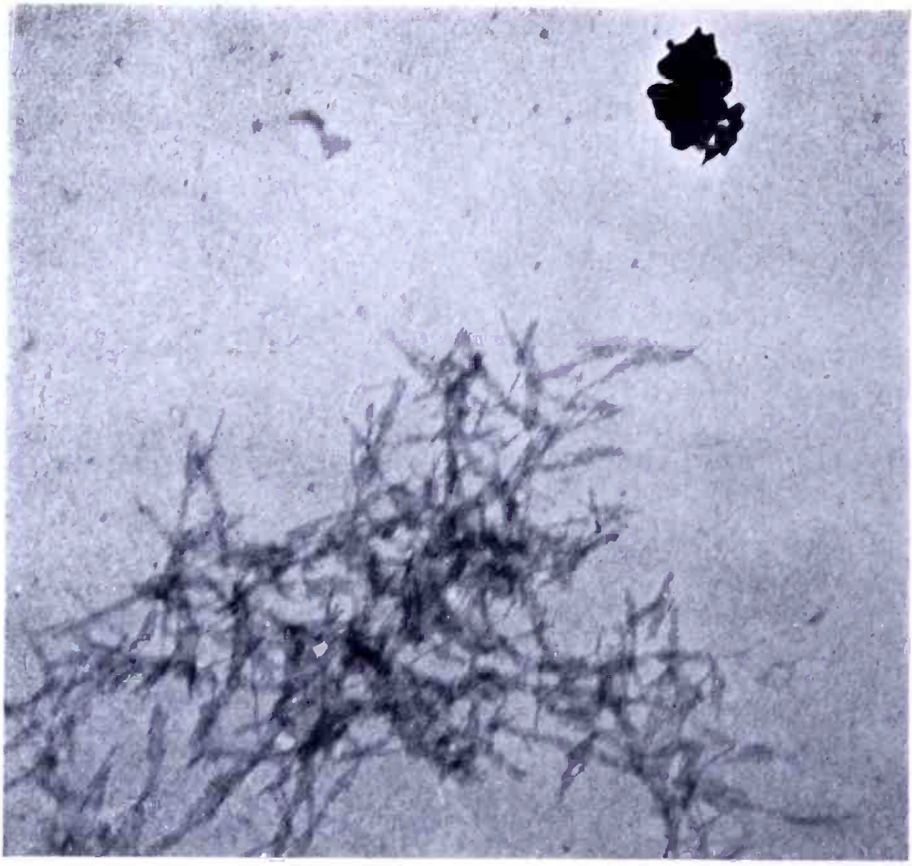


Fig. 18-a.—Tobacco mosaic virus and bushy stunt virus with tobacco mosaic virus anti-serum.
(Magnification 14,000 diameters)

diameter of 4 millimicrons. These molecules are apparently able to attach themselves endwise to the virus, thus causing the increase in size and fuzzy appearance. The reactivity of the outer ends of the antibodies may cause the clumping action, or it may be caused by some

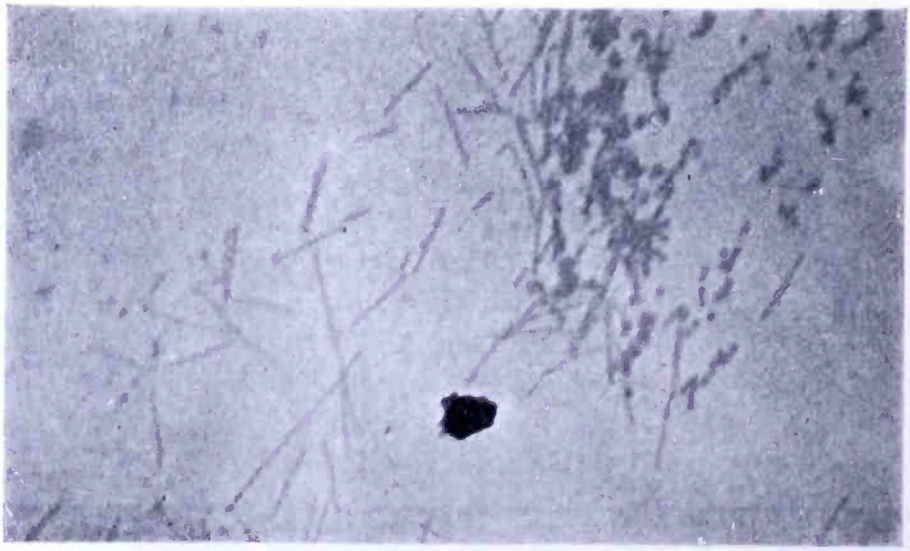


Fig. 18-b.—Tobacco mosaic virus and bushy stunt virus with bushy stunt virus anti-serum.
(Magnification 27,000 diameters)

other colloidal effect. It should be pointed out that the individual antibody molecules have not yet been seen with the electron microscope, but that work is being carried out in this direction.

Figures 18-a and -b illustrate the specificity of the antibody reaction. A mixture of tobacco mosaic virus and bushy stunt virus in the presence of tobacco mosaic anti-serum is shown in Figure 18-a. It will be seen that only the first named virus has been affected by the antibody. The same two viruses in the presence of anti-bushy-stunt serum can be seen in Figure 18-b, which clearly shows that only the bushy stunt virus is attacked.

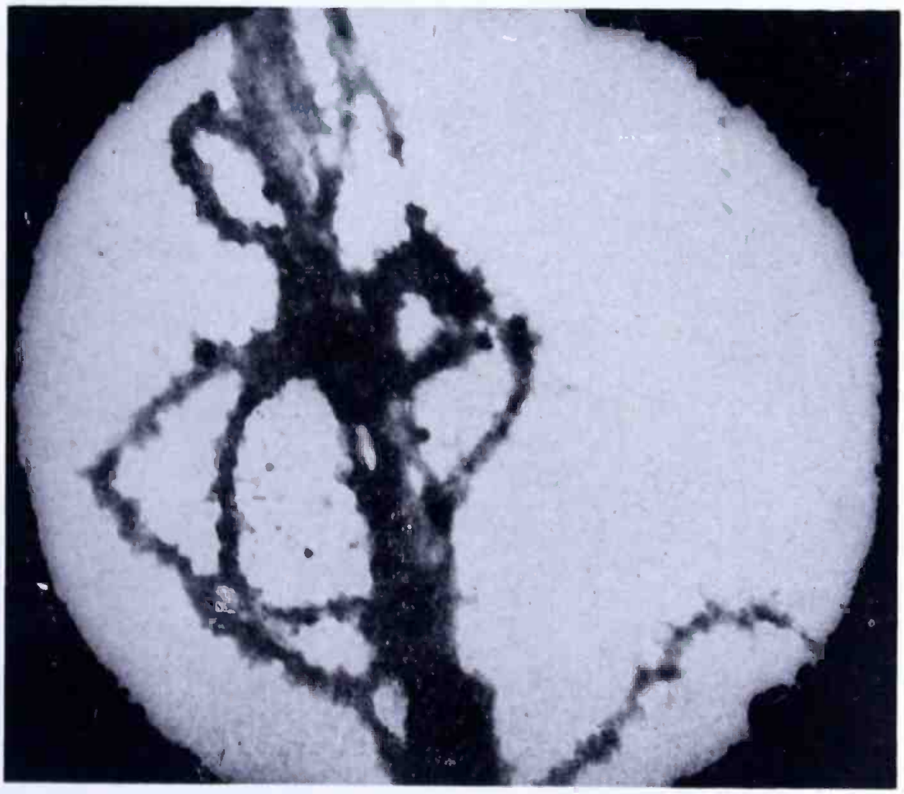


Fig. 19—Fragment of a lampbrush chromosome.
(Magnification 11,000 diameters)

The research on viruses outlined in the preceding pages represents only the initial phase of an extensive program of projected future work. Already many interesting and important facts concerning the nature of these entities have been brought to light, and the value of the microscope as a tool for virus investigation has been demonstrated beyond question.

Biological work in the field of cytology is also being undertaken in connection with the RCA Fellowship. The electron micrographic study of the nature and structures of the cells which go together to make up higher living organisms is extremely difficult. This is because the sections, or cell fragments, used in the investigation must be so extremely minute that it is almost impossible to obtain them without destroying their structure. However, considerable progress has been made in developing the required technique for this type of research.

Chromosomes are among the most important parts of the cell structure. These tiny, rod-like particles apparently bear almost the entire responsibility for the inherited characteristics of the organism of which the cell is part. The number of chromosomes differs in cells from different organisms, but is the same in any one organism,

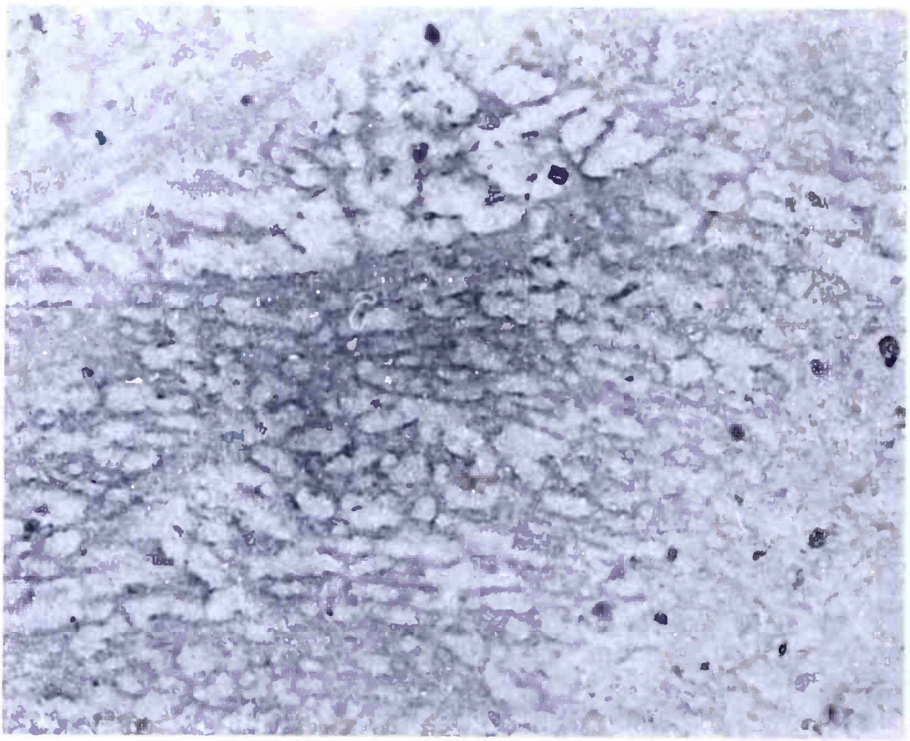


Fig. 20—Bainite (0.78 per cent carbon steel).
(Magnification 11,000 diameters)

irrespective of the function the cell performs. There is one exception to this rule in that the regenerative cells only contain half the number of chromosomes of that type of organism, so that when they combine to form the zygote, or primary cell of the new organism, the latter will have the normal number of chromosomes. The chromosomes are the seats of the genes. It has been definitely ascertained that each gene is responsible for one or more of the specific characteristics the future organism will possess. Thus they are of great importance and interest. By means of very ingenious indirect methods and a vast amount of careful work the location of many of the genes in a number of chromosomes has been determined, particularly in the case of the chromosomes of the fruit flies known as Drosophila. However, little which have a length of about 27 millimicrons and an approximate is known about the genes themselves as they cannot be seen by optical means.

A research program to investigate chromosomes with the electron microscope is well under way. The problem is being approached from a number of directions by three groups of scientists, including several members of the National Research Council Committee on the RCA Fellowship. The groups are composed of Drs. Demerec and Sutton from the Carnegie Institution of Washington; Dr. Nebel of the New York State Agricultural Experimental Station; and Drs. Metz and Boche from the University of Pennsylvania. Dr. T. F. Anderson is, of course, collaborating with each of these groups. The members of the groups are recognized authorities in their several fields, and are applying their special knowledge to the preparation of chromosome specimens for examination and to the interpretation of results.

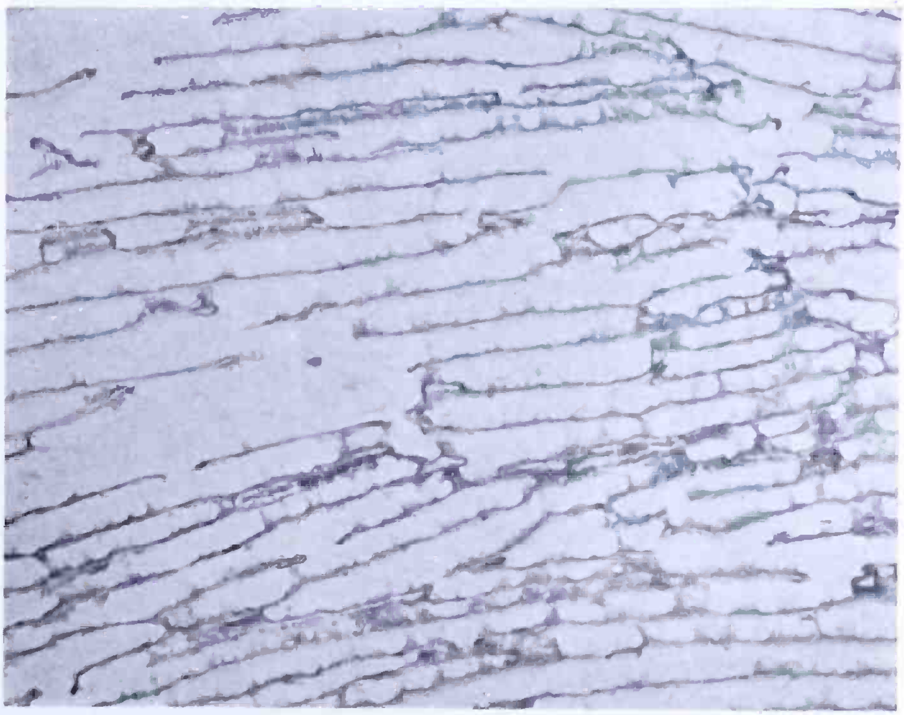


Fig. 21—Pearlite (0.78 per cent carbon steel).
(Magnification 15,000 diameters)

Figure 19 illustrates a portion of lampbrush chromosome from the unfertilized egg of a salamander. This micrograph was made by Drs. Boche and Anderson in connection with the study of this type of chromosome. It will be seen that the structure is far from simple and that considerable work must be done before it can be fully interpreted. A very promising start has already been made on this interpretation.

Among other chromosomes being examined by the various groups are the giant chromosome of the salivary gland of Drosophila, probably the most completely studied by the light microscope because of its great size, plant chromosomes, etc. Many chromosomes will be studied before the investigation is complete.

METALLURGY

One of the newest fields to be opened up to study with the electron microscope is that of metallurgy. A microscope of the type described in the opening pages of this discussion is restricted to the observation of objects which are considerably less than one micron in thickness, and which will therefore transmit electrons with velocities of 60 kilovolts or less. Thus bulk materials such as metals do not lend themselves

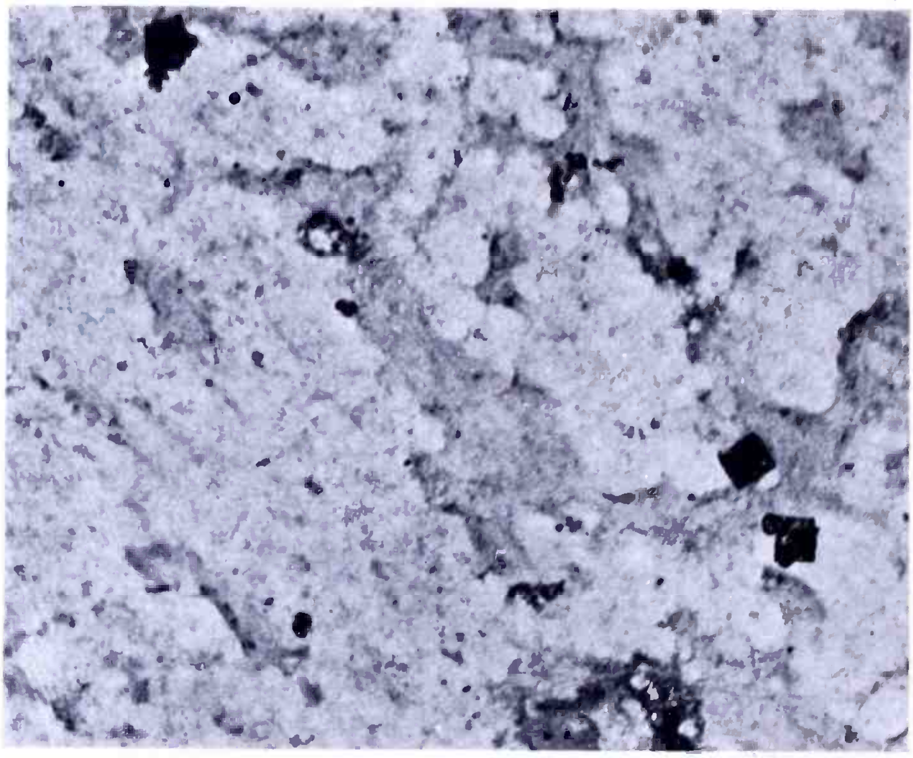


Fig. 22—Steel containing spherodized iron carbide.
(Magnification 8.000 diameters)

to direct examination with the instrument. Of course, metals in the form of thin deposited films, or as colloids, can be observed directly, but they yield little information which can be related directly to the bulk material. Therefore, an entirely new technique for studying the latter had to be developed.

Basically the method consists of forming a thin film replica of the surface of the material being investigated. Such a procedure was suggested and used by H. Mahl in the study of aluminum. The replica in this instance took the form of an aluminum-oxide film formed on the metal surface. The film was removed by etching away the underlying metal. Mahl also suggested forming a collodion film on the metal surface, thus producing a cast replica of the surface. The disadvantage of using an oxide are twofold: first it is restricted to the relatively few metals which form fairly strong oxide films, and second the oxide film is generally not without structure which may be difficult to distinguish from the structure of the underlying surface. When a collodion film is formed directly on the metal surface, it is found to adhere very closely. This is an advantage in that it insures a sharp replica. However, it makes it difficult to remove the film. The binding is so strong that the film cannot be stripped off the surface of the specimen. Hence, the specimen must be dissolved or etched from underneath the film. It is difficult to find a solvent which will dissolve the specimen without damaging the film in the case of many substances such as glass, quartz, ceramics, etc. Furthermore, except where certain easily dissolved metals are involved, it is a lengthy process and one likely to leave impurities on the replica. A number of other replica materials were tested, such as vinylite and gelatine. These were found to give blurred replicas due to insufficient binding, or because they were too easily deformed by the stripping process. Others could not be stripped off from the specimens.

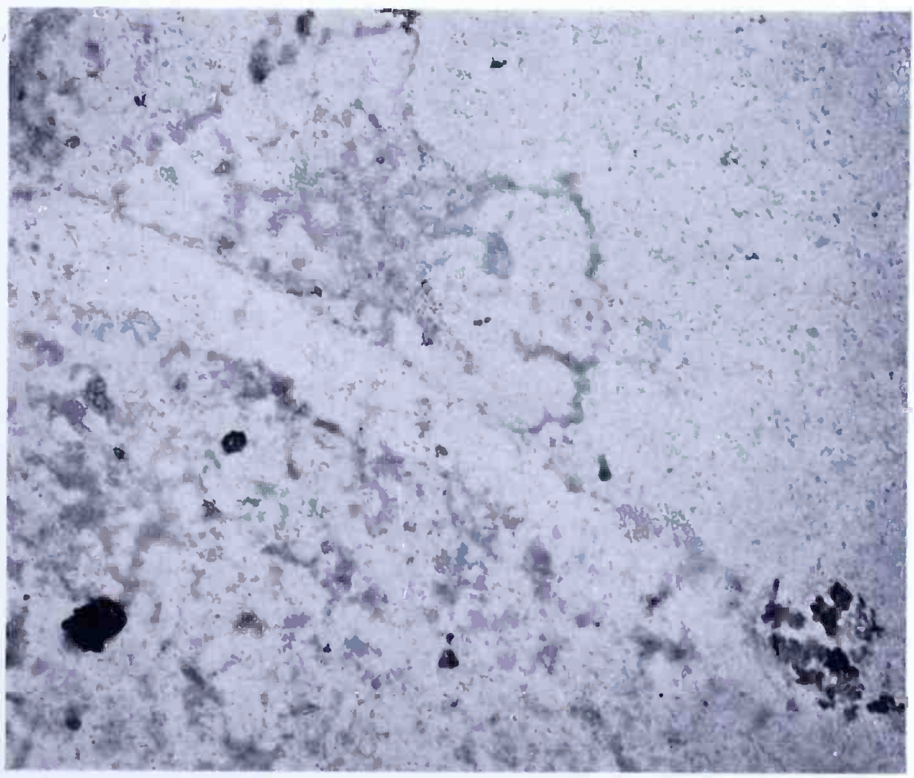


Fig. 23—Alpha brass.
(Magnification 10,000 diameters)

A technique for overcoming these difficulties was developed by Dr. E. G. Ramberg.[10] The procedure involves making a double replica, the first one being metallic, the second one collodion. The metal is deposited on the specimen in a layer thick enough so that it can be readily removed by stripping. The usual procedure is to deposit a thin layer by evaporation, and then, if necessary, to electroplate more metal on top of this until the thickness is of the order of 0.001 inch. Silver was found to be the most satisfactory metal for this purpose because it is easily dissolved, is fine grained, and is strong and flexible enough to strip from the specimen. After the film has been removed from the surface being investigated, a small amount of a dilute collodion solution is flowed over the metal replica. When the solvent has evap-

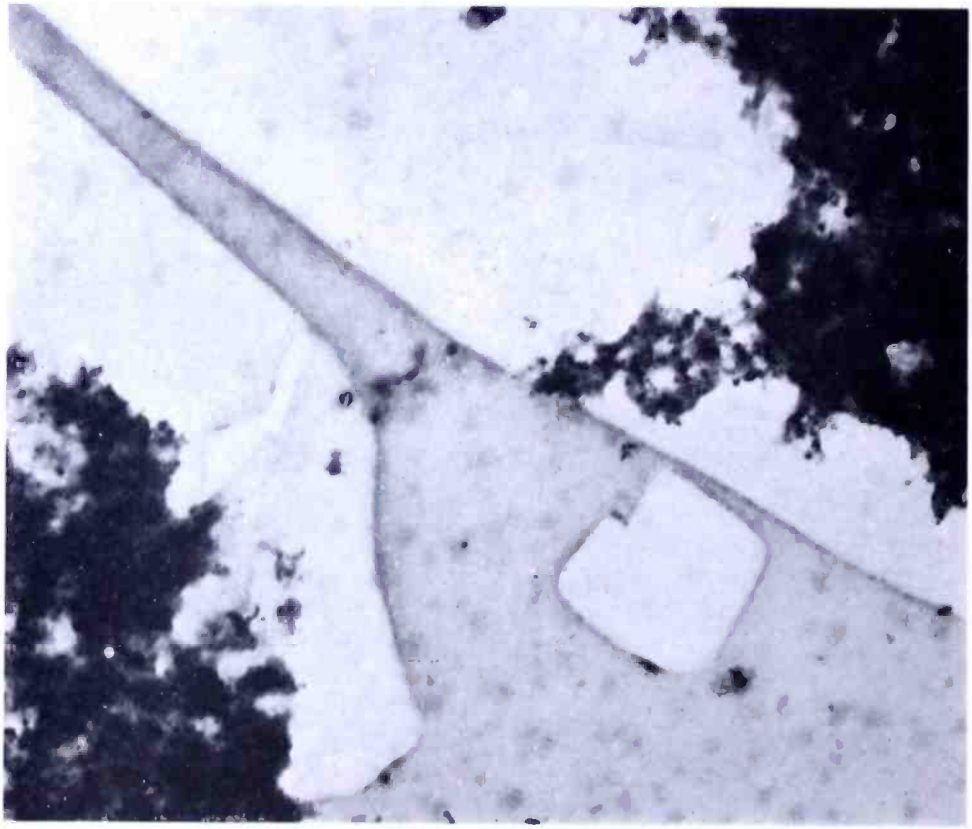


Fig. 24—Surface of glazed porcelain.
(Magnification 13,000 diameters)

orated and the collodion film hardened, the metal and the adhering thin film is immersed in a 2-to-3 Normal nitric acid solution. At the end of a two or three-hour period, the silver will be completely dissolved, leaving the collodion replica film. After carefully washing the film in distilled water it is picked up on a fine mesh screen of the same type as is used to support the films in ordinary specimen mounting. The replica is then ready for examination with the microscope.

Replicas formed in this way are positives, that is, a depression on the replica corresponds to a depression on the specimen, and an elevation to a peak on the specimen. Furthermore, the heights and depths are the same on the replica as on the specimen. In consequence a calibration can be recorded on the photographic plate with the aid of collodion films of known thicknesses, thus permitting a quantitative measure of these heights and depths.

This technique has proved very useful, not only for examining metals, but also in the study of many other opaque materials, among them being porcelain, quartz, glass, and even parts of insects.

Electron micrographs of a number of steel samples are shown in the following three figures. Figure 20 is a steel containing 0.78 per cent carbon and treated so as to produce the structure known as

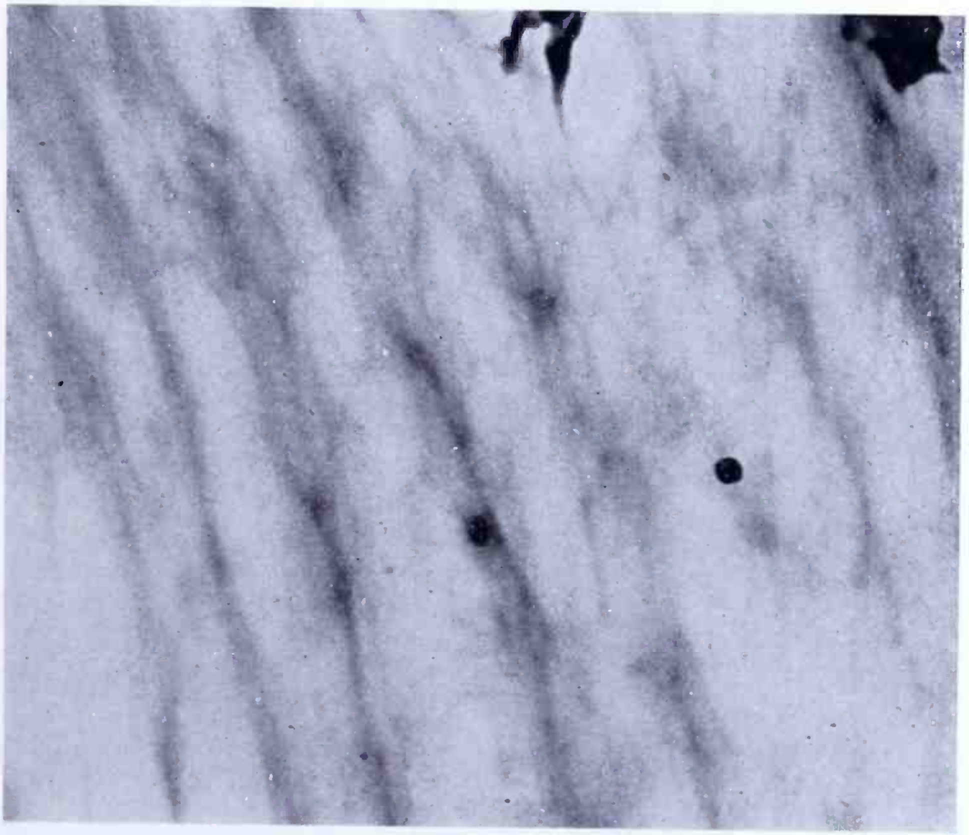


Fig. 25—Cleavage surface of quartz.
(Magnification 16,000 diameters)

"bainite". The same steel, but differently treated to form a second structure known as "pearlite" is shown in Figure 21. The third, containing spherodized iron carbide, is given in Figure 22. These micrographs were made from steel samples furnished by Dr. Mehl of the Carnegie Institute of Technology for study with the microscope. The method has also been applied to the investigation of brass. Figure 23 shows the appearance of the boundary between crystal grains of brass.

Figures 24 and 25 are given to illustrate the method as applied to non-metallic substances. A glazed porcelain surface is illustrated in Figure 24, while Figure 25 shows a cleavage surface of natural quartz. The heavy black particles visible in the last two micrographs are silver grains adhering to the replicas. These could be removed by a prolonged treatment in the acid bath, but are left because they materially aid in focusing the electron microscope.

Chemistry

The electron microscope has a very wide range of applications in the fields of scientific and industrial chemical research. It would be impossible in a limited survey of this type to give a comprehensive list of its possibilities as applied to chemistry. A brief discussion of a

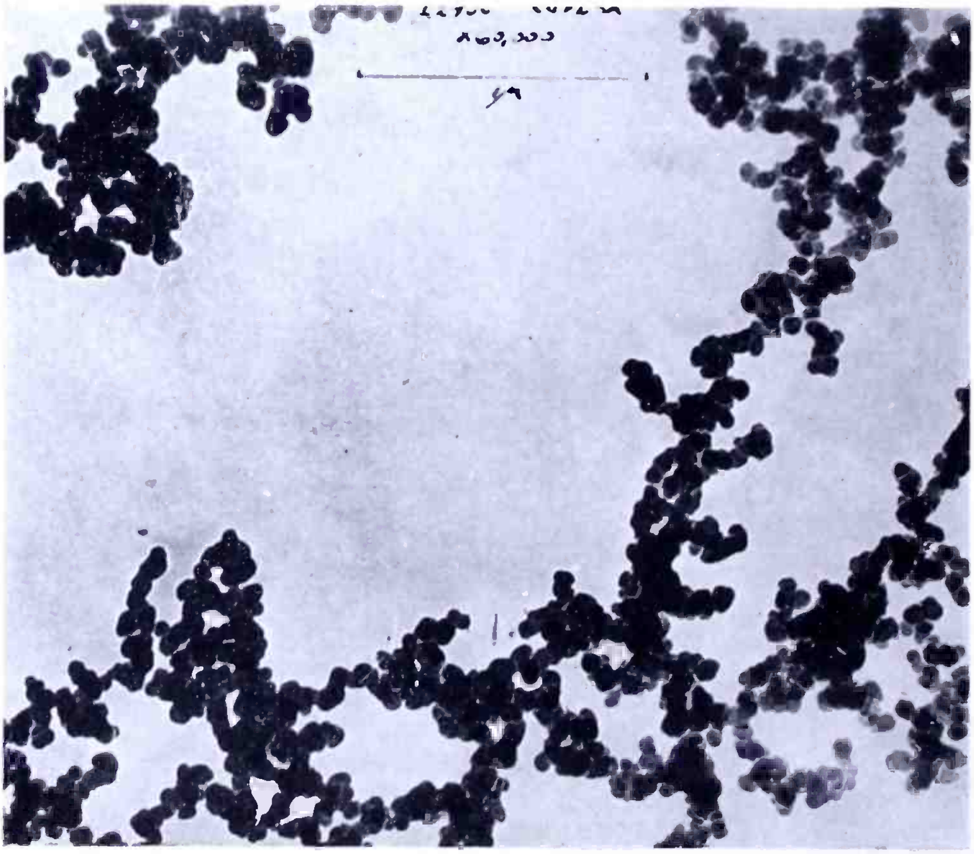


Fig. 26—Carbon particles showing uniform particle size.
(Magnification 30,000 diameters)

few typical problems which have been investigated must suffice for the present.

The new instrument makes it possible to study particle size, size distribution, and shape, where the materials are so fine as to be far beyond the range of optical methods. This information is very important as it determines the chemical behavior of the materials for many purposes. The investigation of colloidal carbon is a typical example of this application.

Very fine grained carbon has many commercial applications. Its uses range from that of a preservative in rubber such as is used for

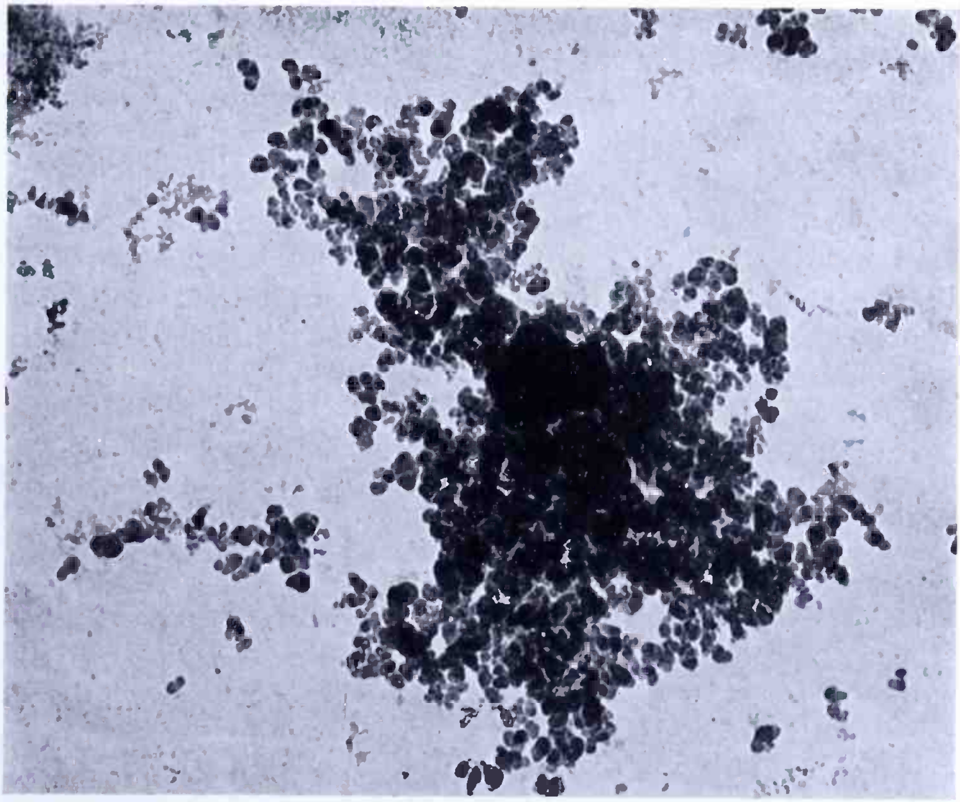


Fig. 27—Carbon particles with a wide range of particle sizes.
(Magnification 36,000 diameters)

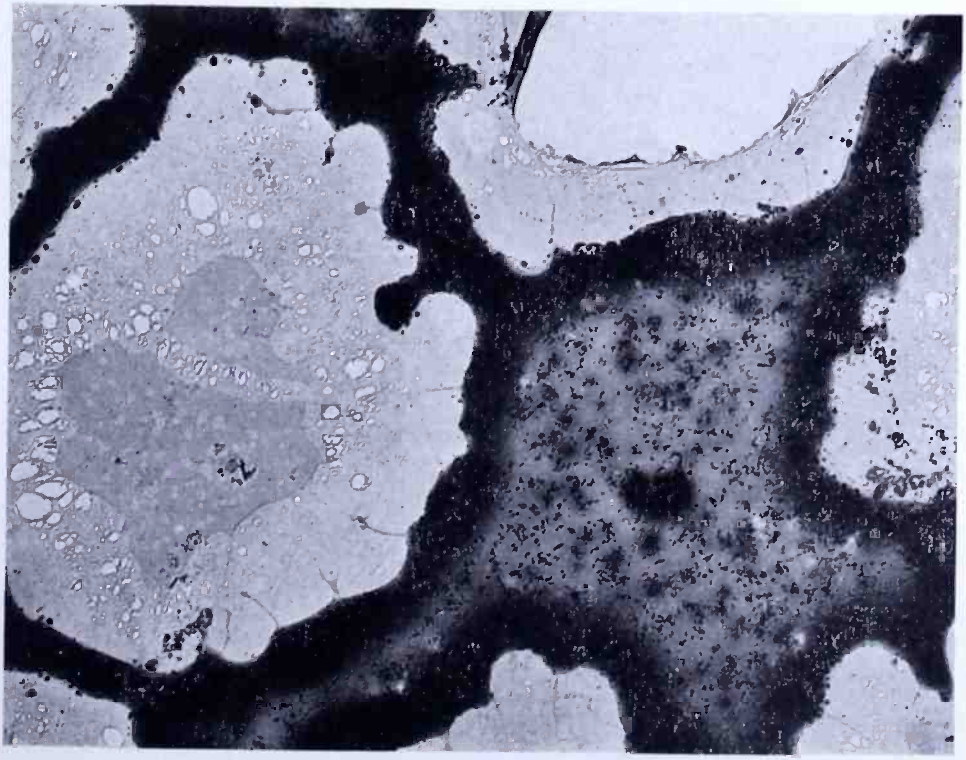


Fig. 28—Rubber cement containing fine grain carbon.
(Magnification 7,000 diameters)

tires to that of a pigment in printer's ink and coloring matter in plastics. Indirect methods have been used in determining particle size and size distribution, and enough data have been obtained to show clearly that the action of the material depends upon these factors. However, these methods are not very satisfactory, and furthermore tell nothing about particle shapes. Therefore, the problem of colloidal carbon was one of the earliest to be investigated with the electron microscope. This study was first undertaken at the University of Toronto and later in the RCA laboratories. Figures 26 and 27 are typical micrographs of

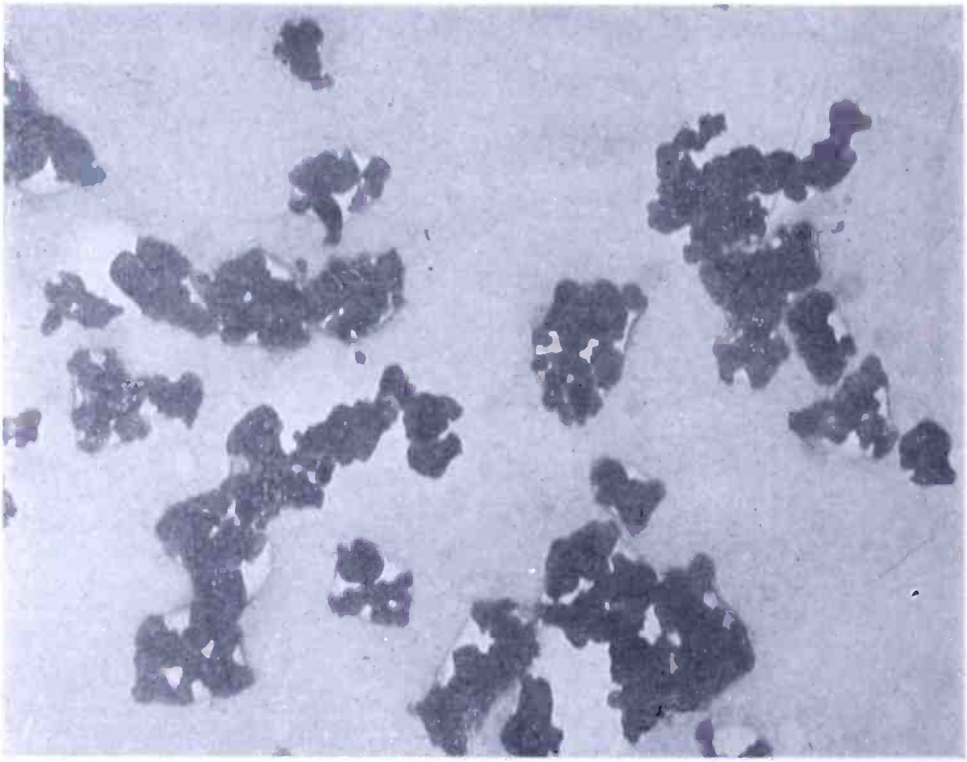


Fig. 29—Rutile, calcined and pulverized (from sample supplied by Sherwin-Williams Paint Company).
(Magnification 25,000 diameters)

carbon. The first shows a uniformly fine grain. The size of each particle is approximately 10 millimicrons, and the individuals are nearly spherical in shape. This type of carbon is formed in a gas flame, but it should be pointed out that the size varies in different parts of the flame. The second micrograph shows a carbon which has a wide distribution in particle size, the sizes ranging from less than 10 millimicrons to more than 50 millimicrons. Like the first, this carbon was also obtained from a flame, but from the entire flame rather than from one particular portion. A specimen consisting of rubber cement containing carbon particles as a preservative is shown in Figure 28.

Another branch of industrial chemistry in which particle size is important is paint manufacture. In this application the way in which the particles aggregate is very important. The two micrographs in Figures 29 and 30 show titanium oxide which is used in the manufacture of white paint. One of the photographs is of the oxide in the form rutile. This specimen has been precipitated from a fluoride solution, heated and then pulverized. The particle size in this specimen varies from 10 to 20 millimicrons. The second micrograph shows the same oxide crystalized as anatase from a sulphate solution. The specimen has also been heated and pulverized. The next two photographs

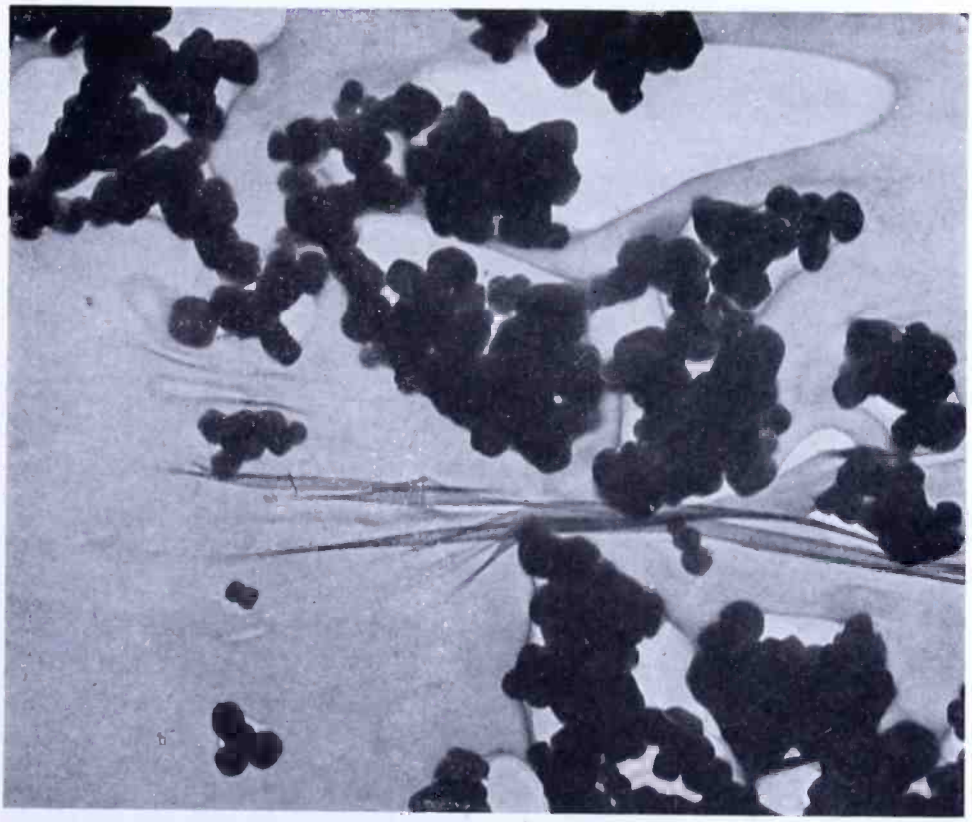


Fig. 30—Anatese, calcined and pulverized (from sample furnished by Sherwin-Williams Paint Company).
(Magnification 45,000 diameters)

show zinc oxide which is also used as a white pigment. Figure 31 is made with the electron microscope, while Figure 32 is an ultraviolet micrograph. The much greater information that can be obtained from the former is immediately apparent.

In the examples discussed, the primary consideration was that of particle size. For other applications the shapes of the particles or the nature of their surfaces is the prime consideration. This is illustrated in Figures 33 and 34. These electron micrographs show two arsenic insecticides, one of which exhibited a very great covering power, while the other was much less effective. Optical examination failed to reveal

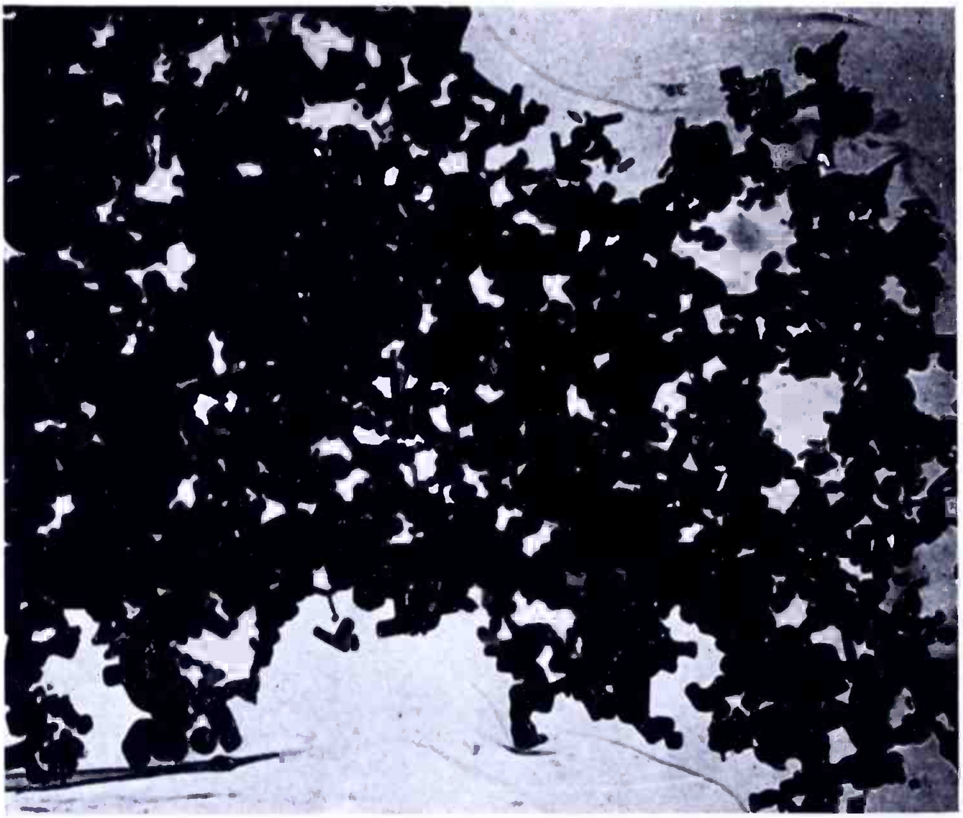


Fig. 31—Electron micrograph of zinc oxide (sample supplied from New Jersey Zinc Company of Pennsylvania).
(Magnification 22,000 diameters)

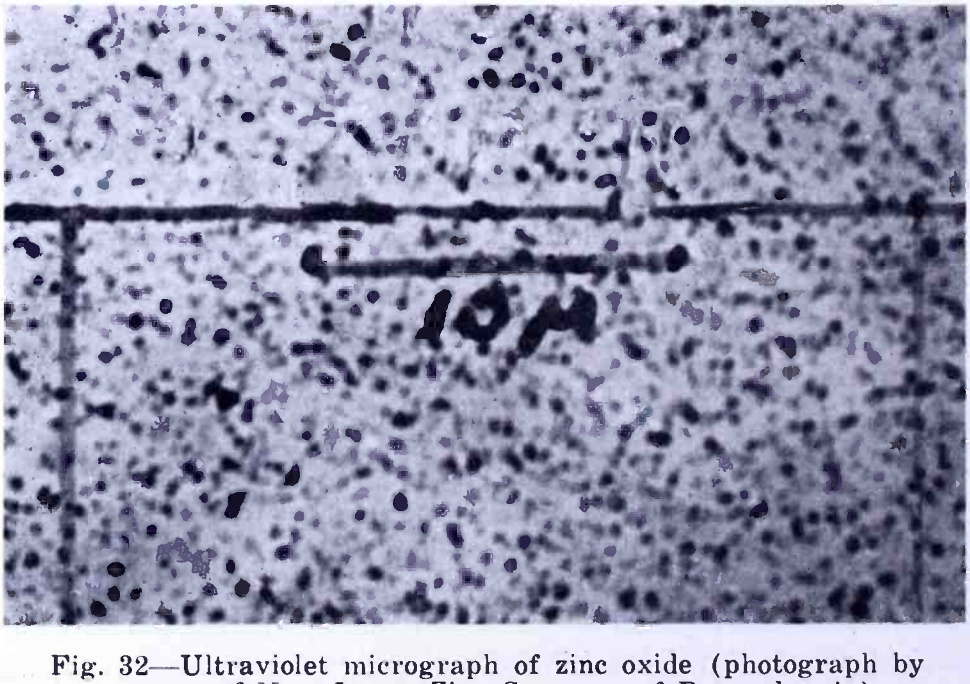


Fig. 32—Ultraviolet micrograph of zinc oxide (photograph by courtesy of New Jersey Zinc Company of Pennsylvania).
(Magnification 4,000 diameters)

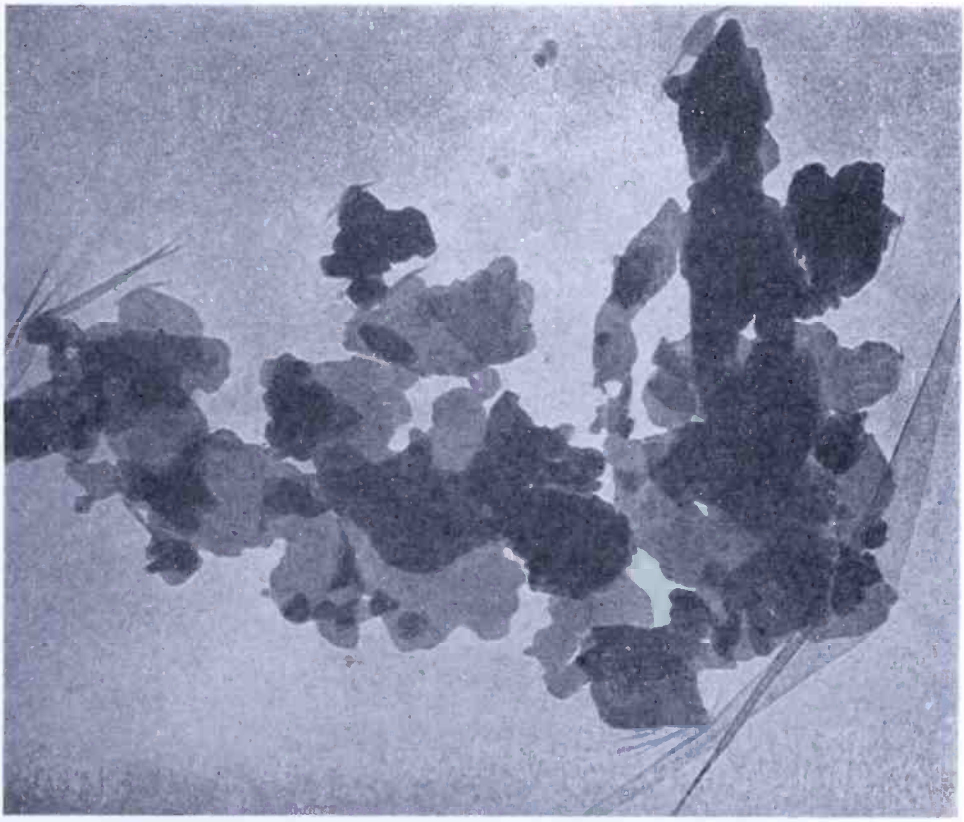


Fig. 33—An arsenic insecticide showing a plate-like structure.
(Magnification 28,000 diameters)

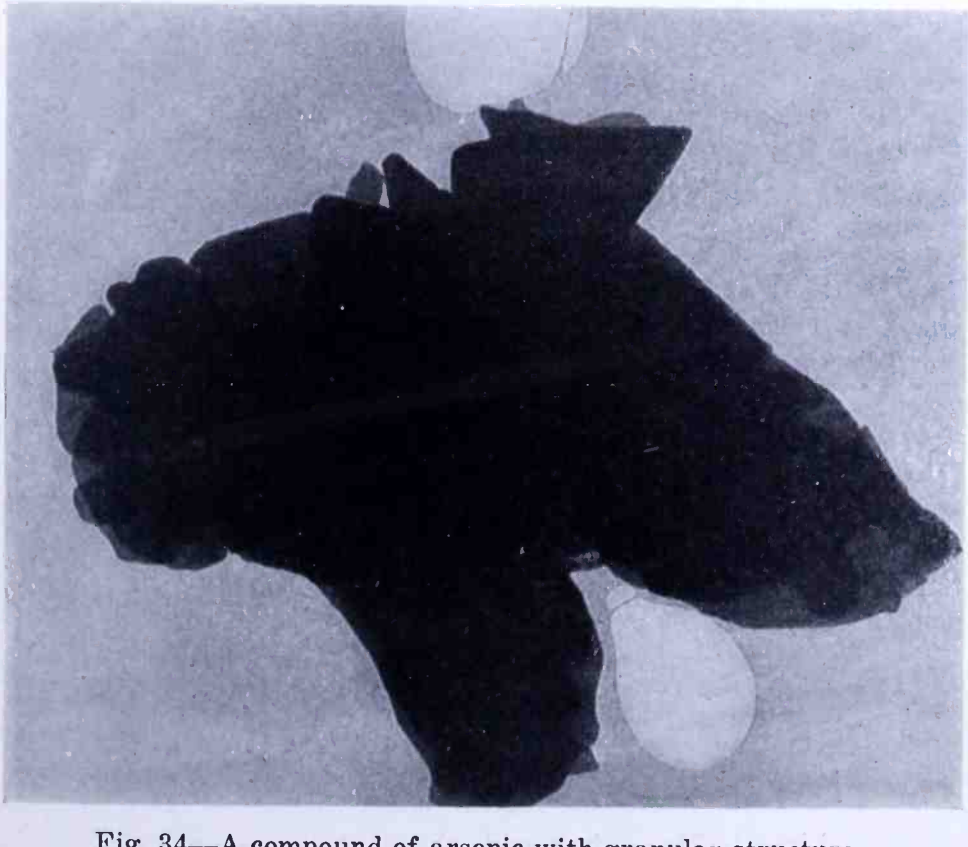


Fig. 34—A compound of arsenic with granular structure.
(Magnification 28,000 diameters)

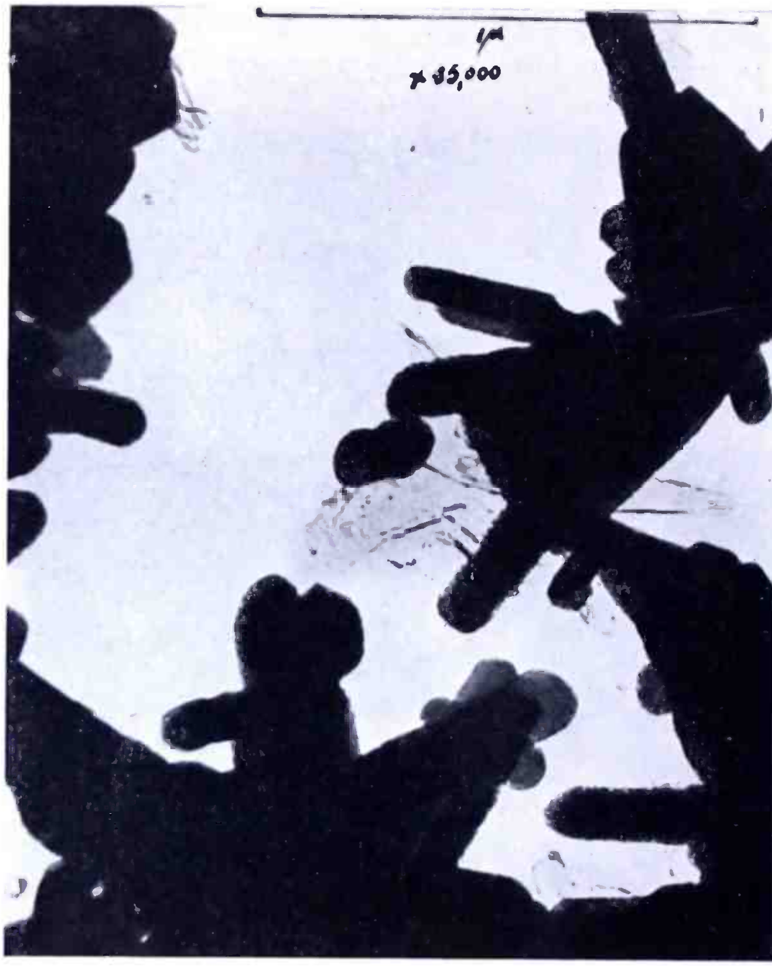


Fig. 35—Calcium carbonate (with large surface area).
(Magnification 35,000 diameters)

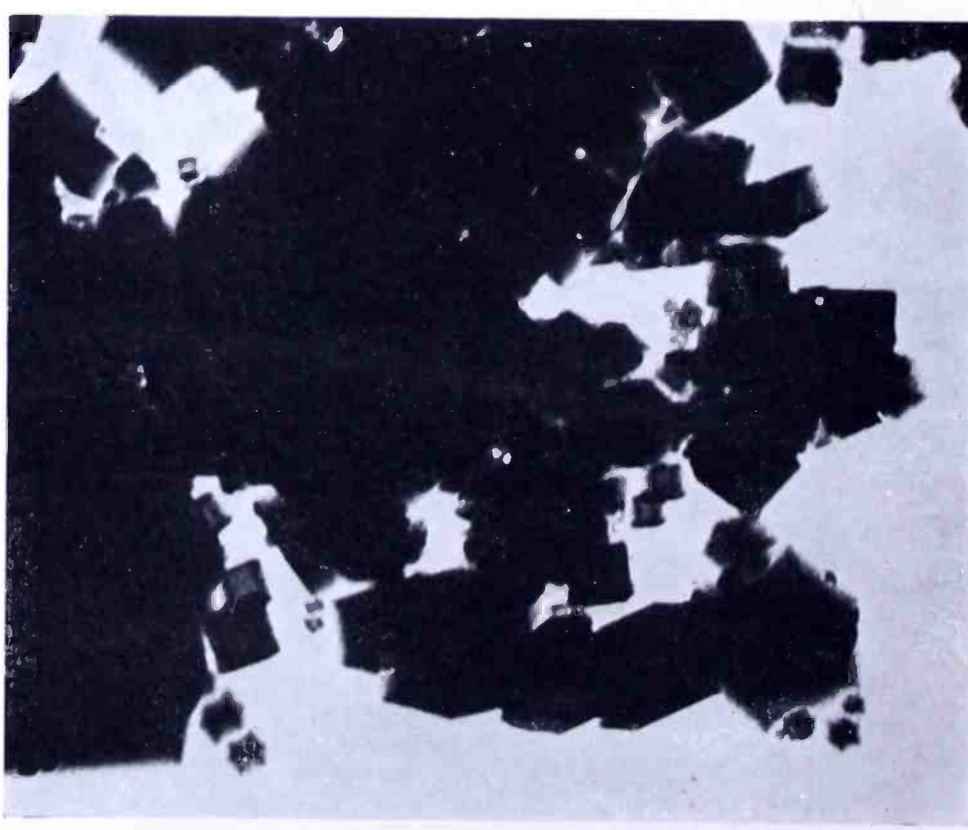


Fig. 36—Magnesium oxide showing cubic crystals.
(Magnification 45,000 diameters)

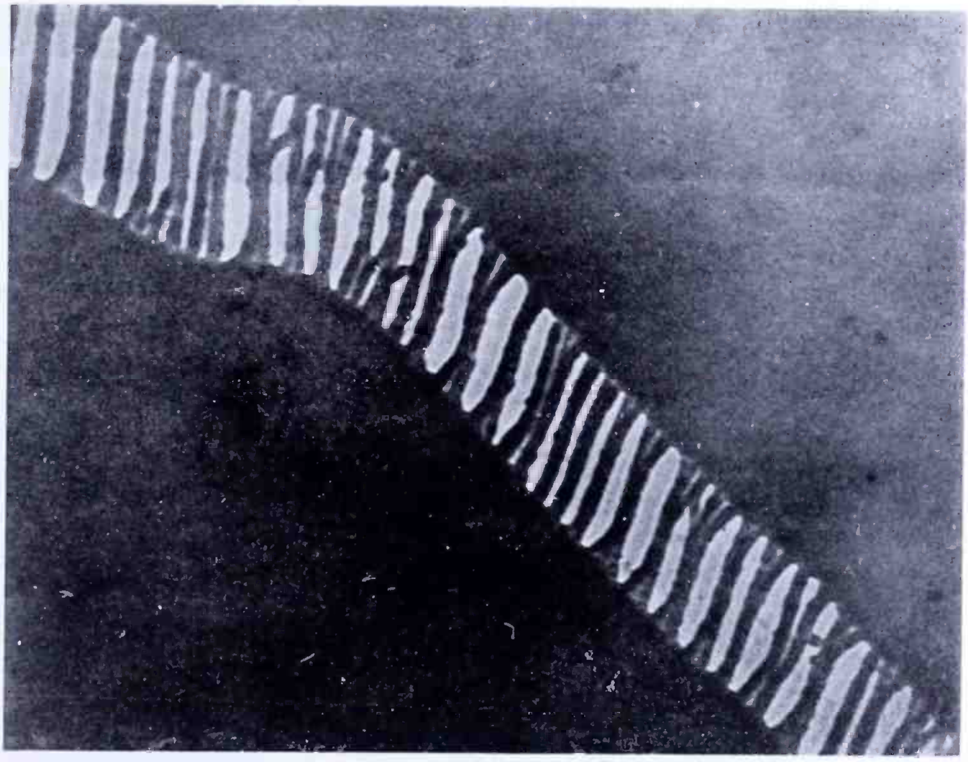


Fig. 37—Polystyrene.
(Magnification 38,000 diameters)

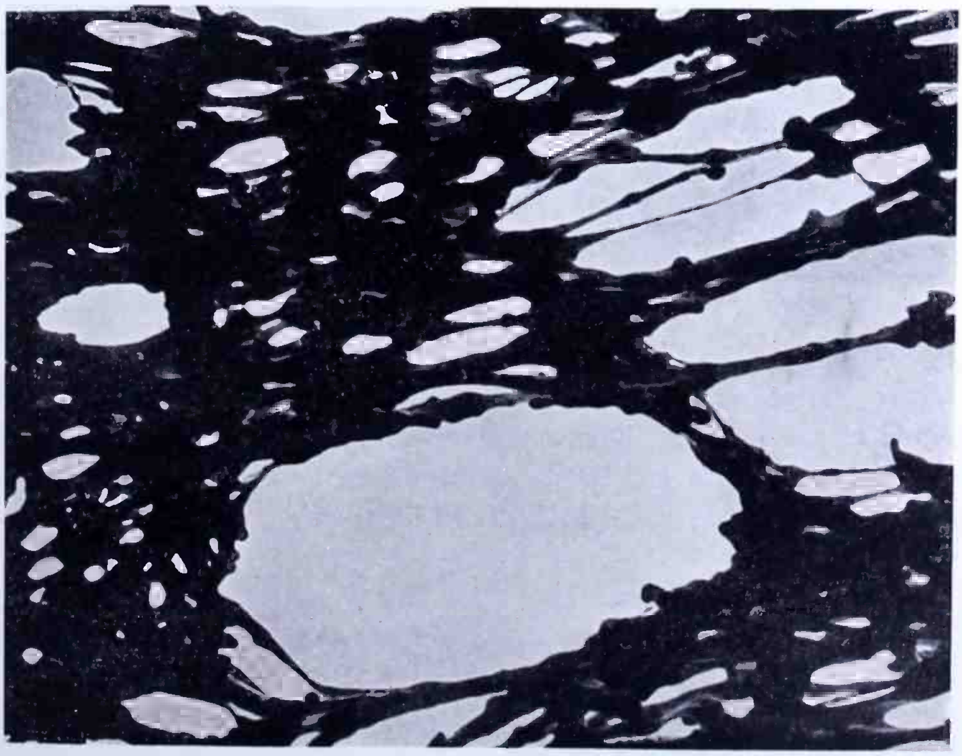


Fig. 38—Vinyl chloride partially polymerized.
(Magnification 17,000 diameters)

any pertinent difference; under the electron microscope one of these materials was found to consist of minute plate-like particles, while the other is made of granules. Another interesting example is given in Figure 35. This is a calcium carbonate which was found to be very active in its chemical absorption, much more so than other samples of calcium carbonate. The electron microscope revealed that the large particles which could be resolved with an optical instrument were in reality aggregates of fine crystals; furthermore, the crystals were

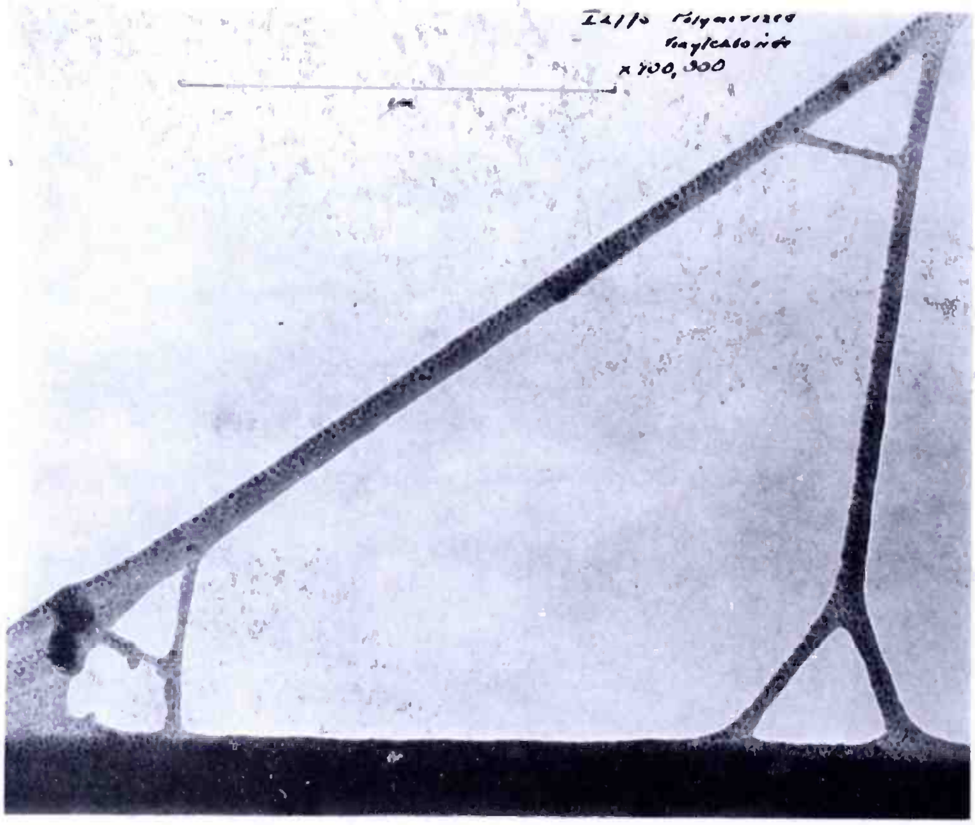


Fig. 39—Koroseal.
(Magnification 50,000 diameters)

found to be porous. Figure 36 is a sample of magnesium oxide, obtained as smoke from burning magnesium. It will be seen that all the particles down to the limit of resolution are minute cubes. This is a matter of considerable interest in connection with the chemistry of combustion.

A final example in connection with the chemical application of the electron microscope relates to plastics. Coherent research in this important field cannot yet really be said to have started. However, a number of micrographs of various materials have been made which illustrate the possibilities of the instrument, although much of the detail seen in the plates cannot at present be interpreted. A micrograph of polystyrene, a material of great practical importance in the radio industry, is shown in Figure 37. The material is in the form of a thin film supported on a fine mesh screen. The minute thread-like fibers ranging in width from 30 to 50 millimicrons, which can be seen where the film has broken, is quite characteristic of this class of material. Figure 38 shows vinylite, that is a vinyl chloride which is only slightly polymerized, used in the manufacture of hemp rope. This same material, after more complete polymerization, becomes Koroseal, an artificial rubber. It is shown in Figure 39, and for comparison

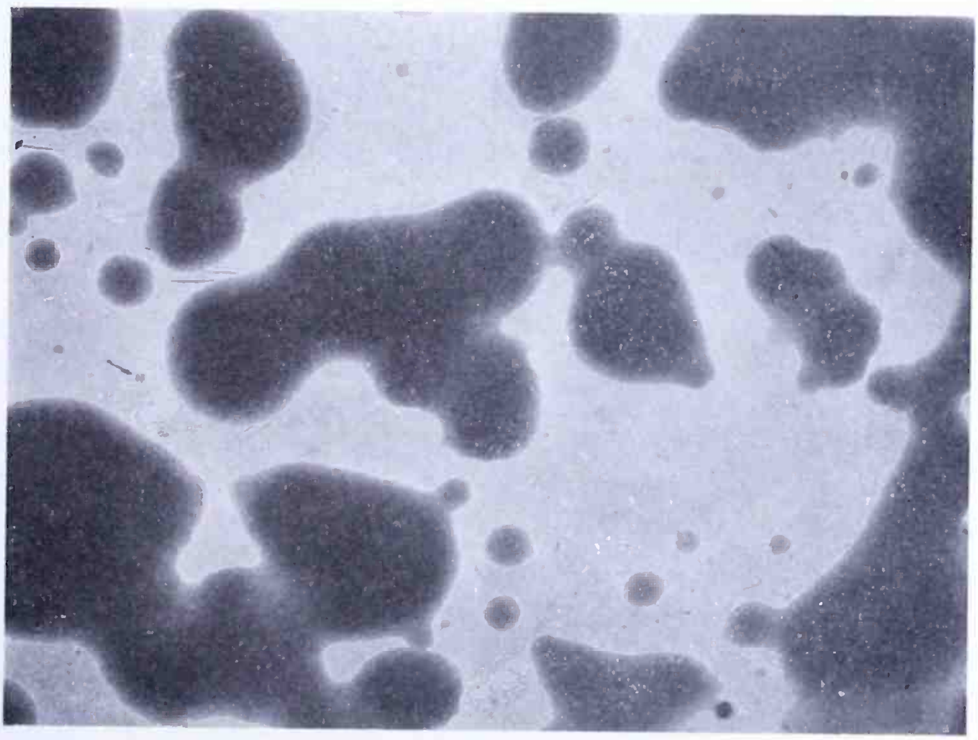


Fig. 40—Natural latex.
(Magnification 5,000 diameters)

natural latex is given in Figure 40. It will be noticed that there are many minute dark specks or micelles visible in the micrograph of Koroseal. Many of these are only about 3 millimicrons in diameter, or less, which is not too large to be a single chemical molecule.

References

[1] "A New Electron Microscope," L. Marton, M. C. Banca, and J. F. Bender, RCA Review, Vol. V, No. 2, pp. 232-242, October, 1940.

[2] "Recent Developments in the RCA Electron Microscope," J. Hillier and A. W. Vance, *Proc. I.R.E.*, Vol. 29, No. 4, pp. 167-176, April, 1941.

[3] "Stable Power Supplies for Electron Microscopes," A. W. Vance, RCA Review, Vol. V, No. 3, pp. 293-300, January, 1941.

[4] "Bacterial Morphology as Shown by the Electron Microscope," Stuart Mudd and D. B. Lackman, *J. of Bacteriology*, Vol. 41, No. 3, pp. 415-420.

[5] "Bacterial Morphology as Shown by the Electron Microscope, II. The Bacterial Cell Membrane in the Genus Bacillus," S. Mudd, K. Polevitzky, T. F. Anderson, and L. A. Chambers, *J. of Bacteriology*, Vol. 42, pp. 251-264, August, 1941.

[6] Electron Microscopic Studies of Biological Reactions, I. Reduction of Potassium Tellurite by *Corynebacterium diphtheriae*," H. E. Morton and T. F. Anderson, *Proc. Soc. for Experimental Biology and Medicine*, Vol. 46, pp. 272-276, 1941.

[7] "Demonstration by the Electron Microscope of the Combination of Antibodies with Flaggellar and Somatic Antigens," Stuart Mudd and T. F. Anderson, *Jour. Immunology* (in press).

[8] "A Study of Purified Viruses with the Electron Microscope," W. M. Stanley and T. F. Anderson, *J. of Biological Chemistry*, Vol. 139, No. 1, pp. 325-338, 1941.

[9] "A Study by Means of the Electron Microscope of the Reaction Between Tobacco Mosaic Virus and Its Antiserum," T. F. Anderson and W. M. Stanley, *J. of Biological Chemistry*, Vol. 139, No. 1, pp. 339-344, 1941.

[10] "Surface Studies with the Electron Microscope," V. K. Zworykin and E. G. Ramberg, *J. of Applied Physics*, Vol. 12, No. 9, pp. 692-695, September, 1941.

[11] "Preliminary Report on 300,000-volt Electron Microscope," V. K Zworykin, J. Hillier, and A. W. Vance, *J. of Applied Physics*, October, 1941 (in press).

RECEIVER CONTROL BY TRANSMITTED SIGNAL — "ALERT" RECEIVER

By

Harmon B. Deal

RCA License Laboratory, New York, N. Y.

Summary—The method and means of using sub-audible frequencies superimposed on radiophone program circuits to accomplish control or switching operations at remote receivers, without interference with regular programs is described. Extensions of the system together with some presently useful applications are discussed.

Introduction

THIS paper describes a method and apparatus for a new service in broadcasting of all types, sound, television, and facsimile. It is believed that the method provides a useful and appealing possibility, which is technically feasible, readily available and, in a time of national emergency, has vital importance.

The scheme permits a broadcasting station to turn on all receivers within range which are equipped with an attachment receiving device, and to turn them off. The plan is feasible from all viewpoints, for either sound broadcast band or ultra-high-frequency band, although perhaps more economical for the former.

Under this scheme, a broadcast station can, at any time of day or night, turn on receivers left tuned to it, then can make news or warning announcements, and then can turn off the receivers. Use of the facility would of course be limited to important news flashes. Any broadcast station which abused its ability and turned on receivers for unimportant announcements would soon find itself without receivers to turn on. The control signals do not interfere with the regular programs in any way, as they are inaudible. The cost of apparatus at the transmitting station is so low as to be negligible since the equipment required is merely a receiving-tube oscillator.

Cost of the receiving attachment is not known exactly, because production design of one special part of it has not been applied. The order of cost of the attachment is clearly apparent, however, from the fact that it consists of a simple receiver with a special relay. It will be readily possible to sell the device at a retail price somewhere between ten and twenty dollars even in beginning quantities.

With the loudspeaker left in, the device is a complete receiver in itself. The model described herein, using a 3-tube t-r-f chassis, of course, has poor radio performance by ordinary home reception standards. Production design for this form would undoubtedly be better with a four- or five-tube superheterodyne circuit, such as is widely used in low-priced receivers. It is this form, that is with loudspeaker, which has been termed the "Alert Receiver," for use in Civilian Defense organizations. A block diagram of this system is shown in Figure 1.

Investigation was made of the possibilities of effecting operations

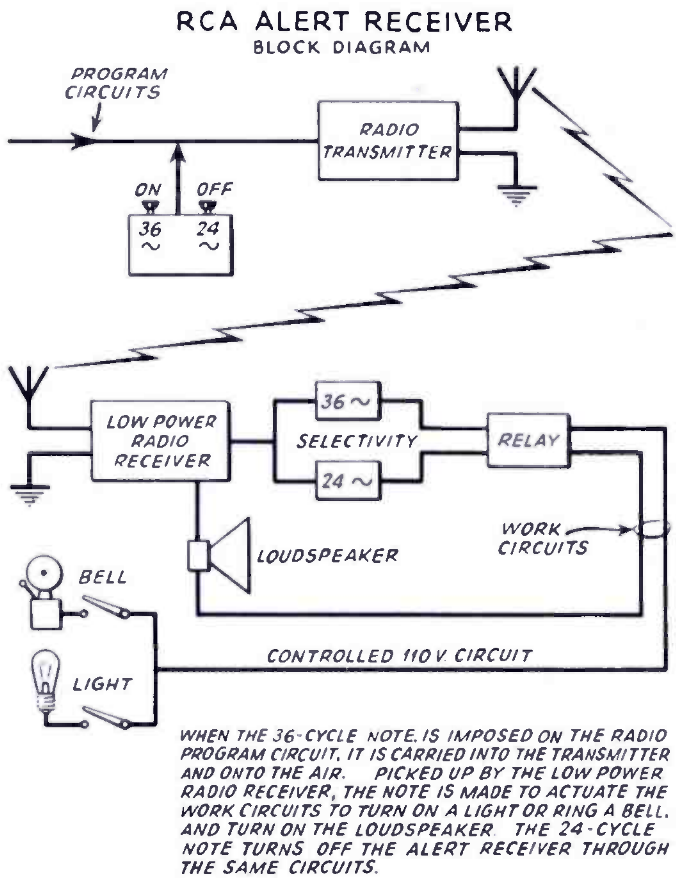


Fig. 1

at a remote radio receiver by signals originating at and controlled by operators at the transmitting station.

One type of controlled-receiver system was built and tried out in actual field operations. These field tests demonstrated the feasibility of such systems.

The control functions performed by the test equipment were limited to the turning *on* and *off* of the distant radio receiver, but simple extensions of the method demonstrated will permit the number of control functions to be increased, as will be made apparent later. The on-and-off functions are in a sense primary and should properly precede inclusion of additional controls which may later prove desirable. The operation of the system, its limitations and possible extensions are demonstrated by the performance of the simple *on*-and-*off* control.

In the system described, control signals are used to modulate the carrier of the broadcast station which is to exercise control.

If a remote receiver is to be controlled only as to *on* and *off*, it is immaterial whether the controlling signal is audible or not, since the control would precede the start, and follow the termination of the broadcast that was the occasion for turning the receiver on. There may be exceptions to this; for example, there may have been in progress a program to which many people were already listening and to whom an audible control signal would be objectionable. Moreover, to make the system universal, it may prove desirable operating technique to transmit the "on" control either constantly, or intermittently for short intervals, during the broadcast. If this is the preferred operating practice, then the control signal obviously should be inaudible. Furthermore, there may be other desirable control functions which from their nature, require that they be transmitted during, and avoid interfering with, the program. For these reasons it was decided to test the system with inaudible controlling signals.

Inaudibility could be obtained by super-audible or sub-audible control frequencies. Super-audible frequencies would encroach on adjacent broadcast channels and were but briefly considered.

The sub-audible frequency band appears to be the proper choice because it is immediately available and is at present not used. The average radio receiver and loudspeaker cut-off below 100 cycles per second and even the best receivers with large speakers and bass compensation do not to an appreciable extent transmit frequencies below 50 cycles per second. This indicates that a band in which control signals will not affect program material being broadcast simultaneously, lies below 50 cycles per second. It is recognized of course that the low-frequency cut-off of the receiver is not abrupt, and the lowest usable frequency and amplitude of the control signals will produce the least program interference.

Harmonics of the control frequency, whether originating in the source or produced in the receiver, will lie in the acceptance band of receivers and will be audible. Harmonics may be produced in the receiver by overload or by cross modulation of control frequency and program. Both effects are aggravated by large control-signal amplitudes. These several considerations indicate that the control-signal amplitude should be kept small.

Except for observations to determine at what levels the control signal did become audible, the control signals during these tests were adjusted to produce 5 per cent modulation of the transmitter. That is, the ratio of program to signal peak amplitude was approximately 20 to 1.

Listening tests with a high-quality radio receiver (television field test receiver) adjusted to give maximum bass and minimum high-frequency response (the most susceptible condition), revealed that a 10 to 1 ratio of program to signal did not cause objectionable interference.

The unit at the receiver by which control is effected is in itself a radio receiver. However, since its function is to operate on control signals only, it may be made simple and inexpensive.

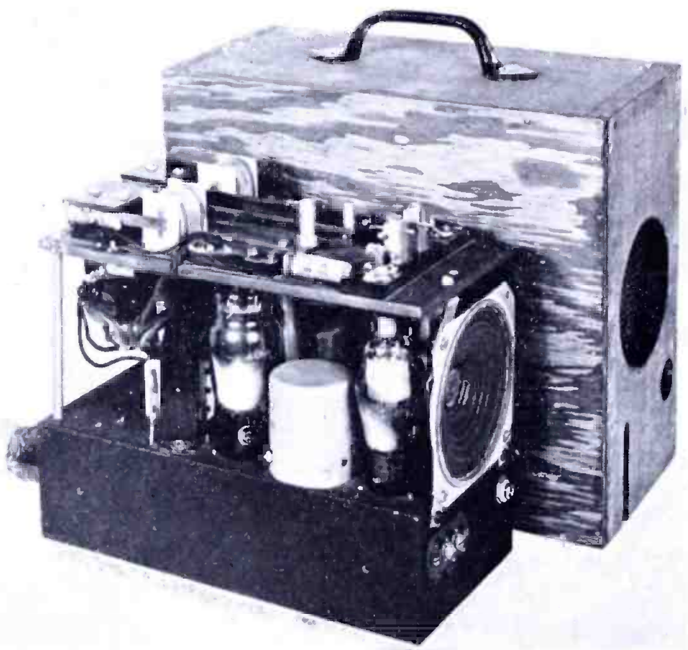


Fig. 2

The cost and power consumption of the control unit is an important consideration affecting the commercial acceptance of such a system. No economy in power or tube life is realized if the control unit has as many tubes or consumes as much power as the set to be controlled. In this event the set itself could be left on continuously, (entirely eliminating the need of the controlling unit), although the controlled set would still have the large advantage of silencing the background noises or undesired programs. If, however, the main receiver has a large power consumption, or a large number of tubes, or expensive tubes (as a Kinescope) the economy and convenience of the control becomes outstanding.

The control unit employs a selective device (a tuned reed in the units to be described) which, when actuated by the proper control signal from the transmitter, operates a relay which has adequate power capabilities and by which final control is effected.

With the possible exception of certain complementary functions, each control function requires a selective reed and a relay at the receiver unit, and a control frequency at the transmitter.

Figure 2 is a photograph of the receiver unit and Figure 3 is a diagram, showing the arrangement of the various receiver components. This unit will operate on carrier signal of 5000-microvolt modulated 5 per cent by the control signal. The power consumption is 28 watts from the 110-volt power supply.

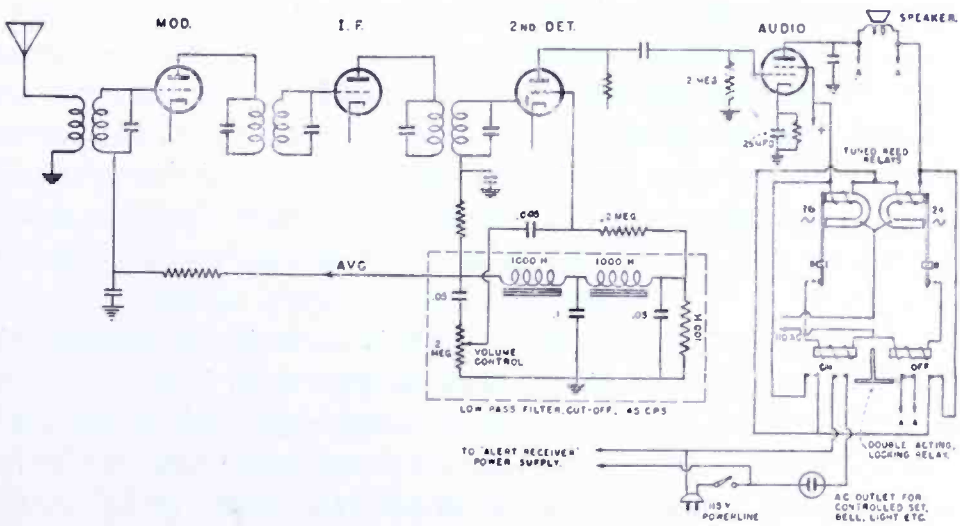


Fig. 3

No attempt was made to attain minimum size or lowest power consumption in this unit. The use of the smaller, multi-purpose tubes now available should secure both. The construction and testing of this equipment did serve to show in broad outline the requirements of such a control unit.

A model built for operation on broadcast band was given laboratory tests, and then modified for operation in the 50-Mc band. In this form, it was field tested for several months in cooperation with the NBC television transmitter W2XBS (Empire State Building, New York). The "on" signal was sent out a few minutes before every scheduled television broadcast and the "off" signal immediately after every broadcast. This was carried on for many weeks and the receiving device, located at various places at different times, from 1 to 45 miles from the transmitter, always functioned.

Alternative and additional control functions may be added either through an extension of the present systems by adding control frequencies, by the use of combinations of two frequencies, or by an entirely different system such as stepped or consecutive switching control systems, always keeping in mind the limitations of the sub-audible control channel available.

The Receiver Unit

The previous discussion has mentioned some of the characteristics of the receiver unit of the control system. The design of such a unit is exceedingly simple.

If a loudspeaker is not included in the unit, audio frequencies above 60 cycles may be cut off, so that side-band cutting becomes a virtue, and linearity of detection, harmonic distortion, etc., need not be considered. When use of loudspeaker is desired, program reproduction can be obtained through a volume control by a high-pass path around the low-pass filter, as shown in Figure 3. Subsequent discussion will be concerned chiefly with factors affecting control functions rather than program reproduction since factors involving the latter are well known.

The input signal of the receiver unit is a carrier, modulated with both program and control signal. The program level is some 20 times the intensity of the control signal. If high-frequency components of the program can be stripped off prior to detection, so much the better. However, the r-f or i-f circuits should not be so sharp that frequency drift, automatic-volume-control, detuning, etc., are serious factors in the proper operation of the receiver unit.

To avoid audio stage overloading, the program signals are filtered out by means of a low-pass audio filter whose cut-off is higher than the highest control frequency used. The passed components are the lowest program frequencies and the required control frequencies. These frequencies are then amplified with lessened probability of overload.

In the application known as the "Alert Receiver," where program material is reproduced on a self-contained speaker, a high-pass path whose low-frequency cut off is about 200 cycles is in parallel with the low-pass filter. This permits speaker operation through the volume control (see Figure 3) for the high-frequency program material, whereas the low frequencies are not affected by the volume-control setting. Moreover, the ratios of low to high-frequency components on the grid of the power tube greatly favors the low frequencies.

This precludes the overload mentioned before. The resultant loss of fidelity is not significant in that the speaker is presumably used only to receive voice announcements.

Control-Frequency Source

The requirements imposed on this unit are:

1. Freedom from harmonics
2. Constancy of output frequency
3. Output voltage of level to equal 5 per cent of signal amplitude.

A control-signal frequency having these characteristics must be provided for each control function. For the test equipment described two control frequencies were provided.

Various types of primary oscillators for generating the control signals were investigated. These included beat-frequency oscillators, tone-wheel generators, vibrating reed, tuning-fork generators, etc. All were rejected for reasons of size, external noise, or failure to meet the three requirements mentioned before.

Two types of oscillators which gave excellent performance were the negative-feedback type and the resistance-capacitance phase-inverting type. Both of these types were continuously variable over the required control-frequency band and neither required inductively tuned circuits, so that frequency control was effected by variable resistance elements. The ability to vary the control frequency was necessary in the preliminary investigations.

The signal frequencies adopted for the field tests were 24 and 36 cycles. The 36-cycle frequency is near the upper limit of the sub-audible band, and thus afforded an operating test of a limiting frequency. Another reason for this choice of control frequencies was that they could be quickly and precisely checked against the 60-cycle power-supply frequency.

This frequency check is an important service consideration. Investigation showed that the largest frequency deviation from 60 cycles for the larger power-supply systems is about 0.2 cycles per second. This is easily within the precision of tuning required for control purposes. If the 60-cycle power-supply frequency is thus taken as a reference standard the reed tuning can readily be checked in the field, and the control-signal source checked against the same standard.

It is more convenient to have only push buttons for the station operators to manipulate for each control. Moreover, there is no need for the control-signal source to be continuously variable, and indeed there are reasons why it should not vary at all.

A control-signal source was built which included these additional features. The control frequency was a fixed sub-harmonic of 60 cycles or of 60-cycle harmonics. This signal source consisted of amplifier circuits for obtaining harmonics of 60 cycles and an additional frequency-dividing circuit for obtaining sub-harmonics of these first frequencies.

The counter output of sub-audible frequency was filtered to improve its waveform and was then available as a control frequency. The ratio of the division was changed by inserting or removing resistance with a push-button switch.

The control-signal source used in the recent tests consisted of a frequency doubler and a frequency tripler operating from the 60-cycle

Fig. 4

power supply. These circuits thus produced 120 and 180 cycles. The input to a frequency divider of the counter type was connected to the 180-cycle output by means of the "on" push-button switch and alternately to the 120-cycle output by means of the "off" push-button switch. The division ratio was adjusted to $\frac{1}{5}$ so that the counter output was 36 cycles and 24 cycles for "on" and "off" respectively. A low-pass filter of 2 stages was sufficient to eliminate harmonics in the output wave so that the residual distortion was of the order of 1 to 2 per cent. A photograph of this unit with cover removed is shown in Figure 4.

The above system can be extended indefinitely by using additional harmonics of the reference standard and by using different counter ratios so that more control frequencies of less frequency separation may be obtained.

Such a control-signal source is believed to meet all the requirements of stability, flexibility, and simplicity, and to possess desirable mechanical features.

The Selective Unit (Tuned-Reed System)

The requirement imposed on this unit is that it be dependable, light, rugged, sensitive, and most important of all, that it be highly selective. Several of these requirements are mutually incompatible.

The selectivity must be high so that low-frequency components of programs that are applied to the selective system are incapable of setting it into forced vibration. Such program components might be, for example, sustained organ or bass viol notes.

The lowest note of any musical instrument probably is higher than 30 cycles so that if the resonant system is tuned substantially below 30 cycles the possibility of forced vibration of the reed is remote. If the reed system is highly selective even the lowest program note will not operate the relays. High selectivity in the tuned-reed system will permit many control functions in a small band of frequencies.

In the preceding discussion the word "reed" has been used to indicate the selective system responsive to the control signal, since a tuned-reed system was used for this purpose in the field test units. Any other selective system that sharply discriminates between two adjacent frequencies could be used. At first thought it would appear that tuned electrical circuits are applicable here. In a sense they are, but reactive elements at frequencies of from 10 to 50 cycles are heavy and large, and above all have very poor Q factor. A Q of 20 would be very good with ordinary electrical circuit elements at these frequencies, whereas a Q of 250 to 300 is readily obtained with a mechanically tuned reed.

Regeneration might be used with electrically resonant circuits to greatly increase the Q, but it was feared that regeneration is too much a function of factors variable with time, temperature, age, voltage, etc. to be reliable. It is possible that the arguments against use of regeneration are not justified. Certainly it would be desirable to achieve the required selectivity by electrical circuits rather than by mechanical moving parts if size, weight, and other considerations are the same.

Mechanical systems too have defects, such as noise, vibration, weight, temperature coefficients of frequency, mechanical fatigue in the spring elements, etc. Also considerable difficulty is experienced in resonating mechanically tuned systems to a fixed-control frequency. Further there is a gravitational effect on the reed frequency in the structure shown in the photograph of Figure 2.

A method of overcoming gravitational effects is to use torsional elastance. The factors then determining the resonant frequency are torsional elastance and moment of inertia of the suspended mass, and gravity has no effect on the system.

The polarizing or d-c flux in the yoke structure also has a frequency effect similar to gravitational effects in that the magnetic pull is increased for motion toward and decreased for motion away from the stationary armature. This condition is not serious however since the reed is tuned with the polarizing flux present, and it can be assumed that it will not change materially under operating conditions.

For exactly tuning large numbers of reeds in production and to facilitate service in the field, some of the parameters of the system

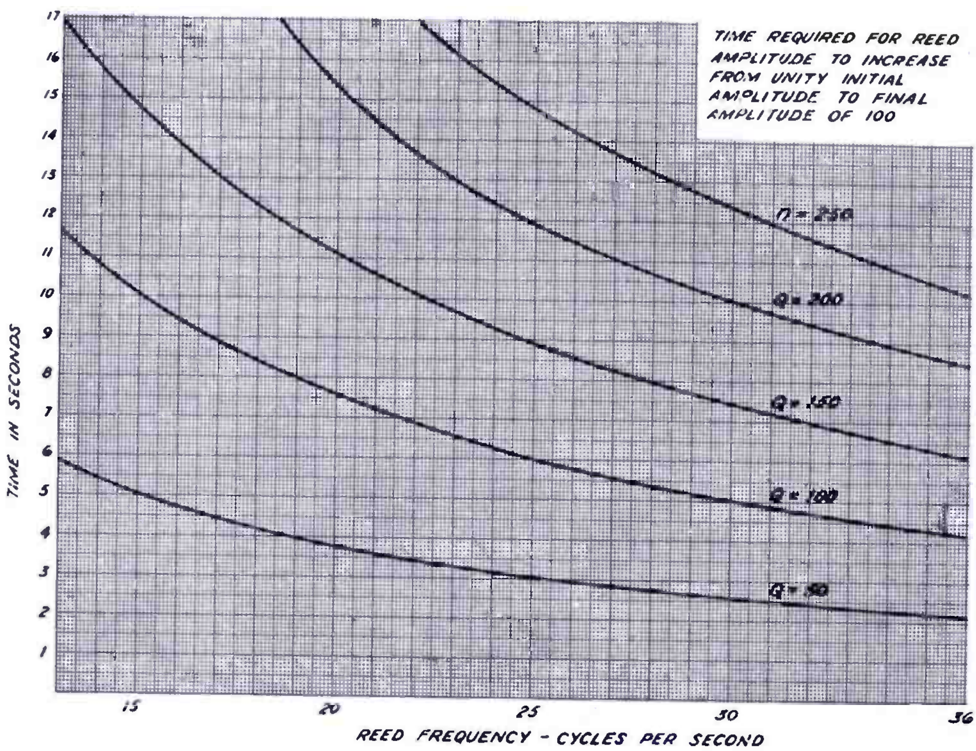


Fig. 5

must be made readily adjustable so that any reed may be quickly and precisely adjusted to its control frequency.

The present reed design includes provision for mechanically tuning the reed to resonance while in operation. Otherwise the operation of tuning will be lengthy, laborious and uncertain. Several methods of reed adjustment were tried sufficiently to show that good mechanical designs satisfactory from production and service aspects are possible.

Another method of varying the reed frequency is to change the position of the driving magnet. This changes the driving point and also the magnetic bias discussed before. Both have a secondary effect on reed frequency. The resonance characteristics of a typical reed system are shown in the graph of Figure 5.

An observation made early in the investigation of reed systems is that the contacts which the reeds strike may, if stiff or massive, affect the reed frequency. This would be of no consequence if the first contact were always sufficient and certain to operate the control relay. The first contact will not be sufficient in a certain percentage of cases if the relay is a-c actuated, because reed contact may occur at a time in the a-c cycle when the voltage is zero. If the reed frequency is close to 30 or 20 cycles or some integral sub-multiple of 60 cycles several consecutive vibrations might also make contact when the a-c voltage has zero or nearly zero phase.

The conclusions to be drawn from this are: that the reed frequency preferably be made a non-integral sub-multiple of 60 cycles, if an a-c relay is used. Suitable frequencies may be 24-36-40-45, whereas frequencies of 15-20-30 or 60 might give erratic operation. This is not to say that integral sub-multiple frequencies of 60 cycles are entirely unsuitable, since the reed tuning and the 60-cycle power supply frequency are unlikely to be exactly at the same frequency and at zero phase. Furthermore, operation will be satisfactory (or even better) if the phase of the 60-cycle supply with respect to the reed is not zero but 90°. It does say that there exists the possibility of failure to actuate the relay on the first few contacts of the reed and contact spring. The second conclusion is that the contact spring must be so light, or so positioned, that the reed frequency is not changed by the first few contacts with the spring.

It was observed that when the reed-vibration amplitude had increased to where contact with a massive or stiff contact spring was attained, the reed was thrown into partial or secondary whip vibrations and its whip vibration amplitude fell off until this vibration had become damped out. In some cases the driving force and the secondary vibrations were such that oscillation at the new mode were sustained. In any case operation was faulty, when the contact spring was not light, and since no trouble with light springs were encountered, they were thereafter used with the units.

The above discussion points out the possibility of coincidence of reed contact and a-c supply voltage occurring at zero time phase. The longer the control frequency at the transmitter is applied the less are the chances that such coincidences will result in failure of the relay to operate.

The reed system shown in the photograph used a single tuned reed for each frequency. This is a quarter-wave reed section and requires a zero impedance point at the fixed end, that is, the clamped end must be held stationary. This requirement can only be approximated with any practical system. Construction of the reed system to use the mass of the transformer, chokes and chassis of the receiver as the inertia system which serves as the fixed point for the vibrating reed is suggested. This feature was not incorporated in the structure used in the first tests, since it was desirable to interchange the reed unit between the various receivers.

In order to provide sufficient inertia to counterbalance the vibrating reeds, the armature contact and reed assembly were mounted on a heavy iron plate. This is shown in Figure 2. This plate was responsible for a large part of the weight of the receiver unit, and even with this large

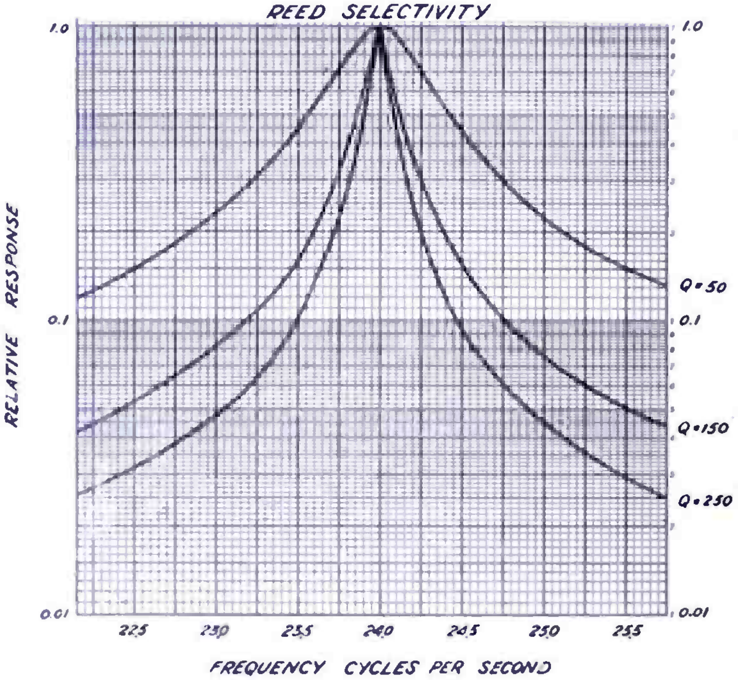


Fig. 6

mass, some reed vibration was transmitted through the plate support rods. At one frequency of the reeds, the supports and mass of the plate were resonant and the entire chassis vibrated. Such vibrations of the "fixed" part of the system introduce losses which diminish the amplitude of the reed.

Reed structures of the half-wave type (tuning-fork types) are balanced systems and have certain advantages, since they require no fixed point. There is the attendant disadvantage, however, that the two tines of the fork must now be simultaneously tuned to the control frequency.

As discussed before, long time application of the reed-driving source (i.e. the sub-audible control signal from the transmitter) diminishes the probability of coincidence of reed contact and zero phase of the a-c actuating voltage. There is another factor which also requires that the driving force be applied for a long time (6 seconds were used in the tests).

The low frequencies used and the low decrement necessary, demand relatively long applications of the driving force. This is fundamental and is applicable whether electrical or mechanical resonant systems are used. This can be understood from the following considerations:

In an oscillating or vibrating system the ratio between two amplitude maxima (of current or deflection) is a function of the damping

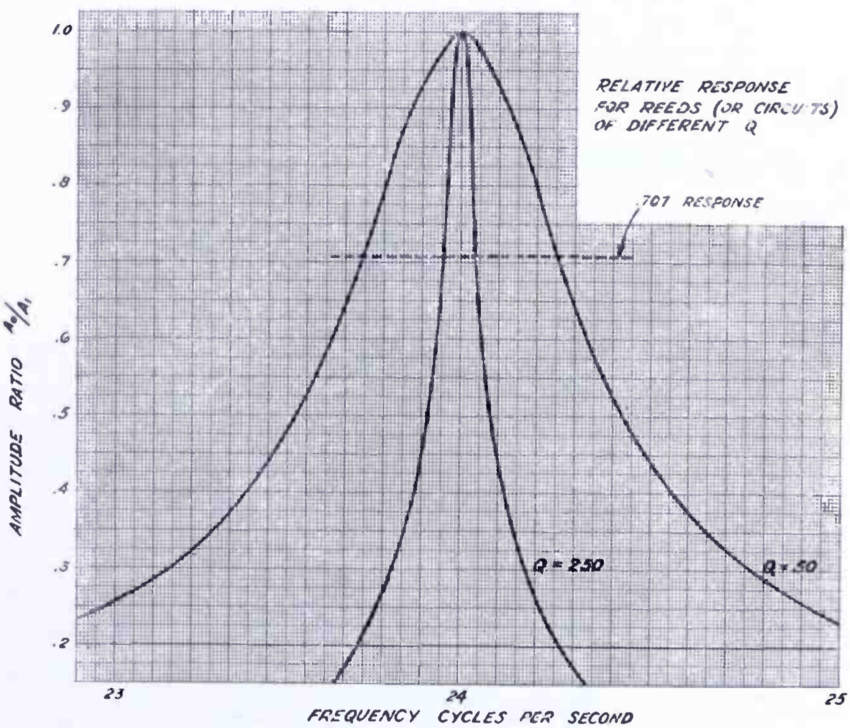


Fig. 7

of the system. This is true if the amplitude is increasing due to the application of a *resonant* driving force, or if it is decreasing due to the removal of a driving force. The signs of the incremental and decremental cases are different, but the coefficients have the same absolute value. If the system selectivity factor is Q, the logarithmic decrement is related as follows:

$$\Delta = \frac{\pi}{Q} \tag{1}$$

If the ratio between the undriven amplitude and the maximum (contact) amplitude of the reed is to be 100 to 1 (where the undriven minimum amplitude is that due to noise, hum, mechanical vibration, or any non-resonant forces acting on the reed) then the number of oscillations required to build up an amplitude (A_o) ratio of 100 to 1 is implicit in the relation

$$n\Delta = \log_e \left(\frac{100A_o}{A_o} \right) = 4.6 \tag{2}$$

So that $$n = \frac{4.6}{\Delta} \text{ or } n = \frac{4.6Q}{\pi} \tag{3}$$

If the reed frequency is f, then $$\frac{n}{t} = f \tag{4}$$

where t is the period of the reed. So that $$t = \frac{4.6Q}{\pi f} \tag{5}$$

As an example, if the Q of a reed is 240 and its frequency is 24 cycles per second,

$$t = \frac{4.6 \times 240}{\pi \times 24} = 14.6 \text{ Seconds} \tag{6}$$

the time required to change the reed amplitude by 100 to 1. This may seem to be a long time for securing control operation. However, it is fundamental and inescapable for either mechanical or electrical system with the Q and frequencies used. A graph showing the relationship between Q, t, and f is presented in Figure 5.

If the attempt is made to secure faster control operation by diminishing the Q of the reed, the selectivity of the system is impaired.

The ratio of response A_o at resonance to response A_1 off resonance is given by the following relationship:

$$\frac{A_o}{A_1} = 1 + jQ\left(\frac{f_1}{f_o} - \frac{f_o}{f_1}\right) \tag{7}$$

Again assuming a ratio of resonant to off resonant response to be 100 to 1, the resonant frequency (f_o) to be 24 cycles per second, and the Q to be 240, it is found that

$$\frac{A_o}{A_1} = 100 = 1 + jQ\left(\frac{f_1}{24} - \frac{24}{f_1}\right) \tag{8}$$

$$f_1 = 21.4 \text{ or } 27.2 \text{ Cycles per Second}$$

Thus, for good Q, the spacing of control frequencies may be of the order of 6 cycles. For low Q the spacing must increase as shown in the graphs of Figures 6 and 7.

The ratio of 100 to 1 has here been assumed for purposes of comparison and computation. Ratios of 10 to 1 or even 5 to 1 between the driven and undriven amplitudes are feasible, and these permit closer possible spacing of control frequencies and substantially diminished time of operation.

The essential point of these considerations is that whether a mechanical or electrical system is used, the time required to effect control at low frequencies is long. To shorten this time the selectivity must

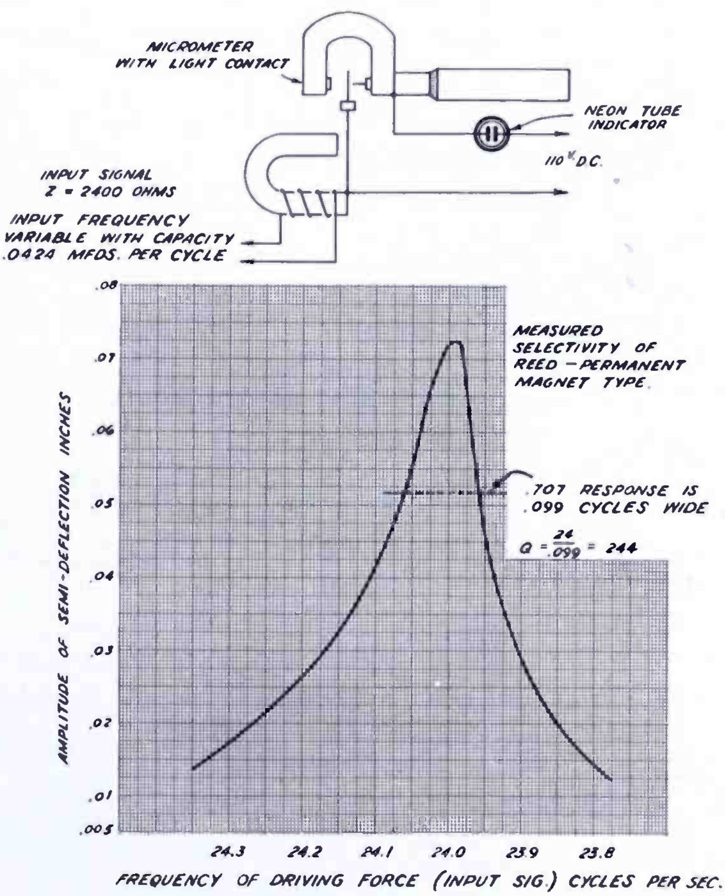


Fig. 8

be lowered, making the system more susceptible to forced vibrations either from adjacent control frequencies or from hum, noise, or low-frequency program notes.

The relay used for *on*-and-*off* functions is an a-c actuated relay with one set of contacts suitable for breaking a power circuit. This relay is double acting with mechanical locks, so that after the control signal has actuated the relay, no further application of control signal is required. Reference to Figure 3 will show that there are contacts on the relay which short the reed driving coil, after the control function of that reed has been attained. This arrangement serves several purposes. It makes available all driving force (control signal) from the output tube on the reed it is desired to operate since the other reed is short-circuited by the relay contacts. The arrangement acts to stop the reed vibration as soon as the control function is attained and it diminishes the possibility of inadvertent operation of that reed by possible program notes with which it may be resonant.

It is of course possible to arrange for the control signals to be applied by a clock switch arranged to complete some schedules of on-off or other controls without attention on the part of the operator. It may be desirable also that the "push-button" *on*-and-*off* switches at the transmitter be supplied with time delay so that manual operation of the switches will provide automatically for a 5- or 10-second contact without need for the operator to hold the switch on for the necessary time.

The resonance characteristic of a reed system is shown in Figure 8. Schematically indicated in the same figure is the method of determining this characteristic. Either constant reed amplitude for varying input voltage with frequency or constant input voltage for variable amplitude with frequency will yield the same results.

It is hoped that the preceding discussion will have shown that channels suitable for control purposes are at present available and unused, and that extensions of the system to include additional desirable control functions is entirely feasible.

A TWO-SIDE NON-TURNOVER AUTOMATIC RECORD CHANGER

BY

B. R. CARSON

RCA Manufacturing Co., Inc., Camden, N. J.

Summary—In the past, automatic record changers which played both sides of the record have been quite complicated and consequently expensive. A new design featuring simplicity of parts is described. It does not require the record to be turned over to play the second side. This is accomplished by the use of a tandem-tone arm and two pickups with reversal of the direction of record rotation for the playing of the under side.

AUTOMATIC record changer popularity has steadily increased since the introduction of the magazine machine in 1926. In that instrument the records were placed vertically upon a magazine, taken to the turntable, and then discharged into a cabinet drawer.

The induction-disc motor used in this machine, though low in torque and having poor governor speed regulation, cost more than a complete record-changer having refined reproduction and more features would cost today. Since the advent of the magazine machine there have been many record-changer developments employing various means for automatically playing records. Some have used individual discs for holding the records while playing and some have used magazines with individual slots into which the records were placed. There have been turntables carrying a stack of records with suitable reject means for tossing the records off after playing, hopper types, and various transfer and claw types. 1937 saw the introduction of the drop-type record changer which has since become the standard for the industry. It presented economies, style, accessibility and the possibility of various cabinet adaptations. Most of the developments in record changers have been on machines designed to play one side of a record. However, there have been some machines developed to play both sides of a record by turning the record over. These instruments were, in general, complicated and high-priced. For some years, therefore, there has been a demand for a record changer capable of playing both sides of records and a stack of records equal to the largest albums, yet sufficiently inexpensive so as to be salable in good commercial quantities and having simplicity in construction so as not to present a manufacturing or a service problem.

A recent development has resulted in a new two-sided record changer having a tandem tone arm; thus enabling both sides of a record to be played without turning it over. This machine will operate a stack of 15 records—playing one side or both sides as desired.

The instrument will play the "M," "AM," or "DM" sequence of album record pressings of ten-inch or twelve-inch records. It has automatic stop, push-button control, reject for one side or both sides of a record and a 12-second record-change cycle interim. The tone-arm positioning is entirely automatic, eliminating the necessity for manually handling it at any time; the two selections on a record are played by merely placing the record on the instrument and pressing a button.

Fig. 1—View of playing position of the tone-arm.

The records, one or a stack, are placed upon the record-separator means. When the instrument is started the lower-most record is separated from the stack and falls on four pneumatic cushions located on top of the top-plate casting. The small turntable assembly, which has swung to a position below the record surface to discharge the previous record, swings back up, lifting the new record as it forces the latter to contact the two separator posts which align the hole on the record with the turntable spindle. The record, now on the turntable and revolving clockwise, is approached and contacted by the upper sapphire in the tandem tone arm and rendition of the top selction begins.

When both sides of the record are to be played, the intermittent cycle operates at the end of the top record selection. When the instrument automatically trips, the tone arm rises to a neutral position and swings counterclockwise clear of the record. The turntable reverses direction and revolves the record counterclockwise; the tone arm again approaches the record—this time from below—and the lower sapphire in the tandem arm rises and contacts the bottom surface of the record. At the conclusion of the selection, the machine automatically trips. The tandem tone arm then swings away allowing the turntable to swing down and to the left to a position where the played record slips into a record-storage drawer located at the side of the cabinet.

The machine may be set to play either ten- or twelve-inch records by manually turning the stationary record support to the proper one of its two 180° positions. The instrument may then be set to play one side or both sides of the records by properly adjusting the lever at the front right side of the instrument. The design of this machine provides a gravity feed of the records from the start when the records are manually placed on the top of the separator through the complete

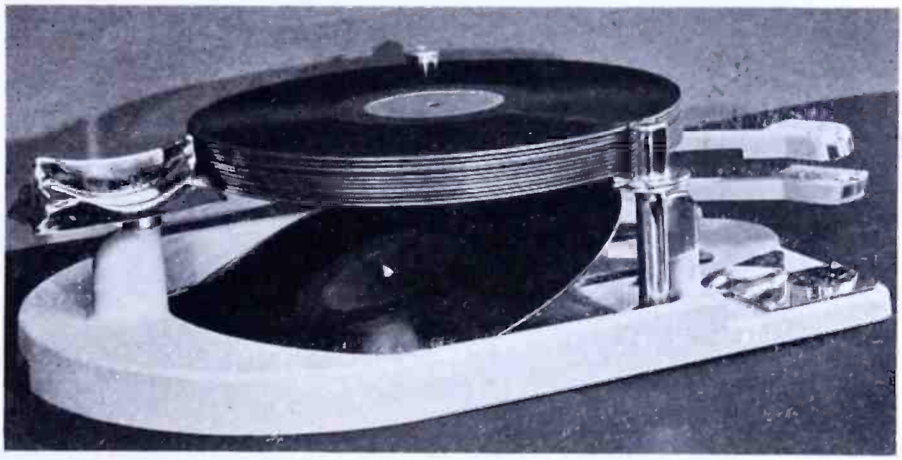


Fig. 2—Depositing record in storage compartment.

cycle of operations ending with the depositing of the records in the storage drawer. This feed eliminates the expensive magazine structure found in many machines having the capabilities of this instrument and the heavy torque which would be necessary for the operation of a magazine mechanism which required the records to be lifted.

The separators automatically compensate for varying record thicknesses, having helical teeth—as part of the die castings—for raising and lowering the separator knife. The separators transmit the load of the records to a ball point at the bottom of the separator shaft so as to exert the least friction; thus enabling a small inexpensive low-torque friction motor to do the work of changing records in a short cycle time.

The tandem tone arm is fabricated of lightweight die castings and its vertical bearing is provided with adjustable cone pivots. Friction must be at a minimum since the sapphires must follow the irregularities in records with a constant one-ounce pressure. The tone arm is counterbalanced by means of a spring for reasons of low inertia; consequently, the up and down sapphire pressures are maintained by the use of springs. The tone-arm horizontal bearing is of the sleeve type employing a top and bottom annular thrust bearing using one commercial ball. This is sufficient for the light load and gives the necessary ease of motion required for proper record traction. The pickup stylus is designed so as to be reversible by the factory and is set in the opposite directions in the upper and the lower pickup respectively. Thus, when playing the top of a record the rotation of the record moves the surface in the direction away from the stylus pivot and when playing the bottom of a record the reversed rotation of the record moves

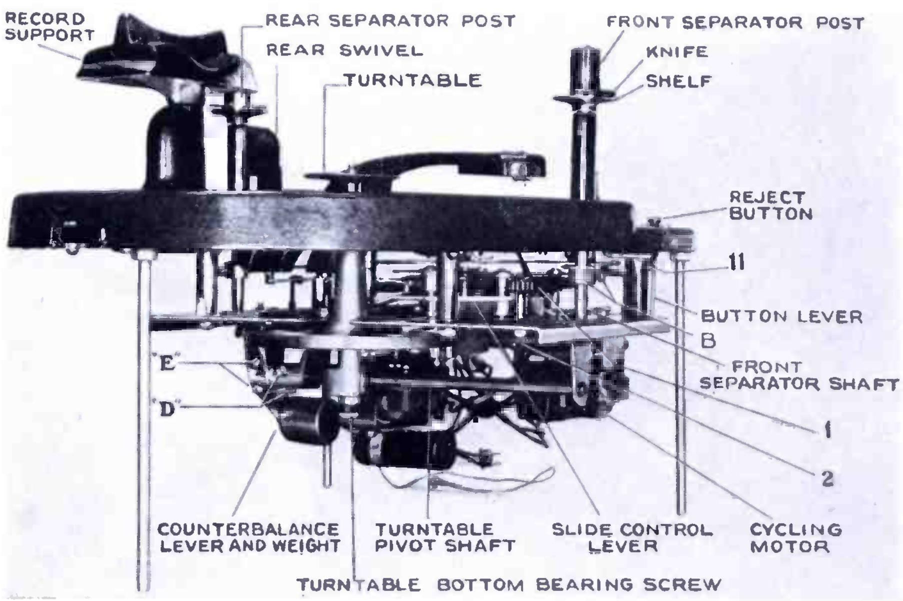


Fig. 3—Side view of the turn-table chassis.

that surface also away from the reversed stylus pivot. This is necessary to prevent snubbing the lower sapphire.

The automatic mechanism is tripped by the back swing of the tone arm actuated by the sapphire riding a record eccentric groove. The tripping means operates a mercury switch hanging as a pendulum, thus requiring the least amount of work for operation of the switch. When the pendulum swings the mercury switch closed, the cycle motor is energized. Finally, after the change cycle has been completed, the switch is reset, automatically ending the cycle.

Two small friction-drive motors are used to operate this record changer. They were employed instead of a larger single-geared motor such as used in the past for the same amount of work. Revolving gears during a record rendition have always been a potential source of trouble, irrespective of the damping means employed. In this present instrument the higher gain needed for the low-noise pickups, together with the possibility of trouble from microphonics, prohibited the use of revolving gears during record rendition. Therefore, the turntable of this machine is frictionally driven by a self-aligning, two-directional-synchronous motor having excellent constant-speed qualities. The cycling (record-changing) motor is of the induction type having high torque for driving the mechanism through its cycle. The small turn-able, drive disc, and one record are all that revolves during the record rendition; the long turntable bearing and low revolving mass gives good anti-rumble performance.

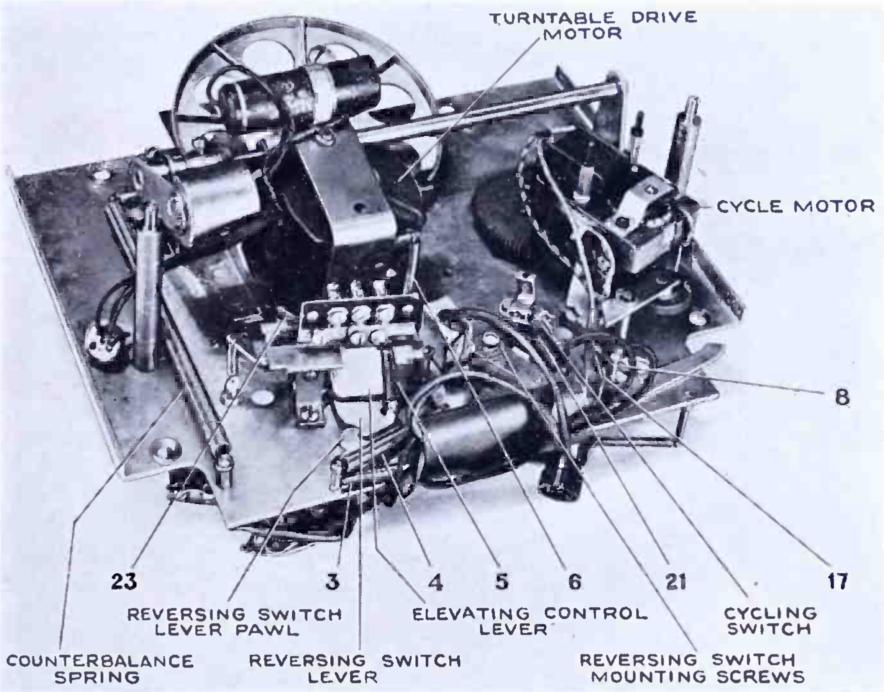


Fig. 4—Bottom view of the chassis.

With the very light pickup pressure—only one ounce—used in this instrument, it was quite a problem to feed the sapphires into the first music grooves without having the needles tend to jump grooves. The problem was further complicated by the fact that the first music groove varies appreciably on different records. On some records it is close to the edge while on others it is half an inch in from the edge. Some records have a lead-in groove and some do not. In order to maintain the best tangential relation, essential for good tracking between the pickup stylus and the record grooves, it was necessary to locate the sapphires at such a distance from the tone-arm pivot that the arc through which the sapphires swing would pass beyond the turntable spindle. Therefore, when the top side of a record was being played, the clockwise rotation of the record had a tendency to frictionally draw the sapphire toward the spindle and into the first music groove while when the bottom side of a record was being played the counter-clockwise rotation of the record had a tendency to frictionally push the sapphire toward the outer edge of the record. Consequently, any immediate energy release means, such as a spring, having sufficient energy to push the bottom sapphire into the first music groove against this adverse force, would be strong enough to drive the top sapphire half way across the record with the help of the force already acting there. The problem was finally solved by resorting to the energy stored in a spring damped with a suitable material. Tests were conducted to ascertain the tem-

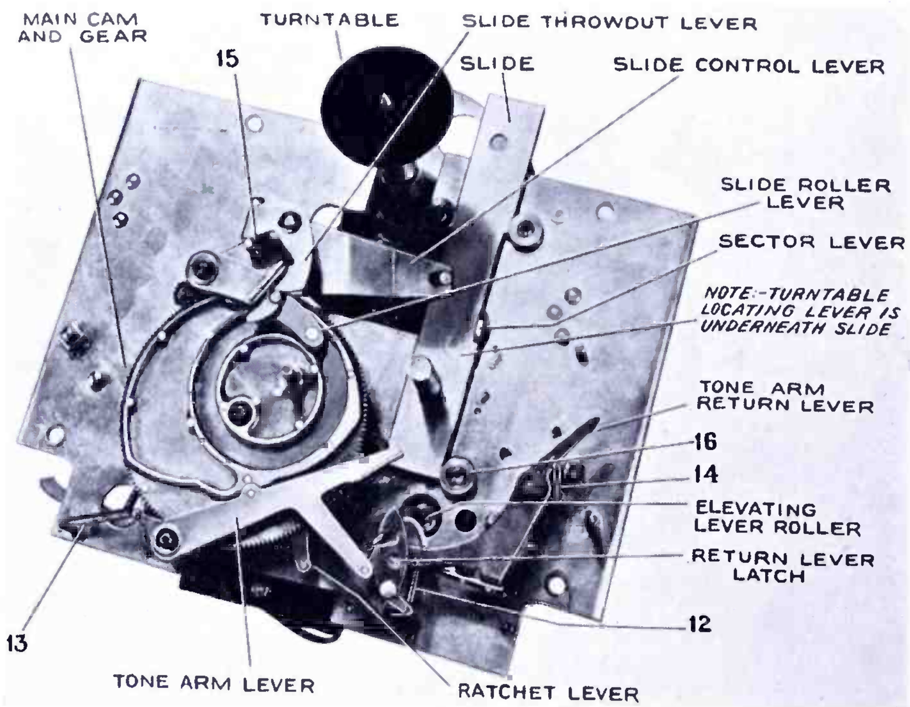


Fig. 5—Top view of the chassis.

perature characteristics of this material. A two-second time differential was found to exist over a temperature range of 35° F to 120° F. This means that at normal room temperatures the feed-in will be practically immediate.

The mechanism cycles necessary for playing either a single side or both sides of a record—known as the main and intermittent cycles—are operated by a cam gear and slide device controlled by a star wheel whose action is governed by a control lever. When only one side of a record is to be played the cam gear and slide device are fixed together and perform simultaneously, turning the separators and taking the record away after one side has been played. When both the top and bottom sides of a record are to be played, the intermittent disengages the slide device at every other cycle, permitting the cam gear only to perform (the cam gear operates the tone arm and the motor directional switch).

Five switches are necessary to provide proper performance of this instrument through its various possible operations. The purpose of the first—the manually-operated on-and-off switch—is obvious, as is that of the turntable-motor-directional switch which operates when the lower side of the record is to be played. The mercury-type cycling switch has been described earlier in the article. To prevent undesired sounds from being generated by the pickup during the record-change cycle, a pickup-shorting switch is provided. The last switch is the tone-arm-operated automatic-stop switch. This is actuated at the completion of the playing of the last record by the tone arm descending on the operating button of this switch in the absence of a record on the turntable. This stops the record changer completely, but does not turn off the amplifier tubes which are controlled by the radio on-off switch.

To start the changer, the desired record or records are placed on the separator posts, the on-off switch is moved to "on", and the "reject-start" button is pressed. This starts the change cycle and the operation of the instrument will continue until the completion of the last record again allows the tone arm to actuate the automatic-stop button, or until the manually operated on-off switch is thrown to "off."

Since the pickup units are not always alike in output characteristics, two adjustable capacitors are provided for regulating the output so the upper and lower units will give equal response. These adjustments are made in the factory.

In addition to being simple in operation this automatic record changer is designed for easy servicing. All parts are accessible without difficulty and disassembly for servicing can be easily accomplished.

A METHOD AND EQUIPMENT FOR CHECKING TELEVISION SCANNING LINEARITY

By

Vernon J. Duke

National Broadcasting Company, Inc., New York

Summary—This paper describes a method and equipment for determining scanning linearity of television picture equipment. Horizontal and vertical scanning are checked simultaneously. This is accomplished by comparing an electrically-generated time-unit pattern with a camera-generated space-unit pattern in such a way that the linearity of scanning of the monitor kinescope does not enter into the problem of adjusting camera scanning. Pictures and drawings are used to demonstrate various operating features of this method, and other uses of the equipment are discussed.

NON-LINEAR distribution of picture detail in a transmitted television signal is not necessarily due to the inability of the camera deflection systems to produce linear scanning. Experience in routine television operation has shown that such imperfections often are the result of uncertainties inherent in the method used for checking linearity of scanning. The usual check method, that of observing a test pattern transmitted by the camera under test on a monitor previously adjusted for linearity, is accurate in theory, but in practical operation has not been found entirely satisfactory. Any error in adjusting the monitor will surely be duplicated in adjusting the camera deflection, and in this connection it is well to remember that it is only necessary for the beams in the camera tube and the monitor tube to travel at the same (not necessarily uniform) velocity across a picture to give proper distribution in the reproduced picture. To meet the standard of uniform constant scanning velocity in the transmitted signal it has been found desirable to employ a check method which gives accurate results independent of monitor scanning linearity.

In order to determine when constant scanning velocity has been achieved in the television camera it is desired to make a comparison between space intervals marked upon a televised test chart and intervals of time. To do this, a method of superimposing two pictures on a standard picture monitor has been used. One picture, which will be known as a "space pattern", is obtained by televising a special test chart with the camera which is to be checked. The other, referred to as a "time pattern", is produced synthetically by special equipment to be described. These two patterns are so proportioned as to permit coincidence of their elements when superimposed electrically and

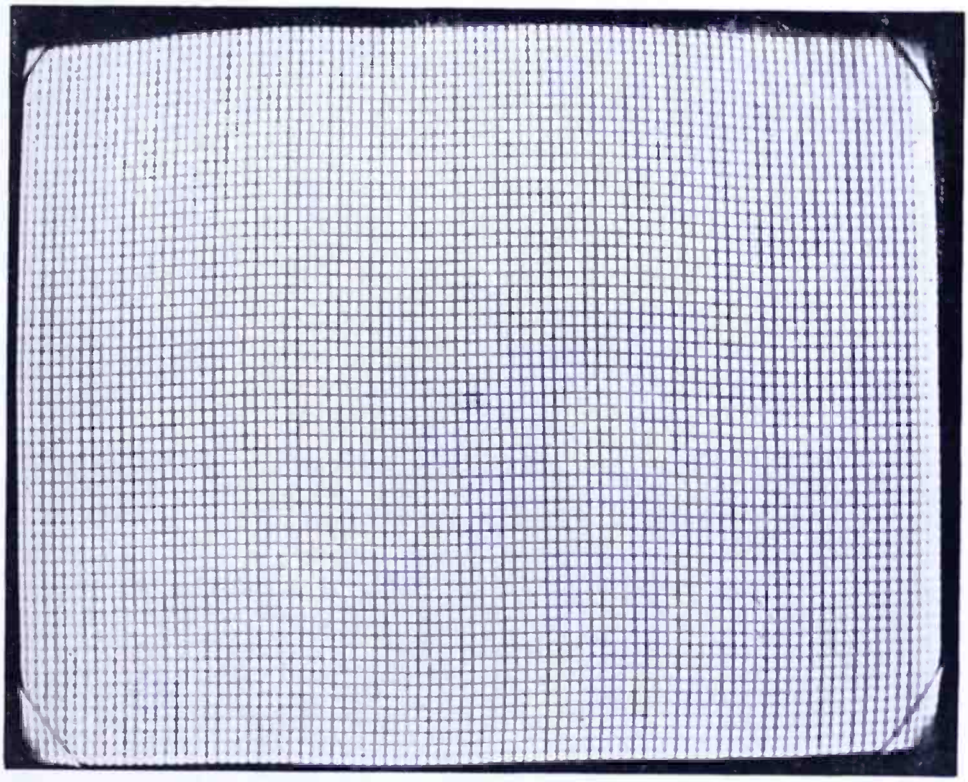


Fig. 1a

viewed on a kinescope monitor, the perfection of this coincidence being dependent upon the linearity of camera scanning, but independent of

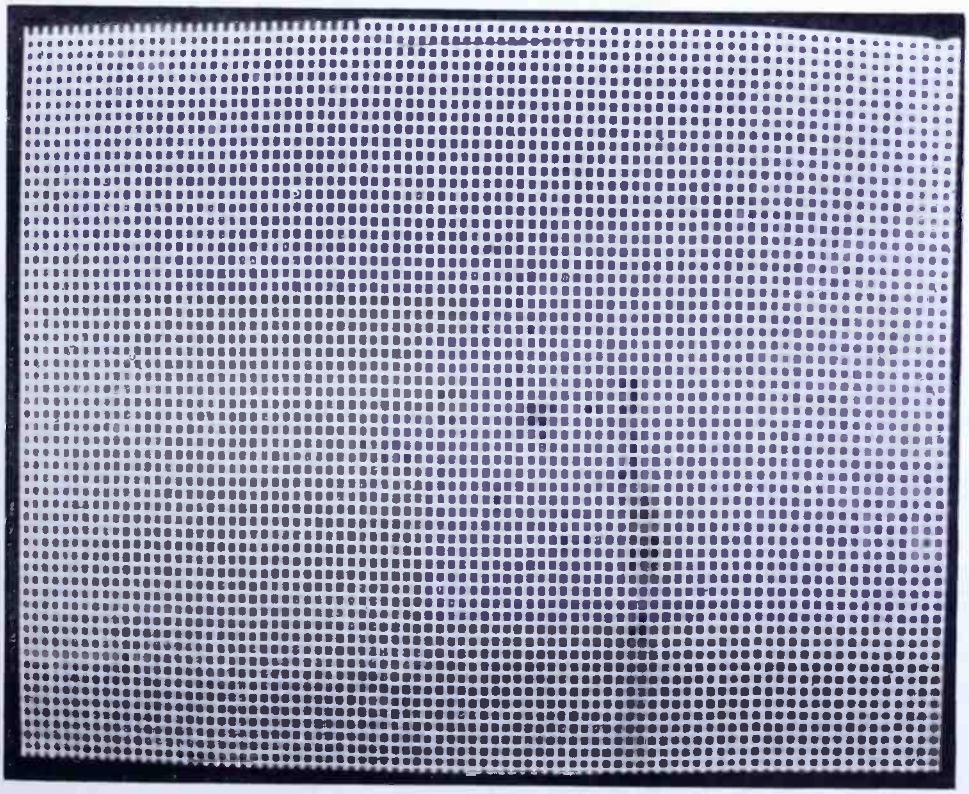


Fig. 1b

the linearity of scanning of the kinescope monitor. This last condition is an important one. Since it is only necessary to produce a comparison between the space pattern and the time pattern, the scanning of the kinescope may be overdriven to magnify or "zoom" up the picture on the monitor for close inspection of a portion of it. If the picture is expanded beyond the limits of the kinescope screen in this manner, the centering controls may be adjusted to permit examination of the entire picture a portion at a time.

As seen on a kinescope the time pattern consists of vertical and horizontal lines. The lines are very narrow, being one scanning line

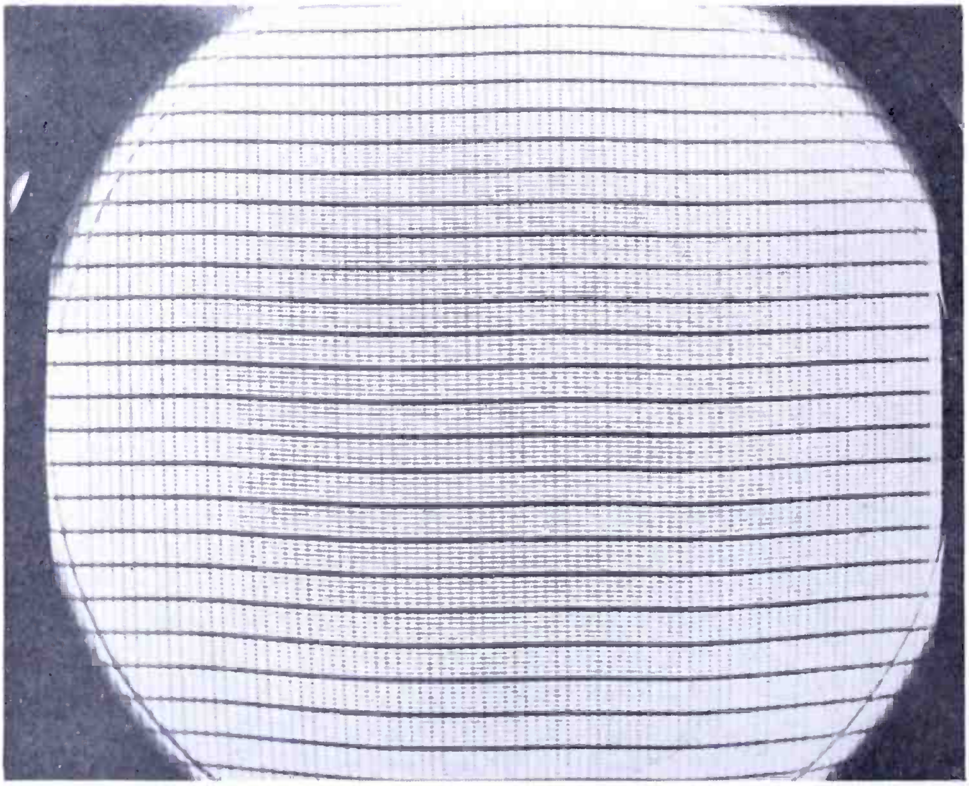


Fig. 2

in width for the horizontal lines and about the same for the vertical lines (provided all circuits have good high-frequency response). The general appearance is that of cross-section paper (Figure 1)—black lines on a white field or white lines on a black field (depending upon the polarity used). In order to produce such a stationary pattern electrically it is necessary for the synthetic picture impulses to be controlled from the synchronizing generator which controls the scanning processes. In the figures shown herewith the one-hundredth multiple and the seventh submultiple of the horizontal driving impulse were used to produce the vertical lines and the horizontal lines, respectively. Figure 2 is a kinescope photograph taken with vertical deflection overdriven in order to show the selection of every seventh scanning line in the time pattern. In the system as set up in the NBC television plant in Radio City each television studio monitor may have this time pattern signal fed in parallel with its video input by turning a switch convenient to the operator. Thus, the deflection characteristics of any camera chain may be checked on any monitor without regard to the monitor characteristics. (This same signal may be, and is in fact, used to check scanning linearity in the monitors also.)

To provide the "space pattern" referred to above, the test chart of Figure 3 was devised. When a sharply focused image of this chart precisely fills the scanned area on the mosaic of the camera tube, its

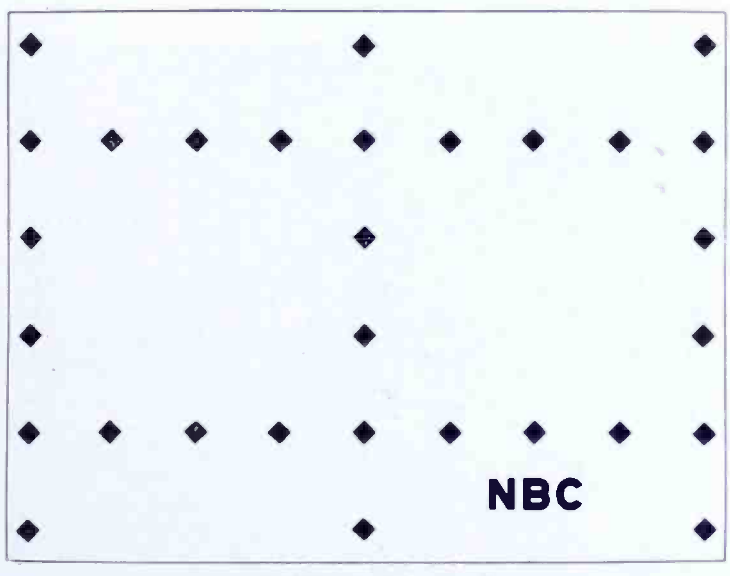


Fig. 3

reproduction on the kinescope monitor may be used with the superimposed "time pattern" to directly compare intervals of time and intervals of space. Since the intervals of time are inherently equal, the perfection of coincidence of the two patterns at all points is a direct measure of camera scanning linearity. The "space pattern" is designed for specific values of frame repetition rate, number of scanning lines, and per cent blanking intervals, and may not, in general, be used with other values of any of these standards. By this method it has been found possible to detect picture-element displacements of one-half of one per cent of the scanning cycles.

Illustrative of the design considerations involved is the application of this check method to a 441-line, 30-frame-per-second television system. From a practical and technical point of view it was found most feasible in this case to illuminate each seventh scanning line to produce the horizontal lines of the "time pattern". The vertical lines of the "time pattern" were chosen arbitrarily to mark intervals of one one-hundredth of the horizontal scanning cycle. This means that the vertical lines are produced by a signal whose fundamental frequency is $(441 \times 30 \times 100) = 1{,}323{,}000$ cps. The sharpness of the vertical lines as they appear on the monitor is made such that they are not wider than a scanning line if the system has good high-frequency fidelity. Due to the electrical sharpness of the vertical lines in the "time pattern" a poor high-frequency characteristic in the monitor amplifier, or beam defocusing of the kinescope is easily observed. (This pattern provides a good check on uniformity of kinescope focus provided the yoke has no defects.)

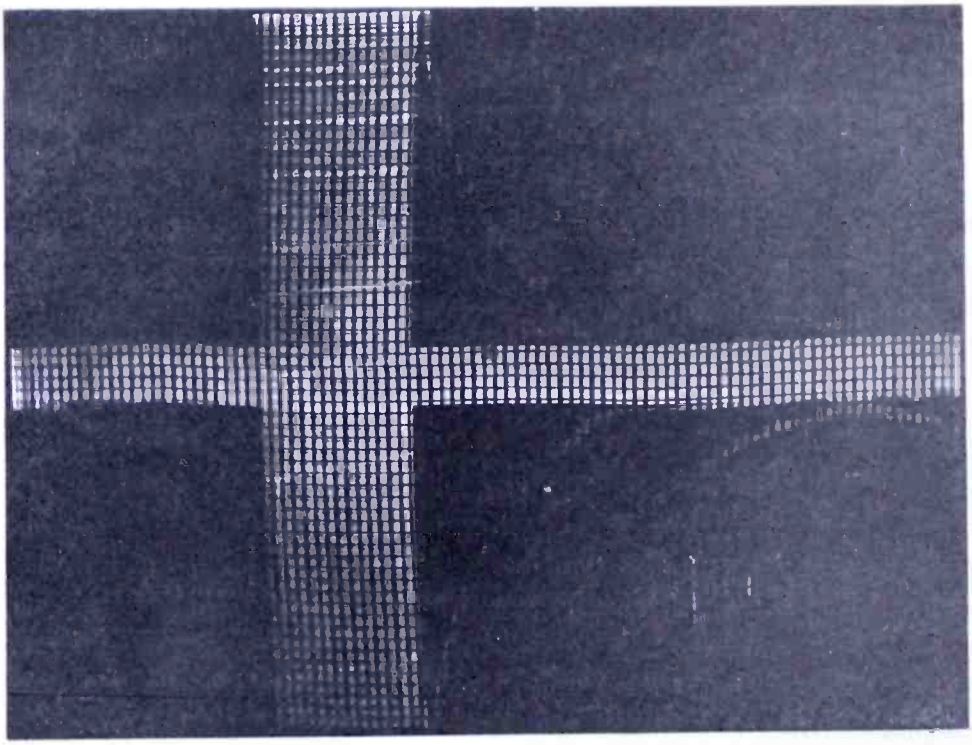


Fig. 4

We now have, except for blanking, a pattern similar to cross-section paper with 63 horizontal lines and 100 vertical lines. When an interval having 10 per cent vertical blanking is considered, the pattern will have 63×0.9 horizontal lines, or 56.7 timed intervals marked off by horizontal lines between the top and bottom of the picture. This means 56 visible lines with a fractional interval consisting of six scanning lines which will exist between the top of the picture and the first visible line, or below the last visible line and the bottom of the picture, or divided between the two spaces mentioned. With 15 per cent horizontal blanking there will be represented $(100 \times 0.85) = 85$ vertical intervals. This condition is represented by 85 illuminated vertical lines and 85 unilluminated spaces. Depending upon the relative position of horizontal blanking and the vertical lines, there will be viewed a pattern ranging from 86 lines and 85 spaces with a line at the extreme left and right edges to a pattern of 85 lines and 85 spaces with the extra space divided between the left edge and the first line and the right line and the right edge. So much for the visible lines on the "time pattern". Consider now the effect of the aspect ratio of 4 to 3 on the "time pattern". For convenience assume the pattern to be $8\frac{1}{2}$ inches wide, and $8\frac{1}{2} \times \frac{3}{4}$, or $6\frac{3}{8}$ inches high. If there are to be 85 horizontal intervals in $8\frac{1}{2}$ inches and the kinescope has linear scanning, each interval will measure 1/10

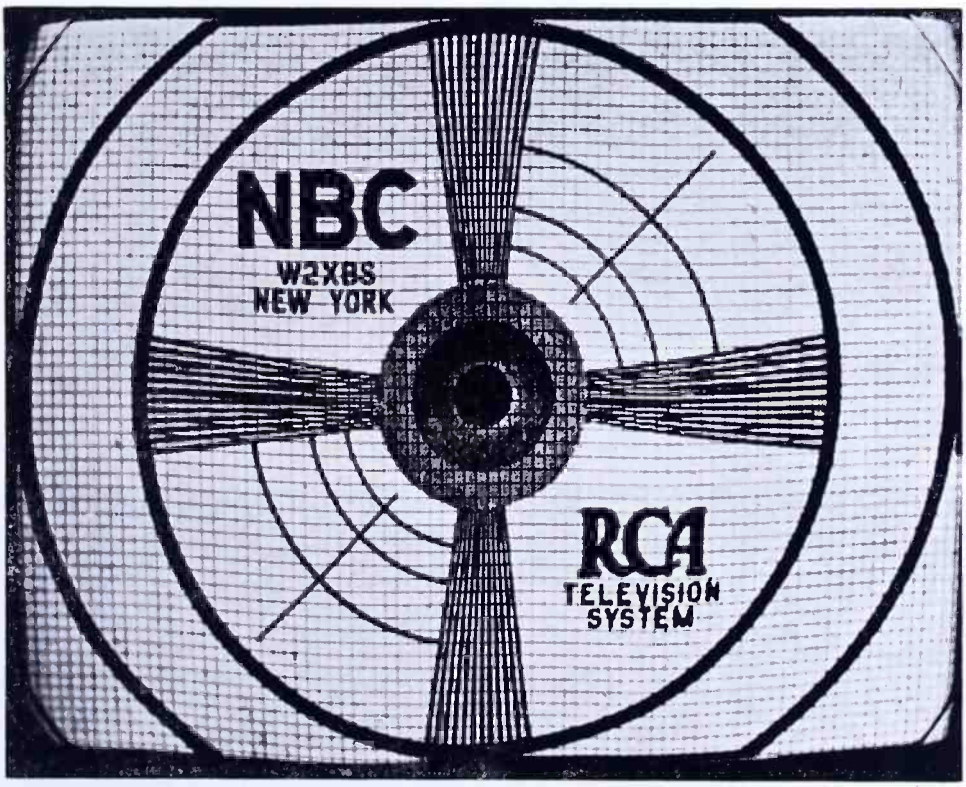


Fig. 5

of an inch. Similarly with a height of $6\frac{3}{8}$ inches divided into 56.7 intervals each interval will be slightly over 0.11 inch high. It is noted that this vertical distance contains one illuminated scanning line and six unilluminated lines. The "time pattern" viewed on the kinescope with proper distribution will appear as a field of small rectangles 0.1-inch wide by 0.11-inch high. From a sweep-frequency point of view the rectangle width represents 1.0 per cent of the horizontal scanning frequency and the height represents 1.58 per cent of the vertical scanning frequency. It will be seen that the horizontal lines of the "time pattern" are interlaced, just as the scanning lines are and, therefore, a complete frame (two consecutive fields) are required to produce the complete "time pattern" a single time.

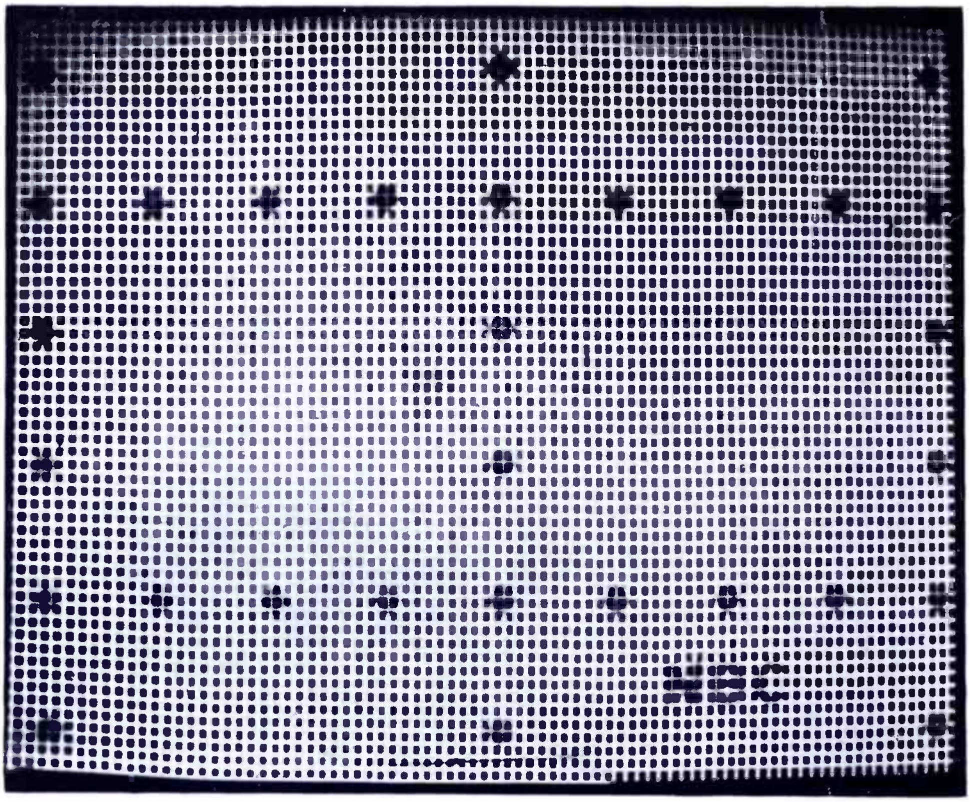


Fig. 6

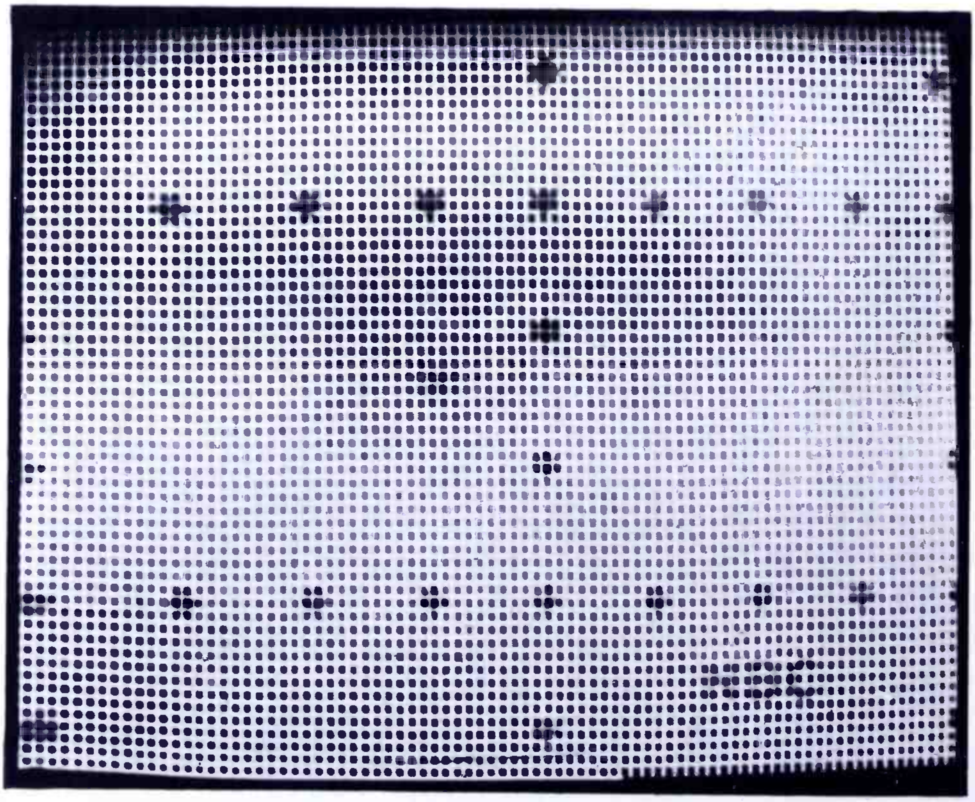


Fig. 7

Other uses of the "time pattern" signal are typified by Figures 4 and 5. Figure 4 shows how per cent blanking may be measured with it. In this photograph the monitor deflection was synchronized with especially phased signals to produce the visible "pulse cross" pattern shown, and polarity was reversed to make blanking white instead of black. Per cent blanking is obtained by counting the rectangles in each direction in the blanking signal area. No synchronizing signal is present on the blanking pedestal in this case.

Figure 5 shows the "time pattern" superimposed upon a test pattern obtained from a Monoscope. Among the imperfections shown up in this case is curvature of the scanning lines in the raster due to stray magnetic fields in the vicinity of the kinescope. This is caused in the yoke itself due to assymetric capacitances of the coil sections.

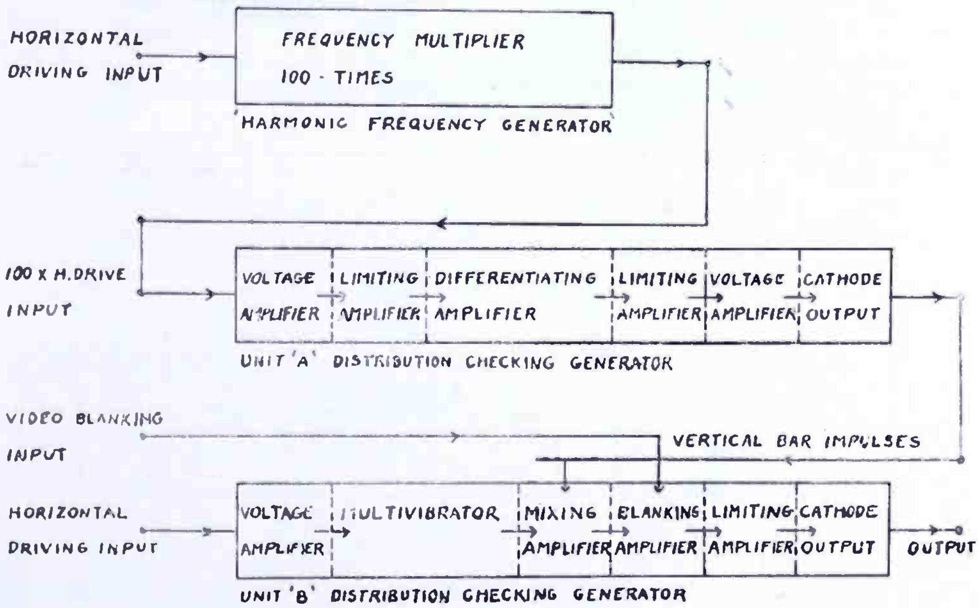


Fig. 8

Now that the "time pattern" has been specified for the system, we can go on to the design of the studio pattern employed in this illustration. The studio pattern or "space pattern" consists essentially of a system of black diamond-shaped dots on a white field, the dots being so spaced as to bear a definite relationship to the "time pattern". In this case the "space pattern" chart happens to be $20\frac{1}{2}$ inches by $15\frac{3}{8}$ inches. It was decided that each 10th vertical line of the "time pattern" was to be represented by a dot on the studio "space pattern" and there are, therefore, 9 dots in a horizontal row across the chart spaced 2.41 inches apart, with a space of 0.65 inch at either end of the row. This extra space represents $2\frac{1}{2}$ intervals on the time pattern. The spacing of the dots in the vertical rows on the chart were chosen to represent ten vertical intervals in the time pattern and since there are a total of 56.7 intervals to be represented, there will be 6 dots in each vertical row. The dots will be 2.71 inches apart vertically with 0.91 inch left over between the end dots of the column and the edges of the pattern. This extra space represents 3.3 horizontal lines on the "time pattern".

When the studio "space pattern" is properly focused to cover the desired area of the mosaic in the camera and the scanning is adjusted to size, it is a simple matter to view the two patterns superimposed on the monitor kinescope. Inasmuch as the studio pattern is optically focused and adjusted to size and position on the mosaic the camera scanning of the mosaic can be shifted horizontally and vertically by

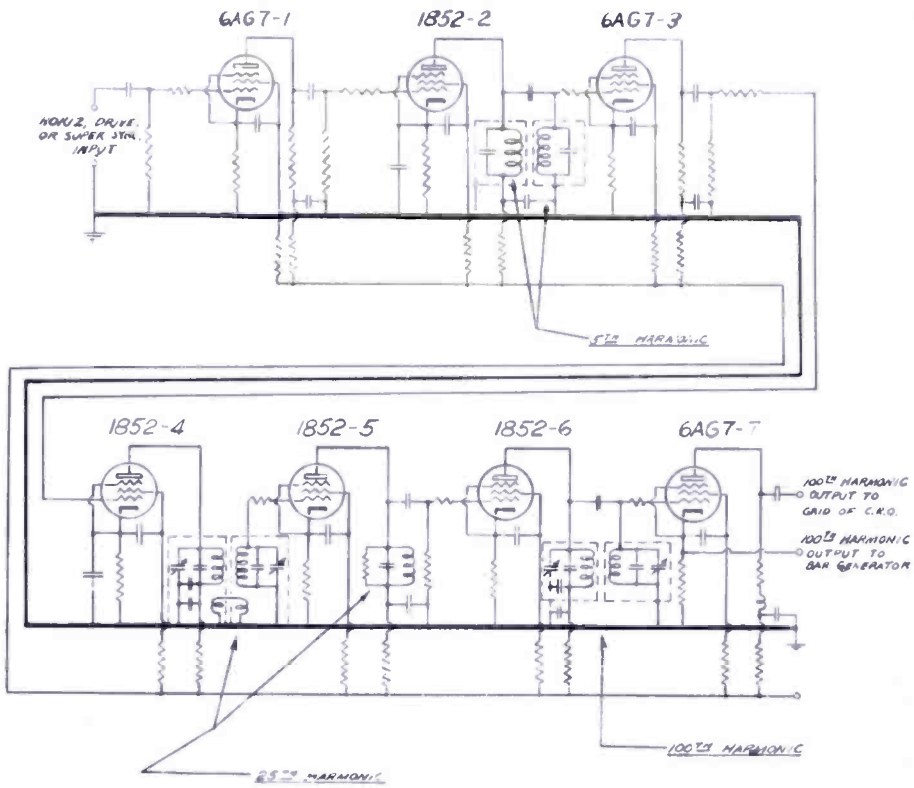


Fig. 9

means of the centering controls so that the two patterns coincide. The camera linearity controls can be adjusted to bring about coordination of those areas where correction is needed. An off-set of ½ of a space is ½ per cent on a horizontal cyclic basis and 0.8 per cent on a vertical cyclic basis. The photograph of Figure 6 shows the composite picture as viewed on the monitor, with the "time pattern" lines superimposed upon the televised picture of the "space-pattern" chart. Figure 7 is the same as Figure 6 excepting that the horizontal camera-scanning linearity has been purposely misadjusted. This method, although somewhat tedious to describe, is quite simple to use in practice, and automatically sets the aspect ratio of the camera without respect to the kinescope aspect ratio.

A single-line block diagram of the equipment developed for generation of the "time pattern" signal is shown in Figure 8. On this diagram a frequency multiplier is shown, which is a device that takes at its input an impulse of horizontal sweep frequency and, by means of a series of harmonic generators and amplifiers, develops at the output a stable impulse one hundred times the input frequency. This frequency multiplier was developed for other television monitoring purposes, but was found suitable for use in this application. A schematic circuit diagram of the frequency multiplier is shown in Figure 9.

Figure 10 is a schematic circuit diagram of unit A of Figure 8. This unit contains an amplifier which amplifies the voltage to such a value that it may be put through a limiting amplifier to give the signal

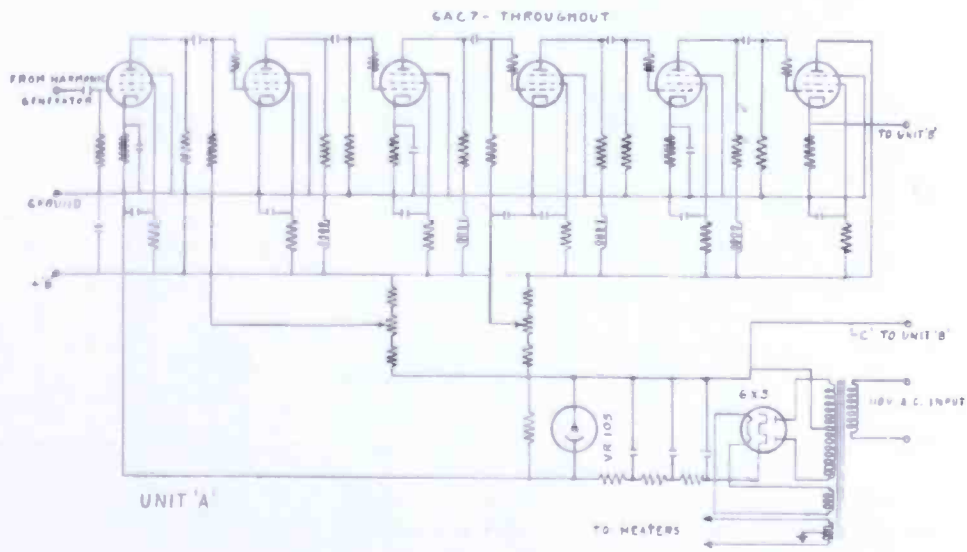


Fig. 10

a high harmonic content. Following the limiter are two differentiating amplifiers, used to select the higher harmonic to produce a narrow impulse with steep sides. Since both a positive and a negative impulse are formed, the signal is again limited to select one-impulse polarity. The signal is then amplified again and sent to unit B through a cathode-output stage.

Unit B (See Figure 11) has for one of its inputs a horizontal driving pulse which is used to lock in a multivibrator. This multivibrator is set for the 7th submultiple of the 13,230 cps. horizontal-driving frequency and the width of the pulse is adjusted to the time of one horizontal line. This pulse starts under horizontal blanking, lasts one line, and remains in its valley for the next six lines.

The 1,323,000 cps impulse of Unit A and the 1,890 cps impulse of the multivibrator are added together in Unit "B". The two impulses represent vertical and horizontal lines and at each crossing of these lines the two signals are added, giving a double-height signal point which is clipped to single-signal level by a limiter amplifier. A blanking signal is added, followed by a brightness control-limiter amplifier. There are two cathode-follower output amplifiers to provide polarity selection on the output. Control "F" is a gain control and "E" is the brightness or pedestal-clipper control.

As may be seen in the photograph of Figure 12 the gain and brightness controls, together with "on-off" switches for the horizontal and vertical lines, are mounted on a panel on Unit B. There are two screwdriver adjustments on Unit A. The first of these provides limiting control for the case of a sine-wave input to facilitate the change to a flat-topped wave before it is fed to the differentiating circuits, and

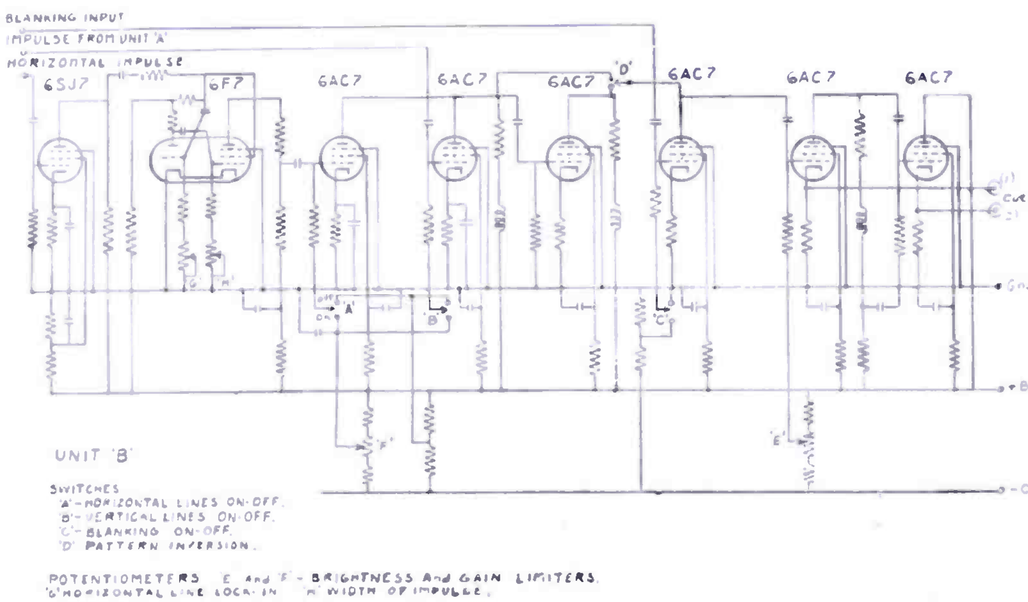


Fig. 11

the second provides for adjustment of the clipper which removes the pulse of unwanted polarity following differentiation.

The standards recently announced by the F.C.C. specify a 525-line picture, vertical blanking of 7.5 per cent ± ½ per cent, and horizontal blanking with a minimum of 16 per cent and a maximum of 18 per cent including the slope of the impulse. In order to adapt this equipment to these standards the resonant circuits in the harmonic generator and the multivibrator-frequency control must be readjusted, and the impulse width control of Unit "B" reset. Also a studio test pattern must be provided to fit the new standards. The frequency adjustment of the multivibrator is the screwdriver adjustment labeled "lock-in" in Unit "B". The pulse width is controlled by the "width" adjustment in Unit "B". The number of horizontal lines will depend upon the submultiple of the line frequency at which the multivibrator is to operate. The third, fifth, seventh, etc. submultiple may be used, but the seventh will produce a pattern which is composed of almost square rectangles with an aspect ratio of 4 to 3. With 16 per cent horizontal blanking, the vertical lines of the time pattern will divide the picture into 84 divisions. With 7½ per cent vertical blanking and using the 7th submultiple there will be $[(525/7) \times 0.925] = 69.4$ divisions of the picture marked by the horizontal lines.

In order to design an appropriate studio pattern for the 525-line standard the above figures may be used. A suggested pattern is one in

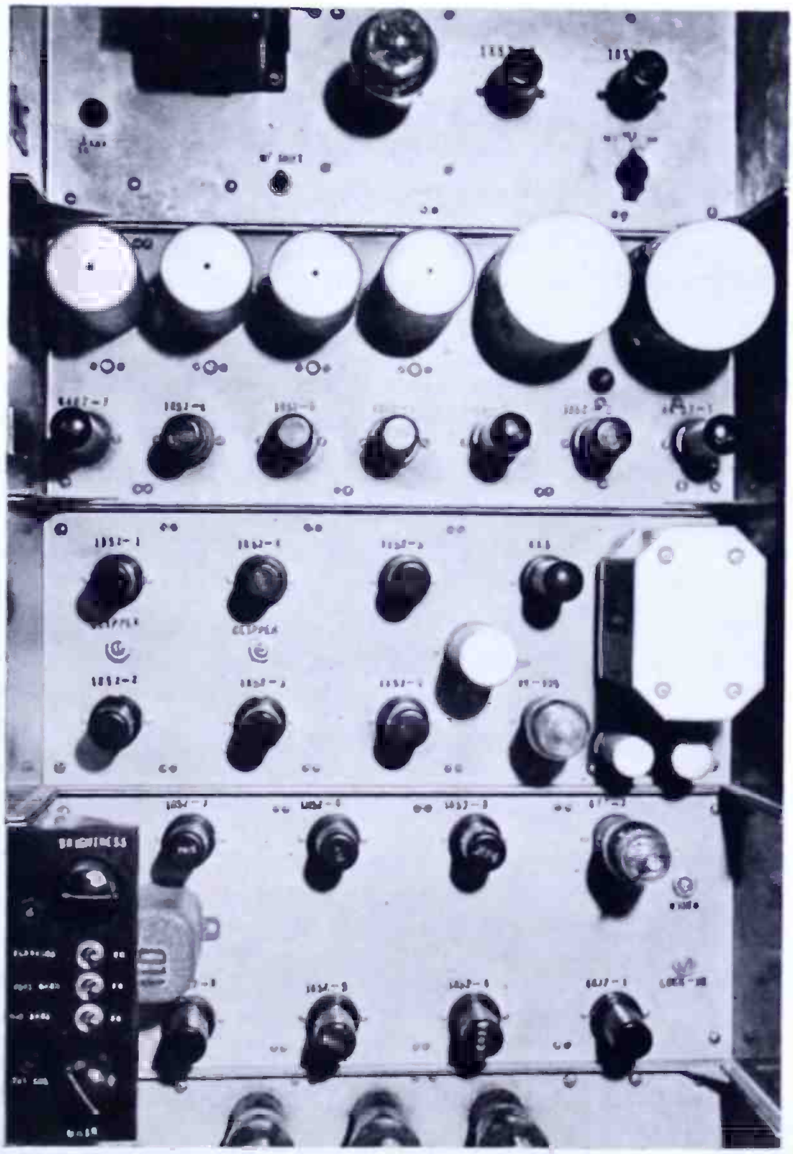


Fig. 12

which each 10th time-bar line, both horizontally and vertically, is represented on the studio pattern by a diamond-shaped dot. It is unnecessary to put in all of the dots and probably some such arrangement as was used in the 441-line pattern (Figure 3) would be adequate.

In adjusting the 525-line deflection by superimposing the two patterns there will be an extra two divisions horizontally and an extra 9.4 divisions vertically.

A MODERN CONTROL ROOM FOR A COMMERCIAL RADIO TRANSMITTER CENTRAL

By

L. E. Fletcher and C. L. Kennedy

R.C.A. Communications, Inc., New York, N. Y.

Summary—A large number of high-powered radio transmitters located at Rocky Point are operated by remote control from a central office at 66 Broad Street in New York City. Due to increasing demands for more adequate high-speed transmission facilities a new control room fitted with redesigned control equipment has been installed at Rocky Point. The new equipment and circuits provided, as well as the unusual structural details which were required to provide a suitable installation, are described in this paper.

A CORPORATION engaged in international radio communications business must locate its message collection and delivery offices where they will be convenient to the public. Consequently, these offices are located centrally in the heart of the business district of the city being served. Commercial radio transmitters and receivers, however, require relatively large ground areas for effective antenna systems and are, therefore, generally located in sparsely settled districts where land can be purchased cheaply and in large tracts.

One of the transmitting plants serving that part of the worldwide network of R.C.A. Communications, Inc., which centers in New York City, is located at Rocky Point, Long Island. The control room of this plant is connected by land lines to the central office at 66 Broad Street in New York City and to the receiving station at Riverhead, Long Island. The map, Figure 1, shows the respective locations of these stations.

The central office must be able to key directly the transmitters at the distant transmitting center in order to provide the accurate and speedy service demanded by the public. The reliable and economical remote control of a large number of transmitters requires the use of highly specialized control equipment[1] and procedure at both the central office in the city and the remotely located transmitting plant. The control equipment at Rocky Point is now located in a new control room which has been installed in the main transmitter building as a part of a general remodeling program.

---

[1] A Modern Radio Telegraph Control Center by D. S. Rau and V. H. Brown, RCA Review July, 1939.

The functions performed in this control room include:

Distribution of control signals to the proper transmitters.

Monitoring of control and radiated signals.

Transmitter status indicators and alarms.

Telegraph and printer connections to Broad Street and Riverhead.

Local dispatching and dial telephone service.

Testing of lines and equipment.

Air-conditioning and cable terminal equipment are located in two small rooms adjacent to the main control room. The plan view (Figure

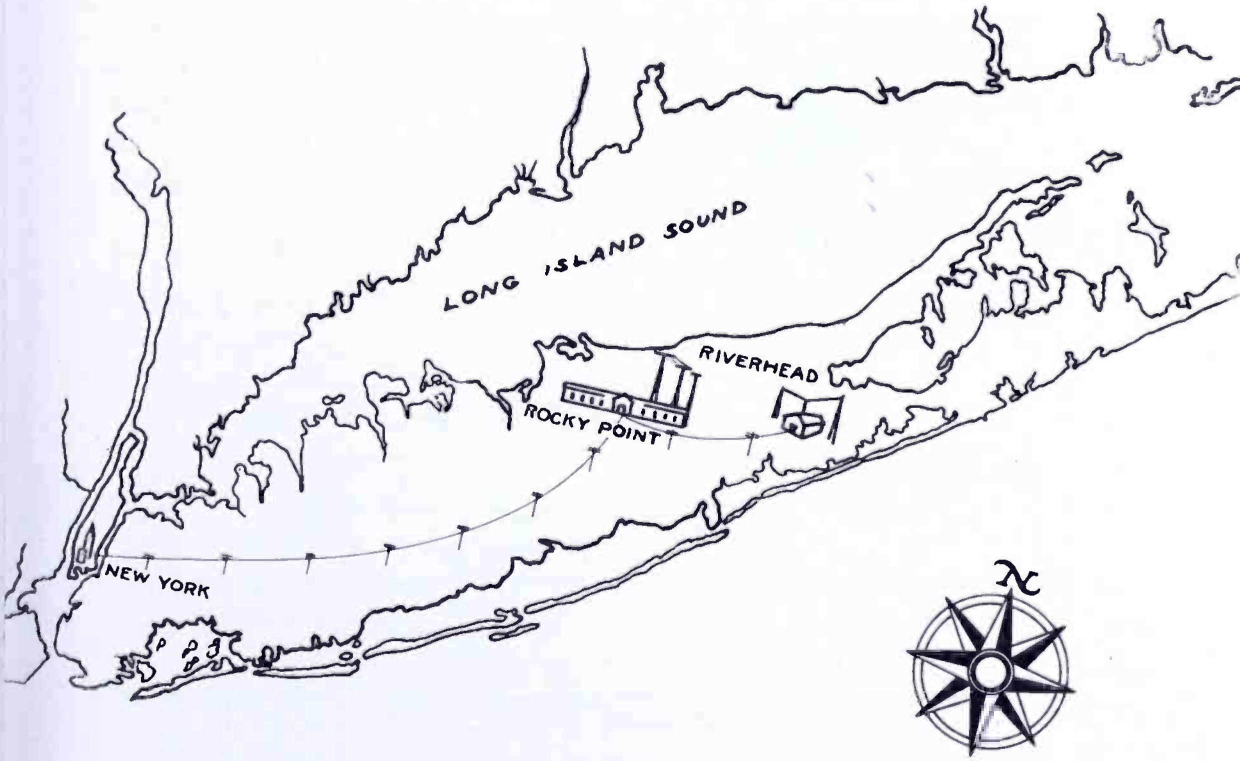


Fig. 1—Chart showing location of stations.

2) shows the arrangement of the apparatus racks and tables in the control room proper as well as the relative locations of the air-conditioning and cable terminal rooms.

Construction Details

The structural methods employed in building the control room were determined largely by local conditions. They play an important part in obtaining high operating efficiency by providing the following features:

Completely fireproof construction.

Protection against transmission of external mechanical vibrations to ceiling, walls, and floor at all points of support.

A reasonable amount of soundproofing and acoustical treatment.

Thermo insulation in ceiling, walls, and floor.
Air-conditioning with summer and winter temperature control.
A well-designed lighting system to relieve eye-strain and fatigue.
Complete shielding of apparatus from radio-frequency interference.
Equipment layout with most-used control facilities within the reach of one operator from a central position.
Provision of space and equipment mountings for an orderly expansion of facilities when required.

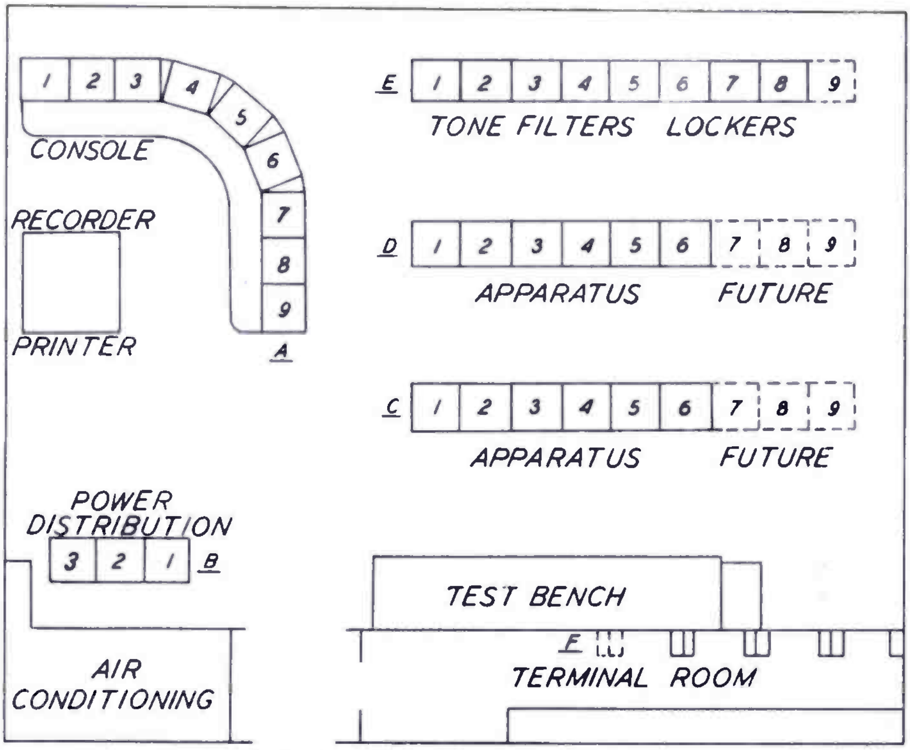


Fig. 2—Control room layout.

The control room is approximately thirty-one feet long by twenty-one feet wide and has a ceiling ten feet high. The end wall near the console is brick and has four large windows. The three other basic walls are constructed of four-inch-thick gypsum blocks.

The door of the control room has a floating buck of special design which consists of an outer frame mounted rigidly in the partition with an inner frame held in place by cork blocks. These blocks are pressed into suitable retainers in such a manner that vibrations from door slamming are absorbed and are not transmitted to the control room walls.

Adjacent to the control room is the terminal room as shown in Figure 2. This room has an eight-foot ceiling and is eighteen and one-half feet long by about five feet wide. A small opening below the floor level and passing through the partition provides a passageway for cables running between the terminal room and the control room.

Considerable care was taken to provide good electrical shielding. This shielding is necessary to prevent interference to monitoring receivers and the other low-level equipment from the high-level radio-frequency fields prevailing at Rocky Point.

If we could look at the shielding we would see two copper boxes placed side by side and joined together by a short duct rectangular in section. The larger box would be the control room proper and the smaller one the terminal room, with the joining duct section serving as the cable passage between the rooms. All windows and ventilator duct openings are shielded with double copper-mesh screens which are bonded to the rest of the shielding. The shielding touches building steel at only one point, this point being one side of a trench in the terminal room. Here the shielding is heavily bonded to building steel and ground.

Sheets of twelve-ounce copper joined together by one-inch-wide lock joints and soldered form the shielding shell. During the time the shielding construction was in progress an alarm bell was kept connected to give warning of accidental grounds to the building steel at undesired points.

On top of the basic concrete floor, thirty-pound tarred felt paper was put down first and the shielding copper laid over that. This precaution was taken to prevent excessive abrasion of the copper from the rough concrete.

The control room is located on a mezzanine floor and extends upward to the building roof. This location is remote from operation noises and vibration centers. However, certain features were incorporated in the design to prevent noise and vibration from entering the control room.

The illustration (Figure 3) shows an elevation view of a typical section taken through the hung ceiling, floating wall, and floating floor.

Rods placed two feet on centers hang down from the ceiling purlins of the building. Pads of cattle-hair felt cushion the rods against vibration, and fibre sleeves insulate them from the steel. These rods comprise the primary support and carry the load of the ceiling copper and the secondary support.

The secondary support is a lattice work of welded steel angle and wood batten strips framed by channel iron. Sheet-metal brackets fitted with felt pads and welded to the channel frame support the wall copper. Strips of cattle-hair felt set in the trough of this channel frame form a firm brace for the top of the floating wall. Wood battens secured to the steel angles provide a support for the sheets of perforated transite used on the finished ceiling surface. The void between the ceiling copper and the transite is filled with glass-wool batts. This structure also carries wiring and fixtures for the fluorescent lights.

The floating walls are constructed of a series of steel frames having channel members for uprights and angle pieces for laterals across the top, bottom, and through the center. Each frame is fitted with felt

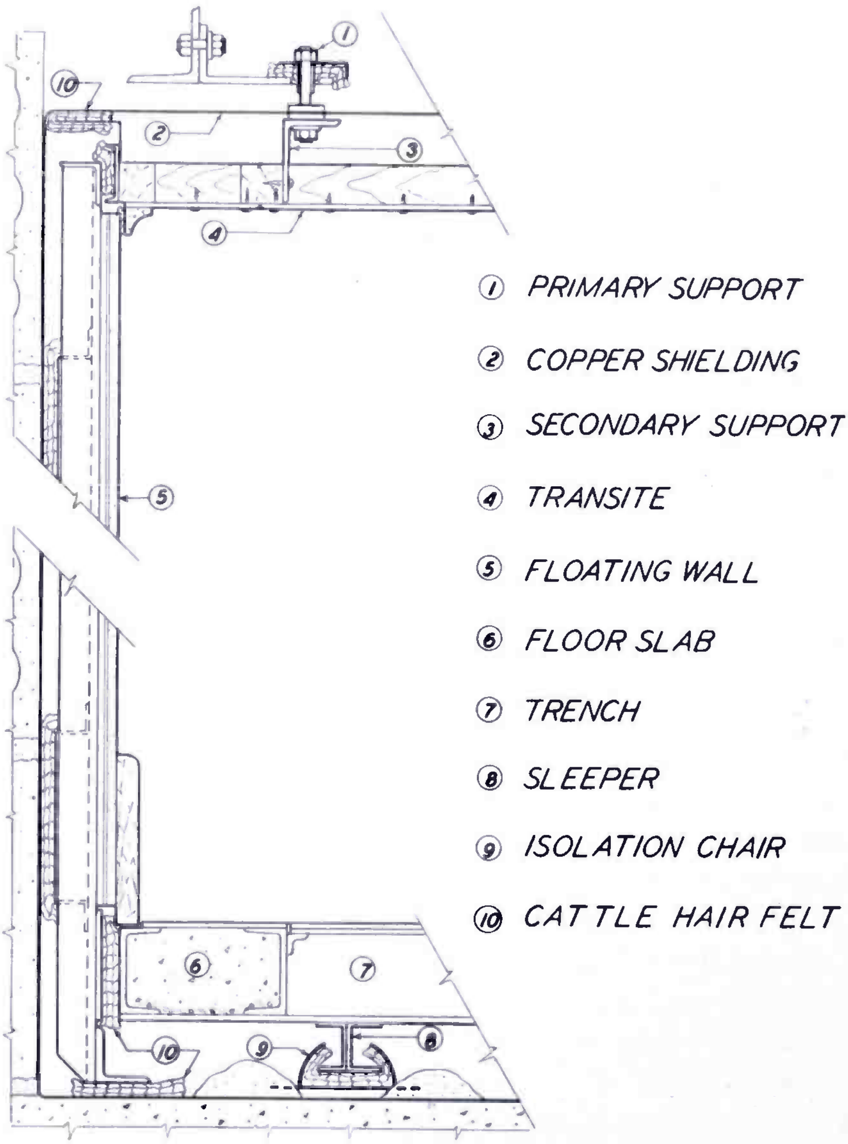


Fig. 3—Sectional view of structural details.

pads as shown in Figure 3, and set firmly against the wall. The frames are welded one to the other with horizontal angle pieces between, forming a single unit. At the level of the floating floor a wide steel strap is welded to the studding to form a continuous band around the room and provide a surface against which to caulk the floor slab.

The walls are insulated with glass-wool batts and surfaced with self-furring lath and smooth plaster finish.

The control room floor is also floating since all load is carried on resilient felt pads. Isolation chairs fitted with felt liners carry light steel "H" section sleepers upon which the floor slab is constructed. The void between floor slab and basic floor is filled with nodulated glass wool. Overlapping strips of tarred felt laid directly on top of the sleepers and extending up on the walls a few inches form a pan to act as a

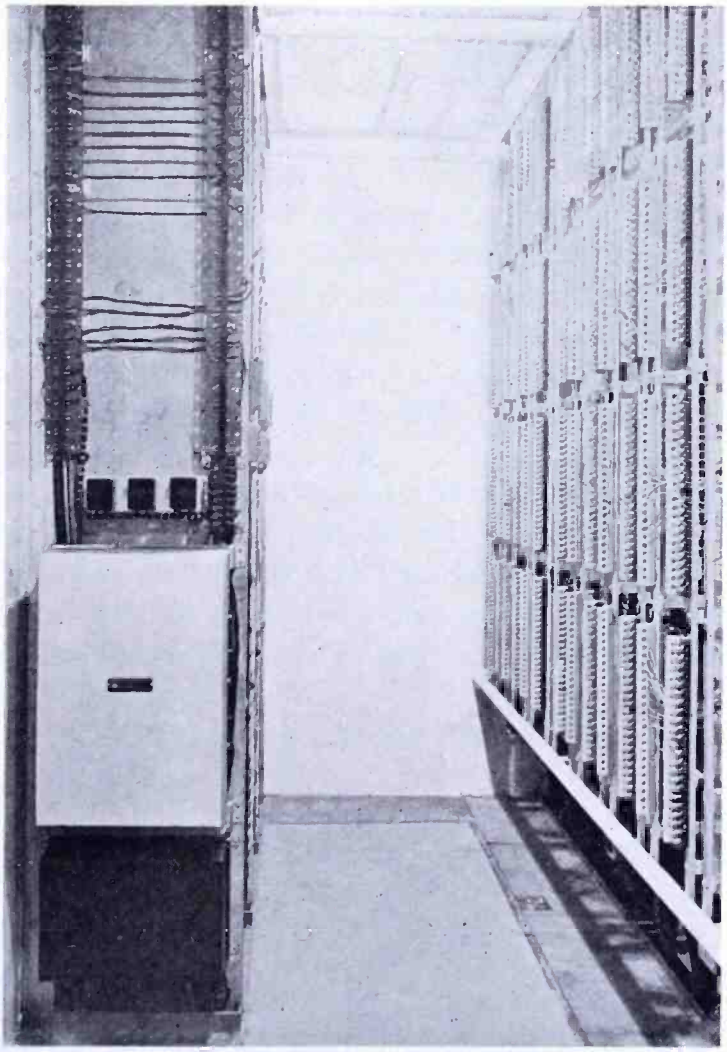


Fig. 4—Terminal room.

catch-all when pouring the concrete. Bottom plates for the trenches and the channel iron which frames the floor slab rest on the sleepers with heavy steelcrete mesh and lath laid between trench and frame to reinforce the concrete slab. The floor slab is spaced away from the wall steel to allow insertion of felt caulking and the top edge of the caulk is sealed with a plastic water-proof compound.

The ceiling, being surfaced with perforated transite and backed up by four-inch glass-wool batts, reduces reverberation when the microphones or loudspeakers are used, thereby improving the general acoustics of the room.

The ceiling, walls, and apparatus are finished in light colors, reducing light absorption to a minimum. Fluorescent lighting was chosen because, by selection of proper color tubes, it is possible to simulate daylight color and intensity with very little heat radiation. The resultant lighting has proven very satisfactory. Operators comment that they no longer notice the eye-strain and fatigue which was experienced with the older lighting system.

Air Conditioning

Air conditioning, with summer and winter control, has been provided. Heating and cooling thermostats, interlocked to prevent simultaneous operation of heaters and refrigerator unit, are located in the control room. The cooling is obtained from a three-horsepower refrigeration unit with water-cooled condenser. Heating is obtained from electric strip heaters built into the upper part of the air-conditioning unit. A large fan circulates the air through both the heating and cooling units and through the ventilating system which supplies another room in addition to the control room. All air entering the system is thoroughly filtered. The air-conditioning equipment is located in a separate room to avoid transmission of noise and vibration to the control equipment. The air ducts are lined with air acoustic sheets.

Electric heating, generally looked upon as very expensive, has proven quite economical due to the thorough thermo-insulation incorporated into the construction of the control room. Electric heating has the added advantage of providing heat for the control room at times when the larger furnaces which heat the main transmitter room may not be required because of the heat radiated from the transmitters.

Terminal Room

The terminal room has a trench system six inches deep laid directly on top of the copper shielding. As has been mentioned previously, one side of one of the trenches in this room serves both as a grounding point for the control room shielding and as the entrance for all cables coming into the control-room from other parts of the building or from other buildings or stations. No circuit is permitted to reach the control room without first passing through this terminal room. Control-room power cables and signal cables from transmitters and other facilities within the main transmitter building enter through copper tubes which pass through the partition and are electrically bonded to the shielding. These tubes have their ends flared to avoid damage to the cables passing through them. On the outside of the terminal room an overhead junction box and associated raceway system diverts the cables to the desired trenches of the main transmitter building floor. Cables from other buildings and stations are routed to the terminal room via steel conduits from outside manholes.

Along one wall, running lengthwise of the room and directly above the trench into which these cables enter, are located the cross-connect distributing frame and cabinets containing standard telephone fuses and arrestors. The conductors in all signal control cables are provided with these protective devices. Along the opposite wall and directly above the other trench, are located power-cable fuse cabinets and racks on which r-f filters are mounted. The two long trenches are connected by two cross-trenches and a number of large ducts to carry cables running between the r-f filter rack and distribution frame.

Local telephone service between offices and divisions at Rocky Point is available through private automatic telephone switching equipment which is mounted on one of the r-f filter racks in this room. This switching unit was not located in the main control room because its operation is rather noisy.

Considerable care has been taken to prevent any r-f interference from entering the control room proper. To carry out this aim all lines entering the control room are filtered to remove r-f and the terminal room is shielded from the main control room. All circuits which enter the control room must pass first through the filter racks. These racks contain filters of several types, depending upon the characteristic impedance of the line or circuit involved. The cables from the control room are terminated on one side of the r-f filter rack. Interconnecting cables, connected to the other side of the filters used on these lines, run between the filter rack and the distributing frame where they are terminated on blocks. All incoming cables entering the terminal room are terminated on other blocks mounted on the distributing frame. The desired cross-connections are made with the jumper wires which lie loose in guide rings. This provides flexible interconnection of equipment to lines, permitting rapid substitution of circuits in case of trouble or alterations.

Control-Room Apparatus Arrangement

The cables leaving the filter racks enter the control room and are distributed to the various groups of apparatus racks via a system of trenches in the floor. This trench system also carries cables interconnecting various rack groups. The steel trench plates are covered with the same type and color of asphalt tile that is used on the floor of the control room. The tile-covered trench plates are set off by chrome trim around the edges, to prevent wear, and are equipped with lifters to provide easy access to the trenchway.

Interconnecting cables are designed to provide maximum protection against crosstalk and interference. The twisted pairs of tinned-enamel and color-coded silk-insulated conductors are individually shielded with copper wire braid. Cables comprising six, thirteen, and eighteen of these shielded pairs, protected by a weatherproof braid overwrap, are used wherever possible. A single-pair shielded cable, without color coding, is used wherever the use of multi-pair cable is not practicable.

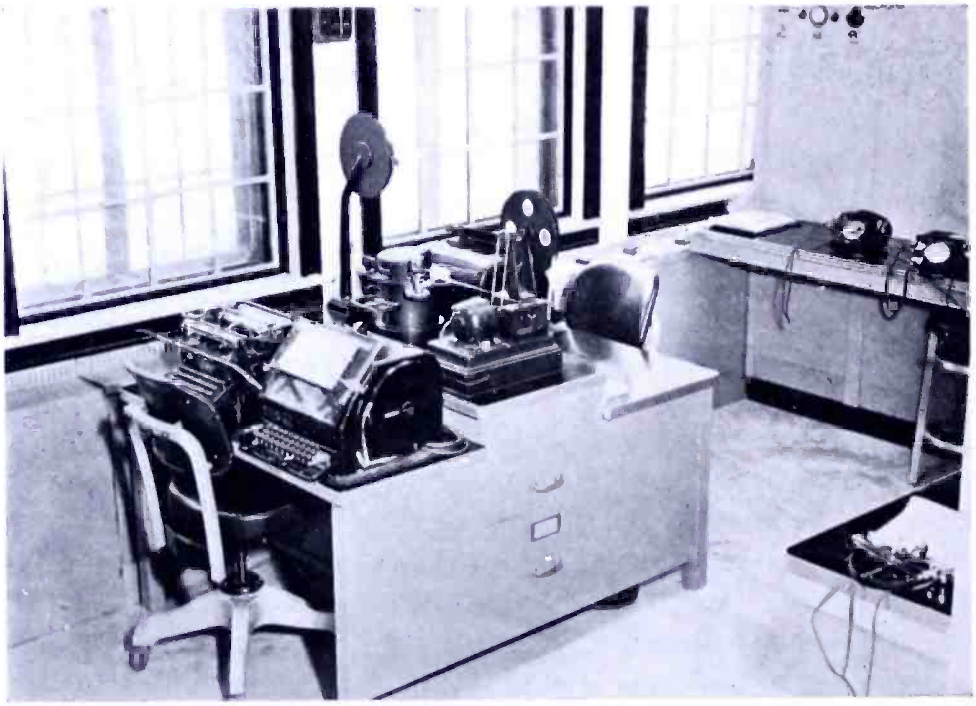


Fig. 5—Printer and recorder table.

All groups of apparatus racks are installed on wiring bases which consist of four-inch structural channel iron fastened with bolts to the trench steel, or by expansion shields to the concrete floor slab. These wiring bases span at least one trench and in most cases two. This arrangement provides the cable entrance point to the rack groups and permits all wiring to be concealed.

The control room apparatus is installed in five groups of standard enclosed nineteen-inch cabinet racks arranged as shown in Figure 2. A recorder and printer table holds two tape signal recorders used for checking transmitter signals, and a teletype tape printer and typewriter which are used in handling inter-office messages. A test bench is provided for experimental or test set-ups where rack mounting would be inconvenient.

The equipment installed in the racks provides the following:

- Facilities for terminating and switching incoming lines.
- Amplification and separation of channelled control signals by means of audio filters.
- Flexible patching of these controls to approximately forty transmitters located in three buildings.
- Simultaneous monitoring of the control signal and radiated signal of any transmitter by speaker, tape recorder, or oscilloscope.
- An alarm system to warn the operator when troubles render any transmitter inoperative.
- A loudspeaker and telephone dispatching system to contact technicians in each building.
- Communication by telegraph and printer to various departments in New York and Riverhead.

The equipment with which these functions are performed is laid out in a systematic arrangement designed to save steps on the part of the operator. All equipment controls and patching panels required for normal operation are located within the reach of one operator from one position at the console. The console is the heart of the Rocky Point Station control system. The operator is in constant touch with the New York control center and the receiving station at Riverhead, as well as with the local staff in all operating buildings.

Console

The console consists of nine standard apparatus racks arranged in a ninety-degree arc with a sixteen-inch shelf mounted in front at standard table height. This shelf is surfaced with a black formica and foil composition top which is not damaged by burning cigarettes. The recorder and test bench tops are surfaced with the same material.

The console equipment is limited principally to essential jack patching panels, key switches, signal lights, attenuators, loudspeakers, telegraph keys and sounders, and various monitoring equipment which require frequent attention from the operator on duty. Equipment and controls requiring the most attention are mounted in the five center racks of the group. The two racks at each end of the console contain equipment and controls requiring less frequent attention.

Rack No. 1 of this group contains a signal generator used to produce test signals required for testing transmitters and equipment, and keyer oscillators for converting rectified r-f signals into tone signals for monitoring purposes. The output of one of these keyers is wired to operate local monitoring equipment. The output of the second keyer may be transmitted back to New York if an operator there requires a monitor of any transmitter.

On the upper panels of Racks No. 2 and No. 8 are mounted attenuators used for adjustment of control tone levels to the transmitter keyers. The attenuators mounted on Rack No. 2 are assigned to transmitters in the main transmitter building while those mounted on Rack

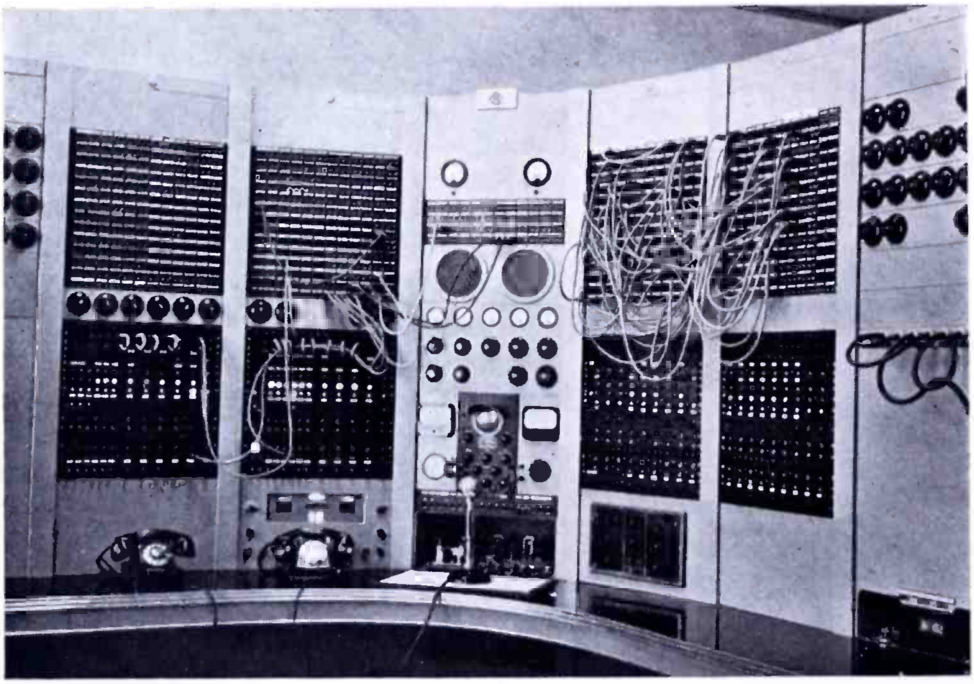


Fig. 6—Center console racks.

No. 8 are assigned to transmitter in the auxiliary transmitter building. Repeat coils are mounted on panels inside these racks, one for each transmitter line. These coils match the outputs of the filters, which are of the unbalanced ladder type, to the balanced lines which connect to the keyers at the transmitters. If repeat coils were not used the circuits would be longitudinally unbalanced and considerable noise and cross-talk would develop. These keyer units further amplify the tone signals and convert them into direct-current impulses which, in turn, key the transmitters. When the former control room was in operation keyers were mounted in racks located in the control room and their direct-current outputs were connected by cables to the transmitters. The capacitance effects of long cables on the direct-current output circuits often caused poor keying and critical adjustments at the higher speeds, such as are required for multiplexed printers. In view of this it was decided to locate the keyers directly on the individual transmitters. This practice has proven very satisfactory and free from trouble.

Racks No. 3, 4, 6, and 7 are similar and consist of one top jack panel group, one combination jack, lamp, and key panel group, and one attenuator panel. A monitor receiver located at shelf level to permit easy operation, is installed in Rack 3.

The upper jack panel group of Rack 3 contains all jacks associated with incoming lines from New York. A typical line-up of jacks on this panel is shown in Figure 8. These jacks are arranged to permit tests

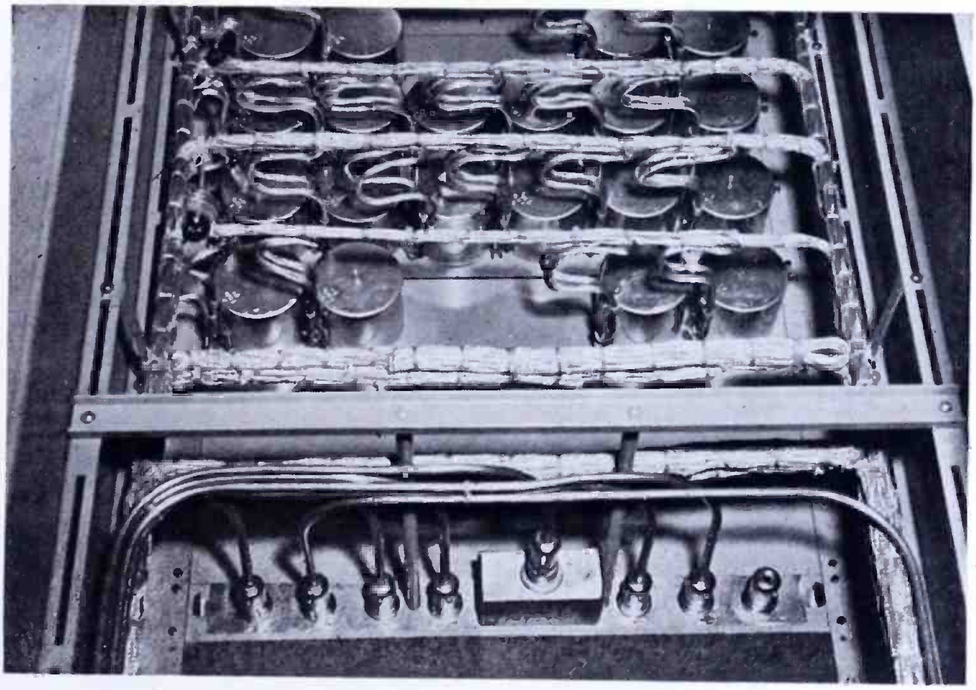


Fig. 7—Typical wiring within racks.

to be made at important points in the line-up as well as to permit cross-patching of lines or equipment in case of failure of any part. Adequate spare terminal equipment is provided so as to avoid any lengthy interruption. Single-circuit jacks have been used for the line circuits, separate jacks being provided for each side of the pair of conductors comprising the line. When these circuits are patched only the tips of the patch-cord plugs are utilized and the pressure of the jack contact springs on the tips of the plugs assures perfect contact. This assurance cannot be realized with two circuit jacks requiring contact to be made between jack and plug sleeves. Since audio-frequency channelling by means of multi-frequency tones is employed, and as many as twelve channels may be interrupted by poor patching connections at this point, the use of extra jacks is well justified.

Line facilities from New York include two lines with usable bands up to 5000 cycles and four lines with usable bands up to 2500 cycles. In addition, a high-quality program material service line is provided. This line does not terminate in the new control room, but is cross-connected in the terminal room to the program service board in another building. These lines are normally one-way circuits, their primary function being the transfer of control signals from the central office in New York to the transmitting station. Three lines are equipped

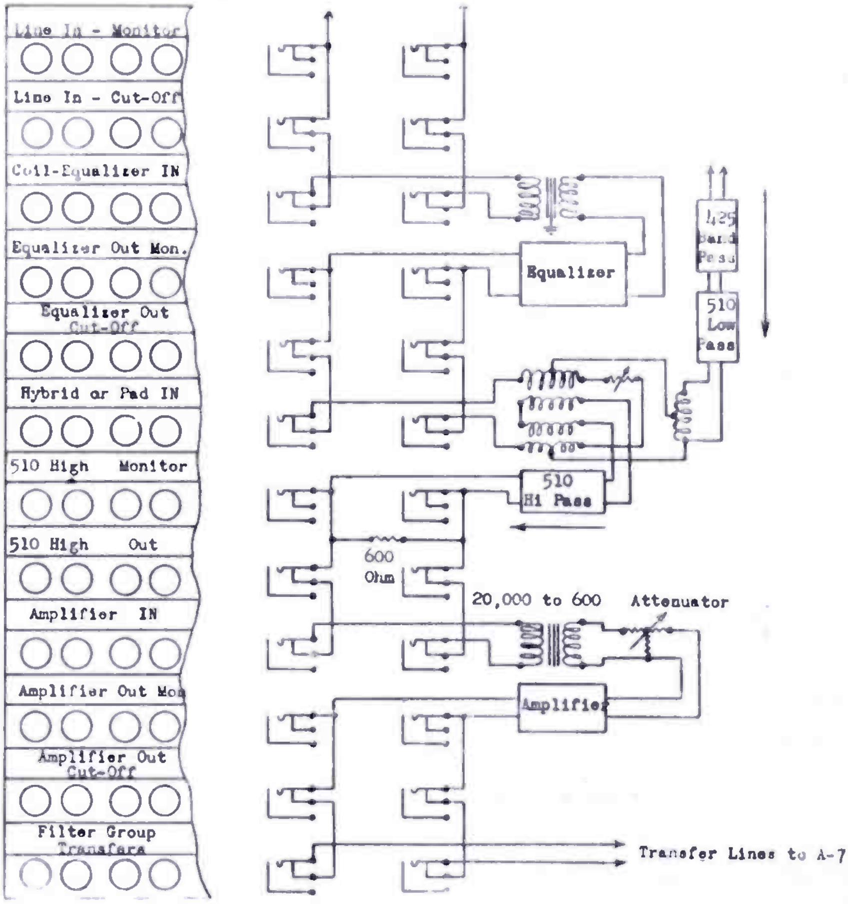


Fig. 8—Line-jack layout and diagram of connections.

with hybrid coils, providing necessary facilities for transmission of communications tones from Rocky Point to New York simultaneously with the normal use of the line in the reverse direction. These communications tones are used in connection with the inter-station telegraph and printer circuits. The 425-cycle channel is assigned to the communications circuit, carrying signals in the direction reversed to that of the remaining channels on the line. The 595-cycle channel is generally assigned to the communications circuit in the normal direction, although, any other channel could be used. Each hybrid circuit is equipped with a 510-cycle high pass filter in the receiving circuit and a 510-cycle low-pass filter in the transmitting circuit. These filters reduce to a minimum the possibility of interference to the traffic channels from the 425-cycle communications tone, as might result from misadjustment of the hybrid networks or from line trouble. The 510-cycle low-pass filter serves to prevent harmonics of the 425-cycle tone from reaching the line where they might interfere with the traffic channels.

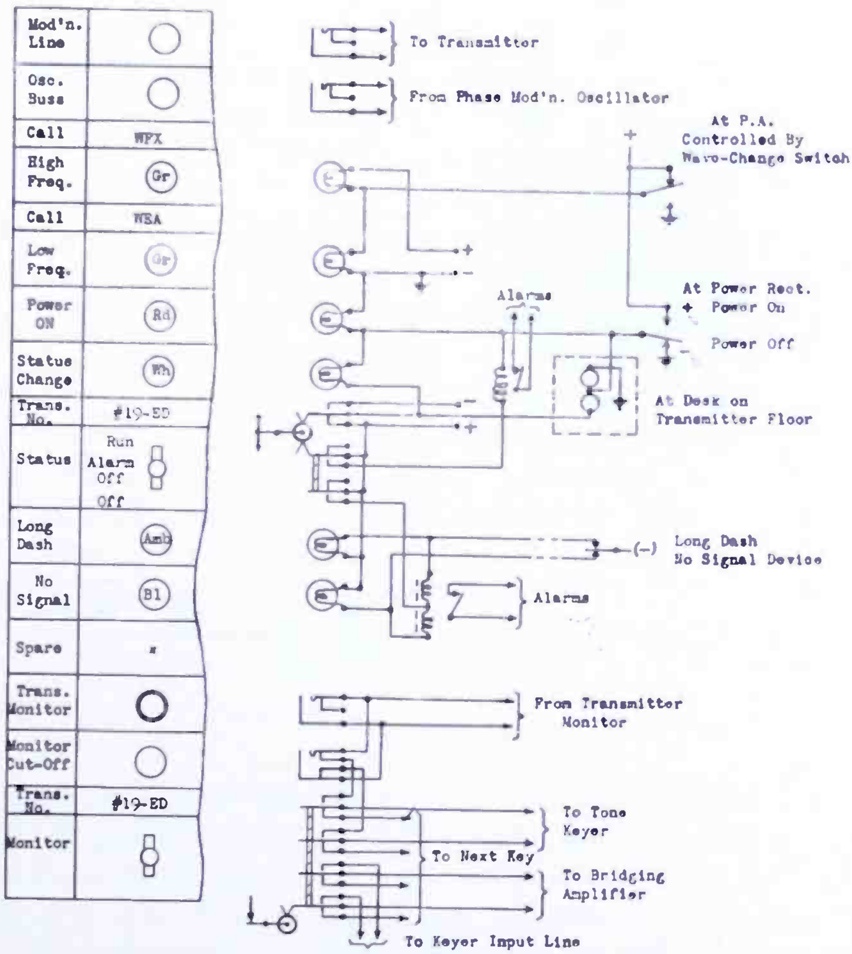


Fig. 9—Transmitter control panel layout and diagram of connections.

Until recently, simplex taps on control-line pairs, using ground return, were provided for use as interstation telegraph circuits. These circuits required critical relay adjustments whenever terminal loops were added or removed. During wet weather these circuits occasionally became unusable due to leaky cables, although the tone circuits were hardly affected. Since at such times it was usually necessary to set up emergency tone circuits to carry on interstation communication, it was finally decided to abandon the d-c telegraph circuits and substitute tone communications circuits. At the terminals, d-c closed-circuit loops were retained because they were more convenient to handle in respect to local branch circuits.

Rack No. 4 upper jack panel group contains all jacks associated with incoming lines from the receiving station at Riverhead and special lines from control boards in the Research and Program Service Departments. The circuits are laid out similar to Figure 8 except that amplifiers, equalizers, and hybrid coils are not provided for each line. Simplex taps are provided on the two lines to the receiving station at

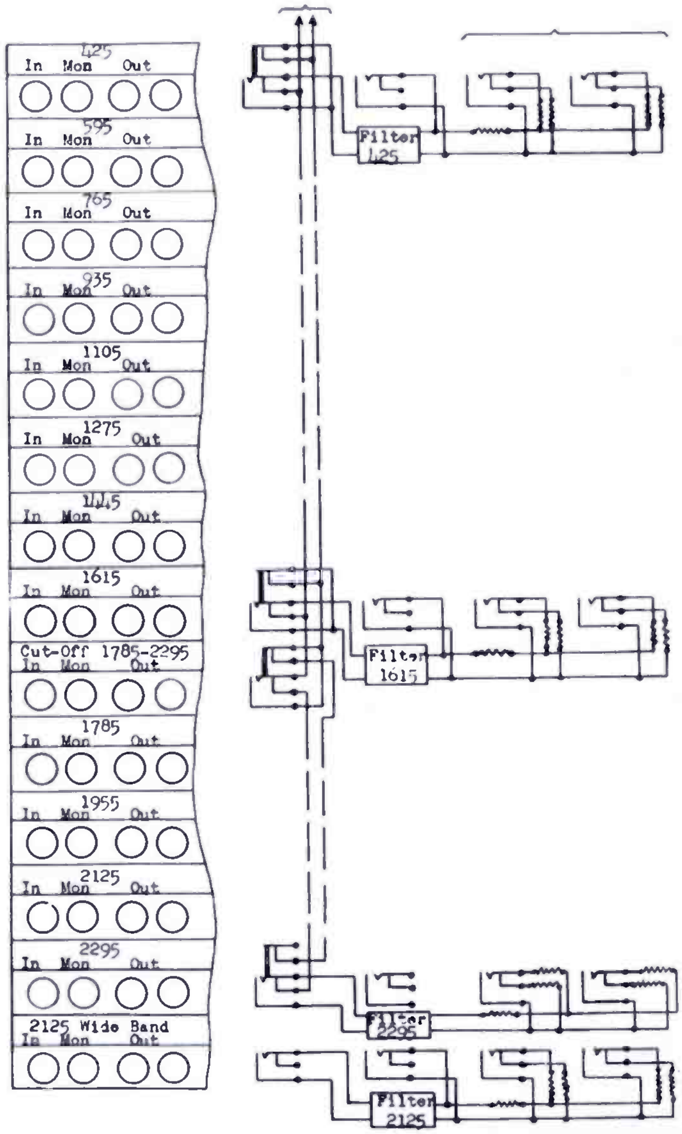


Fig. 10—Filter-jack layout and diagram of connections.

Riverhead, New York. These are used as telegraph loop extensions in the inter-station telegraph net-work. Two amplifiers and associated attenuators are terminated on this panel and may be used as spares or for general purpose. Several groups of transfer lines to jack panels on other racks are also located on this panel. Several groups of paralleled jacks are provided for special circuit connections.

All jacks associated with the inputs and outputs of the keying channel filters, as well as the keying lines to all transmitters at Rocky Point, are located in the upper jack panels of Racks No. 6 and 7. Transfer lines from Rack No. 3 connect the outputs of the line amplifiers to parallel busses to which "normalled through" filter input jacks are connected.

These filters separate the individual signal channels from groups of as many as twelve combined channels on each line. Five groups of filters are provided, three narrow-band-pass groups and two combination narrow-band-pass and wide-band-pass groups. The narrow-band filters have their midband frequencies spaced 170 cycles apart, starting with 425 cycles. These filters are usable for keying speeds up to 80 words per minute. The wide-band filters have their midband frequencies spaced 850 cycles apart starting with 1275 cycles. These filters are usable for keying speeds up to 450 words per minute. Because of their ability to handle this speed these filters are suitable for use with multiplexed circuits. The filters are designed and built to respond to these midband frequencies and the proper amount of sideband, but excluding other frequencies. The outputs of these filters are connected, with patch cords, to lines leading to the individual transmitters. A monitor jack and two loaded output jacks are connected to the output of each filter. Each of these output jacks is equipped with a loading pad which is automatically lifted when the jack is patched to a transmitter line. This feature eliminates the need for readjustment of keying levels, with resultant interruptions to traffic, because the pads maintain constant filter output level when transmitters are dualled or undualled.

Combination jack, lamp, and key panel groups are located at average eye level in Racks No. 3, 4, 6 and 7 and are all similar in assembly. They each consist of eighteen vertical groupings of jacks, lamps, and cam key switches. Each vertical group is assigned to one transmitter. A typical group layout is shown in Figure 9. The two top jacks are provided for patching a 600-cycle tone to the phase modulator incorporated in most of the Rocky Point shortwave transmitters to obtain a few modulation sidebands which are useful for reducing fading in reception by their frequency diversity effect.

Below these jacks are located two green indicator lamps with call letter designation strips. These lights are automatically operated by switches at the transmitter and serve to inform the operator as to which frequency the transmitter is tuned.

Below the green indicator lamps are located red, white, amber, and blue indicator lamps and a three-position status control switch. These are associated with a very complete alarm system. With the key switch in the "run" position, a red lamp indicates that high-voltage plate power is on. If this should fail the red lamp goes out and the white lamp comes on, accompanied by alarm gongs, one in the proper transmitter room and one in the control room. Shifting the key switch to the "alarm off" position stops the gongs, but retains the white lamp as a reminder until the transmitter is on the air again.

If the radiated signal should remain on a steady dash for fifteen seconds, or should go off the air for the same length of time, an amber or blue lamp will light up and the control-room gong will ring. It can readily be seen that this alarm system provides prompt warning of all transmitter troubles except malformation of transmitted characters. Adequate routine monitoring reduces this latter type of interruption to a minimum.

Monitoring switch keys are located at the bottom of the panel groups. A small monitoring rectifier unit is coupled to the transmission line at each transmitter. The rectified r-f output of one of these units is wired to one side of the monitor key; a tap from the transmitter control pair is wired to the other side. This arrangement permits nearly simultaneous monitoring of both the control and radiated signals. When it is necessary to monitor a transmitter, the key switch identified by the transmitter number marked on its label is depressed. This operation transfers the signals to the master monitoring system which is controlled from Rack No. 5. The rectified r-f monitor signal can be observed directly, but is normally connected to a keyer which converts the rectified radio frequency into a keyed tone signal. This tone signal is more easily utilized by the monitoring circuits.

Console Rack No. 5 is the center of the normal operating position. In this rack are mounted meters used for line testing, measuring of monitor currents, and signal levels; a jack panel for patching monitoring and dispatching circuits; loudspeakers for aural monitoring and for the receiving end of the voice dispatching system; attenuators for adjustment of telegraph, dispatching, and monitoring equipment; an oscilloscope for general checking purposes; key panel, telegraph keys, and sounders. The key panel provides switches for switching recorders, oscilloscope, loudspeaker, and volume indicator individually or simultaneously to any signal being checked. It is possible for the operator to check, simultaneously, both the control and radiated signals of any transmitter on a dual tape recorder. Both signals appear side by side on the same tape and any differences can be seen immediately. An electronic switch makes possible the simultaneous observation of both signals on one oscilloscope. This electronic switch is located in Rack No. 6, but may be switched in or out of the oscilloscope circuit by means of one of the cam key switches located on Rack No. 5 key panel. Other key switches connect the dispatcher's microphone system to the loudspeakers located in either building or to the dispatcher's telephone line. Still other key switches cut in a master key and master sounder on to any one of three telegraph lines. Muted sounders are retained on all three lines, the master sounder being switched to whichever line is being used by local personnel.

A coaxial-cable patching panel is located on Rack No. 8. This panel provides a convenient and flexible means of distribution of external pick-up antennas to the various receivers located in the control room.

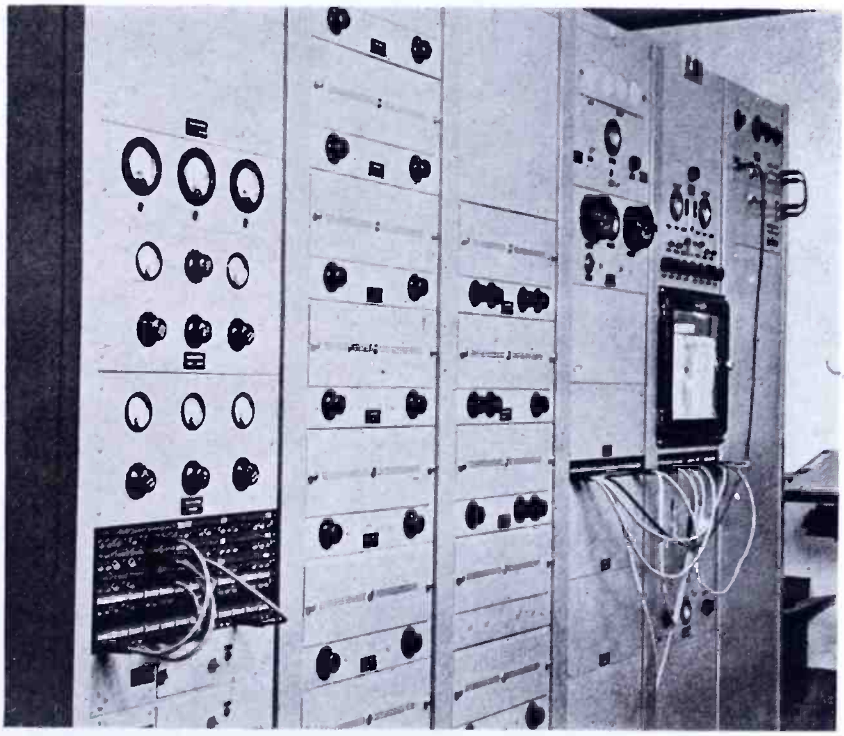


Fig. 11—Apparatus racks, group C.

One principal pick-up antenna is located half-way between the two main transmitter buildings and feeds to both buildings through underground coaxial cable. Other pick-up lines are provided to various parts of the buildings for use when it is desired to check the character of frequency output of the lower stages of a transmitter without actual radiation. Coaxial cable is used for all of the monitor antenna-distribution lines. This prevents radiation of signals into equipment where it might possibly cause trouble and at the same time prevents electrical interference from being picked up and interfering with receiver operation.

An auxiliary telegraph position is provided in Rack No. 8. One sounder and two telegraph keys are provided and arranged so that the sounder and one key may be switched to any desired line by the flip of a cam key. The other key may be used to key a tone into the local loudspeaker dispatching system.

Apparatus Racks

Located in Rack No. 1 of the "B" group are distribution panels for a-c power and lights and for 125-volt d-c power from the station emergency battery. Overload breaker-type of toggle switches are used in place of fuses. Here, controls are provided, which, in case of a power failure, automatically start a small a-c generator, switch vital communications facilities in the "C" group of racks from the normal a-c lines to the output of the emergency generator, and turn on emergency overhead lights. The emergency generator is located outside the control room and receives its power from the emergency battery.

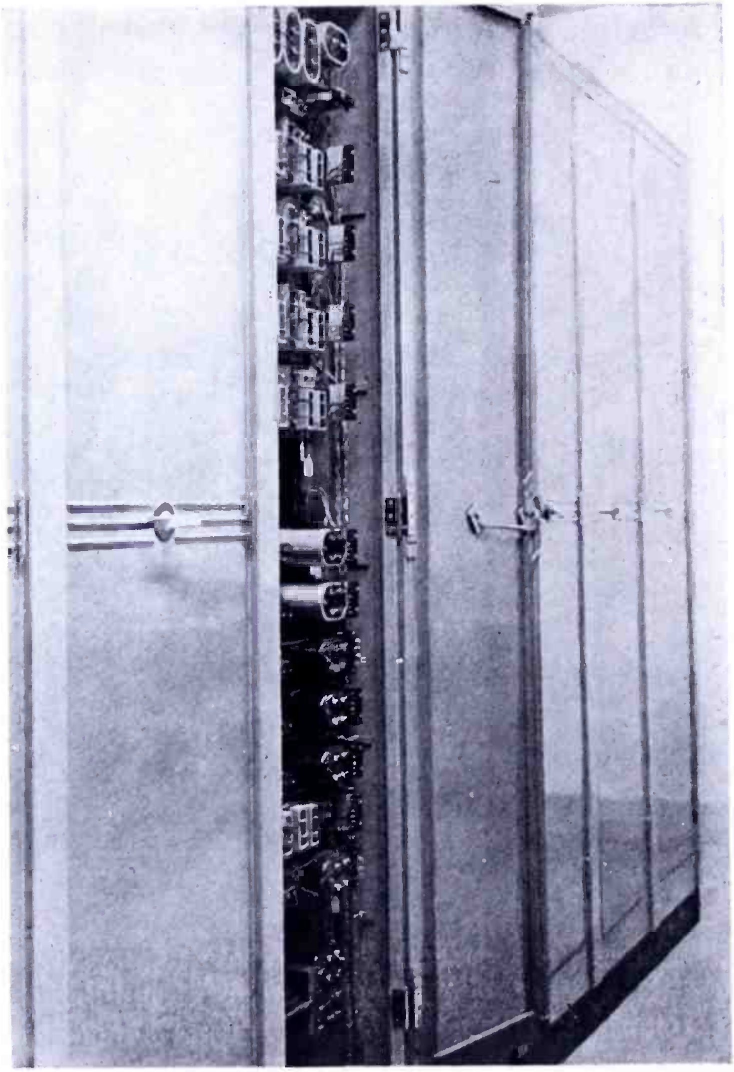


Fig. 12—Tone-filter rack.

So far as possible all equipment is powered directly from the commercial a-c power mains. Battery sources are used in connection with signal lights, alarms, telephones, and telegraph equipment which must be operative regardless of failures of commercial power.

Rack No. 2 of this group is provided as a spare for future requirements. In Rack No. 3 switches and signal lights are provided for remote control of high-tension substation switches. A duplicate maximum-demand meter is also mounted in this rack. This meter is controlled in step with the power company's meter which is located in the substation.

The "C" group of racks contain amplifiers and other miscellaneous equipment requiring power and which are controlled from the console. The first rack in this group contains the printer and telegraph control units and a jack panel for patching circuits associated with these units. The second, third, and fourth racks contain miscellaneous line amplifiers, dispatching amplifiers, telegraph and recorder keyers, an audio oscillator which provides the 600 cycle tone used for phase-modulating transmitters, and several miscellaneous audio amplifiers. The fifth and sixth racks contain apparatus used for conducting short-dot pulse tests and for recording radiation tests.

Control-line repeat coils, hybrid circuit components, and line equalizers are mounted in Rack No. 1 of the "D" group. Long dash-no signal alarm control units are located in Rack No. 2. The remaining four racks of this group are spares which are provided for future requirements.

All of the audio-frequency tone filters are mounted in the first five racks of the "E" group. Standard drilled rack mounting strips were installed inside these racks, permitting the filters to be mounted entirely on the inside of the racks rather than on the front face. Doors were installed on the front as well as the back of these racks. The remaining three racks of this group are used as spare equipment lockers. Spare tubes, of each type used in the control room, are stocked here as well as spare units of important equipment.

THE DEVELOPMENT OF A FREQUENCY-MODULATED POLICE RECEIVER FOR ULTRA-HIGH-FREQUENCY USE

By

H. E. Thomas

RCA Manufacturing Company, Inc., Camden, N. J.

Summary—This paper first describes the general considerations bearing upon design of a frequency-modulated mobile police receiver for use in the 30- to 40-megacycle band where the channel width is restricted to 40 kilocycles. Details of developing the various circuits around these considerations then proceeds with a discussion of over-all performance and field testing. Comparative and quantitative results show very favorable performance using a double-superheterodyne circuit with automatic-frequency control of the second oscillator.

Introduction

In PARALLEL with the general development of frequency-modulated broadcasting and receiving systems during the last two years, there has been a similar advance in equipment employing frequency modulation for police communication in the ultra-high-frequency band between 30 and 40 megacycles where the channel width is restricted to 40 kilocycles. For this service the Federal Communications Commission has established frequency allocations, made various technical recommendations and, in general, has given sanction for frequency-modulation transmitters in this region, to be operated along with existing or new amplitude-modulated stations.

A study of the ultra-high-frequency mobile-receiver possibilities for frequency-modulated reception in this region has resulted in the design of the compact economical unit described in the following pages.

General Theoretical Considerations

In a preliminary analysis of frequency-modulated receivers for ultra-high-frequency police work, five limiting conditions imposed rigid design requirements for this type of service.

I. Because of the channel width—40 kilocycles—adjacent-channel selectivity equal to the best competitive amplitude-modulation performance must exist, together with an optimum combination of gain and bandpass response for distortionless reception of the frequency-modulation signal.

II. To obtain sufficient limiting action, substantially higher gains than necessary for amplitude-modulation receivers should be employed.

III. Since mistuning of a frequency-modulation receiver, in general, produces a greater noise increase than mistuning of an amplitude-modulation receiver, greater care should be used in circuit balance and alignment.

IV. Stability, under conditions of temperature and humidity variation must be better than required for amplitude-modulation equipment.

V. Plate-current drain must not materially exceed the amplitude-modulation receiver requirement; that is, between 75 and 80 milliamperes.

Channel Width and Deviation

To keep the operation of a frequency-modulated receiver within the channel limits, it is obviously necessary to restrict the frequency deviation. In regions of low signal-to-noise ratio, however, frequency-modulation reception with low deviation has a definite advantage over that employing a wider deviation, and, for this reason, is preferred in police systems. The Federal Communication Commission's recommendation of a swing of as high as 15 kilocycles in the u-h-f police band where the audio channel usually cuts off at 3000 cycles makes the deviation ratio around 5 to 1.

From calculated and measured data by M. G. Crosby[1], it is known that for otherwise equal conditions, the advantage in noise reduction for frequency modulation over amplitude modulation, is 15 db. Inspection of the curves in this article shows that below the threshold of improvement (where noise exceeds the signal strength) frequency-modulation reception may show some advantage in regions of weak signal strength with not too rapidly recurring impulse noise and with accurately tuned circuits. Very favorable results[2] from a readability standpoint have been described when frequency modulation using a 1-to-1 deviation ratio is compared with amplitude-modulation.

Problems of Circuit Choice and Limiting

Two factors dictated that a double-superheterodyne circuit arrangement be used: (a) the need for a compact mechanical layout; and

[1] NBC Frequency-Modulation Field Test, Raymond F. Guy and Robert M. Morris, RCA Review, p. 190, October, 1940.
Frequency Modulation Noise Characteristics, Murray G. Crosby, *Proc. I.R.E.*, pp. 472-514, Vol. 25, April, 1937.

[2] Band Width and Readability in Frequency Modulation, Murray G. Crosby. RCA Review, p. 363, January, 1941.

(b) the necessity for stability in the rather large overall amplification necessary for adequate limiting. The circuit uses a double tuned r-f stage, a crystal-controlled first oscillator, harmonically multiplied and applied to a mixer; a 5-megacycle 1st i-f system, a 2nd a-f-c oscillator operating at 5.455 megacycles, and a 2nd i-f system at 455 kilocycles feeding the limiter-discriminator system. With a minimum of 5 volts needed for adequate limiting on the grid of a 6AB7/1853 tube and a sensitivity of 1 microvolt at the antenna terminals for full power output, division of the amplification into 4 parts—r-f, 1st i-f, 2nd i-f, and a-f—produced easily stabilized circuits and afforded the following advantages:

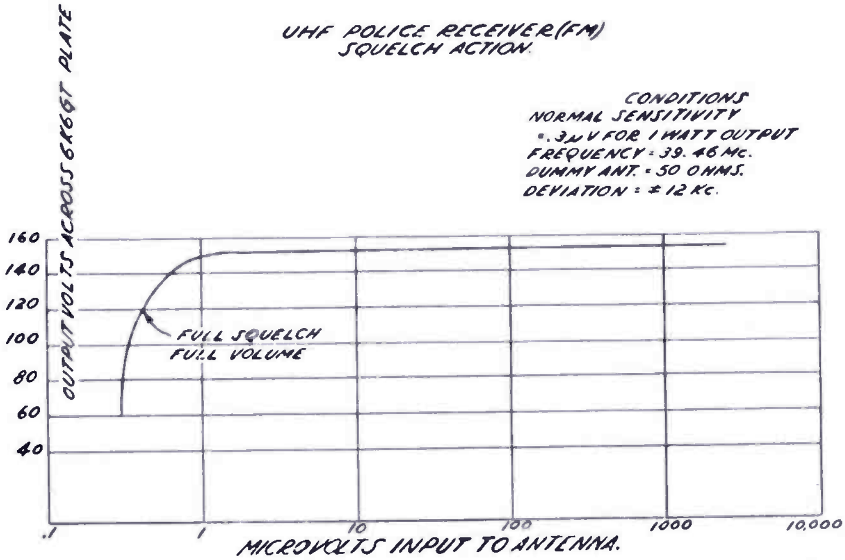


Fig. 1

(1) Good image ratio was possible with the relatively high 1st i-f and double tuned r-f stages.

(2) Stability of the 1st oscillator was provided by use of a crystal and, thus, enabled the 2nd oscillator to be controlled by a-f-c action from differential voltages obtained in the discriminator circuit. (This latter action meant that mid-circuit tuning of the discriminator always existed for received signals, produced a minimum of noise, and followed any drift in transmitter frequency.)

(3) Flat-top selectivity of high order was easily obtainable with the 455-kilocycle i-f system. This type of selectivity, as noted further on, lessened the demands on the limiter, made for more stable operation, and allowed for ease of adjustment and economy of construction.

(4) By correct choice of oscillator frequency, harmonic multiplication, and 1st i-f frequency, a minimum of interfering "tweets" between oscillator harmonics or oscillator and signal harmonics could be provided.

The antenna, 1st oscillator, harmonic multiplier and amplifier, and audio and output circuits differed little from conventional designs. The audio amplifier and squelch arrangement employing a double triode gave overall automatic squelch action as shown in Figure 1. Optimum limiting action or flatness of this characteristic was obtained with lowered plate and screen voltages and with correct time constant of

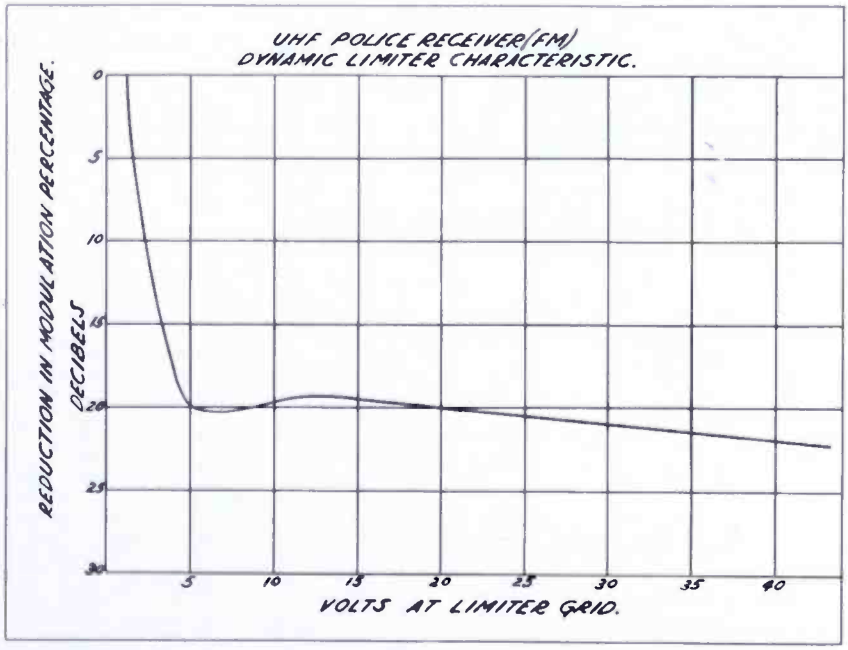


Fig. 2

the conventional grid-circuit zero-bias limiter, as in Figure 2. This limiter gave fair performance, was simple, and afforded an efficient means of obtaining a-v-c potential. Individual stage gains are shown in Table I.

Discriminator Development and Design

Discriminator design, to be usable over the bandwidth employed, was planned with a peak separation of 60 kilocycles. With an i-f bandwidth of 30 kilocycles, linear operation and sufficient gain appeared easily possible over this range. Several types of discriminators were investigated; the form finally decided upon being selected for reasons of simplicity of construction and adjustment, even though its sensitivity did not equal some other types. See Figure 3 for performance curves.

TABLE I—GAINS

	Type Tube	*Stage Gain*	*Cumulative Gain*	*Description*
Antenna		4	4.	
R-f stage	6SK7	6	24.	Double tuned
No. 1 i-f stage	6SJ7	8	192.	Double tuned Including conversion
2nd detector	6SA7	20	3,840.	Double tuned Including conversion
No. 1 i-f stage	6SJ7	40	153,600.	Triple tuned
No. 2 i-f stage	6AB7	30	4,608,000.	Triple tuned

Gain of No. 2 i-f stage was low since the time-constant network in the limiter grid circuit was included in measurement.

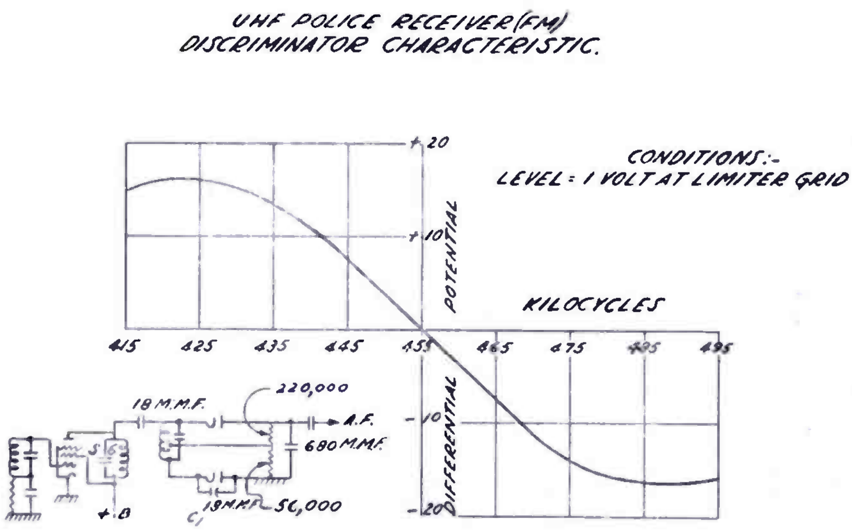


Fig. 3

In final overall adjustment for minimum noise, an exact audio-noise balance was found very important. The variable capacitance C_1 in Figure 3 must be adjusted within accurate tolerance limits to give this condition after the other constants of the system have been determined.

SELECTIVITY

Selectivity and sensitivity are closely related when the limiter design is considered in relation to overall regenerative stability. Flat-topped selectivity proved desirable with a bandwidth of around 30 kilocycles in order to provide sufficient leeway for slight over-swinging of the transmitter frequency (20-24 kilocycles). A more round-topped characteristic using greater overall gain could have been employed if heavier limiting were used to flatten off the top of the selectivity curve. It was felt that the convenience of adjustment provided by this feature would be outweighed by the resulting amplifier instability and more expensive tubes that would be necessary. Since an adjacent-channel attenuation of at least 1000 to 1 should be obtained in two i-f stages together with flat-top selectivity, eight tuned circuits using optimum Q's were needed in the three i-f coil cans.

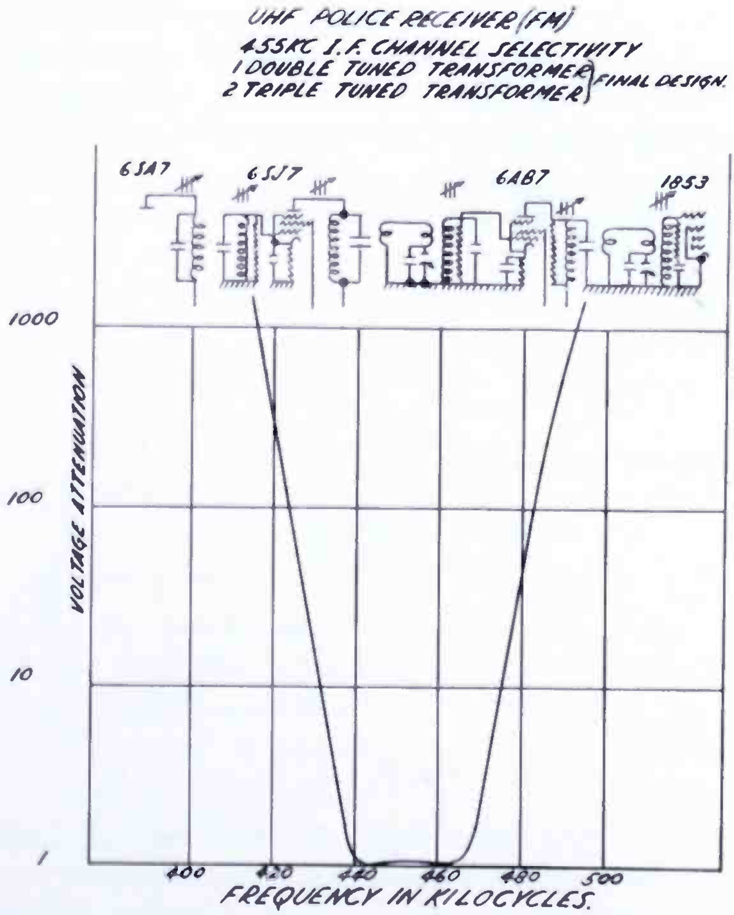


Fig. 4

The arrangement used, consisting of two triple and one double-tuned stage, gave the characteristic shown in Figure 4 for the final receiver. The performance, essentially flat-top (30 kilocycles wide) gave an adjacent-channel attenuation of 1500. The stages were readily adjusted by means of visual-alignment apparatus. The two triple-tuned circuits were adjusted for a slightly peaked characteristic, which together with over-coupling of the double-tuned stage, gave the desired flatness. Inductive coupling between a split middle circuit and the end circuits necessitated capacitive tuning of the link circuit by a trimmer capacitor. Stability was attained by making this trimmer of the ceramic type; it was placed in parallel with a large capacitor of approximately zero-temperature coefficient to make up the total tank-circuit capacitance.

Mistuning, Noise and AFC

Since mistuning of the second oscillator (due to drift or adjustment) or drift of the transmitter produces a rather large increase in noise in a frequency-modulation receiver (because of unbalanced voltages in the detector circuit) some form of automatic frequency control (a-f-c) seemed advisable. Since, on the average, 20 per cent mistuning of a frequency-modulation receiver produces a noise increase of 6 decibels, an a-f-c system with a large tuning-correction ratio was incorporated using a 6AC7/1852 control tube. The high mutual conductance of this tube gave good correction ratio, but also produced frequency variations with supply-voltage fluctuations. Analysis showed that screen-voltage changes produced the major portion of the frequency shift; plate voltage produced very little; filament-voltage change gave only a small shift. A compensating arrangement was devised by bleeding some of the screen-supply voltage through the cathode self-bias resistor. As supply voltage and screen voltage cause the mutual conductance to increase, the bias also increases to compensate. Correct proportionment of the bleeder and bias system produced almost perfect compensation.

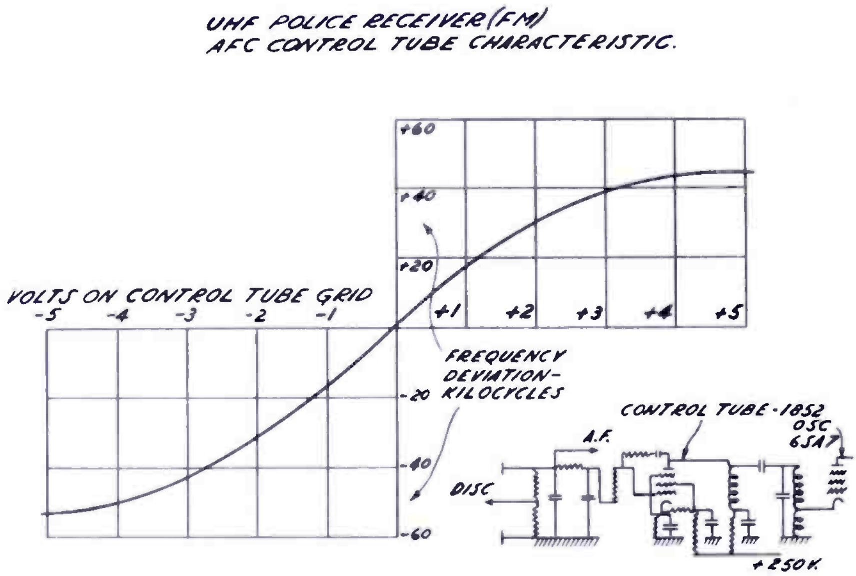


Fig. 5

A-F-C circuit development was concerned chiefly with a symmetrical change of oscillator frequency with changes in control-tube bias about the operating point. With final optimum operation of the tube, a maximum mistuning correction of 20 to 1 was effected at a level of 1 volt on the limiter grid. (See Figure 5.)

Stability with Temperature and Humidity

Stability of the overall frequency-modulation system under temperature and humidity changes proved to be a major problem; although normal oscillator drift under receiving conditions produced no serious results in the presence of a-f-c operation. Under the very worst conditions and with an inoperative transmitter, calculations show that the controlled oscillator is free to drift as much as 19 kilocycles due to combined maximum changes of humidity and temperature. It should be realized, however, that such temperature variations are experienced only over seasonal periods covering months during which servicing and adjustment would be made which would effectively reduce the above calculated drift. Also, the concurrence of such large changes of both humidity and temperature would be very rare. We can therefore expect to encounter in practice a net oscillator shift of under 10 kilocycles. Final operating measurements under extreme temperature and humidity showed less oscillator drift and the results in the presence of a-f-c operation were quite satisfactory.

Audio and Output System, Power Supply and Mechanical Details

The steep-front characteristic of the squelch circuit, actuated by rectified noise voltages, gives full amplification with a 20-per cent difference in signal level from the point at which the squelch starts to open. Conventional output from the 6K6-GT tube gave 2 watts at less than 10-per cent distortion. A control potentiometer in the noise-diode load circuit controls the level at which the squelch system operates. In any complete receiver-transmitter installation the overall a-f characteristic is adjusted in both units for greatest intelligibility under the particular conditions existing in the field.

Plate-current consumption was, of necessity, kept low in order to utilize previously standardized power supplies. The general use of 6SJ7 amplifier tubes wherever possible gave an optimum of gain in relation to plate current requirements; the final design totaled between 75 and 80 milliamperes at 250 volts. The power supply unit draws 6.3 amperes with 5.8 volts input to the vibrator; the heaters consume 3.85 amperes at 6.3 volts.

Other Considerations

An analysis of harmonic interference due to beat notes from various oscillator-frequency combinations indicated a choice of a 1st intermediate frequency of 5 megacycles and a harmonic multiplying of the 1st oscillator frequency by a factor of 6. This analysis aimed at avoiding interference when the receiver was tuned to a police frequency assignment in the 30-40 megacycle band. An intermediate frequency was chosen which gave a minimum of beat-note response points for this band. The desire for a compact mechanical arrangement dictated that care be exercised to locate the two oscillator circuits as far apart as possible. Table II shows possible interference conditions with notes concerning their relative importance. Symbolic notation of these conditions is also shown on the analysis diagram. A graphical solution of the problem appears in Figure 6.

TABLE II—POSSIBLE INTERFERING BEAT NOTES DOUBLE-SUPERHETERODYNE F-M POLICE RECEIVER

No. 1 Intermediate Frequency = 5 Mc
No. 2 Intermediate Frequency = 455 kc

Condition Number	*Interfering Frequencies*	*Difference Frequency*	*Notes*
1	No. 1 oscillator harmonics with signal	Direct	None
2	No. 2 oscillator harmonics with signal	Direct	Not on police assignment
3	No. 1 oscillator harmonics with No. 2 oscillator harmonics	5 Mc	See Fig. 6
4	No. 1 oscillator harmonics with No. 2 oscillator harmonics	455 kc	See Fig. 6
5	No. 1 i-f harmonics with No. 2 oscillator harmonics	455 kc	None
6	No. 1 i-f harmonics with No. 2 oscillator harmonics	5 Mc	See Fig. 6 Neglect those above 5th
7	No. 2 i-f harmonics with No. 1 oscillator harmonics	5 Mc	Low
8	No. 1 i-f harmonics with signal	Direct	Low—6th, 7th, 8th Harmonics
9	Signal harmonics with No. 1 harmonics	5 Mc	Very low
10	Signal harmonics with No. 2 oscillator harmonics	5 Mc	Very low
11	No. 1 i-f harmonics with No. 1 harmonics	455 kc	See Fig. 6
12	Image frequency	5 Mc	Low

Field Testing

Preliminary listening tests upon the models revealed several important precautions to be observed in frequency-modulation operation:

(1) The receiver has to be very accurately adjusted so that the carrier centers on the i-f selectivity and also at the discriminator crossover point.

(2) An accurate audio balance for higher frequencies is very necessary, particularly for reducing impulse noise.

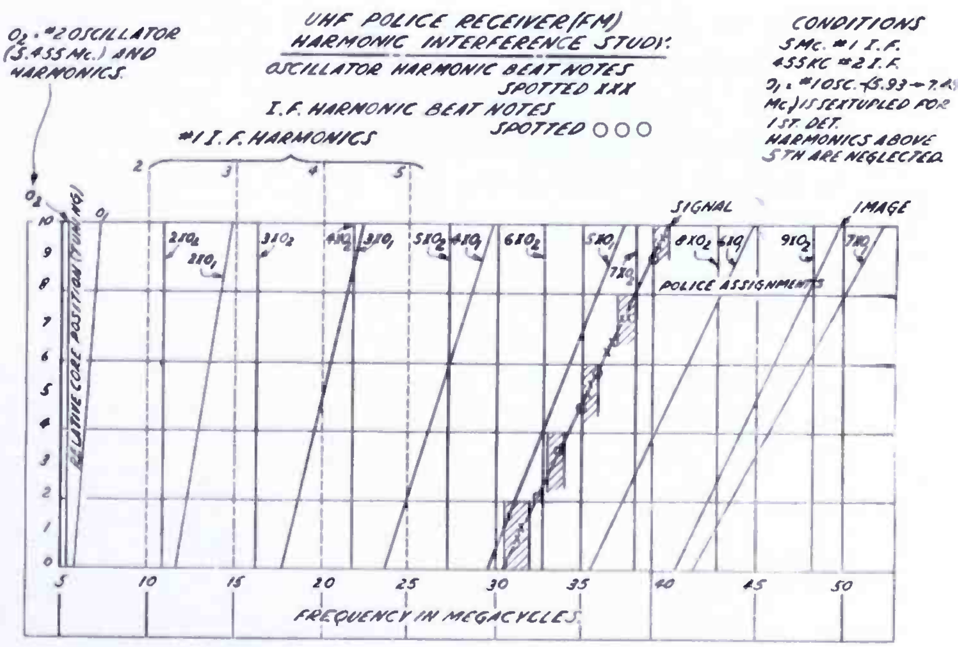


Fig. 6

(3) The selectivity curve must be symmetrical and essentially flat-topped for best noise minimum and also minimum of distortion of the recovered audio. In other words, the i-f selectivity curve must not change materially in shape with signal level and the circuits must not detune under operating conditions.

In arriving at the conclusions given later in this paper a direct comparison was made using two police receivers, one using frequency modulation and the other amplitude modulation. The receivers were of the same general construction and gave similar performance under identical conditions of reception. Each receiver had identical audio-response characteristics and employed the same loud speaker and receiving antenna. It should be noted that the amplitude-modulation receiver was a very late design which had exceptional noise reduction due to a very efficient balanced detector and an automatically operated noise gate; the frequency modulation receiver, of course, included additional circuit elements to provide higher gain, flat top selectivity, discrimination, and a-f-c action, features which resulted in slightly higher manufacturing cost. The comparison used two 22-watt transmitters, one for frequency modulation and one for amplitude modulation, each rated on the basis of equal power-amplifier input power. These radiated equal signals from a common antenna and used identical speech-input equipment and pre-emphasis.

The first installation of the receivers was made in a 1939 Ford Tudor sedan without any form of ignition suppression. These tests showed very little to choose between the receivers, fair reception being possible up to between 10 and 12 miles in a relatively noise-free area

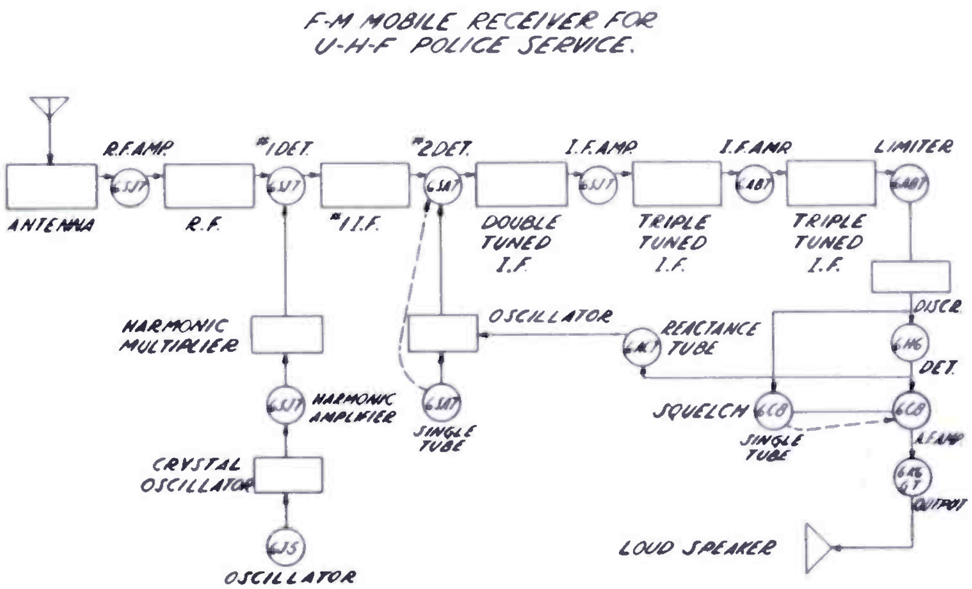


Fig. 7

with little or no ignition noise due to automobile traffic. Laboratory measurements showed the background noise on the frequency-modulation receiver to be 10 to 15 decibels below that on the amplitude-modulation receiver while impulse noise was somewhat worse than on the amplitude-modulation receiver. At less than 9 miles, the results from both types of reception were very satisfactory. In an area where the impulse-noise level remained constant at about 20 microvolts on the antenna, the readability of both receivers was equal; as signal strength improved, the frequency-modulation intelligibility on speech increased somewhat more rapidly than for the amplitude-modulation receiver.

Tests of the typical frequency-modulation characteristic of signal-to-noise ratio versus distance showed that above the threshold of improvement, the frequency-modulation receiver had a definite advantage in background and fluctuation noise over the amplitude-modulation receiver. Below this level, the presence of the automatic frequency control resulted in improved reception in noisy areas. Any noise voltages or shock excitation which might cause detuning of the i-f circuits or might induce shift of the second oscillator gave more noise than if the control were not used. The frequency correction provided by the control circuit served to keep the carrier on tune. Thus, it retained benefit of the discriminator balance for reduction of amplitude noise.

Tests were made with and without audio emphasis on both the amplitude-modulation and frequency-modulation transmitter-receiver systems; a slight advantage resulted for frequency modulation when emphasis was employed.

Performance of the frequency-modulation receiver, midway between two transmitters, both tuned to the same frequency, showed an area of impossible reception of only about 20 feet in width. Outside of this area, complete control of reception was taken over by the stronger station without any crosstalk or other interference. The signal levels at the borders of the area of impossible reception for the particular transmitters used were 15-20 microvolts.

Additional field tests were made with the receivers installed side by side in a stationary set-up using two identical transmitters in a mobile unit. Improvement for the frequency-modulation system was again quite definite. A series of phonograph recordings was made of the audible results. Background noise on the frequency-modulation receiver was again 10 to 15 db less than on the comparable amplitude-modulation receiver and all types of artificial interference were noticeably reduced.

CONCLUSION

From this investigation and these results it may be concluded that frequency-modulation reception in the u-h-f police band offers decided noise reduction in service areas where the signal strength equals or exceeds the noise level.

Such performance is practically and economically obtainable from a service and manufacturing standpoint in the compact arrangement necessary for police use. The addition of automatic frequency control seems advisable from a noise-reduction standpoint and the use of a double-superheterodyne circuit greatly enhances performance.

PHOTOGRAPHY OF CATHODE-RAY-TUBE TRACES

By

H. F. Folkerts* and P. A. Richards

Research and Engineering Department, RCA Manufacturing Co., Inc., Harrison, N. J.

Summary—A permanent record of the trace on the screen of a cathode-ray tube is often desirable. For patterns which may be caused to stand still or follow the same path each cycle the time of exposure is dependent upon the characteristics of the lens, the cathode-ray tube, and the type of film. These same factors affect the velocity of spot which may be photographed as it traverses the screen only once. Some photographs of the latter are taken with moving film cameras. In this case the persistence of the fluorescent screen may be a factor. Constants relating these factors are given for several films and cathode-ray tubes.

Introductory

The cathode-ray oscillograph has now become an essential tool in many research activities and in numerous manufacturing control operations. When the phenomena is such that the shape of the wave cannot be remembered long enough to interpret it properly, or when a permanent record is desired, a photograph of the cathode-ray trace may be required. It is the purpose of this paper to consider the photography of cathode-ray traces and to discuss the factors involved in the selection of the cathode-ray tube, the type of film, the method of taking the picture, and the results to be expected.

Fluorescent Screen Materials

In most oscillograph applications it is desirable to be able to view the trace made by the cathode-ray beam. Where visual observation is the sole object, the fluorescent screen of the cathode-ray tube should be chosen on the basis of the screen material having the greatest luminous efficiency. Such a material is known as No. 1 phosphor. Its maximum fluorescence as shown in Figure 1 is in the green where the eye has optimum response.

The selection of a screen material for best photographic characteristics may require some sacrifice in visual brightness. For example, consider the persistence characteristic of a phosphor. This is the relationship between the spot brilliance and the time elapsed after the excitation has been removed. Figure 2 shows how too long a per-

* Now with National Broadcasting Co., New York.

sistence can blur the picture when an attempt is made to photograph a trace on moving film. This picture illustrates the persistence of No. 1 phosphor and was taken with the film moving horizontally while the cathode-ray spot moved vertically at a frequency of 12 cycles per second. Several similar photographs were taken with moving film to determine the maximum velocity tolerable with the No. 1 phosphor. It was found that persistence did not confuse the picture unduly for a film velocity of less than 1 centimeter per second and a magnification of one-to-one. For other than a one-to-one magnification the maximum film velocity is about M centimeters per second; M being the magnification.

Persistence of the screen material, however, is not a limiting factor for stationary film. For such applications, the No. 1 phosphor is to be

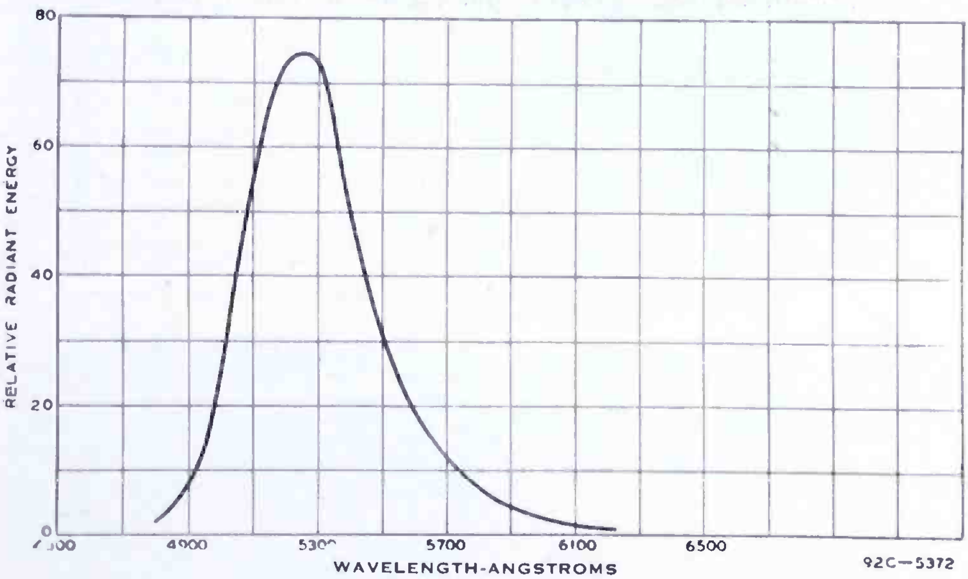


Fig. 1—Spectral characteristics of No. 1 phosphor.

preferred since it combines good observational and good photographic qualities. For moving-film applications where the film speed is above M centimeters per second a screen material having short persistence is essential. The spectral characteristic of such a phosphor, known as No. 5, is shown in Figure 3. As the spectral curve indicates, No. 5 phosphor fluoresces blue. This color response means that its visual efficiency is somewhat impaired, but since moving film is to be used with this type of screen material its actinic response as well as its persistence characteristic is important.

Types of Film

A casual glance into the catalogues of the large film supply houses will reveal a large variety of films, plates, and recording papers. In general laboratory applications where set-up time is valuable and the cost of the photographic material is of minor importance, it is usually good practice to select high-sensitivity plates or films. Selection of high-sensitivity material has the advantage that it permits improvement of other desired qualities of the associated equipment, such as a finer spot on the cathode-ray tube, the use of a slower lens, etc.

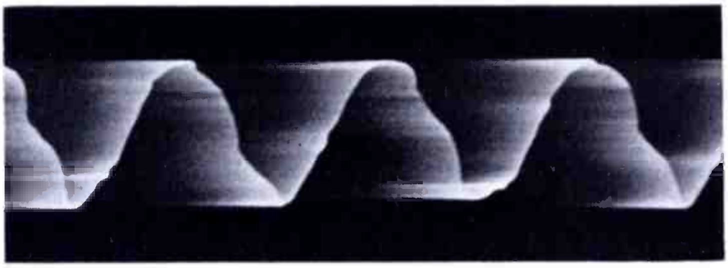


Fig. 2—Photograph showing persistence of screen material.

The choice of the most sensitive film for a particular phosphor involves the summation of the phosphor-energy film-sensitivity products for each wave length of their spectrums. A general impression of this summation may be obtained by noting the curves shown in Figures 1 and 3 and their relation to the curves of Figure 4. The three film materials shown cover the energy spectrum of the No. 1 phosphor

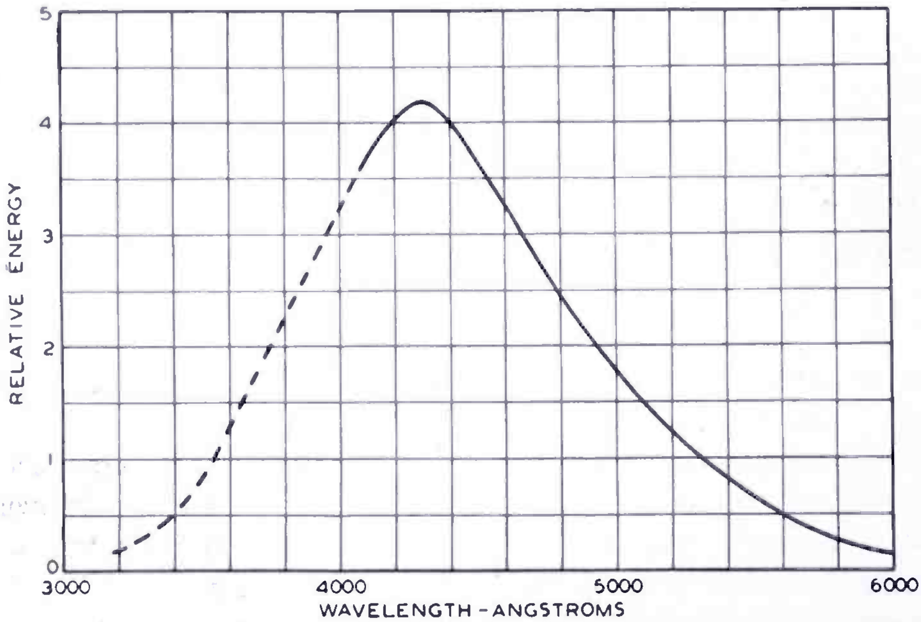


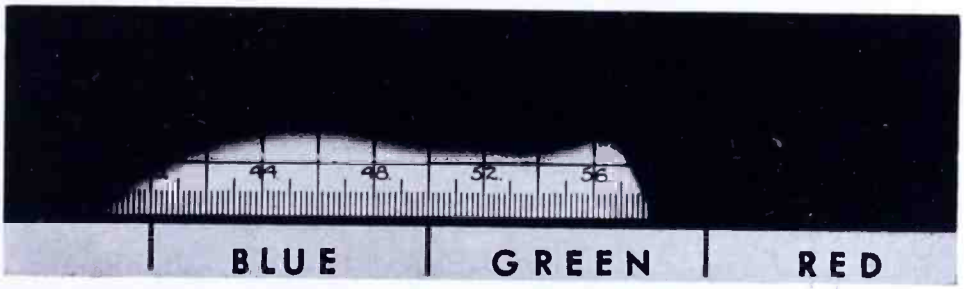
Fig. 3—Spectral characteristics of No. 5 phosphor.

and nearly all of the energy spectrum of the No. 5 phosphor. These materials are, therefore, to be considered practical from the coverage standpoint.

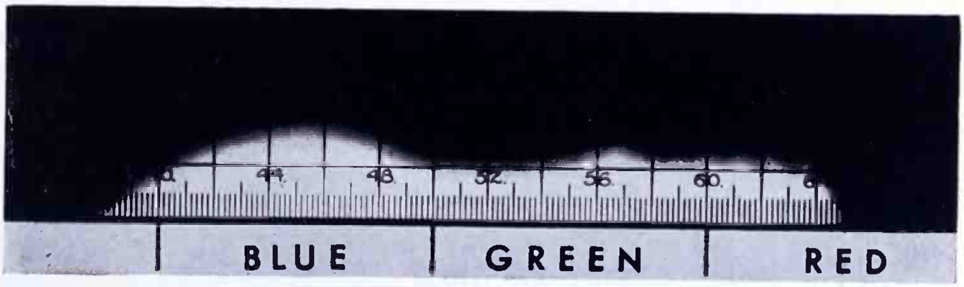
In general, since the photographic process is sufficiently complicated at best the simplest practical procedure is to be preferred. An example of convenience being the determining factor for the choice of film may be cited in the case of the two "X" type films shown in

Figure 4. The Ortho "X" is deficient in red sensitivity and so may be used with a red darkroom light, a procedure helpful in loading film holders and in general manipulation. Because Verichrome film is generally available, its characteristics have been included in Figure 4. Tri X film was found to have sensitivity slightly greater than the other two types.

Several forms of hypersensitizing films have been described in the literature. Hypersensitization in mercury vapor has been reported to give an appreciable increase in film sensitivity.[1] The use of such methods is justified, of course, if only by their use can a suitable record be made.



Verichrome and Ortho-X film



Tri-X film

Fig. 4—Spectral sensitivity of three types of films.

Cathode-Ray Tubes

Characteristics of the tube which affect photography aside from the phosphor itself are those which control the energy density to the phosphor, and the useful area of the screen.[2] The energy delivered to the phosphor may be increased by increasing anode voltage. The increase can be carried only to the maximum value for which the tube is designed. Commercial tubes cover a range of maximum rated anode voltages between 600 and 15,000 volts. Cathode-ray tubes of small

---

[1] New method for the Dry Hypersensitization of Photographic Emulsions, F. Dersch and H. Durr, February, 1937, *Journal of the Society of Motion Picture Engineers.*

[2] The Cathode Ray Tube at Work, published by *John H. Rider, Inc.,* New York City.

mechanical dimensions are often chosen because of space and cost considerations of the associated equipment. While larger tubes usually have a better ratio of spot size to screen diameter, they also usually require a more expensive camera lens with a larger useful field coverage.

The data on Figure 5 show how screen brilliance is affected by the current and voltage to the No. 2 anode of a typical cathode-ray tube.

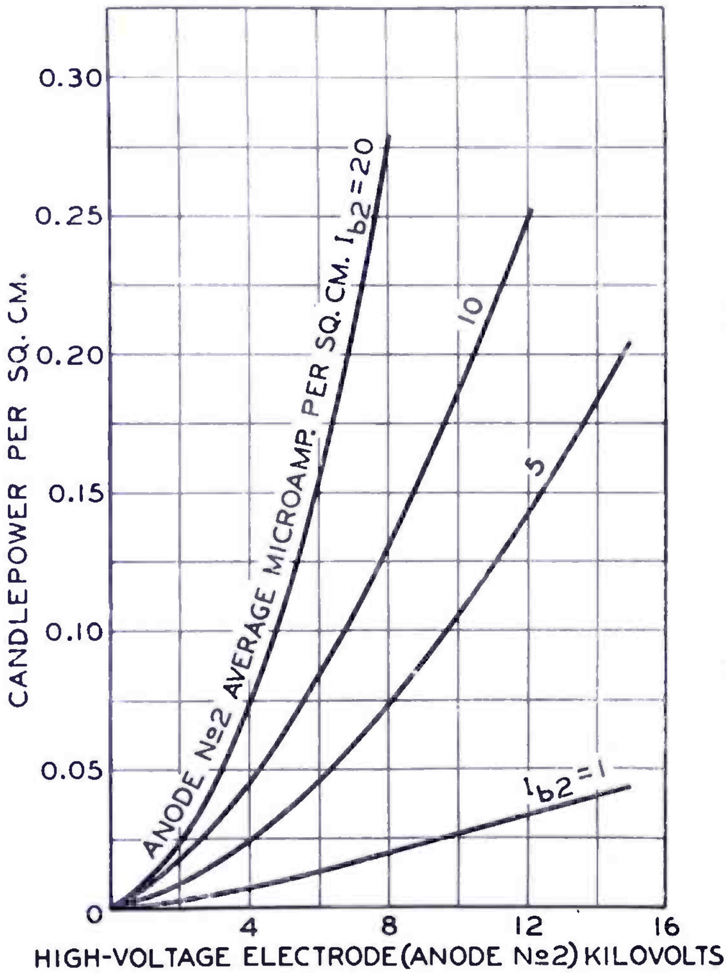


Fig. 5—Typical brilliance vs. high-voltage electrode potential and current.

The control electrode voltage vs. No. 2 anode voltage curve for the same tube is shown in Figure 6. Commercial oscilloscopes are usually provided with an adjustment for the voltage applied to the control electrode.

The spot size will be smallest when the No. 2 anode voltage is maximum and the beam current is low. Since this provides the sharpest pictures, No. 2 anode current should be kept at the lowest value which will provide a suitable picture.

The life of fluorescent screens depends on operating conditions. The crystals of which the screen is composed can be damaged by high beam power. On the other hand the use of high beam power may be advantageous and feasible when the time it is to be applied is small. Its use makes possible the taking of photographs of short-duration, high-speed phenomena by increasing the energy to the screen for only

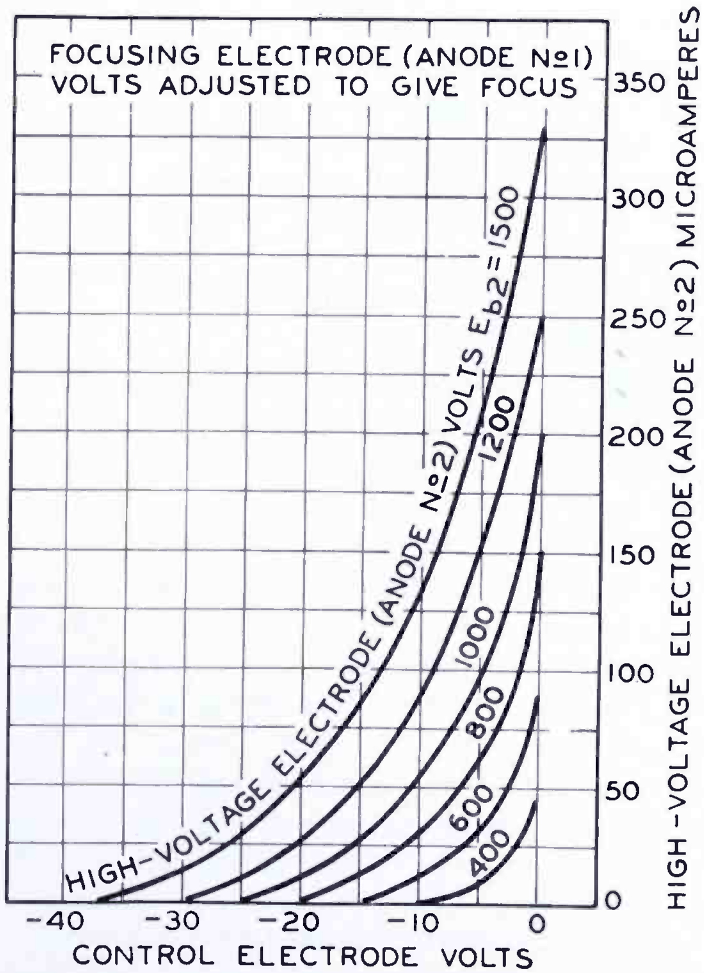


Fig. 6—High-voltage electrode current vs. control-electrode voltage for Type 906 tube.

the length of time required to take the picture. Where the energy level is high and the time must, therefore, be held to a minimum some form of automatic control-grid switching circuit is required.

Screen power in excess of that recommended for the tube causes a gradual deterioration of the surface. The rate depends, of course, on the amount of excess power and its duration. The first symptom of deterioration is a reduction in brilliance of the area affected. The reduction is accumulative in that continued exposure of the screen to excessive beam power will continue to reduce the screen efficiency.

When a part of the screen has been damaged, it is sometimes practical to make further use of the tube by utilizing an undamaged portion for the important part of the phenomena.

When different cathode-ray tubes are compared, the relationship between current density to the fluorescent screen and the second anode current should be kept in mind. In some types of cathode-ray tubes the ratio of the current reaching the fluorescent screen to the No. 2 anode current is purposely reduced to allow a smaller spot to be obtained.

Other factors such as the cost of providing high anode voltages and increased deflection voltages may also be important when the maximum a tube will provide is not required.

Lenses

The lens should be selected for two characteristics. First, the ratio of the image intensity to tube trace brightness should be high and, second, the sharpness of the image should not be impaired by the lens. The image intensity depends on the speed of the lens and on its light transmission. The speed of the lens is defined as the ratio of the focal length to the effective aperture. The light transmission is the ratio of the light leaving the lens to the light entering it.[3] The light transmission of lenses having several elements, such as highly corrected photographic lenses, may be improved by applying a non-reflecting coating to the glass surfaces.

For most applications, a reasonably well-corrected photographic lens will provide a picture of satisfactory quality.

Exposure Formula

It has been found convenient to combine the factors influencing the exposure density of film in a formula. Its use not only allows visualizing the part played by each factor, but it also allows prediction of performance under somewhat different conditions.

For the transient case where only one excursion of the beam is to be photographed the velocity of the spot should be determined. From this value the other factors may be obtained.

In the case of the recurrent phenomena the time of exposure will need to be determined. Its relation to the other factors necessary for a useful record may be shown by the formula.

[3] Handbook of Photography, by Henney & Dudley, *McGraw-Hill Book Company*, New York City.

The formulas relating these factors are:

$$V = \frac{CW}{TF^2(M+1)^2} \text{ for transients}$$

and
$$t = \frac{KTF^2(M+1)^2}{w} \text{ for recurrent phenomena}$$

Where V = the velocity of the fluorescent spot in kilometers/sec.
C = constant (empirically determined)
F = the lens speed
T = the lens light transmission
M = the magnification ratio $\frac{\text{image size}}{\text{object size}}$
W = the total power to the No. 2 anode in watts
w = the power to the No. 2 anode in watts per sq. cm.
t = exposure time in seconds
K = constant (empirically determined), usually $= \frac{0.00004}{C}$

The factors C and K include the cathode-ray-tube parameters and the film constants. They must be ascertained for each tube, for each voltage applied to the second anode, and for each film type. The choice of a suitable density for the trace on the film is somewhat a matter of personal preference. A convenient method of selecting a suitable value is to determine the density at which the picture is just discernible and then to allow double this time or half of the spot velocity for the exposure of an acceptable film. Greater density is usually required when positives are to be printed from the film.

Since the factors C and K depend upon conditions which often differ with individual setups, it is recommended that they be determined experimentally. The data given by the formulas are helpful in the selection of camera, film, type of cathode-ray tube, etc. For this purpose, data on several commercial cathode-ray tubes are presented in Table I. A generous safety factor should be allowed in using these data to allow for probable differences in actual conditions.

The differences between the sensitivities of films must be taken into account. Tests on the three types for which data are shown in Figure 4 indicate that the same factors for C and K are approximately correct for all of these, although the Tri-X actually shows slightly greater sensitivity than the others.

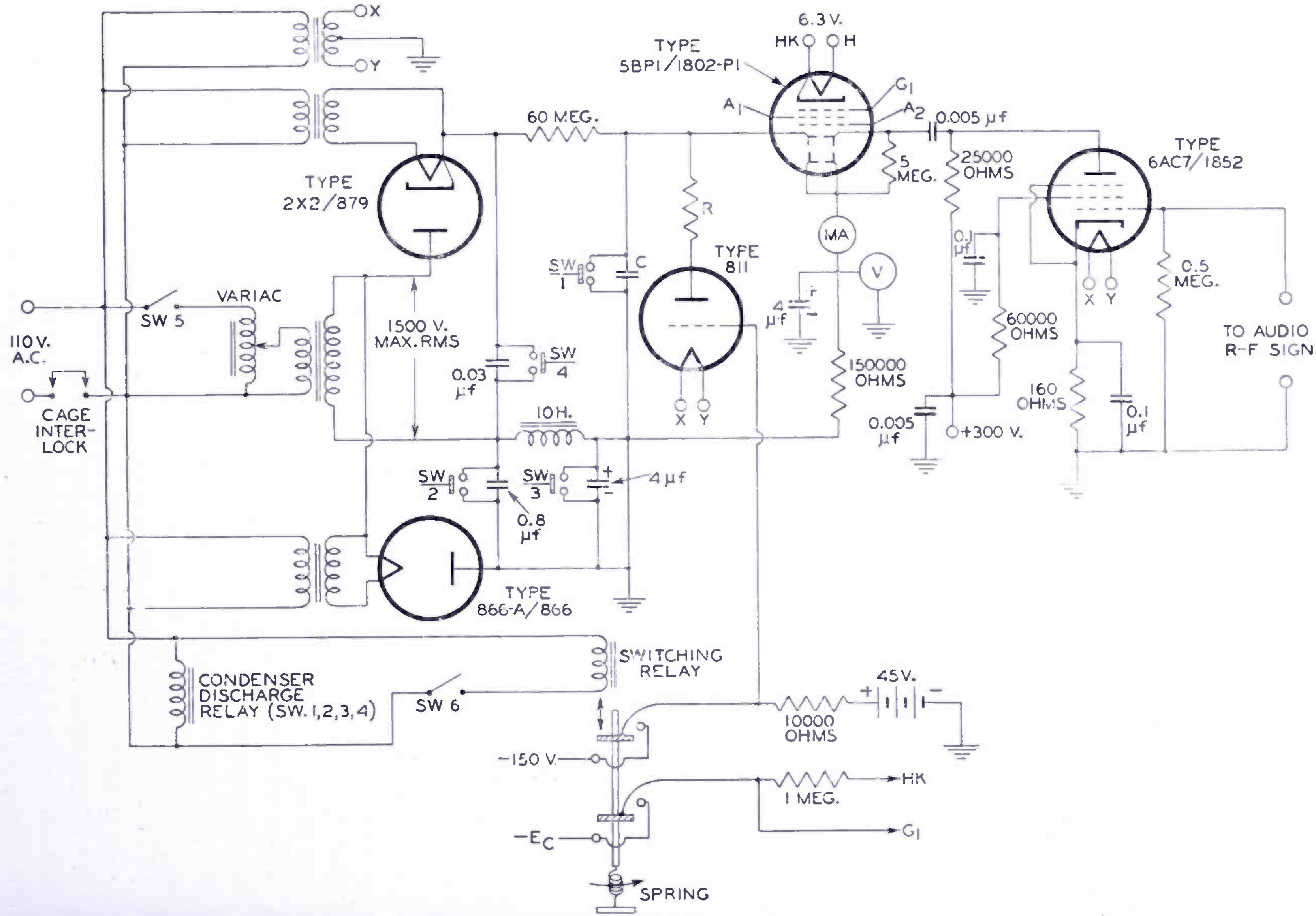


Fig. 7—Test circuit.

TABLE I

Tube Type	Screen Persistence	Screen Diameter	No. 2 Anode Voltage	K Recurrent Phenomena	C Transient Phenomena
5BP4/1802P1	Medium	5″	2000	0.000013	3
5BP4/1802P1	Medium	5″	1000	0.00002	2
Developmental	Short	5″	2000	0.000008	5
Developmental	Short	5″	1000	0.00001	4
3AP1/906-P1	Medium	3″	1500	0.000002	20
3AP1/906-P1	Medium	3″	1000	0.000004	10
3AP1/908	Short	3″	1500	0.0000013	30
3AP1/908	Short	3″	1000	0.000006	7
Developmental	Short	2″	1000	0.000002	20
Developmental	Short	2″	600	0.0000035	11
902	Medium	2″	600	0.000005	8

These data apply to Ortho-X, Verichrome, or Tri-X types of film. For other films the factors will be different.

APPENDIX

THE METHOD USED TO GET DATA

Experience has indicated that the laboratory worker has found it more troublesome to photograph transients than recurrent phenomena.

A single-sweep transient having a range of velocity along its path was selected. This was obtained with the condenser-discharge circuit shown in Figure 7. The cathode-ray tube was supplied with a voltage of known frequency for vertical deflection by a 6AC7/1852 amplifier tube. The sweep circuit consisted of a condenser-resistor network, C and R. The condenser was charged from a power supply whose potential was adjustable. The condenser was discharged through the resistor by controlling the 811 tube in such a way that it acts as a switch.

The velocity of a spot deflected by the voltage across a condenser which is being discharged is shown in the formula

$$V = \frac{d}{RC}$$

Where V = spot velocity in kilometers/second

d = spot deflection in mm (distance from zero velocity end)

R = resistance in ohms

C = capacitance in microfarads

The switch used to control the discharge and cathode-ray tube brilliance was adapted from a solenoid-type contactor. The moving member dropped free from one set of contacts to the other. When the time allowed for taking the photograph was longer than needed for the switch to drop it was necessary to make the bottom contacts inoperative and pick up the switch magnetically at the end of the sweep.

The camera was set up in front of the tube and all light excluded so as to have no stray room light falling on the screen to reduce the contrast. The distances were set to make the image size on the ground glass equal to the cathode-ray-tube trace.

Fig. 8—Photograph illustrating type of sweep used for obtaining data.

Figure 8 shows the type of photograph obtained with the equipment described.

(a) is the trace showing varying velocity sweep.

(b) is the trace with the same sweep velocities, but with a vertical calibrating frequency applied.

For this photograph, the 906 cathode-ray tube was used at a No. 2 anode voltage of 1000 volts. An F4:5 lens was used at full aperture with Tri-X film. The enlargement of the spot at the end of its travel is due in part to magnetic coupling from the switch.

A SIMPLIFIED TELEVISION SYSTEM FOR THE RADIO AMATEUR AND EXPERIMENTER

By

L. C. Waller* and P. A. Richards†

Summary—*A new Iconoscope has made it practical for amateurs to participate in electronic television investigations. An experimental amateur television system including camera unit, receiver, and 2½-meter transmitter is briefly described. In this system the frame frequency and lines per picture are, respectively, 30 and 120.*

FOR many years, leading radio amateurs have dreamed of carrying on two-way television communication. Having satisfactorily mastered the art of projecting their radio telegraph and telephone signals around the world, it is only natural that these scientifically-minded pioneers of the short-wave ether lanes should turn their attention next to the transmission of pictures "through the air."

Early amateur television experimenters investigated the possibilities of Nipkow discs and related mechanical contrivances. But it was not until electronic television began to emerge from the laboratory that the realization of their dream seemed close at hand. As evidence of their interest in this fascinating new electronic art, the American Radio Relay League, national association of radio amateurs, began publishing in *QST*, in 1937, a series of articles on the basic principles involved in electronic television. Many amateurs, especially those in the New York area who were within range of the NBC station atop the Empire State building, hastened to build television receivers. However, the *reception* of signals was only half—and the lesser half—of any radio amateur's existence. What he really wanted was a television transmitter of his own, so that he could televise his own subjects.

Until very recently, there has been one very effective deterrent, or bottle-neck, in the development of amateur television transmissions—and that was the lack of a low-cost picture pick-up tube, or "Iconoscope." The large camera tubes used by the experimental commercial

* Formerly with RCA Manufacturing Company, Inc., Harrison, N. J.
† RCA Manufacturing Company, Inc., Harrison, N. J.

stations were prohibitive in cost, so far as the average amateur was concerned. This bottle-neck has now been removed, by the recent availability of an inexpensive miniature Iconoscope designed expressly for amateur and experimental use. This tube, shown in Figure 1 beside one of the larger Iconoscopes, was developed largely by Mr. W. H. Hickok*.

The new Iconoscope, type RCA-1847, is only 7⅝ inches long. It contains a transparent mosaic, somewhat less than 2 inches in diameter, on which the image of the scene or object to be televised is

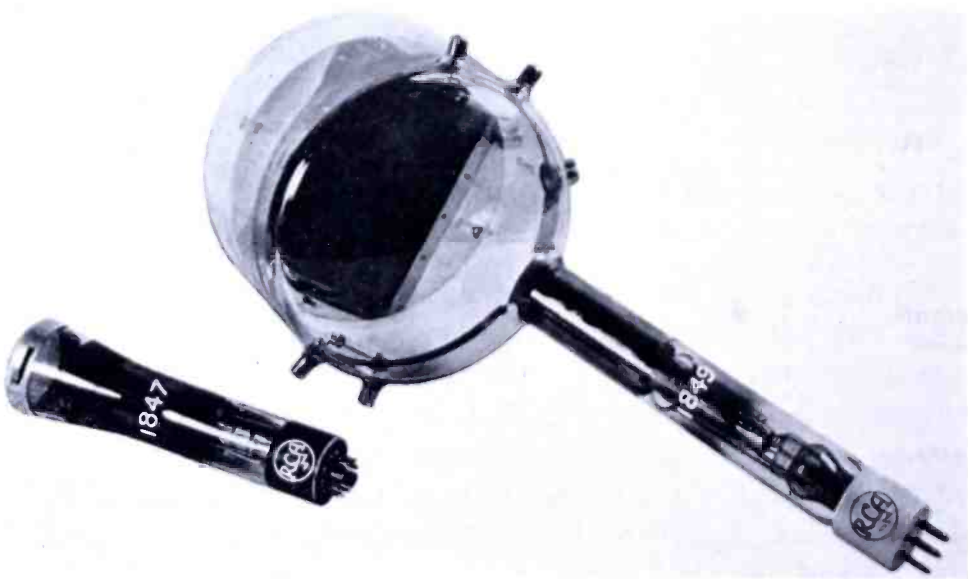


Fig. 1—Comparative view of new amateur Iconoscope and Iconoscope for studio use.

focused. The new tube operates at the relatively low second-anode voltage of 600 volts and employs electrostatic deflection of the electron beam. An excellent explanation of how the 1847 operates has been given by Mr. James J. Lamb.†

In order to demonstrate the possibilities of the miniature Iconoscope in amateur-type television equipment, the essential apparatus for a complete amateur television station has been designed and built in the RCA laboratories at Harrison, N. J. This experimental equipment is illustrated in Figure 2. From left to right, the three major units are the television receiver, the ultra-high-frequency transmitter, and the camera-modulator unit.

* Research and Engineering Dept., RCA Manufacturing Company, Inc., Harrison, N. J.

† "A New Iconoscope for Amateur Television Cameras," *QST*, June, 1940.

The Camera-Modulator

The camera unit, designed by Mr. J. B. Sherman,* is shown in Figure 2. This unit is the heart of the entire system; it includes a Type 1847 Iconoscope and its optical system, a Type 902 monitoring Kinescope, and a 6L6 video modulator. Auxiliary circuits include the scanning oscillators and amplifiers, the blanking- and sync-signal amplifiers, the 4-stage video amplifier, and the low- and high-voltage power supplies. The schematic circuit of this unit is shown in Figure 3.

The system is based on a tentative amateur television standard of 120 lines and 30 frames per second. Straight progressive scanning is used in order to avoid the additional complications involved with interlacing. Thus, the vertical and horizontal scanning frequencies are 30 and 3600 cycles per second, respectively.

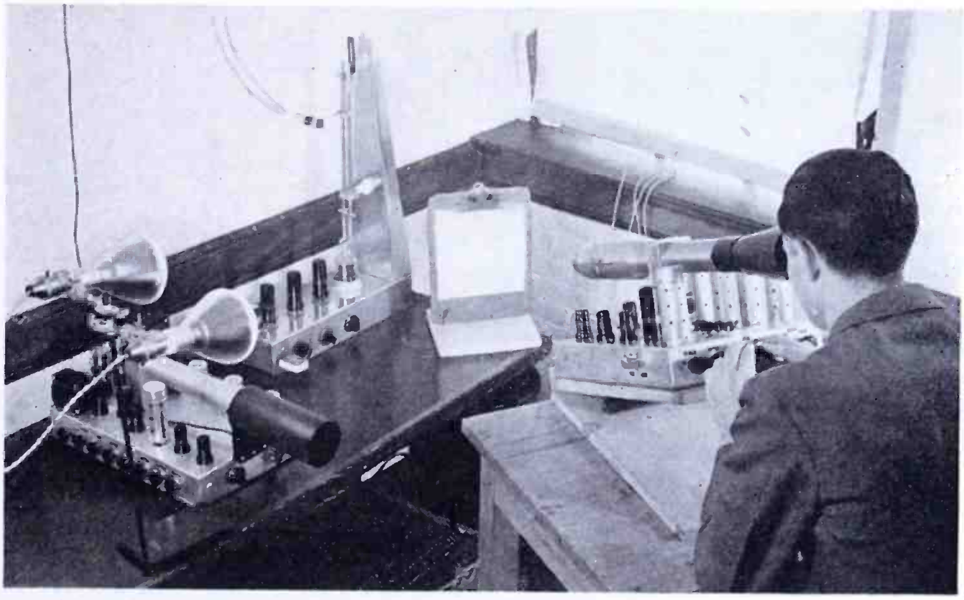


Fig. 2—Component units of amateur television system.

The video-channel width required is quite small, being in the order of 200 kc. With double-sideband modulation of the carrier, a 400-kc channel is necessary. Since the amateur 2½-meter band (for which this equipment is intended) covers 4 Mc, there are about 10 usable channels available in this band alone. In addition, the 224-230-Mc band provides 15 more channels in the vicinity of 1¼ meters. The pronounced directivity of u-h-f beam antennas will tend to reduce interference between stations greatly, even when they are on the same frequency. The limited range of u-h-f transmitters will also help in this respect. Thus, from the technical point of view, there are no serious obstacles to the rapid development of amateur television.

* Formerly with RCA Manufacturing Company, Inc., Harrison, N. J.

The optical system of the camera is quite simple. It is desirable to use a large-aperture lens, but it need not be of camera quality. A projection lens is entirely satisfactory. In this camera unit, a 35-milli-

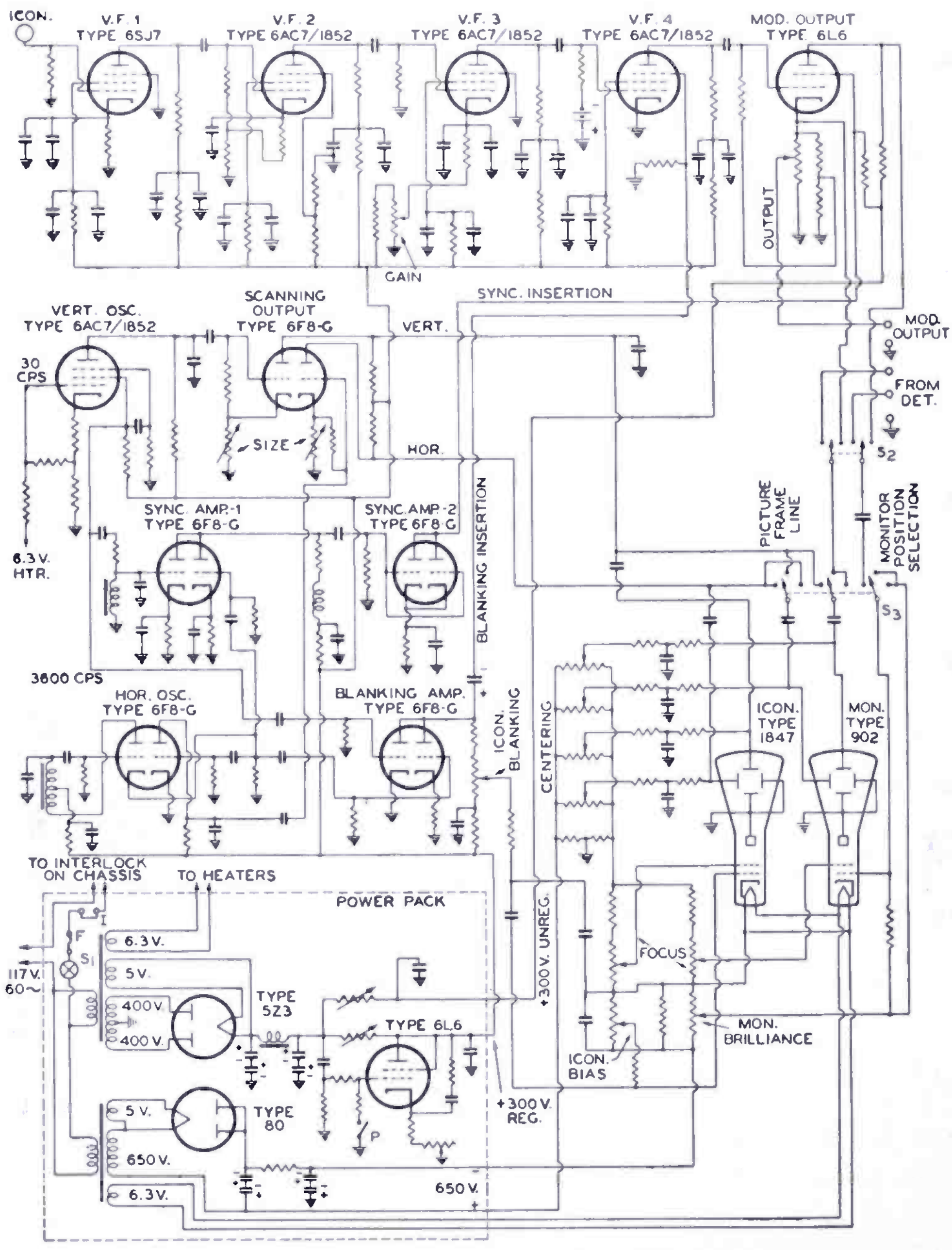


Fig. 3—Circuit of camera-modulator unit.

meter-film projection lens of f2.3 and 3-inch focal length is employed with good results.

One of the novel features of the camera unit is the back-to-back mounting of the Iconoscope and the 902 monitor tube. This arrangement makes it mechanically convenient to use the same scanning circuits and high-voltage power supply for both of these tubes. The monitoring Kinescope provides the operator with an instantaneous check on both the optical and electrical adjustments as they affect the quality of the picture being transmitted.

The U-H-F Transmitter

The crystal-controlled 2½-meter transmitter can be seen in Figure 2. This unit, the circuit of which is shown in Figure 4, is of typical amateur design and construction. Only four r-f stages are employed, although the crystal has a fundamental frequency of approximately 7 Mc.

The crystal oscillator is of the well-known "Tri-tet" type, using a 6L6 beam power tube. The oscillator tube, in its output circuit, quadruples the crystal frequency to 28 Mc. The second stage employs a 6L6 as a 56-Mc doubler and the third stage another 6L6 as a 112-Mc

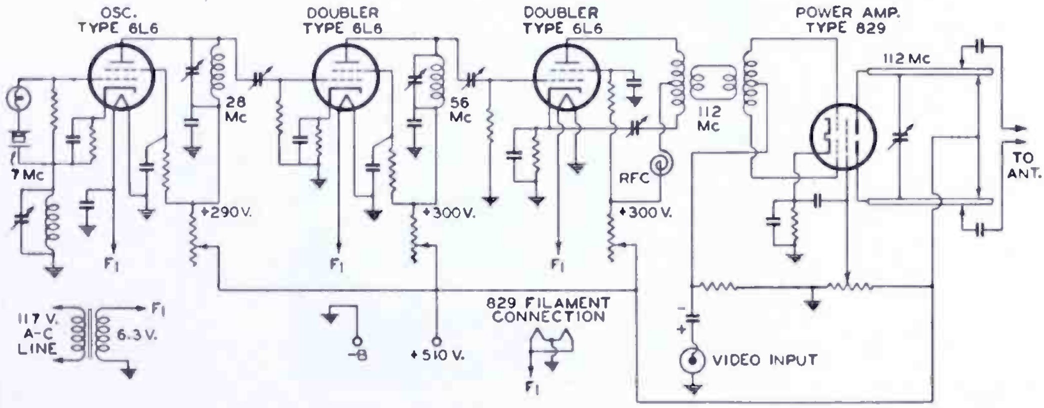


Fig. 4—Circuit of transmitter.

doubler. The final stage uses an RCA-829 twin-beam tube as a straight push-pull r-f power amplifier, with an output frequency in the 112-116-Mc amateur band. Operating at the relatively low plate voltage of 500 volts, the 829 delivers a carrier power of about 23 watts when adjusted for grid modulation.

The video voltage which modulates the grids of the 829 is obtained directly from the cathode circuit of the 6L6 video modulator, located on the camera unit. A short concentric line serves to feed the modulating voltage from one unit to the other.

The 829 r-f power amplifier uses a ¼-wave, resonant-line plate circuit. A plate-circuit efficiency of 35 per cent is obtained, this value being normal for grid-modulated service. In actual operation, the plate tank is capacitively coupled to a 470-ohm non-resonant transmission line, which feeds a 3-element, close-spaced beam antenna.

The Amateur Television Receiver

The receiver, shown at the left in Figure 2, is of the superheterodyne type and is intended to cover only the 112-116-Mc amateur television band. It is designed for use with a three-inch Kinescope such as the 3AP4/906-P4 (white screen) or the 3AP1/906-P1 (green screen).

A circuit diagram of the receiver is shown in Figure 5. A 956 acorn

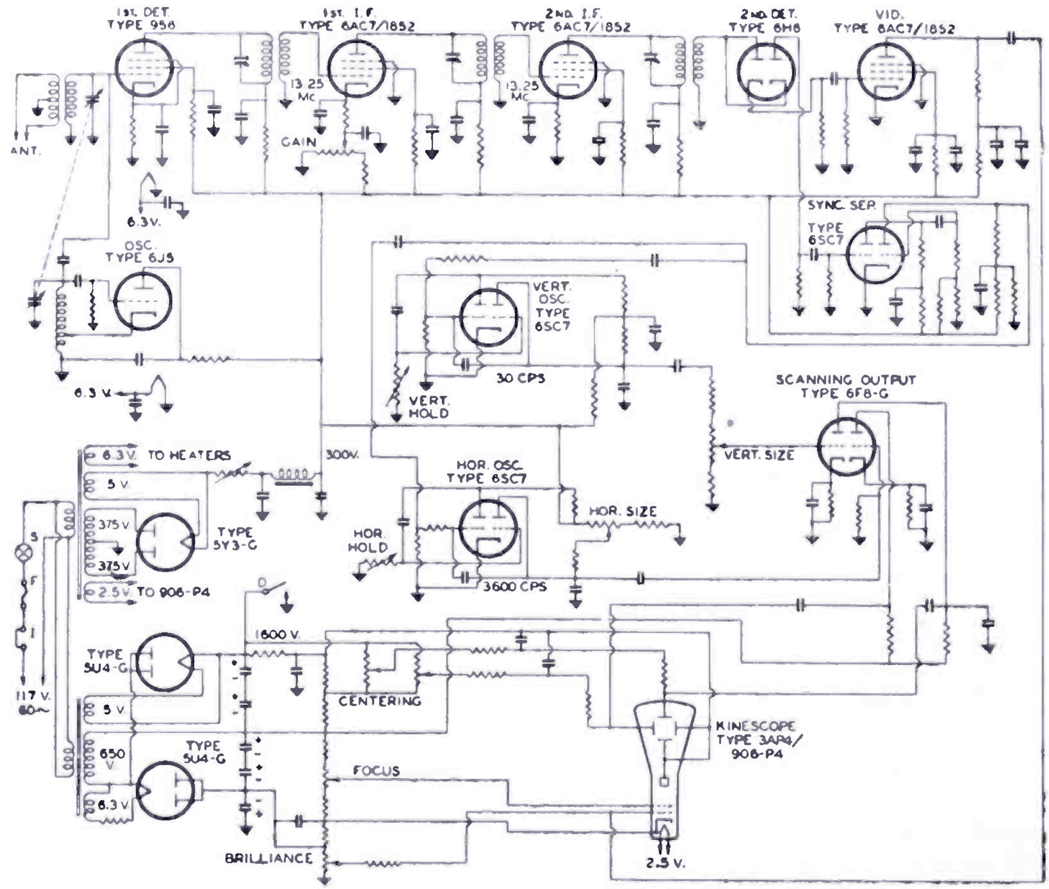


Fig. 5—Circuit of receiver.

pentode is used as the first detector with a 6J5 as a separate, high-frequency oscillator. In the interest of simplicity, no r-f stage is employed. There are two i-f stages using 6AC7/1852's operating at a frequency of 13.25 Mc. The oscillator frequency is placed 13.25 Mc below the signal frequency, so that its tuning range is 98.75 to 102.75 Mc. The second detector is one diode unit of a 6H6, this stage being followed by one 6AC7/1852 video amplifier. The second diode unit of the 6H6 is used as a detector for synchronizing purposes only. This diode feeds a 6SC7 double triode, the first half of which is used as an amplifier and the second half as a sync separator. Multi-vibrators containing one 6SC7 each are employed for the scanning oscillators. Each oscillator feeds one unit of a 6F8-G dual triode, which delivers the vertical and horizontal saw-tooth deflecting voltages to the Kinescope deflecting plates.

The Kinescope is operated at 1500 volts second-anode potential, obtained conveniently from a small receiver-type power transformer in a voltage-doubling circuit. This power supply also furnishes 750 volts for the 6F8-G scanning amplifiers. A low-voltage supply using a 5Y3-G takes care of the remaining stages.

The i-f transformers employed are well suited to the requirements of the receiver. When they are peaked at 13.25 Mc, without resistance loading, the overall response from antenna to Kinescope shows a characteristic which is down 50 per cent at both sides of a 1-Mc band.

Fig. 6—Received picture.

Therefore, the receiver is capable of handling 400-kc double sideband transmissions with no appreciable loss.

A photograph of a picture on the Kinescope screen is shown in Figure 6. This picture was picked up initially by the camera unit and transmitted on the 2½-meter carrier to the receiver. It is interesting to note that, for purposes of test or demonstration, the u-h-f transmitter is not essential. That is, the camera-modulator and receiver units can be employed in an arrangement where the receiver is operated directly from the video-modulator stage by means of a 3-wire line.

PERFORMANCE

The first "field test" of the amateur television equipment which has been described was conducted with the transmitter located at Delawanna, N. J. and the receiver at Nutley, N. J.—an air-line distance of about $1\frac{1}{2}$ miles. The pictures received were quite good, there being no apparent loss of detail in the modulating or transmitting processes. Ample signal strength was obtained, even with a poor inside antenna on the receiver. On the basis of results obtained in this test, it is anticipated that this same equipment will be capable of covering 10 or 15 miles—possibly more—under favorable circumstances. A highly directional beam antenna placed at a fairly high elevation will greatly increase the effective range of the transmitter.

The reliability of the amateur television equipment is well illustrated by its performance at the Radio Parts Manufacturers' Trade Show held at Chicago June 11 to 14, 1940. Operating with the experimental station call W10XEL, the apparatus was demonstrated continuously for four days, running about 12 hours a day, without a single interruption due to technical difficulties. Most observers who witnessed these demonstrations were frankly surprised at the good detail which could be obtained in a 120-line picture, especially in view of the compactness and simplicity of the apparatus. Successful pick-ups were made of stationary pictures, live talent, and street scenes on Michigan Boulevard in front of the Blackstone Hotel. The outdoor pick-ups were surprisingly good on bright, sunny days.

Conclusion

Now that an inexpensive Iconoscope is available, it is apparent that amateur television is in a position to go forward. The pioneering amateur, who has contributed so much to the art of radio communication, again has a vast new field for research and experimentation. As in the field of radio broadcasting, he can be expected to do much in bringing this new art to the American public.

Note—Complete constructional data on the amateur television system which has been described can be found in the following magazine articles:

(1) "A New Electronic Television Transmitting System for the Amateur," by J. B. Sherman, *QST*, May, 1940.

(2) "A Receiver for the New Amateur Television System," by J. B. Sherman, *QST*, June, 1940.

(3) "An Efficient U-H-F Unit for the Amateur Television Transmitter." by L. C. Waller, *QST*, July, 1940.

OUR CONTRIBUTORS

BENJAMIN R. CARSON attended evening classes at Central High School, Philadelphia, the West Philadelphia High School, and Drexel Institute during a nine-year period. He went with the Standard Roller Bearing Company in the Pattern and Tool Design Departments in 1912, and in 1916 joined the Engineering Department of the Eddystone Rifle Plant of Midvale Steel. In 1918 he joined the Wright Roller Bearing Company; 1920, the Electric Service Supplies Company; 1923, the Miller Lock Company; 1924, the Victor Talking Machine Company; 1928, the Philco Radio Company; 1929, the M. Tucker Company; and the Engineering Department of the RCA Manufacturing Company in 1930.

HARMON B. DEAL was born in Charleston, Missouri. Received A.B. from Southeast Missouri State Teachers College and B.S. from Massachusetts Institute of Technology. Has been Marconi Commercial Operator — U. S. Naval Radio Electrician 1917-1918. Engineer with Bell Telephone Laboratories, Atwater Kent, and Philco Companies and Instructor in Electrical Engineering at Iowa State College. Since 1934 has been engineer with RCA License Laboratories.

VERNON J. DUKE attended the University of Denver and later entered the engineering college at the University of Colorado at Boulder, Colorado, where he received the degree of B.S. in Electrical Engineering in 1928. He entered the Student Engineering Course of the General Electric Company at Fort Wayne, Indiana, later transferring to the radio department in Schenectady, New York. In November of 1929, he was employed by the National Broadcasting Company at Station KOA, and in 1937 he was transferred to the Development Group of the Company at Radio City where he has specialized in experimental television work.

LOWELL E. FLETCHER received his B.Sc. degree in Electrical Engineering from Des Moines University in 1928. After his graduation he spent one year in the Engineering Department of the Northwestern Bell Telephone Company. Since 1929 he has been engaged in the Engineering Department of R.C.A. Communications, Inc., at Rocky Point, Long Island.

HERMAN F. FOLKERTS was born June 9, 1914, in New York. He graduated from the RCA Institutes in June, 1934 and attended the Newark Technical School, evenings, for three years. Entered the Research and Engineering Laboratories of the RCA Radiotron Division in 1935 and spent four years in the Television Section until 1941 when he transferred to the National Broadcasting Company's Television Engineering Section.

CLAUDE L. KENNEDY received his B.S. Degree in Mechanical Engineering from Purdue University in 1929. After graduation he joined the Operating Division of R.C.A. Communications, Inc. at Rocky Point, Long Island as a transmitter operating engineer and later followed the mechanical phase of modifying old and constructing new transmitters and apparatus. Since 1939 he has been supervising installations for a plant revision program at the Rocky Point Transmitter Station.

GEORGE A. MORTON was born 1903 at New Hartford, N. Y. Received B.S. degree in electrical engineering, Massachusetts Institute of Technology, 1926. Research laboratory, General Electric Company, 1926-1927. Received M.S. degree, Massachusetts Institute of Technology, 1928; Ph.D. degree in physics, 1932. Research associate and instructor, Massachusetts Institute of Technology, 1927-1933. Research Laboratories, RCA Manufacturing Company, 1933 to date. Member, American Physical Society; associate member, Institute of Radio Engineers.

PHILIP A. RICHARDS received his B.S. degree in Electrical Engineering from Washington State College in 1927, and in the same year entered the Radio Test Course at the Schenectady plant of the General Electric Company. After completing this, he was transferred to the Vacuum Tube Manufacturing Department at Nela Park as factory representative in Chicago. In 1930 he joined the Research and Engineering Department of the RCA Manufacturing Company, Inc., at Harrison where he has specialized in the application of tubes to television.

HARRY E. THOMAS majored in Electrical Engineering at Tufts College and M.I.T., receiving his master's degree at the latter school in 1925. For two years, he served as instructor at M.I.T., going to the Victor Talking Machine Co. in 1927 as receiver design engineer. From 1930 to 1936, he was radio production engineer, sales engineer and receiver design engineer at the American Bosch Co. in Springfield, Mass. In 1936, he joined the export design department at the Philco Radio and Television Corporation; following this, he was associated with the Bendix Radio Corp. and the Westinghouse Manufacturing Co. on aircraft and government receiver design, going with the RCA Manufacturing Co. at Camden in 1940. Mr. Thomas is a member of Tau Beta Pi and an associate of the Institute of Radio Engineers.

TECHNICAL ARTICLES BY RCA ENGINEERS

Published Third Quarter, 1941

ANDERSON, L. J.—High-Fidelity Headphones—*Jour. of the Society of Motion Picture Engineers*, September.

ARTZT, MAURICE and DUDLEY E. FOSTER—Duplex Transmission of Frequency-Modulated Sound and Facsimile—*RCA Review*, July.

BAHLS, W. E. and C. H. THOMAS—New Sensitive and Inexpensive Gas-Control Tubes—*Electronics*, September.

BAKER, J. O. and R. O. DREW—New and Old Aspects of the Origins of 96-Cycle Distortion—*Jour. of the Society of Motion Picture Engineers*, September.

BURRILL, CHARLES M.—Progress in the Development of Instruments for Measuring Radio Noise—*Proceedings of the Institute of Radio Engineers*, August.

CROSBY, M. G.—Observations of Frequency-Modulation Propagation on 26 Megacycles—*Proceedings of the Institute of Radio Engineers*, July.

DREW, R. O.—see BAKER and DREW.

FOSTER, DUDLEY E.—see ARTZT and FOSTER.

GLOVER, ALAN M.—A Review of the Development of Sensitive Phototubes—*Proceedings of the Institute of Radio Engineers*, August.

——— see JANES and GLOVER.

GUY, RAYMOND F.—How and Why of Frequency Modulation, Part I—*Radio-Craft*, July.

——— How and Why of Frequency Modulation, Part II—*Radio-Craft*, August.

——— NBC's International Broadcasting System—*RCA Review*, July.

HARRIS, W. A.—Fluctuations in Space-Charge-Limited Currents at Moderately High Frequencies—Continuation of Part V, Fluctuations in Vacuum-Tube Amplifiers and Input Systems—*RCA Review*, July.

JANES, R. B. and A. M. GLOVER—Recent Developments in Phototubes—*RCA Review*, July.

LUCK, DAVID G. C.—An Omnidirectional Radio-Range Sysem, Part I—*RCA Review*, July.

MALOFF, I. G. and W. A. TOLSON—RCA Theatre-Television Technical Data—*International Projectionist*, June.

——— and W. A. TOLSON—A Résumé of the Technical Aspects of RCA Theatre-Television—*RCA Review*, July.

MILNE, G. O.—NBC Short-Wave Listening Post—*RCA Review*, July.

OLSON, HARRY F.—Calibration of Microphones by the Principles of Similarity and Reciprocity—*RCA Review*, July.

PIKE, E. W.—see RUEDY, ZWORYKIN, and PIKE.

PIPPER, A. L.—Fewer, but Better Finishes—*Industrial Standardization*, August.

PRATT, JOHN H.—The Equivalent Characteristics of Vacuum Tubes Operating in Feedback Circuits—*RCA Review*, July.

RAMBERG, E. G., and V. K. ZWORYKIN—Surface Studies with the Electron Microscope—*Jour. of Applied Physics*, September.

REISKIND, H. I.—Multiple-Speaker Reproducing Systems for Motion Pictures—*Journal of the Society of Motion Picture Engineers*, August.

RICHARDS, P. A.—Report on Round-Robin Tests of Power Factor and Dielectric Constant for Glass—*American Society for Testing Materials*, August.

RUEDY, J. E., V. K. ZWORYKIN, and E. W. PIKE—Silver-Magnesium Alloy as a Secondary Electron Emitting Material—*Journal of Applied Physics*, September.

SARNOFF, DAVID—A New Era in Television—*RCA Review*, July.

THOMAS, C. H.—see BAHLS and THOMAS.

TOLSON, W. A.—see MALOFF and TOLSON.

WINLUND, E. S.—Drift Analysis of the Crosby Frequency-Modulated Transmitter Circuit—*Proceedings of the Institute of Radio Engineers*, July.

——— F-M Engineering Considerations, Part 1—*FM*, July. Part 2, August.

ZWORYKIN, V. K.—see RUEDY, ZWORYKIN, and PIKE.

——— see RAMBERG and ZWORYKIN.