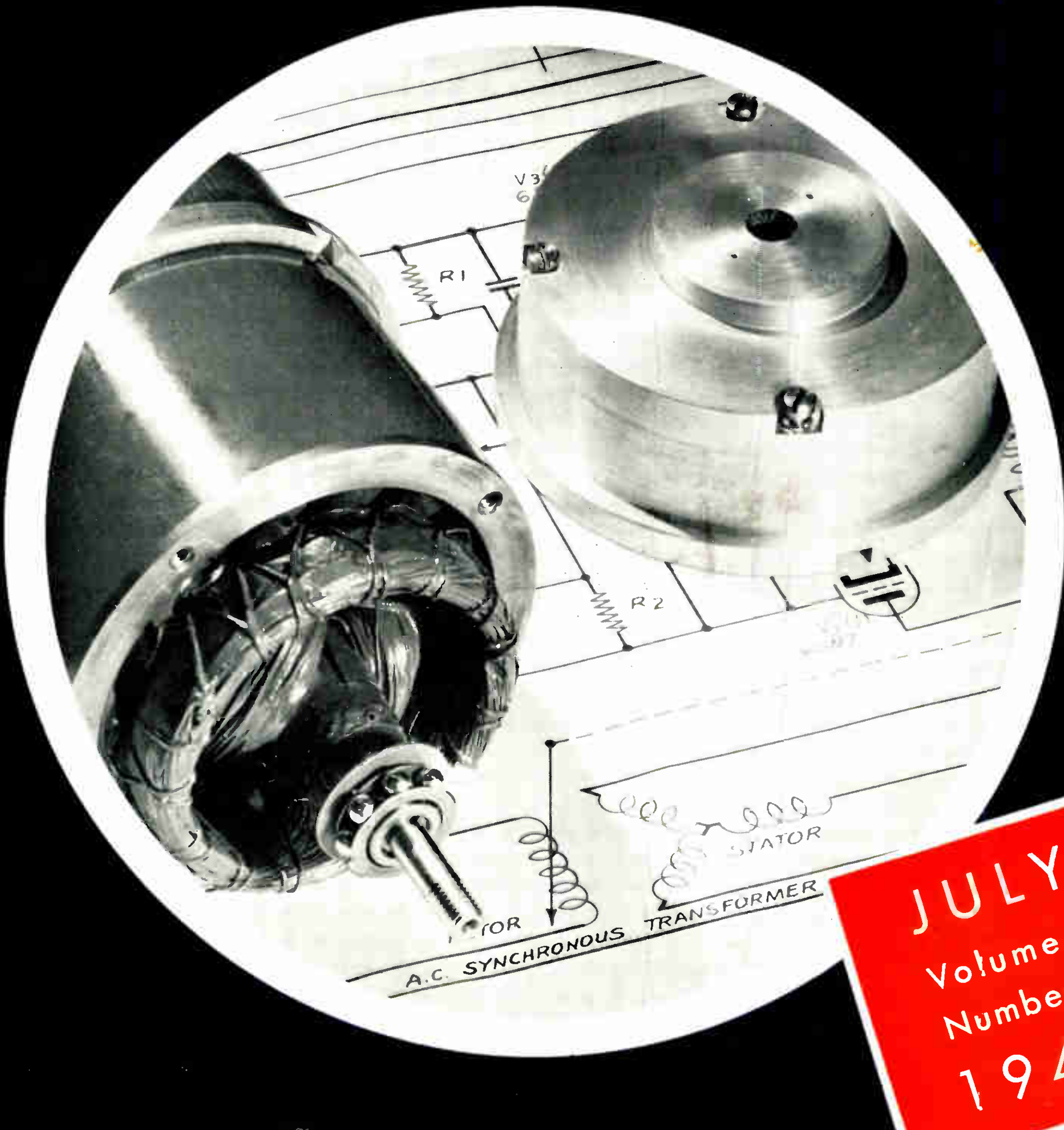
BENDIX RADIO ENGINEER



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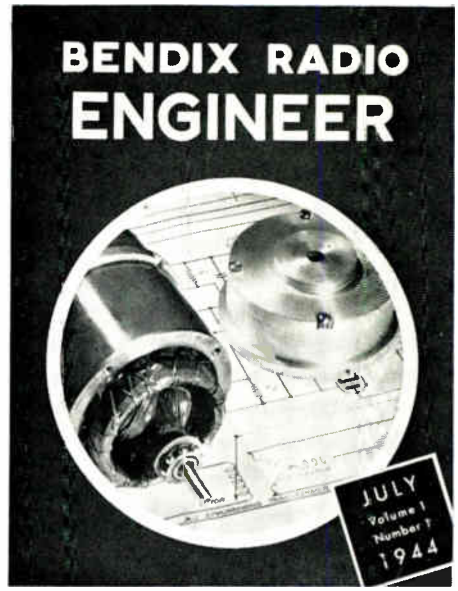

The Cover

Synchronous transformers of the type shown in the photograph are the heart of electronic servo systems, the applications of which range from the solution of differential equations to automatic control of aircraft. A typical continuous-control servo mechanism is described in an article by Joseph T. McNaney, on page 6 of this issue. *Photograph by P. K. Morris.*

BENDIX RADIO

Collective progress stems originally from the efforts of the individual, and is best ensured when honest labor of every man is dignified by the recognition that he brings God-given intelligence to bear on his task, and contributes to the general welfare, not as a cog useful only in relation to the machine, but as a rational being, important in his own right.

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HYPER-FREQUENCY WAVE GUIDES

A resumé of theory of electromagnetic wave transmission and propagation in wave guides.

By FERDINAND HAMBURGER, Jr., D. Eng.*
Chief Test Engineer

USE of higher and higher frequencies in the radio spectrum makes the wave guide an increasingly important unit in hyper-frequency communications. This review of the extensive literature on the subject presents the theoretical background of wave guides, and the general form of mathematical analysis by which practical configurations and arrangements are ultimately designed.

The propagation or transmission of electrical energy always consists of the motion of an electromagnetic wave. The usual form of transmission line for power or telephone circuits serves in reality only as a bounding surface for electromagnetic waves and such transmission lines are actually nothing more than systems for guiding waves.

The truth of this statement might readily be questioned by the engineer whose experience and training has been largely in the low frequency field. It can be shown, however, by the use of the Poynting Vector[1] that the transmission of electrical energy takes place in the dielectric medium surrounding the conductors and that the energy associated with the conductors themselves only serves to supply the required loss. In fact, this loss represents the power that must be sacrificed in order to guide the energy from transmitter to receiver. It must thus be concluded that the familiar forms of transmission lines are means for guiding waves by supplying proper boundary conditions for the electromagnetic field. The name "wave guide" is not used, however, for such lines but is restricted to certain special configurations which provide satisfactory boundary surfaces in the ultra-high and hyper-frequency regions.

Basic Theory

The laws governing the transmission and propagation of electromagnetic waves are based on fundamental classical electrical theory. Starting with Coulomb's laws for electric charges and magnetic poles, and following the classical development of electrical theory founded on the investigations of Ohm, Faraday, Cavendish, Oersted, Ampere, and others, Clerk Maxwell[2] evolved his brilliant electromagnetic theory. The real contribution of Maxwell was the hypothesis upon which the entire theory was based. This hypothesis is sometimes referred to as the "magnetic effect of electric displacement." Maxwell assumed that if conduction current had a magnetic effect, displacement current must also have a magnetic effect. Maxwell's hypothesis combined with the experimental evidence and mathematical developments of Maxwell's predecessors permitted Maxwell to develop the now well-known Maxwell's Equations. The four equations of Maxwell, subsequently verified by the experiments of Hertz, form the basis of all electromagnetic theory, and it is by their application that problems of transmission and propagation of electromagnetic waves may be solved. They are most conveniently expressed in vector form as follows:

$$\nabla \times \mathbf{H} = \mathbf{Ic} + \frac{\partial \mathbf{D}}{\partial t}$$

$$\nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t}$$

$$\nabla \bullet \mathbf{D} = \rho$$

$$\nabla \bullet \mathbf{B} = 0$$

In free space these equations reduce to:

$$\nabla \times \mathbf{H} = \varepsilon \frac{\partial \mathbf{E}}{\partial t}$$

$$\nabla \times \mathbf{E} = -\mu \frac{\partial \mathbf{H}}{\partial t}$$

$$\nabla \bullet \mathbf{E} = 0$$

$$\nabla \bullet \mathbf{H} = 0$$

E = Electric intensity
H = Magnetic intensity
D = Electric induction
B = Magnetic induction
Ic = Conduction current density
t = Time
ρ = Volume density of charge
μ = Magnetic permeability
ε = Dielectric constant
σ = Conductivity

All units are MKS.

The first of the four equations of Maxwell is a mathematical expression of Maxwell's hypothesis. This equation shows that a changing electric field produces a magnetic field. The second equation is a statement of Faraday's law that a changing magnetic field produces an electric field. The third equation shows that the divergence of the electric field is equal to the volume density of charge, while the fourth equation indicates that the magnetic field has no divergence.

The further mathematical analysis of Maxwell's Equations showed that electromagnetic energy was propagated in the form of waves. The resulting wave equations are:

$$\nabla^2 \mathbf{E} = \mu \varepsilon \frac{\partial^2 \mathbf{E}}{\partial t^2} + \mu \sigma \frac{\partial \mathbf{E}}{\partial t} + \frac{1}{\varepsilon} \,\mathbf{grad}\, \rho$$

$$\nabla^2 \mathbf{H} = \mu \varepsilon \frac{\partial^2 \mathbf{H}}{\partial t^2} + \mu \sigma \frac{\partial \mathbf{H}}{\partial t}$$

These equations in free space reduce to:

$$\nabla^2 \mathbf{E} = \mu \varepsilon \frac{\partial^2 \mathbf{E}}{\partial t^2}$$

$$\nabla^2 \mathbf{H} = \mu \varepsilon \frac{\partial^2 \mathbf{H}}{\partial t^2}$$

Transmission in Wave Guides

The theoretical development of propagation in wave guides is not extraordinarily difficult and in fact, seems quite simple when the proper steps are followed. The wave equation developed from Maxwell's relations must always be satisfied if propagation is to take place; thus, the problem is to find the solution to the wave equation that satisfies the boundary conditions of the particular case under consideration. Note that when the wave equation is satisfied, Maxwell's equations are automatically satisfied.

The method of attack is illustrated clearly in the case of rectangular enclosures. Figure 1 should be referred to for clarity. A similar treatment holds for cylindrical enclosures, but is slightly more complicated since in this case the particular solution involves Bessel's equation[3]. Considering the general technique, the approach is as follows (in the case of the rectangular enclosures).

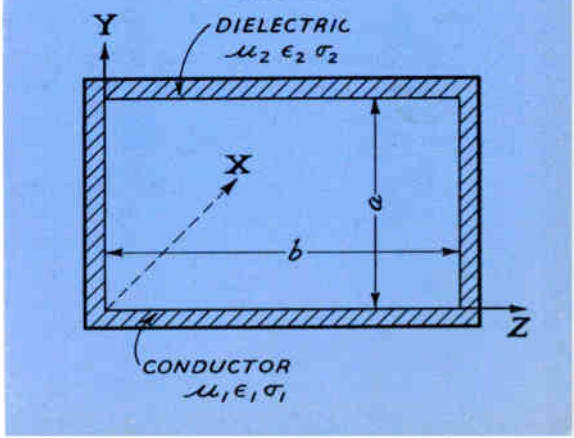
a) Assume fields of the form

$$\mathbf{E} = \mathbf{E}_m \, e^{j\omega t - \gamma x}$$
$$\mathbf{H} = \mathbf{H}_m \, e^{j\omega t - \gamma x}$$

where $\mathbf{E}_m$ and $\mathbf{H}_m$ are the maximum values of the electric and magnetic intensities, respectively, in both time and space. The quantity ω has its usual significance of 2π times the frequency, γ is a constant and x is the distance measured from the origin in the direction of propagation.

b) Substitute these values in the wave equations. It becomes immediately apparent that there are two types of waves which can satisfy these equations and exist independently.

Figure 1—Rectangular wave guide, cross section.



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These waves are characterized by the presence or absence of the component of electric intensity or magnetic intensity in the direction of propagation. They are known as transverse electric waves (TE) denoting the absence of the component of electric intensity in the direction of propagation or transverse magnetic waves (TM) denoting the absence of the component of magnetic intensity in the direction of propagation.

c) Selecting the transverse electric wave (TE) as the form of solution to be derived, we observe that additional boundary conditions are immediately apparent. By definition, for this wave, the component of electric intensity in the direction of propagation is zero, and this boundary condition next applied further simplifies the equations.

d) The resulting equations can be solved simultaneously and lead to six equations giving the value of electric intensity and magnetic intensity in all three planes.

e) Since the boundary surface chosen is a rectangle of perfectly conducting material, further bounding conditions based on fundamental theory appear.

1) At the upper and lower surface of the guide, there can be no tangential component of electric intensity.

2) At the side walls of the guide there can be no tangential (vertical) component of electric intensity.

The application of these boundary conditions permits the evaluation of the constants of integration involved in the solution and yields the following equations for the generalized transverse electric (TE) mode. The complete mathematical development is set forth with excellent clarity in the text by Sarbacher and Edson listed in the bibliography[1].

Equations for Rectangular TE Mode

These equations yield specific results for particular integral values of "n" and "m." The quantity "n" indicates the number of half-cycle variations in the electric field across the guide in the vertical direction whereas "m" indicates the number of half-cycle variations across the guide in the horizontal direction. Thus particular modes corresponding to given values of "n" and "m" are designated as TE_{01}, TE_{12}, etc., noting that TE_{00} is not physically realizable since the boundary conditions cannot be satisfied in this case.

$$E_x = O$$

$$E_y = A \frac{j\omega\mu_2}{\gamma^2_{n,m} + \omega^2\mu_2\varepsilon_2} \frac{m\pi}{b} \cos\frac{n\pi y}{a} \sin\frac{m\pi z}{b} \left(e^{j\omega t - \gamma_{n,m} x}\right)$$

$$E_z = -A \frac{j\omega\mu_2}{\gamma^2_{n,m} + \omega^2\mu_2\varepsilon_2} \frac{n\pi}{a} \sin\frac{n\pi y}{a} \cos\frac{m\pi z}{b} \left(e^{j\omega t - \gamma_{n,m} x}\right)$$

$$H_x = A \cos\frac{n\pi y}{a} \cos\frac{m\pi z}{b} \left(e^{j\omega t - \gamma_{n,m} x}\right)$$

$$H_y = A \frac{\gamma_{n,m}}{\gamma^2_{n,m} + \omega^2\mu_2\varepsilon_2} \frac{n\pi}{a} \sin\frac{n\pi y}{a} \cos\frac{m\pi z}{b} \left(e^{j\omega t - \gamma_{n,m} x}\right)$$

$$H_z = A \frac{\gamma_{n,m}}{\gamma^2_{n,m} + \omega^2\mu_2\varepsilon_2} \frac{m\pi}{b} \cos\frac{n\pi y}{a} \sin\frac{m\pi z}{b} \left(e^{j\omega t - \gamma_{n,m} x}\right)$$

$$\gamma_{n,m} = \sqrt{\left(\frac{n\pi}{a}\right)^2 + \left(\frac{m\pi}{b}\right)^2 - \omega^2\mu_2\varepsilon_2}$$

A similar series of equations may be developed for the transverse magnetic modes following a general treatment as outlined above. For the cylindrical guide also an analogous type of mathematical analysis is required but the solution in this case involves Bessel's functions. The integers "n" and "m" associated with cylindrical modes have mathematical significance in relation to Bessel's functions, but also have physical significance. In this case, "n" represents the number of full-period variations of the radial component of the electric field (E_r) in the circumferential direction and "m" represents the number of half-period variations of the circumferential component of the electric field (E_θ) in the direction of the radius (see figure 2).

Practical Application

Equations obtained from the type of mathematical treatment outlined are necessary for the practical application of guides and much can be learned from a study of these equations. From the equations for the several components of the electric and magnetic field, patterns can be drawn showing the distribution of the lines of force for each field. These patterns not only help visualization of the guide action, but are quite necessary and useful when the problem of exciting or detecting particular modes is to be considered.

The equation for the propagation constant $\gamma_{n,m}$ yields for each particular mode the following important quantities:

a) Critical frequency
b) Critical wave length
c) Phase constant
d) Phase velocity
e) Phase wave length

An examination of these relations shows that practical wave guides are restricted to use in the hyper-frequency region where their physical size is convenient: for example, for the lowest order rectangular transverse electric mode (TE_{01}) the width of the guide is one-half the wave length to be transmitted.

Further examination of the field equations for each mode, by means of the Poynting

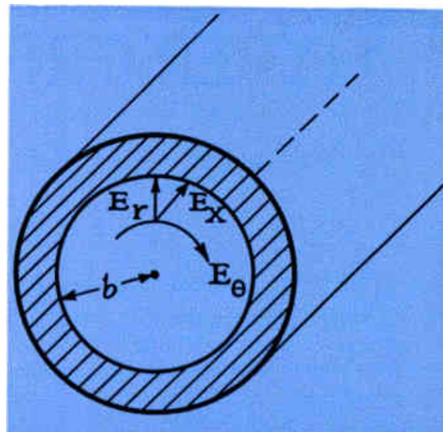


Figure 2—Cylindrical wave guide, cross section.

Vector, yields equations for the attenuation in guides and shows that the attenuation is substantially less in guides than in other forms of transmission lines at the hyper-frequencies hence making guides highly desirable. Strangely enough the present use of guides is restricted to the lower order modes since so far frequencies for which higher order modes would be useful are still in excess of those in use. This is readily seen when the critical or cut-off frequency for various size guides is examined for the several modes.

An analysis of the propagation in guides with respect to attenuation shows in general that there is a frequency of transmission which gives minimum attenuation. Other factors must also be considered, however, in selecting tubes for particular cases. For example, the possibility of a given mode being transmitted in two polarizations should be investigated as well as the possible existence of higher order modes. A consideration of these and other factors yields the conclusion that in general a cut-off frequency equal to the transmitted frequency divided by the $\sqrt{3}$ is desirable for both cylindrical and rectangular modes, and that rectangular tubes having a height to width ratio of one-half are preferable.

Some of the comments above with respect to the relationship between tube size, mode, and cut-off frequency can be better appre-

TABLE I

CRITICAL FREQUENCIES FOR SEVERAL MODES
(FREQUENCIES IN MC)

Mode	*Rectangular Tube 2.5 x 5.0 cm*	*Cylindrical Tube 2.5 cm Radius*
TM_{01}	3000	2300
TM_{02}	6000	5270
TM_{11}	6720	3565
TM_{12}	8480	6700
TE_{01}	3000	3565
TE_{02}	6000	6700
TE_{11}	6720	1758
TE_{12}	8480	5090

ciated by reference to specific calculations. Table I has been prepared to illustrate some of these points. For this illustration, a rectangular tube with inside dimensions of 2.5 cm by 5.0 cm and a cylindrical tube of 2.5 cm inside radius were selected. The table shows the cut-off or critical frequency for each of several modes and thus clearly indicates the higher cut-off frequencies for the higher order modes. The table also emphasizes the fact that critical frequencies are the same for both transverse electric and transverse magnetic modes in rectangular guides.

TABLE II

TUBE SIZE TO TRANSMIT 10,000 MC
(CUT-OFF FREQUENCY $\times \sqrt{3}$ = 10,000 MC)

Mode	*Rectangular Tube (Cm)*	*Cylindrical Tube Radius (Cm)*
TM_{01}	1.3 x 2.6	1.99
TM_{02}	2.6 x 5.2	4.56
TM_{11}	2.9 x 5.82	3.16
TM_{12}	3.68 x 7.36	5.79
TE_{01}	1.3 x 2.6	3.16
TE_{02}	2.6 x 5.2	5.79
TE_{11}	2.91 x 5.82	1.52
TE_{12}	3.68 x 7.36	4.40

Still another illustration of the relationship between tube size, mode, and frequency is shown in table II. This table indicates the required size of tube to transmit a frequency of 10,000 megacycles. In making these calculations, it has been assumed that the cut-off frequency for the tube is to equal the transmitted frequency divided by the $\sqrt{3}$. The increasing size of tube for higher order modes is clearly shown.

In the actual use of wave guides, it is obviously of advantage to use standard sizes of rectangular and cylindrical tubes. Rectangular brass tubes are available in sizes ranging upward from 3/8 inch by 5/8 inch and cylindrical copper tubes are obtainable from 3/8 inch diameter upwards. It should be observed that these are outside dimensions and in wave guides the inside dimensions are important; therefore, wall thickness must be considered. Note further that rectangular sections are available in brass which, although not as desirable as copper, is usually satisfactory. When attenuation is of great importance, sections can be silver plated.

TABLE III

CRITICAL FREQUENCY AND ATTENUATION
RECTANGULAR TE_{01} MODE, BRASS TUBE

Outside Dimensions (Inches)	*Wall Thickness (Inches)*	*Inside Dimensions a x b*		*Ratio Height to Width*	*Critical Frequency (Mc)*	*Transmitted Frequency (Mc)*	*Attenuation db per Meter*
		Inches	*Cm*				
3/8 x 5/8	0.0641	0.247 x 0.497	0.627 x 1.262	0.497	11,880	20,576	0.429
3/8 x 3/4	0.0641	0.247 x 0.622	0.627 x 1.579	0.397	9,500	16,454	0.364
1/2 x 3/4	0.0641	0.372 x 0.622	0.944 x 1.579	0.598	9,500	16,454	0.267
1/2 x 1	0.0641	0.372 x 0.872	0.944 x 2.212	0.427	6,780	11,743	0.207
5/8 x 1	0.0641	0.497 x 0.872	1.262 x 2.212	0.571	6,780	11,743	0.166
5/8 x 1 1/4	0.0641	0.497 x 1.122	1.262 x 2.849	0.443	5,265	9,119	0.138
3/4 x 1 1/2	0.0808	0.588 x 1.338	1.495 x 3.4	0.440	4,410	7,638	0.106
1 x 2	0.0808	0.838 x 1.838	2.129 x 4.67	0.456	3,210	5,560	0.064
1 1/4 x 2 1/2	0.0808	1.088 x 2.338	2.765 x 5.94	0.465	2,525	4,373	0.044
1 1/2 x 3	0.0808	1.338 x 2.838	3.4 x 7.209	0.472	2,080	3,603	0.033

TABLE IV

CRITICAL FREQUENCY AND ATTENUATION
CYLINDRICAL TM_{01} MODE, COPPER TUBE

Outside Diameter (Inches)	*Wall Thickness (Inches)*	*Inside Diameter*		*Critical Frequency (Mc)*	*Transmitted Frequency (Mc)*	*Attenuation db per Meter*
		(Inches)	*Cm*			
3/8	0.065	0.245	0.622	36,916	63,939	0.568
1/2	0.065	0.370	0.940	24,428	42,309	0.3057
3/4	0.065	0.620	1.575	14,580	25,253	0.1409
1	0.065	0.870	2.21	10,390	17,995	0.0847
1 1/2	0.065	1.370	3.48	6,600	11,431	0.0429
2	0.083	1.834	4.66	4,828	8,362	0.0274
2 1/2	0.109	2.282	5.80	3,959	6,857	0.0199
3	0.120	2.760	7.01	3,276	5,674	0.0150
3 1/2	0.134	3.232	8.21	2,797	4,844	0.0119
4	0.109	3.782	9.61	2,389	4,137	0.0094

For general convenience, table III has been prepared showing the cut-off frequency for the TE_{01} rectangular mode for several standard sizes of rectangular tubes. The table also shows the attenuation in each case for the brass tube. Note that approximately one-half this attenuation would be obtained for copper tubing. The attenuation has been computed assuming that the transmitted frequency is equal to the $\sqrt{3}$ times the cut-off frequency.

Table IV gives the cut-off frequency for the TM_{01} cylindrical mode, for several standard size cylindrical tubes, as well as the attenuation for each size assuming a transmitted frequency equal to $\sqrt{3}$ times the cut-off frequency.

The cut-off frequency equation with respect to tube size is such that curves can be drawn

Continued on page 32

Dr. Ferdinand Hamburger, Jr.

SCHOLARLY, FRIENDLY, Dr. Ferdinand Hamburger, Jr.—"Doc" to his associates at Bendix just as on the university campus—is filling the office of Chief Test Inspector while on leave of absence from The Johns Hopkins University. He received his bachelor's degree in engineering in 1924 at Johns Hopkins. Following a brief period as electric testman at the Consolidated Gas Electric Light and Power Company of Baltimore, he did research on high voltage underground cables and other problems. After earning his doctorate in engineering in 1931 at his alma mater, he was appointed instructor in electrical engineering at Hopkins, and in 1941 advanced to associate professor, the position he now holds. A member of the AIEE and the IRE, he has contributed to their publications as well as to *Physical Review*, *Q.S.T.*, *Electrical Engineering*, *Journal of General Psychology* and *Journal of Experimental Psychology*. He is also a member of the Society of Sigma XI and Tau Beta Pi.

The future of BENDIX ENGINEERS

By W. L. WEBB
Chief Engineer

SOME OF THE QUESTIONS in all engineers' minds are: "What will I be doing after the war? Will Bendix reduce the engineering staff and put me out of a job during hard times? Is there sufficient aeronautical radio business to keep all of us busy?" This is an attempt to answer some of these questions.

First let us review some of the past history of our engineering activities. Prior to 1939 we went through a series of ups and downs, desperately trying to gain a foothold in the aircraft business. We were after both airline radio business and government business. In addition, attempts were made in other fields of electronic and radio equipment.

In 1936 Bendix Radio Corporation was formed from a number of small radio companies which were owned or partially controlled by Bendix Aviation Corporation. Mr. Bendix had ambitious plans for the Radio Corporation, and a plant was established in Chicago, as well as Washington, D. C. The plans called for at least twelve million dollars' worth of business the first year. That was pretty ambitious for a brand-new organization and was doomed to failure. Imagine an engineering staff of two hundred being assembled at one time in a new organization to design new products for immediate sale in a highly complicated field!

From Several Companies

Engineering groups were made up of engineers from several companies—strange to each other—some with their own concepts as to the best methods of organizing, others with hold-over jobs from their former company to complete, and all in a bewildered state of mind. New engineers were rapidly hired also. Engineering groups were hard at work designing radio receivers, radio compasses, airborne transmitters, high-powered ground transmitters, microphones, audio equipment, public address systems, industrial test equipment, and automotive test equipment in the Chicago plant. This varied line covered all applications, including broadcast, police, aeronautical, government, export, marine, automotive industry, and others. Here and there we were successful and some good designs resulted. However, the expense was terrific, and some months went by with shipments from the Chicago plant that totaled less than our payroll. Everyone soon realized that this could not go on forever, and a "weeding out" of engineering was started, as engineering was nearly one-half of the entire personnel.

In those days there was no Sales Department, no Manufacturing Department, no Inspection Department, no Personnel Department as we know them today. The engineer supervised the job all the way through—directing the shopmen, doing the testing, packing the equipment, and installing it in the field.

Plant Reorganized

The engineering staff in the Chicago plant was reduced from approximately 200 people to 125 people at the end of the first year. The entire plant was reorganized, and a real attempt was made to get it on a sensible business basis.

In the meantime the Washington plant had outgrown its quarters and was moved to the Fort Avenue location in Baltimore. During 1937 the major business in Baltimore was CAA radio range and marker equipment, and frequency measuring equipment; and for the second half of 1937 and the first quarter of 1938 the Baltimore plant supported the entire Bendix Radio Corporation with shipments of radio ranges.

In the latter part of 1937 a substantial contract was received from the Signal Corps for the SCR-242B Radio Compass. This was the largest single order that the company had yet received, and was for eight hundred radio compasses. Shortly thereafter this was increased to twelve hundred units. The contract was received in November, 1937, the model was submitted to Wright Field in February, 1938, and shipments of production were started in May, 1938. In the meantime most of the radio range contracts in Baltimore had been completed, and for nine months the Chicago plant supported the company with shipments of radio compasses.

Chicago Plant Closed

At the end of 1938 it was realized that there was not sufficient business to support two plants, and therefore the Chicago plant was gradually closed, and all key personnel moved to Baltimore. It was decided to concentrate on the aeronautical business, and do a good job of it before attempting to cover other types of equipment. With this in mind, all the engineering work on sound systems, police radio systems, industrial instruments, electronic cardiographs, microphones, and other special equipment was dropped, and the Engineering Department was organized into a Receiver Section, Mobile Transmitter Section, Fixed Transmitter Section, and a Frequency Measuring Equipment Section. These design groups were supported by a Drafting Section, Editorial Section, and a Model Shop. This was the beginning of our present engineering organization, and it is essentially the same at the present time—except for the additional design groups.

The Bendix Aviation Corporation was beginning to be impatient with the activities of the Radio Corporation, and was determined to put it on a more profitable basis. Our management and entire organization were revised in 1939, and a monthly billing rate was agreed to that we must meet. It was also demanded that we reduce our engineering expenses by at least 20 per cent and concentrate all of our efforts on the design of aeronautical radio products that could be sold at a profit.

In September, 1939, the engineering staff was reduced by approximately 20 per cent, and only those designs and products that would quickly show a profit were worked on. It was soon realized that this reduction in the Engineering Department was a bad mistake because the war in Europe had gained headway, and in December, 1939, large orders for aircraft radio equipment were received from the British and French governments. This was the beginning of our large expansion, and ever since that day the real problem has been to design and manufacture enough equipment to take care of our customers' needs.

When we first discussed some expansion in order to meet these needs it was stated that we must triple our output from the Fort Avenue plant. Although everyone emphatically stated that we could not possibly handle that volume of equipment out of the Fort Avenue plant, the required number of units was shipped.

Bendix Radio Corporation was really on its feet now, and this achievement was recognized by the New York office. Consequently, efforts were made to obtain a new plant, and ground was broken for the Towson plant in the fall of 1940. Bendix Radio Corporation also became a full-fledged division of Bendix Aviation Corporation.

Rapid Expansion

During 1941 and 1942 our business rapidly expanded because of the war, and shipments increased to fantastic amounts, reaching a peak of a hundred times our 1939 shipments. During this period our original engineering staff of 1939 carried the entire design and production follow-up load.

During all of this period it was our engineering policy not to expand engineering any more than absolutely necessary to handle the engineering work required for the production being done, as we did not want to go through another curtailment of personnel. We thought that we should limit our engineering staff to the number of persons it was believed would be required after the war for normal peacetime business. Of course, at that time we were thinking that after the war our peacetime business would return to the same level as it was before the war. The fallacy in this reasoning was that once a plant has been expanded several hundred times, the management, the head office and the employees will never allow it to return to its previous size. Everyone realizes it must shrink considerably, but it will not be allowed to shrink to the size it was previous to the war.

It is important to point out that during the last three years our engineering expense, as related to our sales, has consistently been less than one per cent of total sales. It is normally figured that for this type of business, where the production lots are small and a large amount of engineering is required for each product, that 10 per cent of total sales is allowable for engineering. Our peacetime percentage of engineering cost was between 10 per cent and 15 per cent of total sales—even in our best years. Our output can shrink to one-fifth of its 1944 level and we shall still be within our 10 per cent of sales with our present engineering staff.

Everyone throughout the Corporation now recognizes this Division as a successful operator, and will do everything within their power to see it continue successfully over a number of years. We have been encouraged to expand our research and development, and have been assured that a reasonable amount of development will be carried on for a number of years in order to establish new electronic products.

Obviously, we cannot support a factory even one-fifth the size of our present factory during peacetime without turning out considerably more designs than we are now doing, as there will be no orders for four or five thousand radio compasses or King Georges per month. This means that at the end of the war there will be an even greater burden on the Engineering Department than there is at the present time. This makes it necessary that we get our engineering organization on a sound and permanent basis, with adequate facilities and staff to develop and design sufficient products to support a good-sized factory.

Engineers Key Factor

No one can predict just what volume of business we will have after the war, but it can be emphatically stated that our volume will be dependent upon the ability of our engineers to design new and competitive electronic products. Assuming that we are the equal of other similar engineering organizations, there will be no need for reducing the engineering staff. It is my personal opinion that we shall actually need additional experienced and qualified engineers. However, this period will be used to "weed out" the least qualified engineering personnel, and replace them with more capable people who might become available. It will be a tough competitive field, and everyone of us must be "on our toes."

The purpose of the above is to give all engineers who are capable of doing a good job of design and development a reasonable assurance that they will have jobs after the war has been won. However, at that time competition will be very keen and our very existence will depend entirely upon the ability of our engineers to design competitive products. During the past few years we have been given every possible facility that was needed in order to make our work easier, and every possible instrument that could be used was obtained, as we had to get the job done at any cost. In normal times this is not always possible, and often ways must be found of doing the job without expensive and elaborate facilities. In my opinion, we have working conditions equal to the best of any radio manufacturer in the world. With the proper spirit and initiative it should be possible for us to hold our own in the aeronautical radio business, and even expand successfully into marine, railroad, industrial, consumer, and other outlets for electronic and radio products.

It is all up to us.

AVAILABLE TO ALL callers and ready to hear their problems, busy, serious W. L. Webb brings to his office of Chief Engineer unique qualities of temperament as well as of engineering skill. A native of Spokane, Washington, he received his B.S. in electrical engineering from State College of Washington (1929) and was selected for the test engineering course at General Electric. Then followed in order: five years as radio development engineer for aircraft radio at Bell Telephone Laboratories, a year and a half as Chief Engineer at Lear Developments, one year with Radio Research, Inc., as project engineer in the development of Navy 12 kc Static D.F. and RA-1 Radio Receiver. When Radio Research, Inc., was absorbed by Bendix, he transferred to the Chicago plant, first in charge of receiver engineering and then as Chief Engineer. Although he was Chief Engineer in the consolidated operations when the Washington and Chicago plants moved to Fort Avenue, he became chief of the Receiver Engineering section during the 1939 reorganization described in his article. In 1941 the engineering department moved to Towson, and before long W. L. Webb was back again in the office of Chief Engineer. A member of IRE, he also holds membership in the honorary fraternities Sigma Tau and Tau Beta Pi. He is fond of flying, having trained at the Army Flying School at San Antonio, and has held a pilot's license.

TYPICAL ELECTRONIC SERVO SYSTEM

Automatic and precise control of machines and processes is possible through the application of principles embodied in this continuous-control servo mechanism.

By JOSEPH T. McNANEY
Microwave Engineering

BECAUSE OF THE INACCURACY and uncertainty of manual control in the operation of complex machinery, it has become expedient to devise a machine to control a machine. Servo mechanisms fill this need. They also solve the control problem where direct mechanical links are impossible. Moreover, even where mechanical linking between an operator and a load is possible, servo mechanisms can be employed as torque amplifiers, thus permitting comparatively accurate control of the movement of large loads with a minimum of effort.

In general, a servo mechanism is a device for automatic control, in which a variation in controlling conditions at the input results in a proportional and predetermined variation at the output. The input (point of direction) represents the point in the system at which the arbitrary displacement or change is introduced.

Two General Classes

Servos may be divided into two general classes, namely, the stepping or on-off systems, and the closed cycle or continuous-control systems. Their innumerable applications range from the solution of differential equations to automatic control of aircraft.

The system which will be described here is of the electronic continuous-control type, which may be defined as "a type in which a restoring force is approximately proportional to the deviation of the output, and acts continuously on the output element in both direction and magnitude." Each application of such a system presents its own design problems, the most common of which are instability, excessive error, or both.

The servo system begins to function as a result of a displacement (change) introduced at the point of direction. In the present system, this displacement turns the energized rotor of an a-c synchronous transmitter, which changes the angular position of a flux field already established by the rotor winding and linked to a set of stator windings. (The action is comparable to that of the Autosyn motors used in the Bendix automatic compass.) The change in the field position is transmitted electrically to similar stator windings of the a-c synchronous transformer, where a resultant stator field assumes a new angular position with respect to the transformer rotor. A voltage called the displacement voltage is therefore induced in the transformer rotor. A-C synchronous devices used in this manner are referred to as data systems, and voltages derived from such systems are a function of angular displacements between the transmitter and transformer rotors. Such angular displacements, as will be seen later, are actually an indication of error between the director and the load. It is desirable for such errors to be kept as low as possible, which means that a servo system having sufficient sensitivity will operate with low displacement voltages, but, unless measures are taken to prevent "hunting," systems of high sensitivity cannot be used.

The displacement voltage assumes a direction and magnitude which, when amplified, exerts a control on the driving motor voltage corresponding to the rate and direction of change initially introduced at the input. The drive motor rotates the load in accordance with this control, and, through the load by means of gears, also turns the rotor of the transformer. Positional relationships of the load and transformer rotor are maintained through the gearing, and when the load is moved the transformer rotor moves toward a new position in which no displacement voltage is induced. In the new position the load ceases to receive energy and movement stops. At this point of equilibrium the system is at rest, and will remain so until a further displacement is introduced at the point of direction.

Before proceeding, it would be well to remember that, in the present system, while a certain amount of energy is required to operate the initial control, and a certain amount of electrical energy is fed into the system as a result of the movement of this control, the energy which operates the load comes from an external source. The energy derived as a result of the movement of the initial control, exerts a *controlling* influence only. Inspection of the schematic will show that, while there is amplification of this control energy, it is not used directly to drive the load. The end result is that it simply controls a "valve" through which external motor-driving energy flows in amplitude and direction as permitted by the "valve." The "valves" in this case are the saturable reactors.

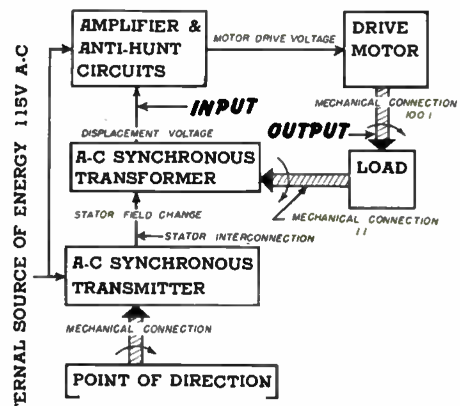
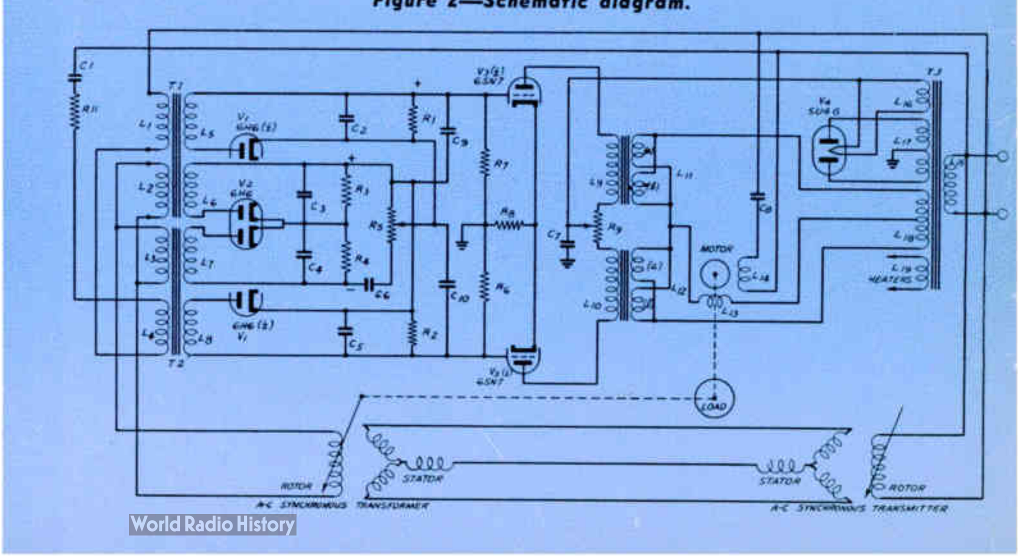


Figure 1—Block diagram, representative of most electronic servos.

Figure 2—Schematic diagram.



Complete schematic and block diagrams of the system are shown in figures 1 and 2. It will be seen that the a-c synchronous transmitter is coupled electrically to the a-c synchronous transformer. The output of the transformer is connected to the input of a pair of phase-sensitive rectifiers, and the output of these rectifiers is fed to a saturable reactor system, consisting of a vacuum tube amplifier and a pair of reactors. Impedance windings of the reactors are connected to the variable-phase winding of a split-phase, low-inertia motor, and a power source. The motor is connected, through a gear train, to the load and also to the rotor of the synchronous transformer.

The electronic design is conventional with the exception of the "anti-hunt" circuit. This circuit has proved a very effective means of stabilization, and is unaffected by variations of line voltage or frequency. A feature of its operation is that it is entirely independent of the output circuit, or the means for driving the load.

The transmitter rotor winding is energized from a 115-volt, 60-cycle source. Its rotating member is geared to the positioning means at the point of direction. Three stator windings are angularly spaced 120° apart. The angle between each stator winding and the rotor is continuously variable over 360°. Individual stator potentials are accordingly a function of the cosine of the displacement angle. The stator windings of the transmitter are connected to corresponding windings in the transformer. Since current flow in each stator is a function of the primary rotor position, the resultant field established in the transformer stator will rotate in synchronism with the transmitter rotor. Coupling between the magnetic field and the output winding of the transformer (rotor) is zero when the angle of coupling is 90°; hence, the output voltage is also zero. If this angle is changed from 90° in either a positive or negative direction, a voltage is induced in the rotor winding, the phase of which will differ by 180° for different directions.

Follows Phase

Although there are two zero positions which are 180° apart, it is characteristic of the induction motor used in systems of this type to respond to off-null voltages in the direction corresponding to their phase. Thus, the motor will always rotate the transformer rotor toward its stable null-point.

When this system is loaded by the input impedance of the amplifier, it will produce 0.925 volt (rms) for the *first* degree of displacement. If the displacement voltage is increased, a sinusoidal voltage of the form

$$E = 53 \sin \theta$$

is produced. At 90°, the maximum is 53 volts rms.

The primaries of input transformers (T1 and T2) have equal windings (L1, L2 and L3, L4), which are designed for 60 volts maximum input. The secondary windings (L5 and L8) are rated at 360 volts and 0.002 ampere. Windings (L6 and L7) have ratings of 720 volts at 0.002 ampere. Primaries (L1 and L4) are connected in series with a dropping resistor, R11, and a phasing capacitor, C1, across the 115-volt a-c source.

If an instantaneous primary current causes the plates of V1 and V2 to go positive, equal voltages of opposite polarity will appear at R1 and R2. A similar condition will exist across R3 and R4. Accordingly, no current will flow in R6 and R7. Resistors R1, R2, R3 and R4, shunted by capacitors C2, C3, C4 and C5, function as filters for the rectified half-wave current. The ripple factor is approximately 0.1. Ripple, introduced by the displacement voltage, cancels across R1, R2 and R3, R4.

Primary windings L2 and L3 are connected in parallel and are energized by the displacement voltage whenever an unbalance exists between the transmitter and transformer rotors. When a displacement voltage is introduced, it will be in phase with the 110-volt external energy, or reference voltage, in one transformer primary (L2 for example), and 180° out of phase with the reference voltage of the other transformer primary (L3). Capacitor C1 provides correct phasing of the displacement and reference voltages.

A displacement voltage of either phase will result in a difference in current flow through R1 and R2 as well as through R3 and R4. The algebraic difference between the current in R1 and R2 determines the direction of current flow through R6 and R7. Reference to figure 3 indicates $IR_1 - IR_2$ as a function of the displacement voltage. Figure 3 also shows $IR_3 - IR_4$ as a function of the displacement voltage. Because of the input transformer ratios,

$$IR_3 - IR_4 = 2(IR_1 - IR_2).$$

The first half of this equation represents the grid-difference voltage. The second half represents the stabilizing voltage.

A variation in the stabilizing voltage will result in a similar variation in the charge on capacitor C6. The voltage drop across resistor R5, is proportional to the current flowing in C6, and acts in phase opposition to the grid-difference voltage.

Condensers C9 and C10 serve as neutralizing condensers which prevent a low frequency oscillatory action of the servo. The function of the stabilizing voltage across R5 is to oppose changes in displacement voltages, and its value is slightly greater than the $IR_1 - IR_2$ difference voltage. Without these condensers in the circuit the following action would result.

During any change in displacement the action of the stabilizing voltage will be in phase with the change. Because it is of a greater potential than the signal, it causes a current flow through R6 and R7 in a direction opposite from that desired. The resulting grid difference voltage will cause an increase in displacement until it has reached 90°. At this angle the displacement voltage and the charge on C6 reaches a maximum and the voltage across R5 drops to zero.

The $IR_1 - IR_2$ difference voltage is now able to act in a manner to correct this displacement, but after having been reduced to zero the above action is again repeated, this time in the opposite direction.

To prevent such oscillation, C9 and C10, in combination with R1 and R2, function as a bridge. Currents resulting from potential variations across R5 are, for all practical purposes, balanced in the bridge.

Electrical Damping

The function of the anti-hunt circuit is to superimpose a voltage on the control signal, which voltage acts in opposition to any potential changes in the signal. Since hunting or unstable conditions produce displacement voltages of an oscillatory character, either electrical or mechanical damping means could be used to offset such action. Actually, the action of the present circuit is analogous to that of an inductance. It can be better understood if a step increment of displacement voltage is analyzed. Consider a 0.5 volt displacement which causes a step increment of the $IR_1 - IR_2$ voltage-difference of 2.5 volts across R2. At the same time, this causes a step increment of an $IR_3 - IR_4$ voltage-difference of 5 volts across R4. During the step increment, capacitor C6 has the effect of a short circuit, and causes an IR drop of 3.3 volts across R5. Voltage polarity of this step function is shown in figure 3.

The voltages across R2 and R5 are oppositely phased. By adjustment of R5, the grid-difference voltage can be made zero during the step increment. The input voltage to the amplifier tube changes with time. The time constant of this circuit is

$$T = \left[R_5 + \left(\frac{R_3 + R_4}{2} \right) \right] C_6$$

The charging time of capacitor C6 produces a servo response that is proportional to an integral of displacement voltage. After this time interval, the motor assumes a velocity that is proportional to the displacement voltage. If the displacement is given a constant velocity, the motor will also attain a constant velocity. Unless the motor runs at a speed that maintains exact synchro-

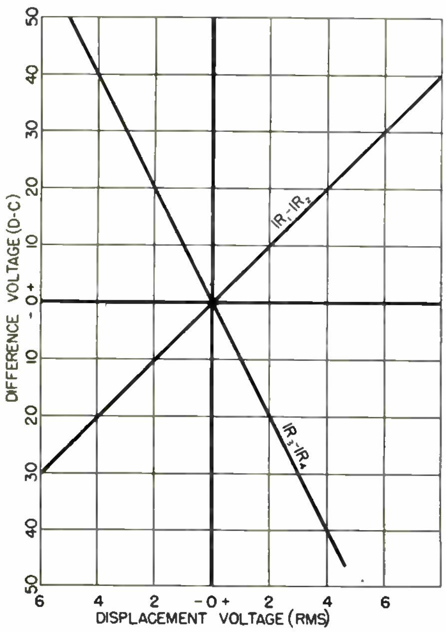


Figure 3—Curves showing difference between rectified potentials across R1 and R2, and across R3 and R4 as a function of displacement voltages in either phase for small angular displacements.

nism between the transformer rotor and the transmitter rotor of the data system, there will be times when it will run too slow and then too fast. Such changes in motor speeds will cause changes in displacement voltage. Since a change in displacement voltage is at all times opposed by potentials across R5, the motor will be under constant control.

A similar stabilizing action results when a constant velocity displacement is suddenly reduced to zero. Under such conditions, the capacitor C6 will discharge through R5 in a reverse direction, setting up a voltage which causes the motor to continue its rotation in the same direction. As soon as the displacement voltage goes through zero, it reverses its phase. This results in a change in polarity of the grid-difference voltage, and stabilizing voltage. The actual potential to which the motor responds reaches a minimum value after the displacement voltage has passed through zero. While the rate of current flow in C6 is decreasing, the motor reverses its direction and again responds to the displacement voltage. But, as has been stated, the anti-hunt potential acts in opposition to any change of displacement voltage. Since, at this point, the displacement voltage is decreasing in magnitude as it approaches zero, its rate of decrease will be retarded. A deceleration of speed will result, allowing the motor to stop when the null point of the data system is reached.

The above is a theoretical description of the anti-hunt circuit function. It has been found in actual practice that when changes in velocity are caused by step increases in angular displacements or sudden change in velocity, about two such cycles are required before the motor comes to rest.

Adjustment of R5

Various factors determine the correct adjustment of R5. Satisfactory results are obtained when the stabilizing voltage is 1 to 1.3 times the changes in grid-difference voltages. R5 was adjusted to the "off" position during the recording of all data so that steady state displacement voltages could be used.

Each half of the amplifier tube (V3) is biased for a normal plate current of 5 ma. The control windings, L9 and L10, of the saturable reactors are connected in the plate circuits of the dual-triode vacuum tube, V3. The normal plate current of 5 ma sets the reactance of the dual windings of L11 and L12 at approximately 250 ohms each. Variations in the plate current of each half of V3 as a function of displacement voltage is shown in figure 4.

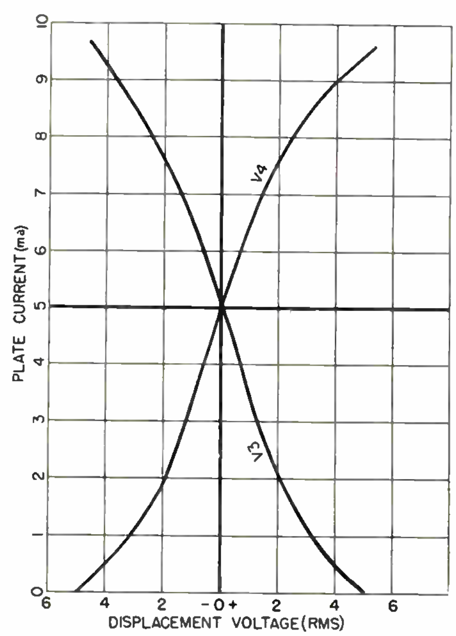


Figure 4—Curves showing variations in plate current in each half of the amplifier tube for different displacement voltages of each phase.

For those unfamiliar with the action taking place in saturable reactors, a brief explanation may be in order.

The field established by the flow of direct current through the primary of saturable reactors (L9 and L10) to the plates of V3 controls the permeability of the iron core. Permeability is a function of a change in magnetic flux for a change in magnetizing force. A curve for the magnetization of a sample of silicon steel is shown in figure 5. It will be observed that when a certain field density is reached, further increase in the magnetizing force does not produce a corresponding increase in density. The flattening of the curve shortly after the sharp bend occurs indicates magnetic saturation. There is a direct relationship between the permeability and the inductance which is apparent from the formula

$$L = \frac{1.26N^2A\,\mu}{10^8 l}$$

where L is in henries, N equals the number of turns, A is core area in square cm, μ is permeability and l is length of coil in cm. Since

$$X = 2\pi FL$$

the impedance of L11 and L12 in figure 1 will be

$$Z = \sqrt{R^2 + X_L^2}$$

and variations in L are directly proportional to μ. Therefore, variations in Z can be controlled by varying the flow of plate current in windings L9 and L10 (see figure 2). Note that this curve in figure 4 is quite similar to the B/H curve of figure 5.

Reference to figures 4 and 7 will show that a displacement voltage of 1 volt will cause a plate current difference of 3.1 ma and an impedance difference of approximately 260 ohms between the windings of L11 and L12.

The question may arise as to why the secondaries of the saturable reactors are wound in two sections. The reason for this arrangement is of some interest. Refer to figure 7. If a single winding were used, there would be a flux impressed on the primary when a-c voltage is flowing in the secondary. By using a dual winding connected in parallel, flux can flow around the outer legs of the core but not in the center leg (primary) since flux from the two secondary windings would be in opposite phase and hence cancel out.

Secondaries L11 and L12 form two arms

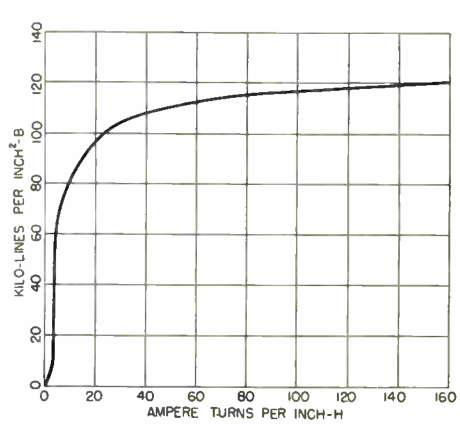


Figure 5—A B-H curve for a sample of silicon steel, indicating permeability and effect of magnetic saturation.

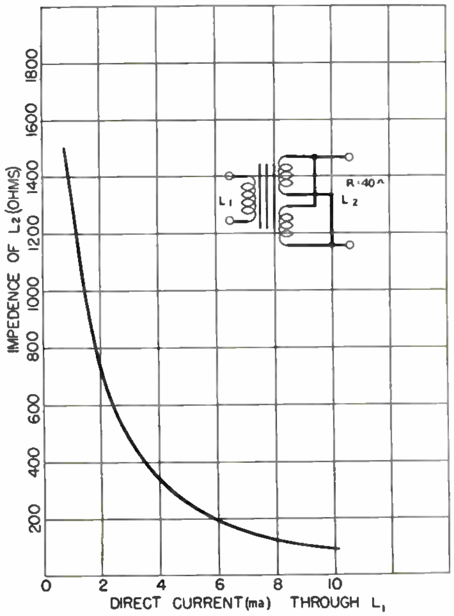


Figure 6—Curve representing impedance of each reactor as a function of a direct current flow in the control winding.

of a bridge which is balanced when the displacement voltage is zero. Resistor R9 is used to compensate for variations in circuit components which might contribute to an unbalanced condition. Resultant motor energizing voltage as a function of displacement voltage is shown in figure 8.

Displacement Errors Small

Dynamic tests have indicated that maximum displacement errors between the transmitter and transformer rotors are below 0.1 degree at standstill to less than 1 degree at a load velocity of 18 rpm. Reference to figures 3, 4 and 6 will show that a displacement voltage of 1 volt (equivalent to approximately 1 degree angular difference between rotors) causes a *grid-difference* voltage of 5 volts d-c, a plate current difference of 3.1 ma, and a motor control voltage of 17 volts rms.

Each winding (L13 and L14) of the low-inertia motor is rated at 75 volts and 0.1 ampere. The motor is a two-pole affair having a normal speed of 3200 rpm. Motor velocity as a function of energizing voltage is non-linear as can be seen in figure 9. For some applications it will be desirable to increase the secondary voltage of winding L18 of transformer T3, thus lengthening the useful portion of the curve.

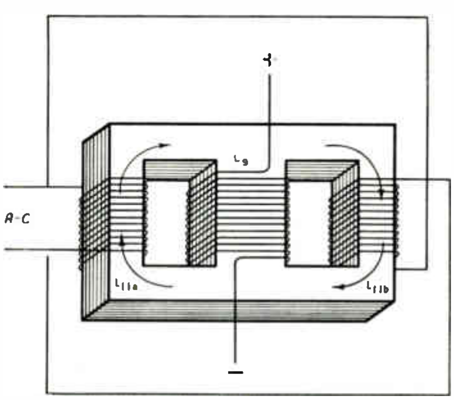


Figure 7—Manner in which windings are placed on the core of a saturable reactor.

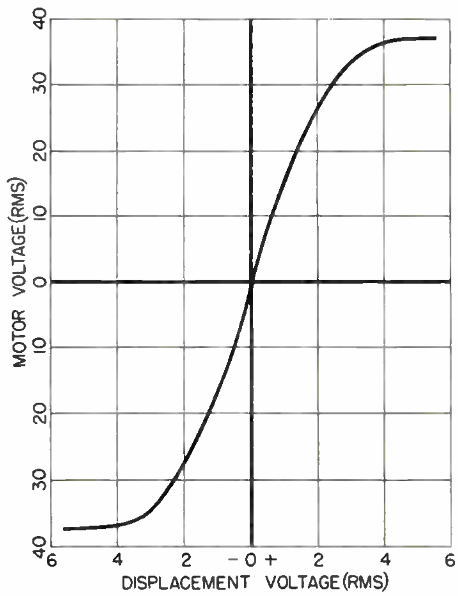


Figure 8—Curve representing a-c voltage supplied to the variable phase winding of motor as a function of displacement voltages resulting from errors in clockwise and counter-clockwise directions.

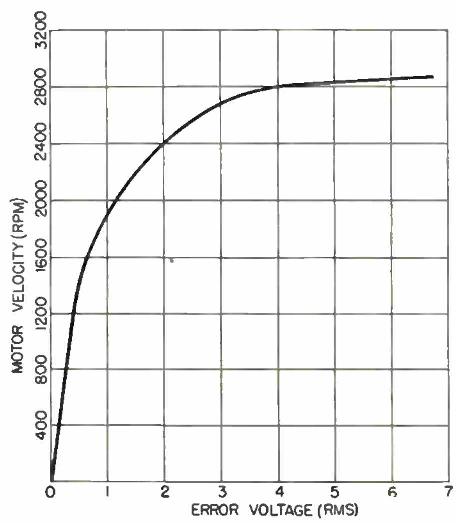


Figure 9—Curve showing motor velocity for different a-c voltages applied to variable phase winding with 75 volts across the fixed phase winding. Voltage across latter winding lags the control voltage by approximately 90°.

Hence, with 75 volts applied to the fixed phase windings, 18 volts applied to the variable phase winding will produce a motor speed of about 1900 rpm. The fixed phase winding is connected to the 115-volt a-c source through a phasing capacitor C8. This capacitor reduces the applied potential to 75 volts, which lags the voltage in L13 by slightly less than 90°. The motor is connected to the load through a 100:1 spur gearing system. The load is geared to the synchronous transformer rotor through a 1:1 gear system. It is essential that backlash in gearing be reduced to a minimum. Spring-loaded gearing should be used wherever practical.

Joseph T. McNaney

"THAT'S FOR ME," is what Joseph T. McNaney could well have said when he received his first assignment at Bendix. His home laboratory research and experiments, dating back to the early days of radio transmission, included investigations of the servo field of which comparatively little was known. Arriving at Bendix in 1942, he was placed in the receiver laboratory, and later made assistant project engineer in the Microwave Engineering to devote himself to the development of servo mechanisms. This not only offers the outlet in commercial engineering he anticipated in transferring to Bendix from the Consolidated Gas Electric Light and Power Company, but establishes him in the branch of radio in which he is most interested. He has several patented inventions to his credit, such as a high-speed signaling system which substitutes electronics for mechanical means of signal recording, and a telemetering system for recording readings from a plurality of meters.

EXPANDER-COMPRESSOR AMPLIFIER

Intelligibility of signals picked up by microphones in noisy locations is considerably improved by the use of this "expressor" amplifier.

By L. R. YATES
Transmitter Engineering

In some types of radio telephone service, operating conditions require that a transmitter microphone be located adjacent to noisy equipment such as typewriters and teletype machines, so that a relatively high noise level prevails at the microphone. The noise level may in many cases be of sufficient intensity to be objectionable in the received signal. When a speech amplifier with a volume limiter or compressor is used, the condition is often aggravated because the amplifier gain is usually increased beyond the minimum required value in order to provide compensation for input signals having a level somewhat lower than normal. Under these conditions, a combination of volume expansion and volume compression in the speech amplifier may be advantageously used to reduce effectively the apparent noise level present in the transmitted signal. At the same time, this combination provides the normal advantages of a compressor amplifier in maintaining a high percentage of transmitter modulation without overmodulation.

Peak Limiter Characteristics

Figure 1 shows a typical response curve for an amplifier utilizing a peak limiter type of compressor in common use at many radio telephone stations at the present time. The output characteristics of this amplifier are such that, for input levels below the threshold value at which the limiter comes into operation, the output level is directly proportional to the input. Above the threshold level, corresponding to 0 db output in figure 1, the output level remains relatively constant and independent of increases in input level. To permit maximum transmitter output, the threshold level is normally set at a point corresponding to approximately 100 per cent transmitter modulation. To maintain a high level of modulation with small changes in speech level, the amplifier gain may be increased beyond the point required for normal speech input, so that the limiter will be functioning under normal input conditions.

With this adjustment the amplifier gain will be greater during periods of no speech input than during periods of normal signal level, as a signal of normal intensity will cause the limiter to function and reduce the amplifier gain. Under these conditions any background noise picked up by the microphone increases during periods of low amplifier input such as occur between words during speech transmission. Action of the limiter circuit then causes the background noise to fade alternately in and out during speech, and thus produces a disagreeable effect at the receiver. A high background noise level may often be a limiting factor in determining the permissible amount of amplifier compression that can be tolerated.

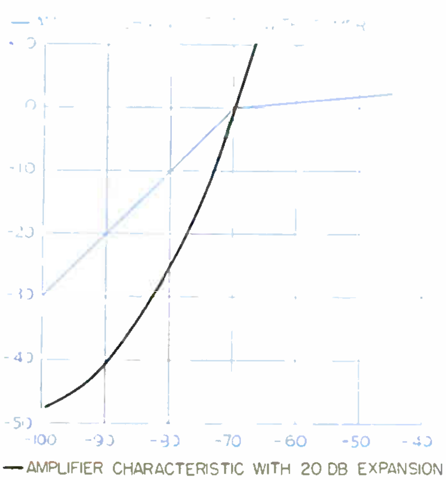


Figure 1—Blue curves represent typical response of peak limiter compressor. Black curves represent typical response for volume expander.

Volume Expander Characteristics

Figure 1 also shows a typical response obtained for an amplifier employing a volume expander circuit. The curve for the normal amplifier without expansion is linear. For 0 db output both the normal amplifier and expander amplifier have the same gain; however, for lower input levels, the expander amplifier has a decreased gain. The decrease in gain is the difference between output levels. Sensitivity of the amplifier declines rapidly as the input level is decreased in accordance with the amount of volume expansion used. In the case shown in figure 1 corresponding to a volume expansion of 20 db, the amplifier gain has been reduced by approximately 20 db for an input level of —100 db which is 30 db below the level required for normal output. Under these conditions, a noise level 30 db below normal input would be reduced to 50 db below the normal level at the amplifier output. Thus low level signals, such as noise, having a normal level somewhat below the normal speech level, will be attenuated by the difference between the two curves at the point corresponding to the input noise level. This circuit, while discriminating against noise, is unsatisfactory for use in conjunction with a radio transmitter since the output level changes rapidly with changes in input level. This characteristic makes it difficult to maintain an output level approximating 100 per cent transmitter modulation.

Expressor Characteristics

It appears that a desirable amplifier would use the expansion characteristic of figure 1 to provide discrimination against background noise, and would also use the compression characteristic of figure 1 to hold the output level constant for strong signal inputs. An amplifier was designed utilizing both of these characteristics, and having the output characteristic shown in figure 2. This amplifier uses a volume expander circuit ahead of a compressor circuit, and has the desirable characteristics of both circuits of figure 1. This arrangement, because of the non-linear expander characteristic, provides discrimination against noise having an amplitude lower than the normal amplifier input level, while the compressor provides a constant output level for normal or greater than normal input levels. The amplifier obviously provides discrimination against noise only during intervals when there is no normal input to the amplifier since during periods of normal signal input the amplifier gain is increased. However, during periods of normal input when the expander has increased the amplifier gain, the normal speech input effectively masks the noise so that the noise is not apparent in the output. In order that the masking be effective, the expander circuit must have a relatively short recovery time so that the amplifier gain will decrease rapidly between words during speech transmission.

Circuit Description

A simplified schematic diagram of the "expressor" amplifier is shown in figure 3. The amplifier proper consists of a single-ended input stage using a pentode tube, followed by a transformer-coupled push-pull output stage using two remote cut-off pentode tubes. A winding on output transformer T3 provides voltage for the plates of the

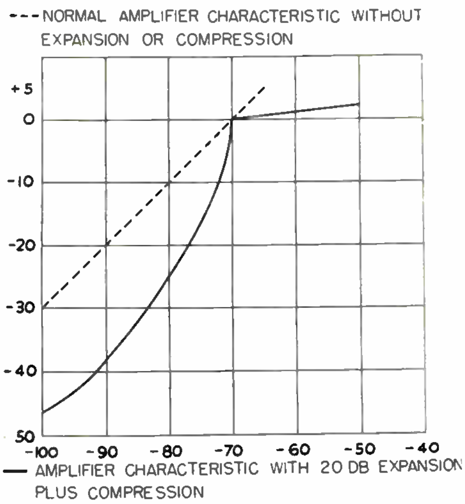


Figure 2—Response curve for "expressor" amplifier.

limiter rectifier V6. The cathode of V6 is biased positively by potentiometer R9 to provide a delayed compression characteristic. Peak audio voltages applied to V6 in excess of the positive cathode bias cause the tube to conduct and develop a d-c voltage across R7 and C6. This d-c voltage biases the grids of tubes V2 and V3 negatively and thereby reduces the output level. The expander circuit consists of an amplifier tube V4, transformer-coupled to expander rectifier V5. An input signal is amplified by V1 and V4 and then rectified by V5. The rectified voltage appears across R6 and C5, and is applied to the grids of V2 and V3 in a positive direction so as to reduce the effective grid bias and thereby to increase the amplifier gain.

Operation

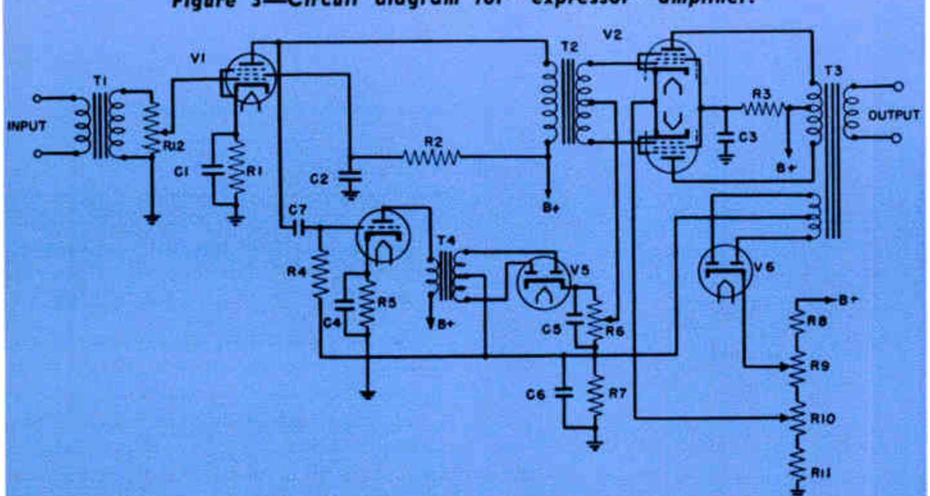
In operation, potentiometer R9 is adjusted to a voltage corresponding with the amplifier output level, at which it is desired that the compressor shall become operative. With the expander rectifier tube V5 and compressor rectifier tube V6 removed from their sockets, and with a normal input signal to the amplifier, potentiometer R10 is adjusted to increase the cathode bias on V2 and V3 and thereby reduce the amplifier gain by an amount corresponding to the amount of expansion desired. The expander rectifier tube V5 is then placed in its socket and potentiometer R6 is adjusted to bring the output level back to its original value. The positive bias voltage developed by the input signal across R6 serves to buck out the cathode bias voltage across R10 so that at normal input level, the amplifier sensitivity is normal; while at low input levels, the voltage developed across R6 will not be sufficient to buck out the cathode bias. The amplifier gain is thereby reduced. At input levels in excess of those required for normal output, the limited circuit will bias the grids of V2 and V3 negatively and thereby reduce the amplifier gain to maintain a constant output level. Beyond the threshold point at which the limiter acts, the negative voltage developed by the limiter overrides the positive voltage developed by the expander because of the greater sensitivity of the limiter, thus holding the output level nearly constant for considerable increases in input level. The grid of V4 is returned to ground through R7 so that negative voltage developed across R7 by the action of the limiter is applied to the grid of V4, reducing the expander output during periods of limiter operation. The time constant of C5 and R6 is made relatively short, on the order of .1 second, to permit the amplifier gain to fall off between words during speech transmission and so prevent background noise from being heard during these intervals. The time constant of R7 and C6 determines the recovery time for the compressor circuit. This circuit has a time constant approximately the same as that of the expander circuit.

Because of the rapid falling off in output level which occurs with decreases in input level below the value required for normal output, it is desirable in normal operation to increase the amplifier gain several decibels above the minimum gain requirement, in order to allow for slight changes in input level.

Considerable Improvement

Listening tests conducted on an amplifier of this type indicate an apparent reduction in background noise equivalent to the amount of expansion used. These tests show no adverse effect on speech quality when expansions on the order of 20 or 25 db are used. It appears that where microphones must be used in noisy locations, a considerable improvement in the intelligibility of the transmitted signal is made possible through the use of an expander-compressor amplifier of this type.

Figure 3—Circuit diagram for "expressor" amplifier.



L. R. Yates

"SEE LES YATES" is a familiar slogan at Bendix whenever transmitter problems crop up. And Leslie Yates is both equipped and disposed to find the solution. Starting out as radio operator at station WLBZ in Bangor, Maine, he became, progressively, draftsman and radio receiver test engineer at Bridgeport General Electric; radio transmitter design engineer at Marine Radio Company; and radio engineer, designing tube-testing equipment at Tungsol Lamp Works. Arriving at Bendix one week after the opening of the Fort Avenue plant in 1937, he has been in transmitter engineering ever since, engaged in radio transmitter test, radio range installations—including the SMRA and MRL type for the CAA—and radio transmitter design on speech amplifiers. As project engineer he has developed miscellaneous types of control and audio equipment. He received his B.S. in electrical engineering at the University of Maine in 1933.

AIR TRAFFIC CONTROL

The Civil Aeronautics Administration is working on plans to bring safe and adequate control to the greatly increased air traffic envisioned in the immediate post-war years.

THE UNQUESTIONABLE EXPANSION in commercial flying and the predicted increase in private flying after the cessation of hostilities involve the big problem of efficient domestic air traffic control. The Civil Aeronautics Administration is charged with the responsibility of setting up a system capable of handling peak traffic in the next decade.

CAA plans already formulated include generous use of radio equipment, some of which is now in general use, and some which is still in the experimental stage.

Half-Million Planes

It has been predicted that by 1950, 500,000 aircraft of various types will be in use in the U.S. Whether or not this particular figure is accepted, everyone agrees that the increased use of private, passenger, and freight air carriers will be tremendous. The Air Traffic Control Division of CAA is well aware of the problems it will have to solve as a result of this increase.

One of the fundamentals of air traffic control is that the controlling agency or agencies must be prepared to handle not the expected average conditions but the *maximum peak* conditions which might occur. Another basic principle is that peak conditions usually arise during periods of poor visibility.

Based on available statistics and expected trends, the ATC division has chosen 60,000,000 total aircraft movements as the probable rate of traffic to be handled during 1950. This figure includes air-carrier and non-scheduled flights. A graph illustrating aircraft movements for the years 1940 to 1950 is shown in figure 1. The flattening of the curve between 1946 and 1950 takes into account a probable drop at the end of the war when the aviation industry will have to change over from the production of military to private and commercial aircraft.

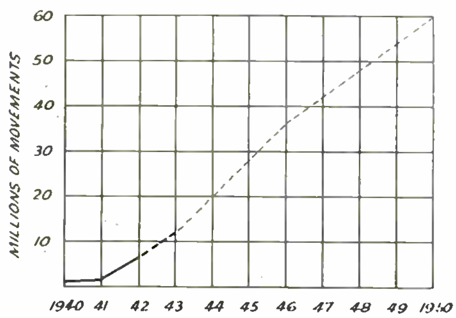


Illustration courtesy CAA

Figure 1—Curve showing predicted increase in aircraft movements.

In the past, large numbers of non-scheduled aircraft were flown under "contact flight rules" (good weather and visibility) whenever possible. Although their movements were handled by the air traffic control service, they were not posted on the flight progress boards. Nevertheless, since these contact flights may become "instrument flights" in the event of unfavorable weather conditions, they have to be considered "potential" instrument flight plan movements.

Since many post-war private fliers will be trained in the technique of instrument flying, it is believed that the total number of instrument flights will be of the order of 20,000,000 movements by 1950 (see figure 2).

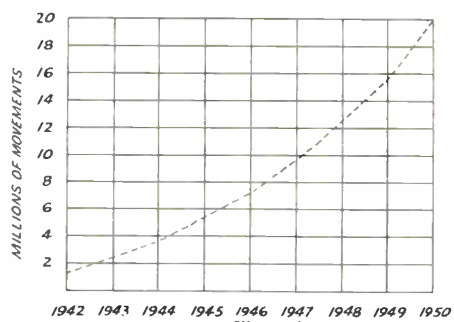


Illustration courtesy CAA

Figure 2—Curve showing predicted increase in instrument flight plan movements.

A comparison of the curves of figures 1 and 2 will show a sharper upward bend in the curve of figure 2. This is to give consideration to the predicted increasing *ratio* of instrument flight plan movement to *total* movements of all affected aircraft.

As previously stated, anticipation of air traffic control requires consideration of peak movements instead of average movements as might seem logical at first glance. Taking the Washington National Airport as an example, estimates indicate that the peak will increase from a rate of 35 controlled movements per hour in 1941 to more than 600 per hour in 1950. These figures are based on the maximum peaks.

Airways Not Limiting Factor

Using the sixteen one-thousand-foot flight levels between 3000 and 18,000 feet of an average stretch of airway, it is possible, under present instrument flight rules, where lateral separation is practical, to accommodate two flights at each level every ten minutes, or 192 aircraft each hour. Variations in the speeds of different planes plus provision for climbing and descending reduce this figure to 125 or 150 per hour. These figures are based on the present state of technical developments and are expected to hold through 1947. Indications are that this capacity will be sufficient for the busiest sector of the New York Airway Traffic Control Area until some time in 1948 and probably until 1949 at the Washington Airway Traffic Control Area.

The more general use of pressure cabins will increase the airway height at least to 25,000 feet and accordingly will raise the practical airway capacity to between 180 and 225 aircraft per hour.

When the war ends, it is reasonable to assume that equipment now of necessity secret will result in an electronic separation indicator. Such a device will permit reduction of the separation between aircraft to about 10 miles or less. Speeds will almost certainly increase. An average of 250 miles per hour in conjunction with higher altitudes and reduced separation would raise the airway capacity to between 400 and 500 movements an hour.

The foregoing indicates that airway capacity is not necessarily the limiting factor in air transportation of the future.

Since it is apparent that airways will not be a limiting factor, what about the airports?

The capacities of airports at present are quite different under contact and instrument conditions. Most airports have only a single runway in any one direction. Since only that runway which is parallel to the wind direction can be used, but one aircraft can land or take off at any one time. This means that under contact rules, a maximum of seventy-five movements per hour is possible providing adequate taxiing facilities are available.

Instrument Landings Restricted

On the other hand, when weather conditions require instrument rules, airport capacity decreases sharply. Aircraft arriving over an airport must maintain radio contact either with the airline operator or operators at the airway station until the pilot receives instructions to descend to his approach level, start his approach and contact the airport tower for further instructions. The pilot then proceeds to make an "instrument approach." He first leaves the radio range at an altitude of 1000 feet or more and proceeds away from the airport for three to five minutes. He then makes a "U" turn and returns to the field while descending to the minimum permissible altitude. The landing is made when the aircraft is far enough below the cloud base to permit sight of the field. Until the pilot has completed his landing or at least is visible to the control tower, other aircraft must cruise at their assigned altitude levels. As a result of this procedure, landings are restricted to one each 10 or 15 minutes with one or two take-offs during the same period. The maximum number of movements under this procedure is between 8 and 15 per hour.

A newer type of approach system has been developed wherein the pilot starts his descent toward the airport upon passing over a radio "fix" located a short distance out from the range station, crosses the station at less than 1000 feet and continues his descent until he is below cloud level. This is known as "straight-in approach" and permits landings and take-offs at a rate of 15 to 24 movements per hour. Due to communications lags, this rate is difficult to maintain. These lags are being eliminated under new procedures wherein control of all aircraft within a short distance of the airport is turned over to the local tower. The pilot contacts the control tower for instructions upon reaching a designated point on his inbound route. Outbound traffic is controlled in a similar manner so that both incoming and outgoing traffic is coordinated. These procedures are called "approach control" and, when used with properly located radio aids for straight-in approaches, can increase airport capacity in instrument weather.

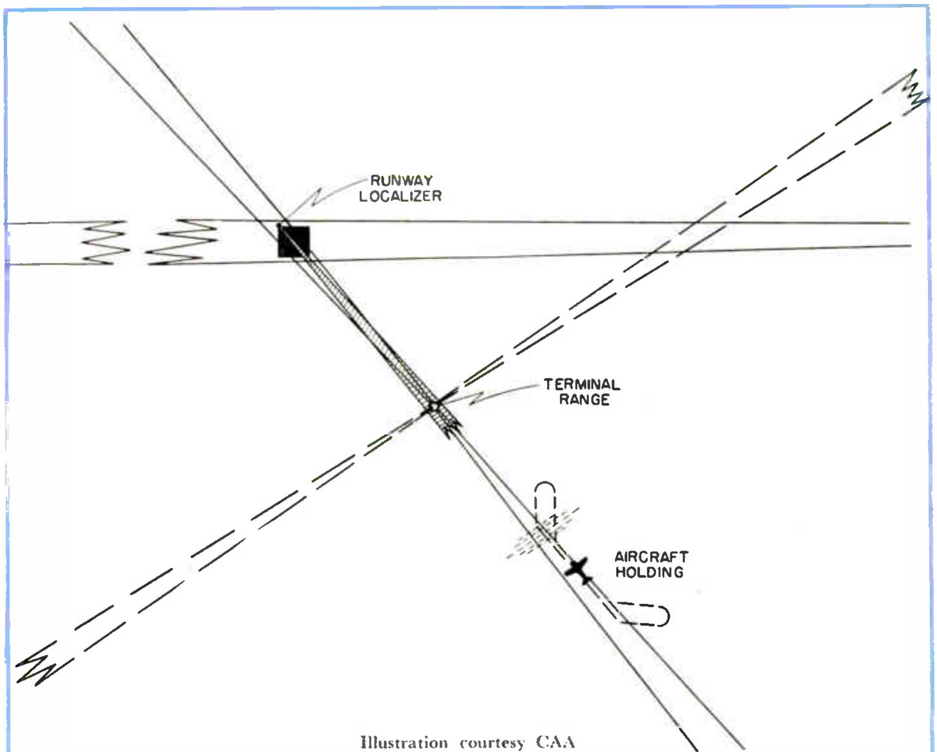


Illustration courtesy CAA

Figure 3—Diagram of radio range and localizer system.

Overcoming Low Ceilings

It will be noted, however, that these methods all depend upon the aircraft arriving below the cloud base at sufficient height to enable the pilot to maneuver to a landing by visual reference to the ground.

Improved radio facilities which are now being installed as rapidly as equipment is available permit landings with only a 100-foot ceiling and quarter-mile visibility. At present, these new facilities consist of a "localizer" (two-leg vhf range) and two markers known as the outer and the boundary markers. (See figures 3 and 4.) If required, a middle marker can also be used. The instrument approach system permits landings under weather conditions which formerly prevented all operation. When combined with approach control, this system is expected to increase airport capacity in instrument weather to thirty movements per hour.

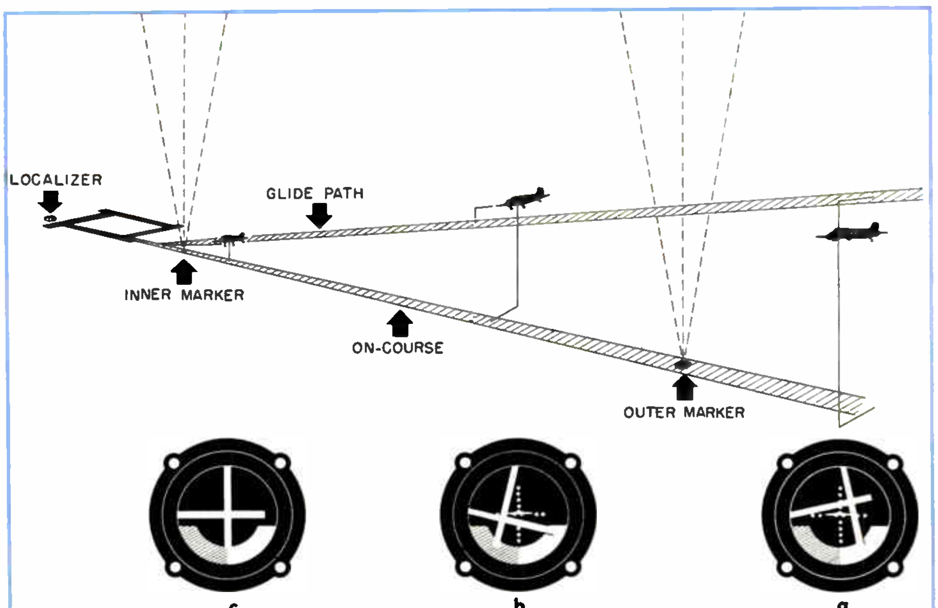


Illustration courtesy CAA

Figure 4—Diagram of glide path and markers showing position of visual indicators when (a) low and to the left (b) high and to the right, and (c) on course.

Three factors concern traffic handling at the airports and each is solvable with facilities which are or can be made available. These factors are dual runways, multiple airports and instrument approach and landing systems.

Increasing the number of parallel runways offers an immediate method of doubling, tripling or even quadrupling take-off and landing facilities at each airport.

As soon as traffic to and from a city outgrows the capacity of one airport, others will be built. Several cities have multiple airports at present. For example, New York City has La Guardia Field for airline operations, Floyd Bennett Field for Naval Aircraft, Mitchell Field for the Army, several private fields owned by manufacturers, as well as airports normally used by private fliers. After the war, it may be necessary to provide a separate field for freight carriers.

An additional facility which will be installed when hostilities cease is the radio "glide path." This device in conjunction with the new vhf localizer and marker system provides a means for descent under any conditions of visibility.

VHF Ranges Favored

Many of the older low frequency radio ranges are being replaced by newer type vhf ranges. The latter, according to the CAA, have been selected because, in addition to being free from static due to storms and precipitation, they are less subject to bent courses in mountainous terrain. In addition, interference between range stations will be practically eliminated. The CAA contemplates complete conversion to vhf radio ranges after the war. Probably some of the low frequency stations will be retained for direction finding and trans-continental flights.

The pilot of the future then will ride a vhf beam towards his destination. When he is within a few miles of the airport, he will meet the crossbeam of the localizer which will guide him over and beyond the runway. Upon instructions from the control tower, he will make a 180° turn and return along the localizer course. The markers provide reference points along the approach path, and the glide path leads him to a safe landing.

Insofar as the pilot is concerned, use of the new landing system merely requires that he maintain a pair of cross pointers on his visual indicator at right angles to and intersecting each other at the center of the dial.

The vertical pointer indicates lateral deviations from the localizer. The horizontal pointer shows variations from the glide path.

It is evident that this system will shift considerable work and responsibility from the tower operator to the pilot.

Operation of the vhf radio range is on a somewhat different principle from the low frequency ranges. The antenna system is similar except that physical dimensions are greatly reduced. One pair of range legs radiates a signal which is indicated visually in the aircraft whereas the other pair transmits an aural signal at right angles to the visual course. This arrangement avoids quadrantal ambiguity since its courses are formed by four uni-directional patterns instead of two bi-directional patterns.

While conversion of receiving equipment will be necessary after the war, it is highly probable that worthwhile weight reductions will result since it seems logical that some of these services can be combined in one piece of equipment.

Future Electronic Devices

Much has been written about electronic devices which will emerge as a result of war developments. One item which is often mentioned is an anti-collision device. Others are automatic monitors, separation indicators, block signal systems, traffic clearance indicators, electronic posting boards and many other robots which are yet to be perfected. The CAA will not adopt any contrivance unless tests prove them safe, sure and accurate.

On the other hand certain definite conclusions concerning post-war traffic and control devices can be drawn from the foregoing. They are:

1) There will be a tremendous increase in aviation after the war;

2) The CAA is preparing to control the increased traffic, with equipment in operation or in the experimental stage;

3) VHF radio ranges are definitely "in";

4) VHF instrument approach systems are practical and are being installed already;

5) Plans are made to use the "glide path" for blind landings immediately after the war;

6) Anti-collision and other automatic devices will be approved and installed as soon as they are proved practical;

7) If any radically new navigational facilities developed during the war are adaptable to peace-time aviation, they will be used;

8) There will be a huge demand for vhf receiving equipment;

9) The manufacturer who produces an inexpensive radio for private flyers will have a ready market for his product.

Proposal in Technicolor

Vernon Moore, of Receiver Engineering, discovered on a trip to the South Pacific that the young New Caledonian males treat the tops of their thatches of bushy black hair with lime juice to give it a red color. This indicates their willingness to marry.

Human Radar

"At one airport in Central Africa, where construction work was under way by sheet-clad, barefoot natives, a tall, lanky African, draped in a spotless white cloak, stood on a ten-foot mound of dirt. In his hands he held a horn, handmade of pieces of scrap pipe, and long enough to be used as a flagpole. When applied to his lips, this horn emitted the most weird tune I have ever heard. I was told that he was a lookout to warn the workers of approaching planes. It was said that he had the ability to spot planes, with his naked eye, from five to eight minutes before the average person was aware of their approach."

—*Report by Russell Harper.*

AUTOMATIC IRON CORE CHECKER

Permeability measurement of iron cores for r-f coils on a quantity production basis is facilitated by use of an automatic checker designed in the Receiver Engineering Section.

By DAVID MARTIN
Receiver Engineering

Quantity production of r-f coils for precision radio brings up problems in tracking not encountered in limited-quantity manufacturing. Since tuned circuits in a radio receiver comprise coils of known Q and inductance, and since they are resonated by variable capacitors, the inductance of the coils should be matched in all sets. When a limited number of sets is being manufactured, turns may be added, removed or spread out, in order to secure the desired inductance. Obviously, these adjustments are not practical where precision radios must be turned out in large quantity.

At Bendix, as in other industrial plants faced with tracking problems, we are using powdered iron cores, movable along the axis of the coils. These cores consist of finely powdered iron in which the average particle is 2 to 5 microns in diameter. These particles are compressed with a bakelite binder, which insulates them from each other. Moving the cores in and out of the coils results in a substantial range of inductance variations.

Problem In Measurement

Permeability measurement of r-f coil iron cores, under conditions of quantity production, has also presented a problem. To facilitate measurement, an automatic checker has been built which seems to offer certain advantages over previous methods. To discover these advantages it will be helpful to consider procedures now in use.

In actual practice at Bendix, we use the coil assembly shown in figure 1*a*. The coil is held in two cups or half-shells of iron, and the core moves along the axis of the coil. The assembly gives practically a closed magnetic circuit, so that the effect of surrounding objects on the coil is minimized. Further reduction of coupling results from the electrostatic shielding of the iron particles. The particle size of the iron is so small that eddy current losses in the iron are considerably reduced and effective permeability is raised, since greater penetration of the magnetic lines of force is allowed at radio frequencies. Thus the ωL term of $Q = \frac{\omega L}{R}$ is raised without unduly increasing R. The result of this construction is an extremely small coil of good Q up to about ten megacycles.

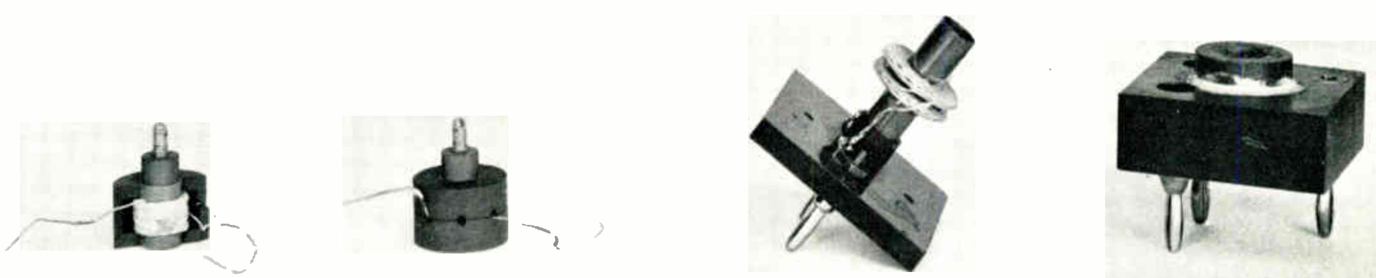
We know that winding tolerances establish a certain spread of the inductance of coils as they are wound in production quantities. The spread reduces the range of adjustment about the desired inductance, since the nominal center inductance is shifted up or down. To this reduced range must be added the range of permeability to be expected in production runs of the iron cores and half-shell. In other words, limits must be set by trial to give a reasonable rate of good coil production, without an unreasonable rate of iron rejection. The allowable range of permeability deviation of good iron also must be logically divided between cores and half-shells.

In our production setup, the cores have an allowable range of effective permeability change of ±2.5%, measured against an arbitrary center standard. Fortunately, experience has shown that, whereas the Q of a coil using iron may vary widely with frequency from one sample to another, the permeability (measured by measuring inductance) remains proportionately constant: therefore, it is entirely practical to measure this permeability at a single radio frequency. We have chosen 1210 kcs as a reasonable measuring point.

Comparison Coil

Since all the manufacturers supplying iron in accordance with our specifications have Q-meters as part of their test equipment, we decided to design our permeability measuring equipment to include a Q-meter. Figure 1*c* shows our first attempt at a comparison coil. It was a two-section, universal-wound coil of very high Q. This coil was used for a period of several months in checking samples of production lots of iron cores. In that time, two limitations were discovered. First, it was difficult to correlate measurements made this way, with results obtained when the iron was actually used in assemblies. Secondly, since the coil was exposed, it was subject to mechanical damage, and iron dust sometimes changed its basic inductance.

The jig was subsequently redesigned as shown in figure 1*d*. Here you will notice that the coil is completely enclosed in iron half-shells, the core completing the magnetic path. Therefore, the assembly closely approximates the actual circuit used in the radio. The coil-winding form goes through both half-shells, preventing the uncertain iron-to-iron contact



A B C D

Figure 1—A. Cut-away view of, B, complete coil assembly. C. First test coil found unsatisfactory because of open construction. D. Test jig that has proved to be satisfactory. Readings check to within 0.1% between jigs.

which would otherwise occur. A jack, which plugs into the ground terminal of the Q-meter, assists in holding the assembly solid, and allows for the possibility of grounding the core screw while making measurements. With this jig, it is possible to make measurements, then repeat them within 0.1% accuracy, and also to check measurements made by our manufacturers to ±0.2%.

The procedure used in making these measurements follows. First, a piece of iron of known good quality is chosen as an arbitrary standard of measurement. This iron has been found by previous trial in a final assembly to be a "center" piece as far as permeability is concerned. It is put in the test jig, which is plugged into a Boonton Model 160-A Q-Meter. The capacity dials are set at 100 μμf (main capacitor) and 0.0 (trimmer). The oscillator tuning is varied to give peak indication on the Q dial. When this operation has been completed, the Q-meter is correctly set up for testing other samples, and on future samples only the capacity dial is changed. Therefore this is referred to as the ΔC method of measurement. Secondary standards are then chosen by testing a large number of pieces and selecting

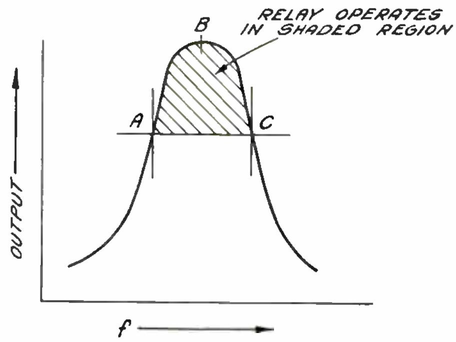


Figure 2—Overall selectivity curve as filter unit.

those which peak under the described conditions (±0.05 μμf). The secondary standards are distributed among the iron manufacturers and our own inspection department. There they are kept as primary standards, used only as a criterion for the choice of secondary standards, which in turn are used to measure iron in production. In production, iron is accepted if it falls within ±2.5 μμf on the Q-meter dial, which, to simplify discussion and measurements, is referred to as ±2.5% change in inductance. This description is not strictly accurate, however, since it ignores the distributed capacity of the measuring coil and jig.

Accuracy Checked

Before proceeding with the design of an automatic checker, it was thought advisable to investigate carefully the accuracy of the system in use. A series of measurements was taken to ascertain the actual ΔL as compared to the ΔL determined by substituting the ΔC for ΔL. With a sample core selected at random by the ordinary method, it was found that the ΔL = 2.8% (ΔC). The iron was then re-tested, using the "two-frequency" method, by which measurements are made at one frequency, then repeated at the second harmonic. Now, taking C as the capacity (in μμf), to resonate the circuit at the lower frequency f (in mc), the distributed capacity of the jig and coil is

$$C_d = \frac{C_1 - 4C_2}{3} \text{ and } L = \frac{.0189}{f_1^2(C_1 - C_2)} \text{ (in } \mu h\text{)}.$$

The change in distributed capacity from the standard to the sample cores was 0.07 μμf, a negligible amount, proving that the change in resonance was due almost entirely to a change in inductance. Correcting for distributed capacity, the inductance change was ΔL = 2.45%. By the two-frequency formula, ΔL = 2.34%; hence the agreement without correction for distributed capacity is 0.46% and with correction is 0.11%. It may be stated, therefore, that the change in effective permeability between samples of iron may be measured with adequate accuracy by the ΔC method.

However, while accurate, this method does not lend itself to production quantities. Though each box of iron is sampled, only about 10% of the total iron received is checked. It cannot be said that this system gives a truly representative sample, since the iron is merely selected at random. When everything is running smoothly, the testing may be found adequate. But should trouble develop, there is a possibility it may not be discovered immediately.

The superiority of an automatic checker requiring only loading and unloading was obvious, since it would speed up the test procedure and permit permeability test of *all* received iron. Such a checker would, in addition, permit salvaging out-of-tolerance coils by segregating low and high permeability iron which could be matched with high or low inductance coils. Design of the automatic permeability checker was undertaken.

Enclosed Jig Selected

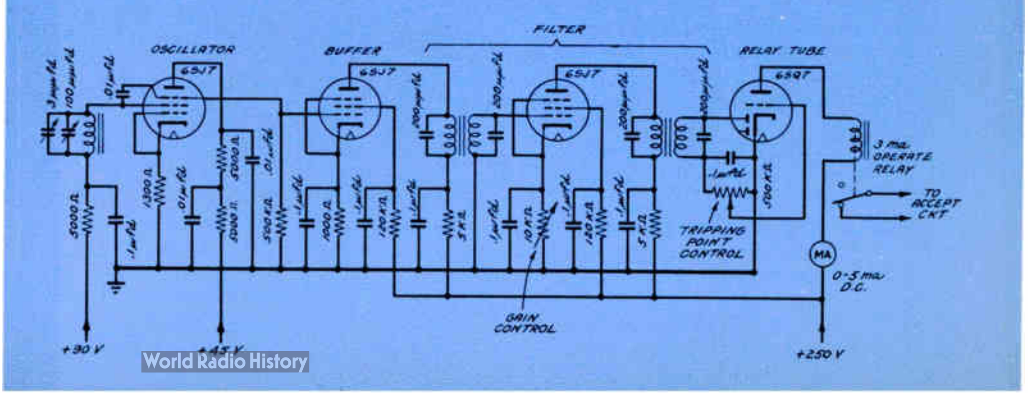
As a result of past experience, we decided to use a complete coil assembly as shown in the coil jig of figure 1c. In order to obtain a readily measurable effect, the coil was connected into a two-terminal r-f oscillator, using the coil tuned by 100 μμf capacity as the tuned circuit. The use of a two-terminal oscillator has definite advantages. Coils are simple and therefore easily made and replaced. Also this oscillator permits building a circuit of known excellent frequency stability and constant output voltage. The oscillator circuit decided upon was of the transitron type. Running 45v on the plate and 90v on the screen of a 6SJ7 gave a constant output of approximately 20v over a wide range of Q and permeability.

Using the same iron standards and samples as before, we obtained Δf of 1.2% representing a ΔL of 2.4%. This value is extremely

David Martin

DAVE MARTIN, tall, lanky and likable, is an irrepressible pioneer. In his glory when tinkering with some unpromising gadget, he usually succeeds, so his associates say, in making it work. The device described in his article is his solution for speeding up a process which seemed to him too tedious. While still in college, he spent about a year doing general electrical maintenance at Lukens Steel Company and also held several temporary jobs as electrician. He received his B.S. in electrical engineering from Drexel Institute, Philadelphia, in 1940, having specialized in communication engineering. Soon after, he came to the Receiver Engineering Section at Bendix and is now project engineer on a high-frequency ground station direction finder.

Figure 3—Schematic Diagram.



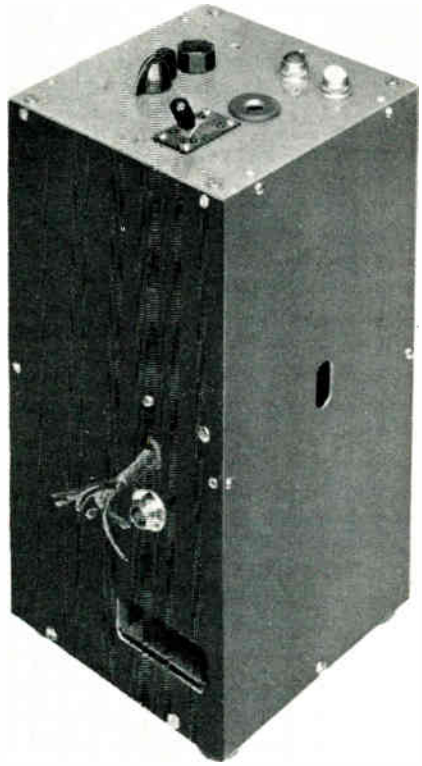


Figure 4—Top view showing mouth of feed tube.

close to the previously calculated value (2.34%). Since we have a measurable variable appearing as the frequency change which is directly related to the permeability change of the iron, the problem of automatic measurement must be overcome. Here there is a choice between two alternatives. First, the voltage can be fed into a discriminator circuit which will give no output at the center frequency, and rising output voltage each side of the center. The method is excellent for a direct-reading permeability meter using a zero-center meter with low permeability on one side and high permeability on the other side. This type of measuring device, however, has a serious deficiency. There is *no* output at the center frequency and also *no* output considerably off resonance. Therefore, if the iron is badly off tolerance, it would not be rejected but would be treated as though it were center value.

The second alternative is to feed the variable frequency through a band pass filter and use the output to operate a relay tube. The response curve is shown in figure 2. Between A and C, the output is above the rejection level; hence the relay operates and causes acceptance of the iron. Below A or above C in frequency, the output falls off, and there is no tendency toward an erroneous acceptance. This is the method used in the first workable model of the automatic checker. The complete circuit is given in figure 3. The oscillator output is fed into a pentode buffer stage to eliminate any possible locking effect between the tuned filter and the oscillator which would tend to reduce the range of the frequency change obtained for a given inductance change. The pass band of the filter is adjusted so that, for the desired maximum limits of permeability change, the frequency is down on the rapidly changing portion of the filter skirt. This adjustment gives the desired sharpness of control which is accentuated by mechanically adjusting the relay for minimum differential. The exact operating point is obtained by varying R_1 until the relay trips on the limits. A small variable capacitor is incorporated to allow checking the relay action. The two limits are indicated as dots on this capacitor scale. A standard piece of iron is inserted, and the capacitor is set first to one dot, then to the other. If the relay does not trip at the same point on each side, the oscillator is not set correctly. Then the main trimmer is set to give minimum current with the standard core, the trimmer being on 0. This setup was checked using the coil jig as used originally on the Q-meter. It proved to be precise, easy to operate, and comparatively trouble-free.

Automatic Feed

Thereupon, the present model (figures 4, 5, and 6) was constructed embodying automatic feed. The electrical circuit is again the same as in figure 3. The relays visible in the rear view, are chain-connected, slow-release relays. These relays, in conjunction with the positioning relay contacts, feed two cores per second. The cycle is as follows:

1) The feed tube is loaded with cores to be tested. This process of loading is continuous throughout the entire operating procedure.

2) The bottom core is stopped on a pin projecting through the side of the feed tube just below the coil.

3) The switch at the top of the unit is moved to the "operate" position, which energizes the feed mechanism.

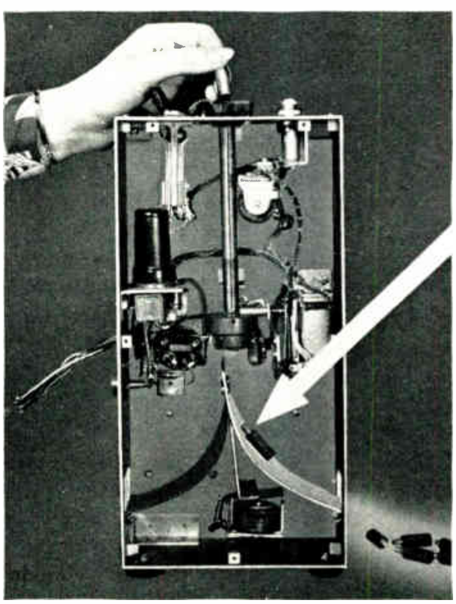


Figure 5—Front view, cover removed, showing rejected core.

4) The core is checked by the permeability unit, and if acceptable, the feed-out chute is moved over to the "accept" position. If unacceptable, the chute stays where it is.

5) A top pin is pushed through a hole in the tube above the core being checked.

6) The bottom pin is removed allowing the core just checked to slide down the chute and out the proper opening.

7) The bottom pin is then replaced and the top pin is removed, allowing another core to drop into the test position.

8) The cycle then repeats.

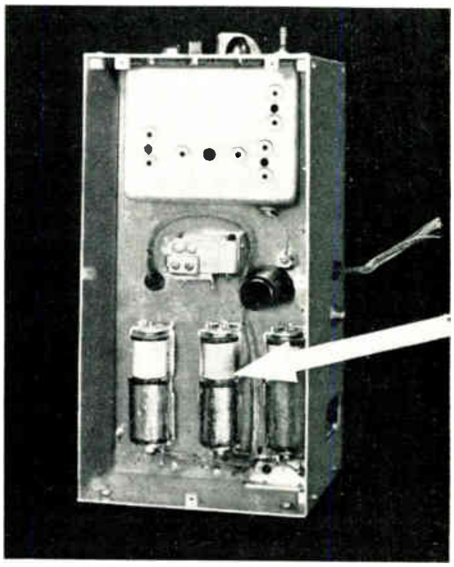


Figure 6 — Rear view, cover removed. Arrow points to center slow-release relay.

At any time the cycle may be halted by throwing the switch to the center position. Also, periodically a standard core is inserted and the switch is thrown to the check position. The equipment may then be rechecked for center setting and the tolerance operation checked as previously described. One of the two pilot lamps at the top of the unit lights during the test part of the cycle, indicating whether the core is accepted (green) or rejected (red).

This unit is entirely practicable, but in future designs certain refinements might be desirable. A horizontal, motor-driven feed would be smoother and quieter, and would eliminate any tendency toward clogging. Automatic stacking of the finished iron to insure keeping pace with the speed of the machine would be desirable. Finally, it may prove more logical to use a thyratron for a relay tube.

In general, it seems practical to build an automatic permeability checker for testing in instances where the piece to be measured is used in large quantities, and where an accuracy of measurement up to ±0.2% must be held. Most of the problems involved in the design of such a checker will be found to be mechanical rather than electrical.

BENDIX ACTIVE ON RTPB

Bendix engineers are getting into the work involved in the extensive program of investigation outlined for the Radio Technical Planning Board.

The Radio Technical Planning Board, which came into existence in September 1943, has settled into its stride. The thirteen panels through which it functions have been organized and the members are now engaged in preliminary research assignments. Bendix executives and engineers, W. P. Hilliard, W. L. Webb, A. E. Abel, G. O. Essex, A. R. Perong and R. B. Edwards, have been appointed to membership either on panels or on committees. Interest in the outcome of the proceedings centers largely in the expected orderly solution of two vexing sets of problems which cannot be settled by any agency working alone; problems arising from recent advances in radio applications, and those attendant on the reorientation of the radio industry and services at the end of the war.

The Radio Technical Planning Board is the brain child of the Radio Manufacturers Association and the Institute of Radio Engineers. Sponsored by an impressive group of non-profit organizations, its object is two-fold. It proposes, first of all, to make an exhaustive study of present frequency allocations. Existing dissatisfaction due to interference and overlapping, the demands of the various services for additional space, the need of high fidelity stations for increased band widths, are among the problems clamoring for attention. After assembling and sifting all available data, the Radio Technical Planning Board will be in a position to make recommendations from a technical standpoint for an allocation of frequency channels which will enable all services to operate at greater efficiency. It does not require a wide reach of imagination to predict the value of a document in the hands of the Federal Communications Commission, for instance, expressing the coordinated opinion of the domestic radio interests, when the matter of new frequency assignments comes up for action.

Trends Studied

The Board proposes, secondly, to take stock of recent developments and trends in the radio industry and to reach some definite conclusions about designs and types of technical equipment required for proposed new radio developments and for uses growing out of proposed new frequency allocations.

The form of organization of the Radio Technical Planning Board gives all interests a chance to be heard. The administrative chairman, Dr. W. R. G. Baker of General Electric, has appointed chairmen for panels designated to study and report on spectrum utilization; frequency allocation; high frequency generation; standard broadcasting; vhf broadcasting; television; facsimile; radio communication; relay systems; radio range, direction and recognition; aeronautical radio; industrial, scientific and medical equipment; portable, mobile and emergency service communications.

W. P. Hilliard
Chairman of Panel 10

The panel chairman, in turn, appoints the personnel of his panel. The roster of panel membership shows representation from a wide assortment of affiliated services: the sponsoring associations, radio and electronic manufacturers, telephone interests, broadcasting companies, state and municipal police, marine services, television engineers, teletype, facsimile and telephoto manufacturers, airlines, medical associations, research organizations, instrument suppliers, forest fire control, electric-light companies, railways, motion picture engineers and others.

Key men from these services, all directly concerned in the future of radio, are now doing the ground-work of the prescribed comprehensive survey. They will meet as often as necessary, and when their job is completed will report to the Radio Technical Planning Board. The recommendations will then be released to government agencies and to industrial and professional organizations as a guide for future action considered to be consistent with the public interest and at the same time acceptable to the radio industry and services.

Bendix Men Active

Typical of the operation of the board's activities are the experiences of Bendix Radio appointees who serve in various capacities. Mr. Hilliard, as chairman of Panel 10, Radio Range, Direction and Recognition, has completed the personnel of his panel, among whom is included Mr. Abel. One meeting has been held. As the outcome of an agreement with the chairman of Panel 11, Aeronautical Radio, Panel 10 is restricted exclusively to the consideration of radar for marine as well as aeronautical uses. Difficulty has been encountered in securing the necessary clearance for all panel members to permit open discussion. This situation is holding up further action.

Mr. Webb is a member of Panel 11, Aeronautical Radio, with Mr. Essex as his alternate. In order to facilitate the studies of this panel the assignment has been broken down into three major parts and the panel is awaiting the reports of these committees before it proceeds to make final recommendations.

Bendix Radio engineers are busy on all three committees working out of Panel 11. Committee I, of which G. A. O'Reilly of Transcontinental and Western Air, Inc., is chairman, and Mr. Edwards is a member, is assigned to study aeronautical air-ground communications. Representation on this committee is held by engineers from Transcontinental and Western, United Air Lines, Federal Telephone and Radio, Eastern Air Lines, Pan American Airlines, Bell Telephone Laboratories, Northeast Airlines, Wilcox Electric Company, and American Export.

Mr. Edwards attended the first meeting held in New York on March 30, where the directive issued to the committee was thoroughly reviewed, and individual assignments discussed. A study of domestic and international air-ground communications problems is proposed, including all aviation needs except military, and recommendations sought on technical equipment and frequency allocation with a view to providing the most efficient service for airplanes on both domestic and international routes. The committee is also considering the need for public correspondence facilities in planes, as well as the outlook for plane-to-plane communication. Instructed, as are all the committees, to evolve an immediate post-war as well as a long range solution, the members of Committee I are looking forward to concrete results at subsequent sessions.

Point-To-Point Study

Committee II, with J. E. Mears of American Airlines, chairman, is directed to explore the field of aeronautical point-to-point communications, and recommend the best techniques, facilities and frequencies for aeronautical operations and agencies, both domestic and international. Mr. Perong is a member, along with representatives from United Airlines, Federal Telephone and Radio, Bell Telephone Laboratories, General Electric Company, and Northwest Airlines. At two meetings, held on February 22 and March 29 in the American Airlines offices at La Guardia Field, New York, this committee considered requirements for the operation of air carriers, for airways and traffic control in the federal agencies, and for collecting and disseminating meteorological observations in the weather service, in connection with point-to-point transmission. In the case of the air carriers, for instance, the committee seeks data on flight operations, passengers, cargo, administration and relaying aircraft-to-ground information.

Tabulation of replies to a questionnaire sent by the committee to all air transport companies has placed at its disposal an authentic statement of the more harassing problems in point-to-point message traffic, together with a relatively acceptable solution for the immediate and post-war period from the viewpoint of the carriers.

Mr. Perong was designated with two other committee members to make a survey of the types and capabilities of existing as well as contemplated equipment in connection with a proposed increase in the number of communication channels—telephone, telegraph or facsimile—which can be placed in a given frequency space. This committee has already made definite recommendations covering immediate and post-war domestic point-to-point communication.

Committee III was assigned Aeronautical Navigation Aids, the scope of which includes airway navigation devices, direction finding devices—both homing and position finding by triangulation—automatic position reporting, altitude measuring devices, anti-collision devices, airport instrument approach and airport instrument landing devices.

Rentzel Chairman

Mr. Essex serves on this committee and attended the first meeting in New York in March with the other members drawn from Eastern Airlines, Bell Telephone Laboratories, Federal Telephone and Radio, Private Fliers Association, Sperry Gyroscope, Wilcox Electric, Radiomarine Corporation of America, Philco Corporation, United Airlines, Transcontinental and Western Air, Inc., Aeronautical Radio, Inc., and American Airlines. D. W. Rentzel, of Aeronautical Radio, Inc., chairman of Panel 11, is also temporary chairman of Committee III.

As a preliminary step this committee has made a study of the limitations of navigation aids now in use in the domestic field, such as low frequency radio ranges, marker beacons (75 mc), airport localizers, instrument approach systems, non-directional low frequency beacons, certain broadcast stations and ground direction finders. They then considered limitations of available navigation aids not at present in commercial use, such as the radio altimeter and vhf range (125 mc) direction finders.

In the course of future meetings discussion will cover the expansion and modification of existing navigation aids, and the technical developments necessary for embryo navigation aids scheduled to appear in the immediate or remote future. Consideration of the international aspect of the same questions will come up when the domestic situation has been thoroughly explored.

It goes without saying that any discussion of trends, either in familiar equipment or in prospective post-war projects, is of live interest to radio manufacturers. It is equally obvious that the engineers from their wealth of experience, have much to contribute. In aircraft radio, the branch of the industry in which Bendix is particularly concerned, present information warrants the conclusion that existing equipment will be to some extent outmoded for post-war usage. Here are some examples: multi-function apparatus will be required as a necessary simplification of the present single-function equipment; radioteletype, instead of voice instruction, for certain uses is a possibility; use of facsimile for weather map transmission may replace present lengthy voice broadcasts involving laborious mental calculations.

Wide Investigation

It is inevitable too that new lines of equipment will have to be introduced when military requirements are satisfied. Radio communication from trains, and mobile apparatus in general, extension of communication now carried by wire to reach beyond the frontiers where there are no wires, new applications in marine navigation, adaptations for various public utilities and for public safety devices, and a wide variety of other uses are being seriously investigated.

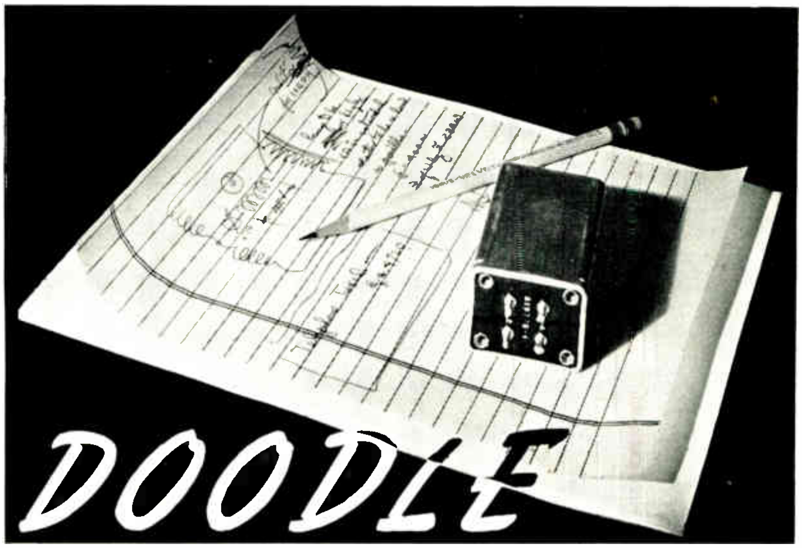
Opportunity to keep a finger on the pulse of current developments by exchange of ideas with others in kindred lines may be an indirect benefit which the engineers attending the meetings derive from such an organization as the Radio Technical Planning Board. In the last analysis, even if the Board does not entirely fulfill its twofold objective, its findings will undoubtedly go a long way toward pointing the direction of the radio industry in the post-war era.

Damchee Transportation

When American boys first arrived in India, they were not aware of the fact that the natives would render services cheaply. Likewise, they could never quite accustom themselves to the value of the rupee. Ten rupees is the equivalent of three dollars, but an American would spend ten rupees much as he would ten cents.

Sightseeing Americans would hire gharrys—four-wheeled horse-drawn vehicles, with two facing and adjacent seats. After asking the price of hire and being unable to comprehend the gharry walla (driver), the Americans would become disgusted, toss a ten-rupee note to him, and exclaim "Damn cheap." From that day to this, the gharry wallas are asking "Damchee" as the price of a gharry ride. Since "Damchee" bears no resemblance to rupee or anna, which is the money exchange, the later arrivals have had a hard time understanding just what the fare is. They wonder at the gharry wallas jabbering and gesticulating to a gathering public when they toss him a rupee or two, while he is asking for ten rupees, or "Damchee."—*Report by Russell Harper.*

DESIGN *by* DOODLE



By A. J. ROHNER
Transformer Engineering

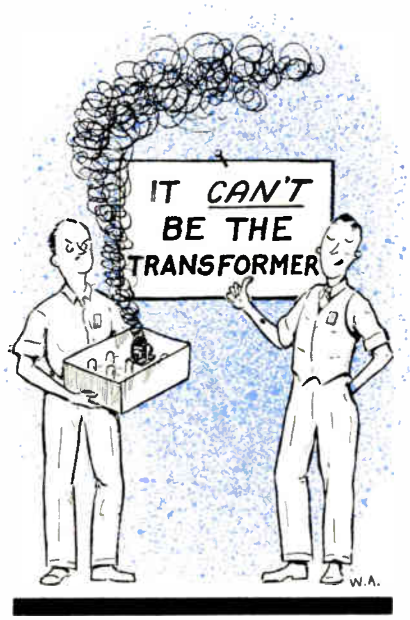
Tucked away in a corner of the Charles Street plant is a small group of engineers who build transformers on specifications derived from an occasional phone call and telepathy. Fortunately, the transformer engineers, whose work is tied in closely with that of the Towson sections, have learned by years of experience, to read the minds and anticipate the wishes of the fraternity, making even those rare phone calls superfluous.

Transformer Engineering is not an independent department, designing and building equipment for separate sale, but rather, it is a service section for other Engineering labs. Carrying on under the militant, but somewhat fly-specked motto, "IT CAN'T BE THE TRANSFORMER," which is still prominently displayed in the office, it tries to satisfy its customers, the Bendix engineers. There are no exciting trips to strange places halfway around the globe, and no vest-button popping as heavy bombers zoom away with "my baby" to guide them, but only the satisfaction of knowing that Joe's job or Bill's job or Frank's job turned out well. Consequently, the thrill of creative accomplishment, which other engineers enjoy, is of necessity shared only at second-hand.

Hand In Many Jobs

Nevertheless transformer engineering is far from a dull job. Since most engineering projects require transformers, there is rarely a project in which the transformer engineers do not have a hand. Consequently, they are interested in all projects and all engineers. In fact, experience shows that not hearing from some particular engineer at Towson for awhile is usually a sign that he is cooking up a new project and a new, impressive list of transformers soon to land on Transformer Engineering with the force of a block-buster.

Orders given for new transformers are usually informal, to say the least. Most of the instructions consist of a doodle on a telephone pad, especially in the early stages of a new project. Or, the orders may be



given by word of mouth. In a few cases, specifications are neatly typewritten or printed, but these usually go through so many changes of the oral or doodle variety that they are soon reduced to mere scrawls of blue, red, and black pencil marks. It is the duty of Transformer Engineering to convert such non-crystallized ideas to mechanisms of copper, iron, and varnish that will do the job. The business of crystallizing a transformer design is very exciting indeed, and often leads to unexpected results.

Take, for instance, the familiar little solder-lug terminal on audio transformers. It was designed to be simple and strong, and to be made on automatic screw machines at the Fort Avenue plant. No one thought then that the quantities required would overload the Fort Avenue machines. No one dreamed that one day all the screw machines in the country could not keep up with the flood of terminals required. Yet we have it on the authority of the Purchasing Department that such is now the case. So a different style of terminal must be designed.

Another illustration of unexpected results before reaching a final design, is found in the saturating reactors which control the loop-turning motor of the automatic compass. When this compass was first made, it was found that the loop would not stand still. The trouble was traced to inequality of the two reactors. So reactors having equal impedance were used. Even then, the loop would not stand still. Investigation of wave-form showed that inequality of the peak currents of the two reactors was to blame. It was necessary to pair the reactors by equal peak currents, and to install them in compasses as matched pairs, before the trouble was remedied. The drawing of the saturating reactor shows two identical reactors on one drawing, and parts lists call for one pair, not two reactors, much to the confusion of Material Control personnel from that day to this.

Keep Up With Specs

Most engineers ask that their transformers be made to conform to "the latest Army and Navy specifications." As these specifications are undergoing constant changes, it is up to the transformer engineers to determine which are the latest specifications and how to meet them. The trend toward hermetically-sealed transformers for all equipments, for example, has led to an interesting line of development. Hermetic sealing means the use of a metal can, since no varnish or impregnant has yet been discovered which is a perfect seal. This can must be soldered along all seams, since solder alone of all metal-joining materials is watertight. Soldering irons don't work on large metal surfaces; a flame is more practical. But flames don't work with ordinary air blast, which is too cold, or with acetylene, which is too hot. Moreover, the surface must be tinned, if the material is steel, and tin does not take readily on hot-rolled steel. Tin-dipping is unsatisfactory because of non-uniform surface and waste of tin. Electro-tin-plating is unsatisfactory because it does not completely cover the surface. Best results to date have been secured with cold-rolled steel cans, electro-tin-plated, heat-treated and soldered by a gas and oxygen flame.

As an integral part of these transformers, the terminal board, too, must be hermetically sealed. This necessitates a solid (not hollow) terminal of simple construction molded in phenolic. Other companies are using terminals molded in glass or porcelain, but such construction will not work for Bendix because too much space is required. Since molds are hard to make, standard types of terminal boards have been developed. As time goes on, a standard 8-terminal molded board for audio transformers will become increasingly familiar.

Trouble In Screen Room

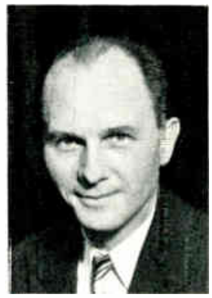
Recently, trouble has been experienced in some of the screened test rooms at Towson, because of high - frequency disturbance brought in on the power lines. Now, one way of getting around this difficulty is to generate the power inside the screen room. A hand-cranking device, such as used on life rafts in the mid-Pacific, will do the trick nicely. However, the test engineers do not care for the idea. They prefer to get their power from outside, minus the electrical disturbance. It was suggested one day that it would be mighty nice if a transformer were built that would transmit power without transmitting electrical noise. A transformer was therefore designed having its secondary completely enclosed in heavy copper. The secondary leads, also heavily shielded, were brought into the screen room, while the primary was connected to the external power line. Bigosh, it worked!

At another time Towson engineers, with their usual nonchalance, requested designs and models of high-voltage oil-filled transformers. It was very much like asking Lionel to build real locomotives. A new and unfamiliar technique was involved. Handbooks give data on the dielectric strength of oil, but they fail to mention such details as the surface tension of oil, which traps air bubbles like molasses. Nor do they explain what to do to bring high-voltage out of an oil-filled transformer into the open air, where it can be connected to something. These things had to be learned the hard way. Adequate spacing of coils to prevent air traps cured one of the problems; and large porcelain bushings, solder-sealed to the metal cases, solved the other.

Any Odd Corner

After a radio chassis has been laid out, and the tubes, resistors and condensers have all been placed, the radio engineer looks around to see if there are any odd corners here and there where his transformers can be located. Usually the available space left is pretty small. Because of this fact, and because transformers are inherently heavy, there is a constant demand to make them smaller and lighter. Two core materials which offer relief in this direction, are at present in the limelight. One is hypersil, the other is thin-gauge nickel steel. Both materials have been known for many years, but only recently have they been available for the types of transformers Bendix uses. Transformer Engineering is giving careful consideration to both these materials on all new designs.

So you see, between the doodle and the model, there is many a fascinating problem to solve. And once solved, the transformer engineer has the satisfaction of knowing that Joe's job turned out O.K., and is ready for production.



A. J. Rohner

A penetrating sense of humor seems to be nature's gift to the transformer engineer. A. J. Rohner is a typical example. Equipped with an electrical engineering degree from Stanford University (1924), he began his radio career at General Electric where he was admitted to the test course in the radio department, and later engaged in engineering work on transformers and radio receivers. After four years he transferred to RCA Victor. There he spent five years working mostly on transformers and power supplies. He came to Bendix in December, 1938, six months after transformer engineering had been made a separate department, and has had a conspicuous share in the development of this department. Here his special interest has been audio rather than power transformers. Highly respected in his field, he can still comment, tongue in cheek, on the lowly position to which the transformer engineer is subordinated when testimonials on finished equipment are passed around.

Rigid Shaft for Loop

One sample of the MN-24 with a gear drive was installed on a B-24 and flown on a round trip from California to Australia. By locating the loop over the navigator and rotating it with a short rigid shaft instead of a flexible shaft, the operators found it possible to take bearings satisfactorily at all speeds of the aircraft.—*Report by W. L. Webb.*

HEDGE HOPPING THE Himalaya

By CHARLES LUSCOMBE
Service and Parts

THE DONA ANICETA sailed from Newport News at three o'clock, January 30, 1942. Unlike my apprehensive fellow-embarkees, I was eager to continue the travels that had permitted me only four months in the United States during the preceding five years. Yet for me also, the embarkation was packed with drama. We were leaving peaceful American shores and God alone knew when and where this voyage would end.

The *Dona Aniceta* was a Filipino merchant ship which had been taken over by our government when the war began, and was now to bring relief to the battered garrisons at Rangoon, Burma. She was carrying small arms ammunition, dynamite, motorcycles, trucks and airplanes. The crew was made up of approximately 75 Filipinos. In addition, there were twelve passengers—men bound on divers missions to the Far East.

During the first few days and nights at sea the radio operator constantly was receiving SOS messages from torpedoed ships as close as twenty miles away. We ex-

pected the worst—we hoped for the best! And we were lucky for we encountered but one German U-Boat. This we narrowly escaped in the South Atlantic by a quirk of fate that caused our rudder to jam at the crucial moment. Although the skipper intended to run for it, our jammed controls headed us straight for the submarine. It seemed that we were deliberately trying to ram. The sub crash-dived and we never saw it again.

Thankful For Hurricane

We were fortunate enough to run into a hurricane soon thereafter. Strange to consider a hurricane an asset, but for us, it was the lesser of two evils. Nature was dreaded less than the enemy.

Singapore and Rangoon fell to the Japanese while we were at sea so a new destination was picked for us by the Royal Navy at Capetown, South Africa—our first stop.

On March 16th, after a 45-day sea voyage without escort through sub-infested waters, we arrived in India. This was, as you remember, just after we had entered the war and the Allies were still on the march—backwards. We landed at a port well behind the fighting front. This port was to become the largest aircraft assembly base in the Far East, but at that time it was only beginning to be set up by Americans.

A large balloon hangar had been leased from the British for an assembly line. It was also serving as living quarters until better quarters, even tents, could be secured. Evidently the birds had been using this hangar as a sanctuary for a number of years, because when we moved in they began a bombardment from the heights of the hangar, which lasted until we moved out. As the birds always slept at a higher level they had a natural advantage, and as the days passed the fellows swore that the birds were acquiring an uncanny accuracy.

It was not long before I began to appreciate the seriousness of the strife, both national and international. The Republic test pilot, who had been my shipmate on the way over, and the Vultee test pilot, who had arrived later, were both killed in airplane crashes shortly after beginning operations in India. I was a pallbearer at both funerals.

About this time Mahatma Gandhi began his civil disobedience program throughout India, and the Indians really made trouble for us. I celebrated the Fourth of July in the confines of my hotel, which the Army had partially taken over. Long lines of Indians, in all manner of dress, paraded up and down the streets, throwing rocks at any military personnel or white civilians they saw. They derailed street cars, and on windows and on sidewalks all over the city, they wrote signs such as "Quit India." The British seemingly ignored the whole thing, leaving the restoration of order up to the Indian authorities, who were, of course, under the British supervision. The Indian police, instead of using a revolver, which customarily is a part of a policeman's get-up, were armed with a "lathi," a bamboo pole about eight feet long used as a club. They are adept in handling the weapon.

To China By CNAC

On November 21, 1942, I flew to China by a China National Air Corporation ship after an uneventful trip over the Himalayan Mountains. China presented quite a different picture from India. Cut off from the outside world as it is, China is little exposed to luxuries common to us.

Because demand so greatly exceeds supply, prices are exorbitant. At the time I was in China, whiskey was selling for 250 American dollars per fifth; American cigarettes, for 35 American dollars per carton.

The Chinese largely depended upon foreign trade for most of their necessities, and all of their luxuries. When the Burma Road

was captured by the Japanese, all chance for free trade was cut off. For a time small amounts of luxuries, to which the rich Chinese and Americans in China were accustomed, were brought in by the only commercial airline, and sold at fabulous prices. Consequently, those who had the means to do so were flying back and forth from India, to purchase all kinds of articles for re-sale in China at huge profit. Because the Chinese currency is not accepted internationally, a serious shortage of currency for trading in India developed. A money market was started in China to obtain the necessary currency to carry on smuggling operations. The price of the American dollar went from $20 in Chinese money, the legal rate, to $60 in Chinese money, the black market rate. As the black market was legalized in the province in which the largest group of American forces was congregated, and in order for the Chinese to buy necessities, they boosted their prices ten times over the ordinary price level. It was difficult to get used to spending $10 for a haircut, $25 for a scoop of ice cream, and $50 for a ride in a ricksha. Of course, it was Chinese money but I couldn't help feeling like a millionaire, with two or three thousand dollars in my pocket, no matter what kind of money it was. And imagine the feeling when three deuces gets a $2000 pot!

The Chinese people are very peculiar in many ways but they certainly have a keen sense of humor, and love to display their loyalty to, and appreciation of, the American people. The city where I was stationed most of the time while in China was known before the war as "Thieves Exile"; that is, the place where all the thieves from the eastern coast of China were sent for punishment. I think most of them were there all right. There was so much stealing going on that a regular thieves' market was established in a vacant lot, where all the stolen goods was collected and sold to the highest bidder. Numerous times a stolen article could be located, provided the rightful owner was prompt enough in going to the market after he had realized his loss. By digging deep into his pocket, he could buy back the article.

It was a distinct relief to find that beggars, so plentiful in India, were seldom seen in China. The "New Life Movement" was responsible. In most cases, a man would starve to death rather than beg. Many times I have seen a poorly clad Chinese lying dead on a pathway, the flies already gathering for a feast. In all probability the body would be buried on the spot four or five days later.

Worked On Compass

Most of my work in China was on our Army radio compass, commonly considered the most valuable possession a pilot can carry on his plane. Although a few commercial type compasses were on transports in this area, by far the largest number were the Army type. The Automatic Direction Finder on these ships is in use almost constantly because of the rough terrain and bad weather over the mountains. All landings in China during bad weather are made by use of the radio compass. Some of these let-downs are in such rough terrain and bad weather that it is used almost as a blind-landing instrument. At that time the only homing stations set up for Army use were seventy-five watt transmitters, which had far from sufficient output to carry an appreciable distance. They were used principally for landings in low overcast. Several mountain ranges close to one field are completely covered by clouds most of the time. In low visibility the only way a ship can land at this base is by radio. Many times I saw ships coming into an airfield at less than a two-hundred-foot ceiling, visibility zero to 12,000 feet. With so much reliance placed on compass operation, it was imperative to have someone in China who knew something about the repair and operation of the unit.

Eventually, when high authority realized the value of the radio compass, two were installed on each transport ship flying in the India-China theater, and one left-right commercial compass was installed on each pursuit ship. These compasses definitely cut down the number of aircraft lost because of navigational difficulties.

Pilots who have not flown over this type of country cannot possibly imagine the difficulty of navigation. In crossing the Himalayan Mountains, nicknamed The Hump, the first part of the trip is spent climbing, and the last part gliding. An altitude of 14,000 feet is a safe minimum for the southern route over the Japanese lines close to an enemy airport; but for the northern route, which is rarely visited by Jap airmen, the minimum altitude is 18,000 feet. A person has to listen only once to a pilot in trouble over this range to realize that he has practically no chance of survival if he is forced to bail out. Twice in crossing The Hump we encountered Japanese aircraft. A third time, a ship which took off from India immediately after ours met Japanese pursuit ships. For ten minutes, I listened to the unfortunate pilot pleading for help over his radio. Neither plane nor crew was ever seen again. I was almost afraid to risk flying back into India after listening to that pilot.

Frequent Alerts

The Japanese used to come inside our interceptor net almost every day in an attempt to catch our planes on the ground. The air raid alert system, used by the Chinese and adopted by the American Army, was three balls on a flag pole. On the first warning that enemy planes were approaching the flag was pulled down and one ball was hung on the pole, supposedly indicating that the enemy was about thirty minutes out. When this alarm was given, fighter pilots on alert went to their planes to stand by. All stores were hurriedly closed and

everyone started running down the road toward the nearest city exit, hollering "Ching Pow, Ching Pow," meaning "air raid." As time went on the "one ball" alerts became so frequent that civilians paid little attention. When two balls were run up on the flag pole, warning that the enemy was approximately ten minutes away, all the fighters took off and circled the field at about eighteen thousand feet. Then the city was deserted. When the Jap planes kept on coming, all of the bombers and transports took off, *if* they had enough gasoline. Usually, there wasn't enough to get the larger ships off the ground.

The Japanese came over at the same time every day. Promptly at ten o'clock on the morning of every clear day a "one ball" alert was displayed. Then the Japs would fly around inside of our interceptor net sparring for an opening to reach the field undetected. Evidently the Japs were well informed of any activity on our field, for they always went home if we sent up fighter planes. One of their objectives was to get us to burn up our supply of aviation gasoline—all of which was flown in over The Hump.

One day, during a "two ball" alert the Japs caught us with our "pants down." We were on the field as usual, watching the planes take off. Everyone was standing out in the open, thinking that the Japanese would turn around and go home as they had always done. This time the Japs did not turn back. The fighters were just getting off the ground when the first bombs dropped. I ran so fast that my legs ached for a week afterward. I headed for the nearest thing resembling a slit trench, and was running so rapidly that, when I saw about four feet of water in it, I could not stop, but plunged feet first into water up to my waist. There were already four or five soldiers in the ditch. There we stood in the water until the raid was over.

Numerous Casualties

Twelve Americans were killed that day, and it was a miracle that more were not. Approximately three hundred Chinese were slain; the number was great because most of the bombs landed in the middle of a Chinese village. Fourteen of the enemy planes were shot down by our pilots, who, incidentally, were flying P-40's.

The Japanese were very attentive to the American Air Force in China. About once a week they announced over the radio that they were coming over the next day and that they would wipe out the Americans with a gas attack on the particular city where I was stationed. Immediately after the announcement was made, we carried gas masks everywhere we went. A few weeks later the Japanese announced over the radio and sent a letter to the American general by a Chinese native stating that they were going to wipe us out with paratroops. Following this announcement everyone took precautionary measures and carried a gun. This went on for so long with nothing to back it up that, finally, the warnings were regarded as harmless enemy propaganda.

In one instance the Japanese dropped pamphlets on our base of operations. These were engaged by our fighters and five Japanese ships were shot down. We did not lose a single plane. The following is a direct quotation from the pamphlet:

To the Officers and Men of the United States Air Forces

We express our respects to you men who have taken great pains to come to the interior of China.

We of the Fighter Command of the Imperial Japanese Air Forces take pride in the fact that we are the strongest and best in the world.

Consequently, we express our desire as sportsmen to hold a decisive air battle with you in a fair and honorable manner.

We then can best prove to you the spirit and ability of our air force.

With hearty wishes for a decisive battle,

The Fighter Command of the Imperial Japanese Air Forces.

Of course, we all know what the Japanese meant by "a fair and honorable manner."

A Word On Equipment

But enough of the experiences which I encountered in my two years abroad as a Service Representative of Radio Division. I would like to add a word about our equipment.

I believe I can safely state that the Bendix Automatic Radio Compass is used more extensively in the China-Burma-India theater than any other place in the world. It has been a godsend to the men who are required to fly there. Not only has it saved countless human lives, but it has also saved a tremendous number of airplanes for our government and our Allies. It has, without a doubt, enabled our airmen to keep open the only available supply route into China. Our air force in China receives its materiel by this supply route over the highest range of mountains in the world. I'm proud to have had the chance to be even a small cog in the huge wheel which produced the Bendix Automatic Radio Compass. We are well known in the Far East and our reputation, I might add, is spotless.

I would like to end this piece by quoting my certificate of membership in the *Benevolent Order of Misfortunate Yankees.*

This is to certify that Charles F. Luscomb did prove his Supernatural Prowess and Endurance by completing twenty-four long consecutive months, constituting a period of two calendar years on the 15th day of January one thousand nine hundred and forty-four years after the coming of the Messiah in the Mystic Land of Exalted Cows, Flying Carpets, Princes and Princesses, Rajas, Sweepers, Beggars, Gharee-wallas, Naee-wallas, Akbar-wallas, Mochee-wallas; in fact more Damn wallas than Carter has pills.

He has shared his soup and vitamins with the flies and hawks in a share and share alike manner.

He has braved the heat of the mid-day sun and is a firm believer that the dead of the East are buried in overcoats to keep them from freezing to death in the hub of hell.

He has, by sheer will power, refrained from joining in chorus with the jackals as they howl to the tropical moon.

He has partaken of, or witnessed, the effects of Bengal tiger sweat, concentrated and served as an intoxicating beverage.

Be it known by his lengthy and enforced stay on this foreign soil, our misfortunate comrade has contributed in no small manner to his personal discomfort, has fully satisfied our demands on his happiness and baksheesh and is entitled now to sojourn peacefully in his native land. Now, therefore, all greenhorn troops, regardless of race, rank, creed, color or sex, are hereby to return our miserable brother to the land of his birth; this on pain of our displeasure to be eternally endowed by withholding the intercession of our order from all who disobey our lawful command.

When the time comes, as it must to all men, and his mortal flesh is reduced to dust, may the keeper of the keys open wide the gates of the promised land and give first priority to the immortal soul of Charles F. Luscombe for he surely has had his hell on earth.

Charles Luscombe

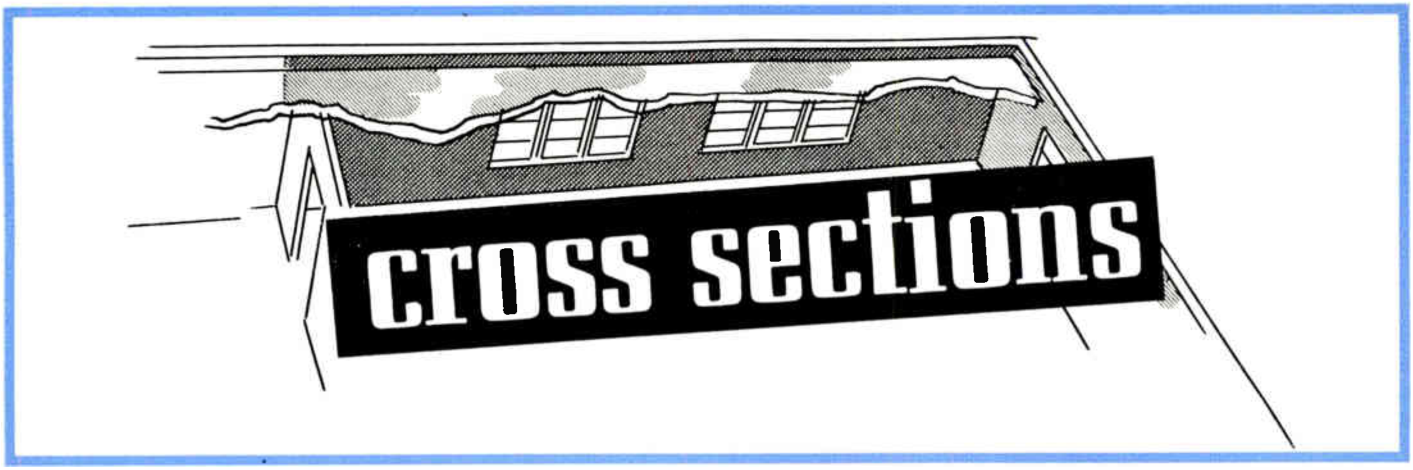
Two and a half years in the Navy and only nine days on a ship would be an anomaly in any man's life. And yet Charlie Luscombe can match this experience with another almost as unusual. In the three years he has been with Bendix, he has spent only five months in the United States.

Iowa-born, he studied engineering at Iowa State College. Then he joined the Navy Air Corps, training at Hawaii and other Pacific bases.

A brief period as Army flying cadet preceded his arrival at Bendix on June 4, 1941. Three days later he was on his way to Canada as field service engineer to find out how Bendix equipment was performing.

Such a mission took him on his second trip around the world, going into India and China where he was over the Jap lines four times and learned what it means to be bombed.

Home again after two years' absence, he is bringing himself up to date on recent developments in Bendix equipment, meanwhile continuing his Capitol Radio Engineering Institute correspondence course. At 25 he looks forward to an opportunity after the war to resume his interrupted formal engineering studies.



New Calibrator By Instrument Engineering

A MODULATED CRYSTAL calibrator for producing standard frequencies in ten-to-one ratios has been developed by Instrument Engineering. In the new calibrator harmonics do not fall off between major check points, as they do with controlled oscillators of the multivibrator type. A more accurate check of higher frequencies is possible, therefore, with less difficulty than is encountered with the latter equipment.

● Mr. Holey, section chief, also announces a new method of plating metal windings on fused quartz or glass to give a high Q and an extremely good temperature coefficient in vhf applications.

● Further investigation in frequency control and supersonics is possible as a result of a 5000 cycle plated crystal produced by the department. The crystal is 2 inches long, 1/4 inch wide and 1/64 inch thick, and is supported at four nodal points on fine wire springs.

● Instrument Engineering is rather proud of turning out optical flats, ground and polished to the point where the surfaces are so flat and parallel that they can be placed one on top another, twisted, and be held together by adhesion. The flats, 4 inches in diameter, and 1-1/2 inches thick, are being used to grind paper-thin crystals for fundamental frequencies as high as 30 megacycles.

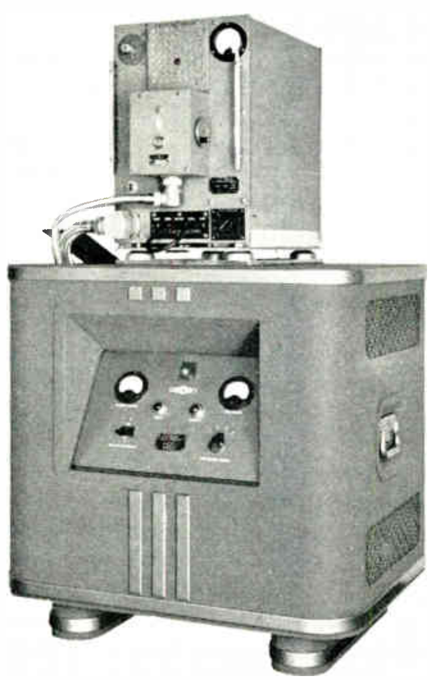
Variety of Uses For X-Ray Machine

THE 150 KILOVOLT INDUSTRIAL X-ray machine installed in the Photographic Unit of Technical Publications has proved very useful in locating air spaces in pitch impregnation of transformers. Air spaces allow condensation of moisture and a consequent break-through. The machine is also being used to detect flaws in plugs, crystals, switches, aluminum castings, and painted surfaces.

Other possible applications include non-destructive analyses of spot welds, aluminum welds, shock mounts, antenna reels, loops and loop mountings.

A fluoroscopic viewing device has been added for inspection of small parts in conjunction with the X-ray. The equipment is available to any section of the Engineering Department experiencing difficulty in locating flaws and imperfections.

TA-2JB Used In Ground Stations



BECAUSE OF ITS REPUTATION for dependability and effectiveness, the Bendix TA-2JB Aircraft Transmitter has been selected by one of the South American airlines for use in fixed ground stations to handle traffic to planes and point-to-point stations.

In aircraft, the TA-2JB Transmitter is operated from a d-c dynamotor energized by storage battery, but a rectifier-type power source was found to be more satisfactory for ground use. To utilize the 115 volt, 60 cycle current available, A. F. Pruitt of Transmitter Engineering, designed a power supply capable of handling the rather heavy d-c load imposed by the TA-2JB and its component equipment.

The power supply is housed in a modernistic cabinet, is equipped with safety devices, and provides easy access for servicing (see photograph).

Local Section of I.R.E. Reactivated

REACTIVATION OF THE Baltimore section of the Institute of Radio Engineers has been sponsored by a group of executives of radio, electronic and electrical organizations in this area. W. L. Webb, Chief Engineer of Bendix Radio, has been named chairman, and H. L. Spencer, also of Bendix Radio, secretary-treasurer for the coming year.

Bendix Radio engineers and all others "interested in the theory or practice of radio engineering or of the allied arts and sciences" are eligible for membership. All members of Associate grade or higher receive the *Proceedings of the Institute of Radio Engineers*. Representatives have been selected in each engineering section to promote the membership campaign. Applications and other information may be secured directly from them or from H. L. Spencer (Ext. 316 or 276).

Meetings are held at the Engineers Club of Baltimore, 6 West Fayette Street. At the opening meeting May 23, the speaker was Major E. A. Post of the Signal Corps, Aeronautical Radio Branch, Aircraft Radio

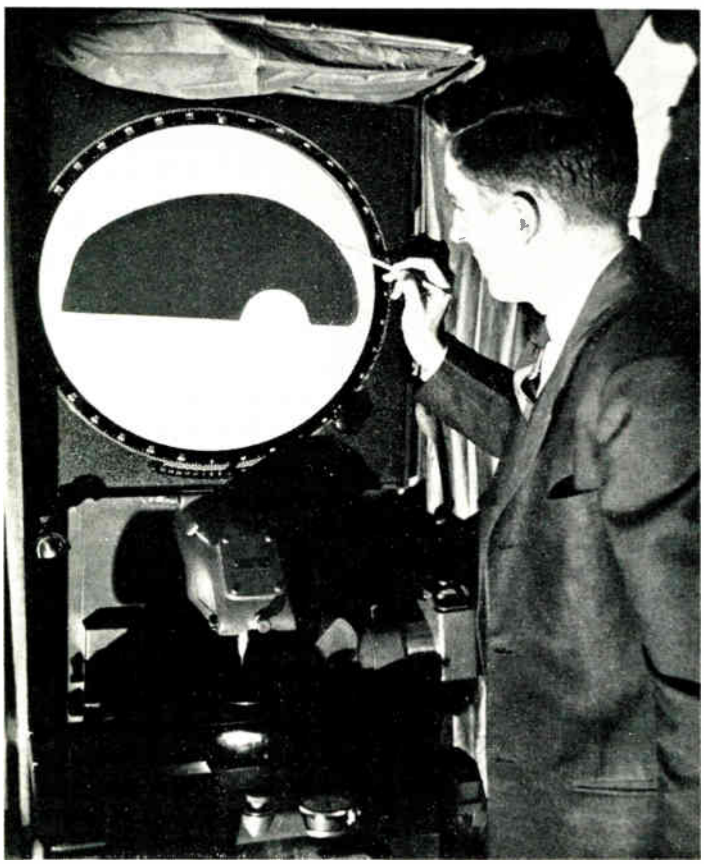
Laboratories, Wright Field, Dayton, Ohio. Major Post, who has recently completed a tour of several active theatres of war in the South Pacific, presented a paper on "Recent Experiences with United States Military Equipment in the South Pacific Combat Zone."

Other topics suggested for future meetings include: Automatic Calibration for Frequency Indicators; Television (Broadcasting and Receiver Development); Induction Heating (Amplification and Heat-Treating Applications); Carrier Current (Telephony, Load-Control Signaling, Switching, etc.); Flux-Gate Compass; AM-FM (panel discussion on analysis and respective merits); FCC-RTPB Cooperative Planning for Post-war Radio; Post-war Aviation (CAA, Radio, Marker Beacons, etc.); Broadcasting; Electronic Microscope (Application and Design); Magnetic Tape (Wire Recording); "Fosterite" (Impregnation Sealing of Transformers, etc.); Stable Platforms for Portable Field Equipment(s); Oscillographic Analysis (Transients, etc.); Westinghouse Electronic Analysis (Quantitative and Qualitative); Industrial Electronic Applications and Devices; Medical Application of Electronics.

Scope of Mechanical Engineering Enlarged

MOVED FROM THE Fort Avenue plant to the Towson plant, the Metallurgical Laboratory of the Inspection Department is now a part of Mechanical Engineering under Mr. R. J. Streb. Research on new projects, and testing and analyses of mechanical parts fall within the scope of the section. With its added facilities, Mechanical Engineering now offers a two-fold service to all other sections of the Engineering Department: service consulting and independent engineering.

New equipment has been installed to carry out the enlarged responsibilities of this section. With the contour measuring projector, images may be reflected, profiles projected, measurement and comparison problems solved by optical projections, and angles and longitudinal dimensions checked. The installation of complete vibration test equipment, operated by a structural engineer, is an important innovation. Mechanical aspects of organic finishes are also evaluated for abrasion resistance and scratch hardness by an abrader. A printed record of variations, to one-millionth of an inch, in the smoothness of surfaces such as glass, crystals, and wrinkle lacquer, is given by the new surface analyzer. A tensile strength machine tests either tension or compression under pressure of from 5 pounds to 60,000 pounds, permitting checks on spot welds, shockmounts, and other mechanical parts.



Contour measuring projector in Mechanical Engineering showing magnified profile of rotor plate.

New Molding Press Prevents Bottlenecks

INSTALLATION OF A 100-ton pressure molding press enables the Experimental Engineering Section to turn out plastic terminal boards, knobs, transformer caps and other parts in sufficient quantities to meet emergency needs when outside sources of supply fail. On the hand-operated hydraulic press, which the new automatic press supplements, it was possible to produce only a relatively few parts in a given period.

Production quantities will still be purchased from plastic manufacturers, however. The new press is intended only to prevent delay in completing equipment for experimental purposes.

Transformer Data In Convenient Form

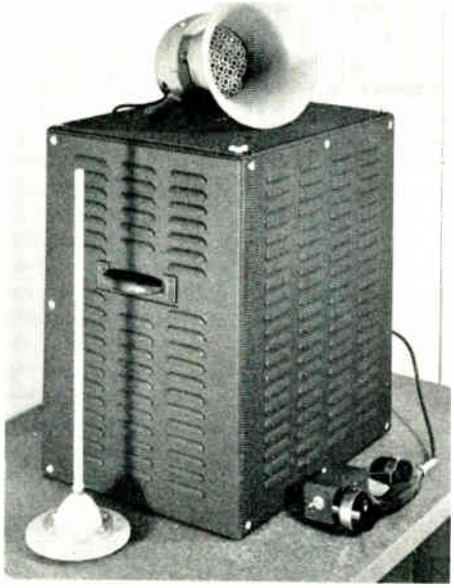
DESIGN ENGINEERS will find the transformer catalogue, currently being brought up to date by Transformer Engineering, extremely useful in quickly determining the type of unit best suited to a particular circuit. The catalogue gives specification numbers, print file lists, outline drawing numbers, voltage ratings, current ratings, rms tests, and cross references.

- Bendix transformer designs are being made available to outside manufacturers, and some ten or twelve are producing equipment from the prints furnished.
- Uniform expansion and contraction of varnish, bakelite and aluminum at temperature extremes between —55° and +85° has presented a major problem in hyperfrequency design. Experiments indicate that the solution may lie in oil-filled transformers.
- Mr. Oosterling is Bendix Radio's representative on Bendix Aviation Corporation's Magnetic Materials Committee. All eastern Bendix divisions are represented, including Pioneer-Eclipse, Marine Division, Red Bank, Scintilla, the Research Laboratory at Detroit, and the New York office. Established more than a year ago, the committee was formed to standardize materials and to draw up material specifications which can meet the needs of every division of the cor-

poration. All divisions will use these specifications, when completed, and several specifications will be released soon. Already, this committee has encouraged steel companies to acquire and use test and laboratory equipment, before delivering their products to Bendix.

Tests Under Way On Train Radio

PRELIMINARY TESTS ARE now being conducted in conjunction with the Baltimore and Ohio Railroad involving the application of radio to the operation of trains. The equipment, according to S. J. Holland, Sales Engineering, under whose direction the tests are being made, is using a frequency of 156.525 mc. The fixed station, 50-watt output, for use in dispatching freight trains, has been installed atop the Baltimore and Ohio building, and is remotely controlled by the yard master in the freight yards.



Mobile equipment for train radio.

The mobile equipment (see illustration) is placed in both engine and caboose. Diesel type engines only are used for yard tests, though road tests are made on steam engines also.

In addition to the yard tests, experiments are in progress between the central station and engines on the road to determine how far from the central station results can be obtained. Field tests for observing effects between mountain cuts, in tunnels and from end to end of freight trains—frequently as much as a mile and a half in length—are being made on the road as far out as Pittsburgh.

Similar types of tests are under way on the Chicago, Burlington and Quincy and Seaboard Airline. Rock Island, with equipment supplied by Bendix Radio, is conducting its own experiments under Bendix supervision. R. B. Moon, of the Bendix West Coast Branch, is in charge of tests on the Santa Fe.

ENGINEERS FROM THE different laboratories have in the past few months visited a number of out-of-town manufacturers and customers, and attended important meetings, in connection with the projects on which they are working.

E. O. GAGUSKI called on the Corry-Jamestown Manufacturing Corporation in Corry, Pennsylvania, to keep in touch with latest developments in the use of sheet metal in fabricating cabinets for ground station radio equipment.

W. L. WEBB, A. A. HEMPHILL and HOWARD WALKER consulted with representatives of Aircraft Radio Laboratories at Wright Field, on various production difficulties and proposed changes in equipment.

A. L. BOHN canvassed a number of condenser manufacturers in Chicago, New York and New Bedford in an effort to procure a special condenser.

W. H. SIMS, JR., and J. P. SHANKLIN participated in conferences with Bendix Marine engineers and representatives of the Signal Corps and Bureau of Ships, in New York City.

L. J. HRUSKA flew to the Banana River Air Station in Florida one morning to discuss the inauguration of a new project, and was back in Baltimore with his data the following evening. He has also been to the Radiation Laboratory at the Massachusetts Institute of Technology to confer with John Woodward, formerly attached to the Bendix Sales Department, and now located at Aircraft Radio Laboratories at Wright Field. Another trip was made to New York to obtain information on remote control devices manufactured by Bendix Marine.

W. A. WILLIS visited Lewyt Corporation at Brooklyn to consult about manufacturing difficulties on Mounting Rack FT-244.

R. F. HOOVER attended the national light aircraft meeting of the Institute of Aeronautical Sciences in Detroit to secure information on new developments in both planes and aircraft accessory equipment.

W. H. SIMS, JR., and E. L. WEIGEL spent some time at the Aircraft Radio Laboratories to discuss an interphone amplifier and demonstrate one preliminary model.

D. E. CORNISH attended the two-day session of the American Physical Society held in May at the Mellon Institute in Pittsburgh.

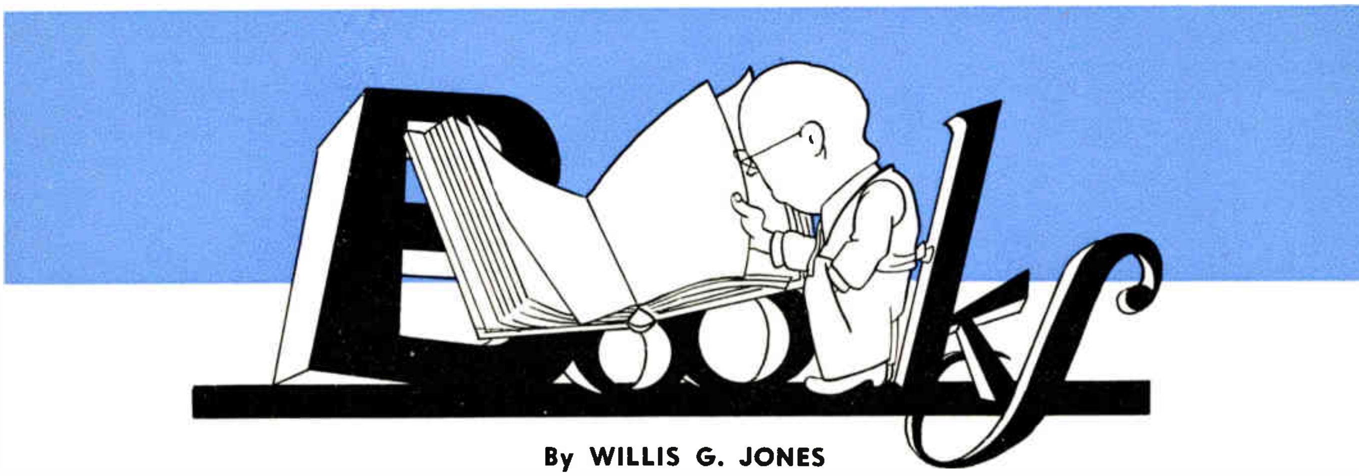
A. A. HEMPHILL went to the Aircraft Radio Laboratories at Wright Field to discuss the Army automatic compass.

VERNON MOORE called on W. W. BOES in Dayton, Ohio, regarding inspectional difficulties on the left-right compass indicator.

R. J. DAVIS, SAMUEL REISMAN and J. T. MCNANEY spent some time at the Propeller Research Tunnel, Langley Field, Virginia, testing equipment developed by the Microwave Engineering Department.

HOWARD WALKER, W. A. WILLIS, E. O. SWANSON, C. B. LAU, R. J. STREB, R. C. MACARTHUR, G. F. SHRYOCK, NORMAN RAYMOND, E. O. GAGUSKI, R. V. LINDNER and W. H. SIMS, JR., attended a conference at Colonial Radio Corporation at Buffalo to get information for preliminary drawings on equipment scheduled for early production.

R. J. DAVIS went to Pittsburgh to discuss details of an antenna tower with representatives of the Blaw-Knox Corporation.



By WILLIS G. JONES

AIRCRAFT RADIO AND ELECTRICAL EQUIPMENT, (Revised), *by Howard K. Morgan. Published by Pitman Publishing Corporation, New York, N. Y. 369 pages. Price $4.50.*

We have received a revised edition of this book which has been in print for several years. Since it is favorably known in the aircraft radio field, no review is believed necessary. It is one of the few books for aircraft radio service and maintenance men which covers its field thoroughly.

COMMUNICATION CIRCUITS (Second edition), *by L. A. Ware and H. R. Reed. Published by John Wiley and Sons, Inc., New York, N. Y. 325 pages. Price $3.50.*

The material in this book deals principally with transmission lines and wave guides. It is intended primarily as a first-course text for communications engineering students interested in ultra-high frequency technique. A sound background in mathematics, including calculus, is assumed by the authors.

This second edition incorporates important new material with special emphasis on the practical use of wave guides. A discussion of the use of circle diagrams for graphically determining impedance matching conditions has also been added.

The first part of the book is devoted to the development of transmission-line theory with requirements for attaining optimum efficiency through the determination of characteristic impedances. This treatment is followed by an introduction to the transmission of ultra-high frequencies in wave guides of both the rectangular and cylindrical type. The authors point out that Maxwell's equations are required for both types and, in addition, Bessel functions are necessary in the treatment of the cylindrical wave guide. (Accordingly, they have included in the appendix a discussion of Maxwell's equations and the elements of Bessel functions.) Proper operating conditions for the several types of guides are discussed in this chapter.

The next two chapters are devoted specifically to rectangular and cylindrical wave guides. A comparison between the desirability of wave guides and coaxial cables is made and it is demonstrated that, at least at frequencies where physical size is not a factor, the use of wave guides is more desirable. These two chapters are followed by one on the theory of coaxial lines.

The concluding chapter consists of a series of practical experiments designed to provide a better understanding of the text. These experiments require equipment usually found in communications laboratories such as oscillators, vacuum-tube voltmeters and bridges.

The final forty pages comprise an appendix divided into seven parts. Subjects include an introduction to the Fourier series, loop equations, Maxwell's equations and elements of Bessel functions.

In view of the increasing use of ultra-high frequencies with their special techniques, this book should be of interest to the student and useful as review material for the engineer.

AIRCRAFT ELECTRICAL ENGINEERING, *by F. G. Spreadbury. Published by Sir Isaac Pitman & Sons, Ltd., London, England. 269 pages. Price $6.00.*

This book contains information about aircraft electrical systems that is important to those who design aircraft radio communications and navigational equipment.

While the book, written and published in England, may not always be in accord with American practice, it is evident that the general principles are similar. The author has covered the subject quite thoroughly, if not in great detail.

Important subjects covered include design, construction and test of ignition systems, generators and motors, the use of alternating current devices, voltage regulation, radio power supplies, ripple smoothing and measurements, applications of permanent magnets, and aircraft pyrometry.

Obviously, a book of this size can not cover so much subject matter in great detail. Nevertheless enough information is presented in the text, and by the use of graphs, when applicable, to present a clear picture of the aircraft electrical system. The chapter on radio power supply in aircraft will be of particular interest to Bendix Radio engineers. Special attention is given to the use of alternating current for radio power. The following chapter presents a treatment of filter systems with ripple measurement methods, including a short discussion of voltmeters of the vacuum-tube type.

The author concludes with an interesting chapter on aircraft pyrometry which covers the design and testing of thermocouples of the type used in aircraft.

For those seeking a general knowledge of aircraft electrical systems in concentrated form, this book is heartily recommended.

GRAPHICAL CONSTRUCTIONS FOR VACUUM TUBE CIRCUITS, *by Albert Preisman. Published by McGraw-Hill Book Company, Inc., New York, N. Y. 234 pages. Price $2.75.*

Graphical constructions, as defined by the author, mean "those geometric manipulations by which are obtained solutions to problems on *nonlinear* circuits, particularly those involving vacuum tubes." (The italics are ours.) This definition must be kept in mind while reading the book for it has been customary, at least in texts published in the United States, to use graphical constructions based on static characteristics rather than dynamic characteristics, although the latter seems more logical.

The opening chapter, titled "The Nonlinear Circuit Problem," is essentially an argument for the book. The author points out limitations in the use of Taylor and Maclaurin's expansions which are not valid if their curves have violent bends.

The second chapter on "Thermionic Vacuum Tubes" is a general discussion of tube characteristics and seems superfluous in a text of this nature.

In Chapter III, "Elementary Graphical Constructions," some limitations of the use of graphical solutions are outlined. Of special interest is the statement that although graphical treatment provides a particular answer to a particular set of conditions, it does not, as a rule, indicate the optimum initial conditions that will give best results. It is also pointed out that when more than three variables are introduced, the graphical solution tends to become impossibly involved. After this introduction, the author compares static and dynamic characteristics for resistive loads. He then proceeds to the practical application of the graphical method.

The fourth chapter, "Reactive Loads," covers the use of the graphical method where a reactive load is involved and discusses several examples combining linear and nonlinear reactances with linear or nonlinear resistances.

Chapter V on "Balanced Amplifiers" includes a physical as well as graphical analysis of balanced (push-pull) circuits. It is the high point in the book.

The following chapter on "Detection" emphasizes the use of diode detectors since, as Mr. Preisman points out, that type is in almost universal use today.

The concluding chapter is devoted almost entirely to voltage and current feedback constructions.

So far as we know, this book is unique in its field and that fact makes it interesting. Aside from this, however, the author presents a good case for the use of graphical analysis as he defines it and the book will undoubtedly be useful to engineers interested in vacuum tubes and their many applications.

BASIC RADIO, *by C. L. Boltz. Published by the Ronald Press Company, New York, N. Y. 266 pages. Price $2.25.*

Basic Radio is one of a series of elementary science texts published in England. The subject matter is said to follow the syllabus for British Air Training Cadets.

Aside from a few unfamiliar British terms such as "valves" for tubes, and "accumulators" for storage batteries, this little book offers a solid foundation to the radio novice who is willing to start at the beginning and work his way up with the author.

In each chapter, the text is accompanied by simple experiments to supply the necessary practical background so often lacking in the radio beginner's early efforts. The experiments require simple equipment and are reasonably easy to perform.

A knowledge of high-school algebra is helpful in following the development of the fundamental laws of electricity but is not prerequisite. The book should be useful as a text either in the classroom or for home study.

Simple circuits including a tuned radio-frequency receiver are described and analyzed. However, the author has wisely left the more complicated circuits, including the superheterodyne, to more advanced texts.

have you read---

VHF BEHAVIOUR OF RADIO COMPONENTS, by E. L. Hall, *Electronics*, March. Variation of power factor and apparent capacitance at 27.5 to 200 mc.

MEDICAL ELECTRONIC PRACTICE AND RESEARCH, by John D. Goodell, *Electronics*, April. Electro-Shock therapy, electrical anesthesia, brain waves and measurements on living tissues.

FM DISTORTION IN MOUNTAINOUS TERRAIN, by A. D. Mayo and Charles W. Sumner, *QST*, March. Some observations of multi-path reception of FM signals.

FUTURE AUTOMATIC AIR TRAFFIC CONTROL DEVICES, by Glen A. Gilbert, *Radio News*, March. Possible future navigational aids.

AUTOMATIC RADIO COMPASS, by Myron F. Eddy, *Radio News*, April. Automatic compass theory and the MN-31.

HIGH-Q AUDIO REACTOR, by Colin A. Campbell, *Communications*, March. An analysis of factors affecting design and production.

1944 ELECTRONIC ENGINEERING SECTION DIRECTORY, *Electronic Industries*, March. An index of products, equipment, instruments and materials.

AUTOMATIC CALIBRATION, *Electronic Industries*, April. Motor-driven recording systems read settings while dials are in motion.

CARRIER CURRENT SYSTEM HELPS RUN 'PENNSY' R.R., *Electronic Industries*, April. Two-way carrier telephone using rails as main signal path.

JAP RADIO EQUIPMENT, by R. A. Gordon, *Electronics*, May. Description of Model 13 high frequency command set used in aircraft.

CAA-RTCA INSTRUMENT LANDING INSTALLATION, *Electronic Industries*, April. Details of instrument-landing system at Indianapolis Municipal Airport.

D-C AMPLIFIER DESIGN TECHNIQUE, by Edward L. Ginzton, *Electronics*, March. Design data and practical examples of d-c high gain amplifiers.

MEDICAL ELECTRONIC PRACTICE AND RESEARCH, by John D. Goodell, *Electronics*, April. Electro-shock therapy, electrical anesthesia, brain waves and measurements on living tissues.

FM STATION LIST, *FM Magazine*, March. FM Stations on the air and applications filed.

INDUCTIVE AND REACTIVE EFFECTS IN STRAIGHT LEADS, by Clark Jackson, *Radio News*, April. An analysis of inductive and reactive effects in high frequency circuits.

PATENT DIGEST

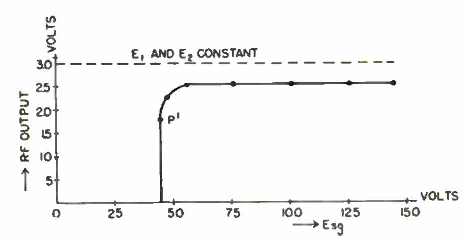
Discharge Tube Oscillator, Henry M. Bach, Pat. No. 2,311,631.—This device eliminates d-c potentials on oscillatory electrodes and the consequent load on tuned circuity by sustaining oscillations solely through space charge, or electron coupling, thus insuring higher Q and greater stability.

The oscillator is readily applicable to commercially available tubes. It does away with the need for elaborate by-pass and filter elements, since d-c voltage is completely isolated from r-f circuits. Extremely high output is easily obtained without impairing stability or wave form by means of an oscillator-buffer arrangement.

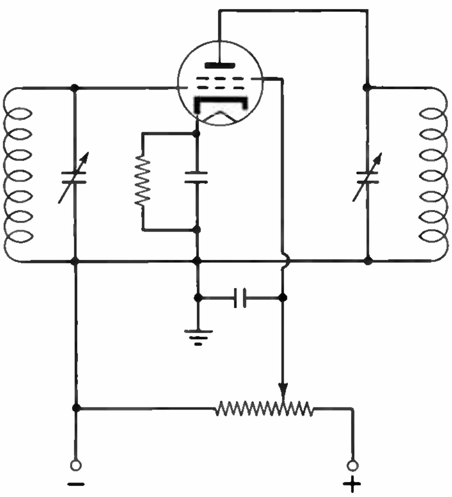
It can be frequency or amplitude modulated by varying positive bias applied to non-oscillatory electrodes, and frequency may be varied by a small change in d-c bias on a negative electrode.

The principle on which the oscillator operates is as follows:

Sustained oscillations are produced by maintaining grid and plate at a steady



Graph showing amplitude of oscillations as a function of the positive screen or accelerating voltage.



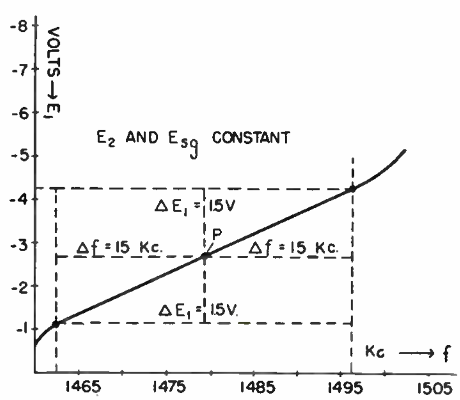
Circuit diagram of discharge tube oscillator.

negative potential with respect to the cathode. An accelerating grid, between the negative biased control grid and the plate, is maintained at a positive potential with respect to the cathode. If an input signal is impressed between the control grid and the cathode, the electron stream moves from the cathode toward the positive accelerating grid, and is modulated in accordance with the signal voltage. Since most of the electrons pass through the accelerating grid mesh, a concentrated space charge, or virtual cathode, is formed between the accelerating grid and the plate. Variations in the input signal cause a fluctuation of space charge density, which in turn causes a current to flow in a return connection between the plate and cathode. The induced current is of the same frequency as the signal voltage.

If a tank circuit between the plate and cathode is tuned to the frequency of the signal voltage, the current induced in the plate-cathode circuit will be 90° out of phase to the signal voltage.

The potential impressed on the plate, however, produces a corresponding potential on the control grid as a result of a second space charge set up in the vicinity of the control grid. This potential, when fed into the tuned grid circuit is 90° out of phase with the plate current, and therefore in phase with the signal current. This current induced in the control grid circuit tends to sustain oscillation.

Pseudo - Extension of Frequency Bands, Louis A. DeRosa, Pat. Nos. 2,113,-976; 2,315,248; 2,315,249.—By pseudo-extension is meant the utilization of a psychological phenomenon, the non-linearity of amplitude vs. response characteristic of the ear, to increase the apparent frequency range of a transmitted signal.

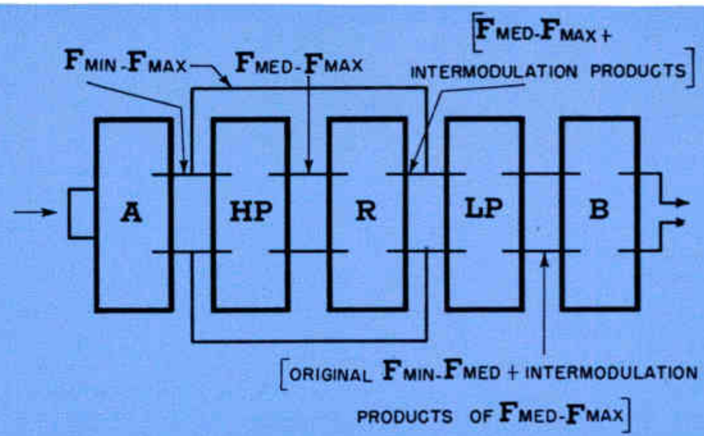


Graph showing frequency as a function of the positive voltage applied to the accelerating grid.

The ear is a delicate translating system which receives acoustical vibrations and converts these vibrations into nerve-impulses. These nerve-impulses are transmitted along the eighth cranial nerve to the superior temporal convolution of the cerebral cortex.

If a single audible frequency is conveyed to the ear and the frequency of this acoustical stimulus is varied from a low value of, for example, 400 cycles per second to successively higher frequencies and at the same time a fibre of the eighth cranial nerve is examined by a coaxial prod, associated with an audio amplifier and an oscilloscope, it will be found that the nerve impulses vary in number with the stimulating frequency until that stimulating frequency is increased to a value of approximately 900 to 1000 cycles per second. Above this point, an impulse occurs at every second cycle of the stimulating frequency until the stimulating frequency is increased to about 3000 cycles per second at which time a nerve fibre contains an impulse on every third cycle of the stimulating signal. At the highest audio frequencies, the impulses do not conform in any way with the periodicity of the stimulating frequency but assume a random character. It seems evident therefore that the sensations accompanying the presence of higher frequency stimuli must be conveyed to the brain by a pattern contributed to by a large number of nerve cells, no individual cell being able to furnish impulses of frequency higher than probably 900 to 1000 cycles per second.

The exact process by which the high frequencies, probably those above 4000 cycles, are translated into sensations recognizable



Block diagram of pseudo-extension amplifier.

by the brain as being indicative of the presence of these high frequencies, is a highly hypothetical one, and the advanced suppositions are numerous and contradictory.

The improved process of pseudo-extension is, however, probably made possible by two effects occurring in the ear.

First, to produce the sensation of hearing a certain frequency, it is not necessary that the stimuli must excite any definite section of the basiliar membrane. Therefore, the alteration and successive stimulation that the nerve cells undergo when a high frequency is heard can be produced by a lower frequency which is transitionally or dynamically varied as a function of time so as to alternately and successively stimulate adjacent nerve terminations on the basiliar membrane.

Secondly, due to the non-linearity of the hearing mechanism the intermodulation frequencies formed by the pseudo-extension process tend to produce high frequency subjective tones in the ear.

A complex sound (frequency range: f_{min}-100 cycles, f_{med}-3000 cycles, f_{max}-10,000 c) may be picked up and faithfully translated into electrical variations by the microphone amplifier A.

The frequency band (f_{min}-f_{med}) will be blocked by the high pass filter HP, but permitted to pass freely to the PA section B via the low-pass filter LP.

The frequencies (f_{med}-f_{max}) while blocked by LP are passed freely by HP into the rectifying network R, where a new frequency distribution occurs.

Intermodulation products of (f_{med}-f_{max}) together with the band (f_{min}-f_{med}) are then permitted to pass into B by LP.

From B the currents are suitably transmitted as electromagnetic waves in the well-known manner, and if received will create the same sensation upon the ear as if the original band had been transmitted.

Patents To Bendix Engineers

The following patents have been issued to employees of Bendix Radio Division since January 1, 1944.

VERNON MOORE, Design for Inductor Housing, Patented 2/8/44, Pat. No. Des. 137,250.

RICHARD S. BAILEY, Piezo-Electric Apparatus and Method, Patented 2/1/44, Pat. No. 2,340,843.—The shock impulses occurring in a crystal during the grinding operation cause the crystal blank to vibrate in its natural frequency, thereby generating voltages which are picked up in a calibrated receiver for a determination of the crystal frequency.

RICHARD S. BAILEY, Crystal Holder, Patented 2/15/44, Pat. No. 2,341,683.—A tubular transparent housing containing a plated crystal secured in position by bifurcated retaining clip. The housing ends are closed by conductive caps carrying the clips and affording connecting means.

RADFORD K. FRAZIER, Variable Capacitor, Patented 3/21/44. Pat. No. 2,344,689.—A capacitor structure adapted to carry a vacuum tube in which a projection on a shield plate serves to enhance the grid-plate shielding.

Do It The Hard Way

"In most captured German radio equipment, the units have been extremely inaccessible, hard to build, and complicated. The German Radio Compass, Model EZ-6, however, is compact, well designed and well built. Nearly all of the important subassemblies are made plug-in and are readily removable. The unit covers three frequency bands and, according to all reports, has highly satisfactory performance. I feel that they accomplish results the hard way, with intricate mechanical units, rather than by a simple electronic or mechanical design. The compass gives the impression of having been built by a watchmaker."

—Report by W. L. Webb.

Before being flown to the United States for disassembly and study, the captured German JU-88 bomber at the right was equipped with a Bendix automatic compass, the only American equipment aboard.

WAVE GUIDES

Continued from page 3

conveniently showing this relationship. Figure 3 shows such a curve giving the critical frequency for several modes plotted against tube width for rectangular tubes and tube radius for cylindrical tubes.

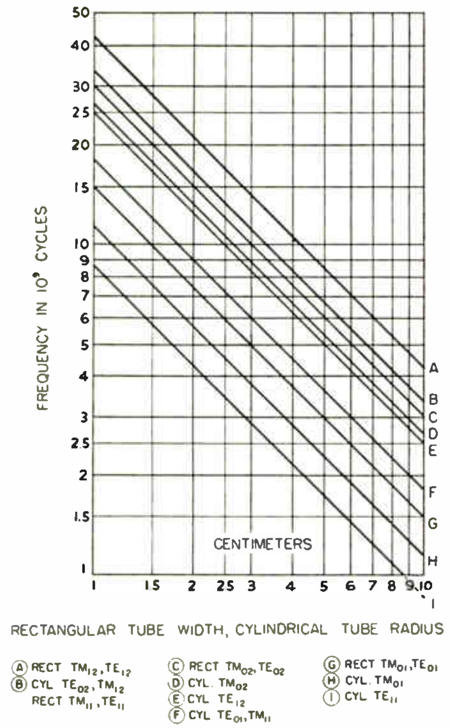


Figure 3—Critical Frequencies for various modes.

Conclusion

This paper has presented a brief review of the fundamentals and certain practical relationships to aid the reader in developing specific magnitude appreciation of the quantities involved. No attempt has been made to cover all aspects and those interested may find further details by reference to the appended bibliography.

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3. An Elementary Treatise on Fourier Series and Spherical, Cylindrical and Ellipsoidal Harmonics, W. E. Byerly, 1893, Ginn and Company.
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* This text contains an excellent bibliography.

INTERCOM

The INTERCOM column is for the airing of your opinions, enthusiasms, and annoyances. The editor also welcomes short items of general interest.

To the Editor:

I am convinced we will wind up far in advance of our competitors in product desirability, if we begin to lean now toward *modern styling* in the design of our equipment. Already we have proved that we can build equipment modern in style and extremely pleasing to the eye, without sacrificing rugged and high quality construction—a very desirable combination for sales.

Modern styling takes on the appearance of high cost, although there is actually little reason for sky-rocketing cost of equipment to improve its appearance. By judicious selection and assembly of standard metal and plastic flat sheets, and extruded or rolled shapes, an unlimited number of pleasing design effects can be made quickly and economically.

Manufacturers who make a specialty of producing cabinets and cases of modern appearance can be consulted for advice on economical production. The results of several such consultations have been highly satisfactory from a cost and delivery standpoint.

I have given several design men their head in modern styling of equipment. The talent uncovered was of a very high degree. Several proposed designs for ground station transmitters and associated equipment, make today's products obsolete in appearance. I am of the opinion that the day of the square-cornered box with the black wrinkle finish, is about over. Such equipment will be obsolete the moment it leaves the assembly line. Compared with equipment to which modern styling has been applied, it will be entirely lacking in appeal, and consequently a very undesirable sales item.

It may prove wise for Bendix Radio to be out in front in modern styling.

E. O. Gaguski,

Chief Mechanical Engineer, Transmitter Engineering.

Pere Marquette steamship on which S. B. Littauer, P. H. Kreager, and L. B. Gilmer conducted tests of an MN-31 compass. Ship officers on Great Lakes freighters of this type are interested in the direction finder with a visual indicator.

FIELD ITEMS

Problems in Pretoria

The chief problem of air transport in South Africa is how to get more equipment. A few months ago, Gus Treuke noted that transport personnel understood and had great confidence in Bendix aircraft equipment, which is installed in most anything that will fly. In one German-built plane, J. U. 86, a TA-12 transmitter, RA-10 receiver, and MN-26 radio compass are used. This equipment is neatly installed in one rack which also serves as the radio operator's desk.

To satisfy the demand for an 800-cycle tone modulation in the compass, Treuke used a method suggested at the Bendix Radio plant. The South African staff had already tried to use the unfiltered output of a full-wave selenium rectifier connected across the primary winding of the power transformer, but the outcome was unsuccessful. The unfiltered component of the high voltage rectifier output was therefore used, and the resultant 800-cycle tone modulation was satisfactory.

In one PV-1 aircraft, electrical and ignition noise interfered with radio reception. Apparently the real problem was to find a means of probing conveniently for these sources of noise, and the solution was a shielded lead attached to the antenna post of the receiver and terminated in a loop with a handle on it. This device showed definitely what part of the engine caused the interference.

The Personal Touch

There's something personal about an air raid, Tom Stangeby, formerly of Sales Engineering, discovered while in Cairo for Bendix.

Stangeby was in Egypt when Rommel was practically at the gate of the capital. He was, in fact, one of the two technical representatives permitted to remain in the city when even non-combatant troops were evacuated.

After supervising the unloading of the last supplies for a Bendix maintenance depot at an airport on the outskirts of Cairo, Tom and Squadron Leader Jaquemet, Chief Maintenance Supply Officer in the Middle East, were enjoying the evening on the terrace of the latter's apartment which overlooked the field. They had just settled themselves when the air raid signal sounded.

"The air raids were frequent in those days, and caused little excitement among the population," says Tom. "The Germans were fairly accurate and, for the most part, confined their bombing to military targets. Jaquemet and I decided to stay outside and see the show.

"The Jerries were after the airport. They made their runs from about 5000 feet, passing over our heads, and dropped their eggs from approximately 1500 feet. We had an unobstructed view of the target, and were protected from falling flak by a roof overhanging the terrace. The British threw up a terrific barrage of anti-aircraft fire which, together with their night fighters, brought down five of the enemy planes. It was quite a show."

But Stangeby soon discovered that an air raid is not a thing one can view with detachment.

The only building on the airport completely destroyed was the newly completed Bendix depot. Along with the building Tom lost his supply of spare parts for TA-2's and RA-1's, a number of precious tools, and one of the two tube-testers in that section. For the next three months, until a new shipment of supplies came in, he kept equipment going by stealing parts from one set to repair another.

Dustless Assembly

Autosyn motors for compass indicators are assembled in a dustless room which is sealed off from the rest of the plant at Delco Appliance Corporation in Rochester, New York. Every possible precaution is taken to keep any dust, dirt, lint or other foreign matter from clinging to the parts of the autosyn motor.

Before assembly, the parts of the motor are put through a small gas flame which burns off any lint or particles which may have been picked up during their preparation. All of these sub-assemblies are handled on special carrying trays which fit on a continuous metal conveyor belt system. Each tray carries the parts required to make one indicator motor, and moves into the assembly room through a specially devised opening.

The assembly room is completely air-conditioned. A dust count of the air is continuously being taken in order to make sure that the air filter is removing any dust particles. The pressure in the assembly room is greater than that outside in order to prevent any dust from blowing in when the door is opened. All fixtures, benches, and air ducts in the room were designed to eliminate any edges or corners under which dirt or dust could collect. A crew of men are kept busy cleaning the room constantly. During the lunch period of the assembly workers and at the end of their shift, the room is again completely cleaned.

All of these precautions to keep dust out of the assembled motors, reduce friction in the motor to an acceptable minimum.

Interference Eliminated

Major Spencer, of Base Operations, Bolling Field, Washington, D. C., is proud of the radio installation on his ship. The equipment, all from Bendix Radio, includes the RTA-1 transmitter, and the MN-26H standard commercial receiver and its accessories.

The RTA-1 unit has been modified by removing the variable audio control so that the r-f sensitivity is the only control over the receiver. The r-f sensitivity control was increased from 5000 ohms to 10,000 ohms and the 1500-ohm section to ground was removed. The audio output was fed directly into an auto-transformer and thence to the interphone system. With this modification, the noise level is almost nil over the major portion of the sensitivity control range. The air lines were called for checks, and perfect readability reports were received from Buffalo, New York, Detroit, Chicago, Kansas City, and Wichita.

The MN-26H is used with a whip antenna and an MN-24 fixed loop on the nose of the ship. Major Spencer reported to C. F. Luscombe that with static dissipators installed, he has flown through all kinds of weather with this ship and has never been bothered by interference.

They Like It

Pan-American Grace Airways uses TA-2 transmitters as standard equipment on its planes, and is well satisfied with their performance, according to "Dud" Kesselhuth of our West Coast Branch, who recently returned from an extensive tour of South America as Bendix service representative.

He says, "I talked with the flight operators and they like the way the TA-2 follows a speed key. The ground station operators say that the strength of the signal and the quality of the note make it almost perfect to copy even through atmospherics."

With an unexpected service, Kesselhuth partially repaid PANAGRA for the compliment. Because of the high line voltage (220v) in Peru, the company had been unable to rig up a satisfactory dummy antenna with available light bulbs. The problem was solved when Kesselhuth went down to the harbor in Lima and "chiseled" a proper light bulb from the crew of a United States tanker.

BENDIX RADIO

DIVISION OF BENDIX AVIATION CORPORATION

BALTIMORE, MARYLAND