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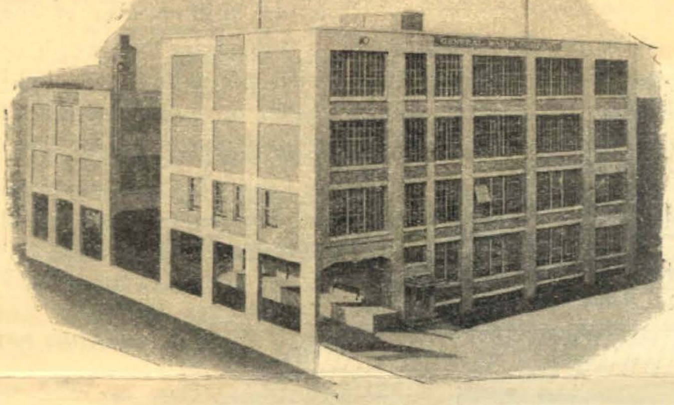
EXPERIMENTER



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Permalloy

By ARTHUR E. THIESSEN

PERMALLOY is a name given to the series of alloys of nickel and iron having a composition varying from about 30 per cent nickel and 70 per cent iron, to 85 per cent nickel and 15 per cent iron. They possess unusual magnetic properties. The position in the nickel-iron series of a given alloy is usually designated by a numeral which, preceding the word permalloy, gives the percentage of nickel in the composition: thus, 45 permalloy means an alloy containing 45 per cent nickel and 55 per cent iron.

Figure 1 shows how the inital permeability of the permalloy series varies with the composition. The extreme left of the curve is pure iron which has a permeability of about 4[illegible]. As the nickel content is increased, the permeability declines slightly until 30 per cent nickel is reached, when a sharp increase in noted. This increase reaches a maximum at about 45 per cent nickel, 55 per cent iron at which composition the permeability has reached 2,000. This value is maintained until the alloy becomes about 70 per cent nickel, where a second sharp rise occurs which reaches a peak at about 80 per cent nickel, 20 per cent iron. The permeability at this point is not definitely fixed but may vary with the mechanical treatment the alloy has received in preparation. Small amounts of foreign material such as magnesium, copper, and silicon affect it greatly. However, 12,000 or 15,000 permeability is not at all exceptional at this composition and the addition of a small percentage of chromium, which helps nearly all of the permalloys, together with proper heat treatment may raise the initial permeability to the astonishing figure of 100,000 or more. In the commercial preparation of permalloy, a fractional percentage of manganese is added to aid the malleability and ductility of the alloy which, without it, is quite springy and brittle.

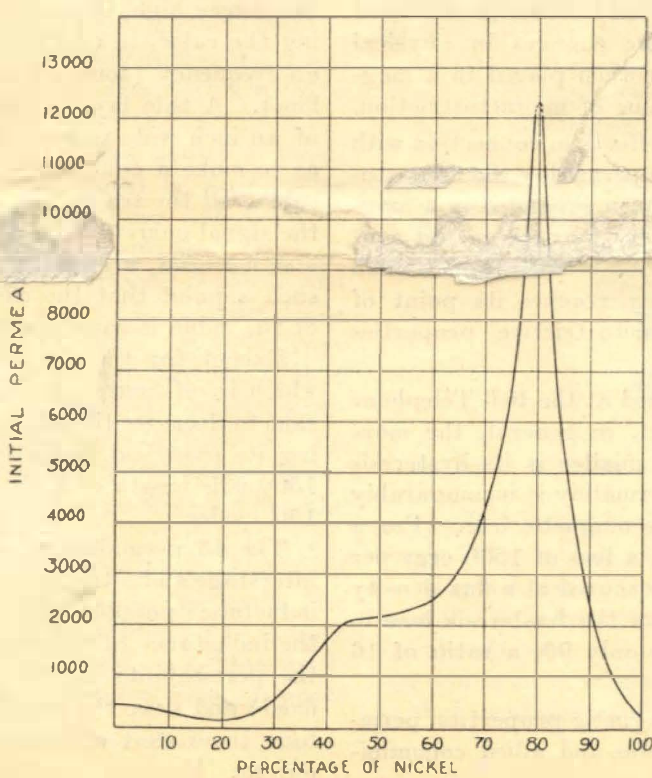

FIGURE 1. THE INITIAL PERMEABILITY OF PERMALLOY AS A FUNCTION OF THE PERCENTAGE OF NICKEL

Proper heat treatment is important in getting the best magnetic properties. The usual method is to perform all of the necessary mechanical operations before heat treating so that it is subjected to no undue mechanical strain after annealing and before being put into service. The heat treatment, which is the same for all permalloys, consists of heating the alloy in an air-tight nickel pot to about 1100 degrees Centigrade, holding it at this temperature for an hour, and then allowing it to cool very slowly to room temperature with the furnace in which it was heated. The pot is sometimes sealed with iron filings, which fuse together before reaching maximum temperature, at the same time forming an iron oxide with the air left in the pot. This prevents the residual air from oxidizing the alloy.

If, after the above heat treatment, the alloy is re-heated to 600 degrees Centigrade and allowed to cool rapidly, the permeability is found to increase to a still greater value. Due to certain limiting mechanical considerations, however, this double treating is not always feasible.

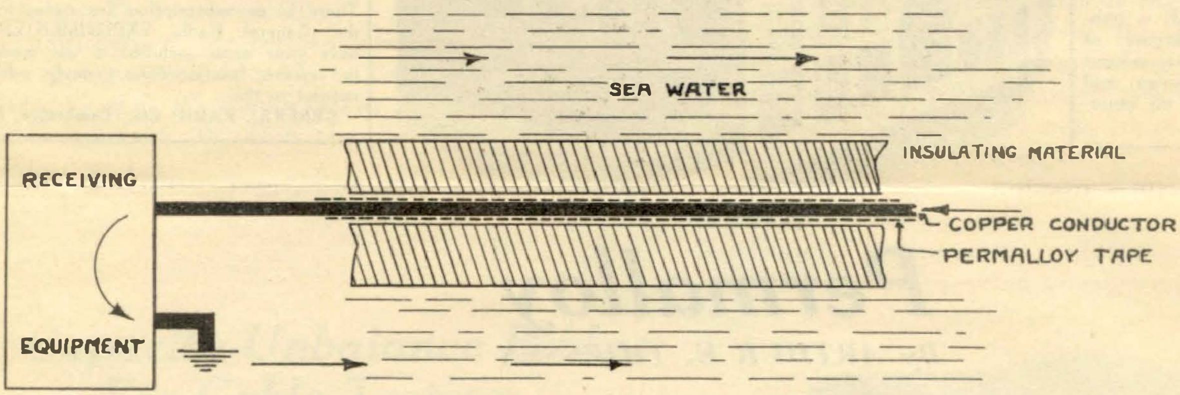

FIGURE 2. A CONTINUOUSLY-LOADED SUBMARINE CABLE SHOWING DIRECTION OF CURRENT FLOW

L. W. McKeehan found the phenomena of magnetostriction to be closely related to the remarkable magnetic properties of the permalloys. In 1842 Joule discovered that a specimen of iron on being magnetized actually increased its physical length along the axis of magnetization. Subsequently it was discovered that nickel exhibited exactly the reverse effect. These changes in physical dimensions of magnetic materials when placed in a magnetic field have been given the name of magnetostriction.

McKeehan, investigating these effects in connection with permalloy, found that at about 80 permalloy the magnetostriction became zero. The specimen expanded in a magnetic field as its composition became more iron, and contracted when the percentage of nickel became greater than 80 per cent. Thus, as the alloy reaches its point of maximum permeability its magnetostrictive properties pass through zero.

A series of experiments conducted at the Bell Telephone Laboratories seems to show that, in general, the more permeable an alloy becomes, the smaller is its hysteresis loss. The hysteresis loss in 80 permalloy is incomparably smaller than in the best available magnetic iron. For a very good grade of Norway iron, a loss of 1500 ergs per cubic centimeter per cycle when measured at a flux density of 5,000 lines is average, whereas the hysteresis loss in permalloy at this flux density is only 90, a ratio of 16 to 1.

Because of these remarkable magnetic properties, permalloy has found many uses in radio and allied communication fields.

The telephone companies make use of the alloys in many of their transformers, hybrid coils, loading coils, and sensitive low-current relays. The reasons for these extended uses in voice-frequency circuits are apparent when it is considered that a good flux density is required for a few milliamperes of current available in the windings.

Submarine telegraph cables, when continuously loaded with permalloy are capable of a transmission speed of 2,000 or more characters per minute as compared with a maximum speed of less than 250 letters per minute on the old style unloaded cables. The continuous loading of submarine cables has so revolutionized the art of trans-oceanic telegraphy that a few words of explanation may be interesting.

A submarine cable consists essentially of a heavy-gauge, single copper conductor surrounded by a one-quarter-inch layer of gutta percha, steel armor wires, and a layer of saturated hemp, the whole being about one or one and one-half inches in diameter. The sea water provides a return path for the current.

The capacity of the copper conductor to the sea water is very high, bypassing the high frequencies, and making the cable, in effect, a low-pass filter with a low cut-off frequency (some 15 or 20 cycles for the unloaded cables). A thin layer of permalloy tape about one-eighth of an inch wide is wound spirally around the copper so as to make a continuous layer of permalloy between the cable and the sea water. As may be seen from Figure 2, the signal current flux then links a core of highly permeable material, which raises the inductance of the path to such a point that the effect of the tremendous capacity of the cable is counteracted to a great extent.

Except for the direct-current resistance of the cable which is, of course, fixed, the permalloy loading may be said to decrease the effective length of the cable by reducing its electrical capacity. The cut-off frequency of a 1500-mile length of such a loaded cable may be well over 150 cycles.

The 45 permalloy is sometimes used for the cores of interstage audio transformers because of the high primary inductance possible with a small number of turns. Since the inductance of the primary is in direct proportion to the permeability of the core (other factors remaining fixed) and since the permeability of 45 permalloy is some four times that of silicon steel, the advantages are apparent. However, care must be taken in using permalloys

(*Concluded on page 4*)

Power Transformers for the 245-Type Tubes

THE General Radio Company is about to place upon the market two new power transformers for use with the recently-announced 245-type power amplifier tubes. One is designed to supply a single tube; the other, to supply two tubes.

It will be remembered that the 245-type tube has an undistorted power output rating between that of the 171-type and the 250-type. With the maximum of 250 volts on its plate, it is capable of delivering 1600 milliwatts, which is more than twice that of the 171- and about one-third that of the 250-type tube. At 250 volts the plate current is 32 milliamperes when the recommended grid-biasing voltage of -50 is supplied.

Either alternating or direct current may be used to heat the filament, which requires 1.5 amperes at 2.5 volts. This is the same voltage as is needed for the 227-type tube, so that it is entirely feasible to run the filaments of both kinds from the same transformer winding.

For the operation of a single 245-type tube, the new TYPE 545-A Power Transformer has been provided. When used with a full-wave rectifier of the 280-type and low resistance filter choke coils such as are contained in the TYPE 527-A Rectifier Filter[1], it will supply the correct plate and grid-biasing voltages for one 245 tube. The permissible current drain is over 50 milliamperes, more than sufficient to supply a 227- in addition to the 245-type tube.

In designing the filament supply windings of the TYPE 545-A Power Transformer this was kept in mind, and the 2.5 volt winding has a carrying capacity sufficient for one 245 and one 227. In addition there is a 5 volt winding for the rectifier tube.

When it is necessary to operate two 245-type tubes, a TYPE 545-B Power Transformer must be used. This is wound in the same manner as the TYPE 545-A Power Transformer previously described except that the high voltage winding has larger current-carrying capacity and a larger voltage to compensate for the increased voltage drop in the rectifier tube and in the filter. It will deliver full rated voltage with a drain of 80 milliamperes, so that it, too, can be used to handle one 227-type tube in addition to the two 245-type tubes for which it is rated. To perform satisfactorily, however, the TYPE 545-B Power Transformer must be used with a low-resistance filter like the TYPE 527-A Rectifier Filter.

If for any reason it is desired to use a high resistance filter—the TYPE 366 Filter Choke[2], for instance—the TYPE 545-B Power Transformer may be used to supply plate power for a single 245-type tube, since the additional voltage drop in the higher-resistance chokes is practically equal to the increased voltage of the larger transformer. Limitations in the ability of the full-wave rectifier tube, to withstand higher voltages, however, makes it impossible to further increase the transformer voltage in order to compensate for high-resistance chokes when two tubes are to be used. The only solution of the problem is to use chokes of lower resistance.

The following summary is presented for ready reference:

TYPE *545-A Power Transformer*

Supplies grid-biasing and plate voltages for one 227-type and one 245-type tube using a 280-type full-wave rectifier and low-resistance filter chokes.

Supplies filament current for one 227-type and one 245-type amplifier tube and one 280-type rectifier tube.

Code Word: POSSE — Price $10.00

TYPE *545-B Power Transformer*

Supplies grid-biasing and plate voltages for one 227-type and two 245-type tubes using a 280-type full-wave rectifier and low-resistance filter chokes.

Replaces TYPE 545-A Power Transformer when using high-resistance chokes.

Supplies filament current for one 227-type and two 245-type amplifier tubes and one 280-type rectifier tube.

Code Word: PRIOR — Price $10.00

Both of the new power transformers are scheduled for delivery by June 15.

[1]The TYPE 527-A Rectifier Filter contains two chokes, each having a direct-current resistance of 175 ohms.

[2]The TYPE 336 Filter Choke contains two independent sections, each having a direct-current resistance of 350 ohms.

Variable Air Condensers for Use with High Voltages

EXPERIENCE extending over several years has shown that the TYPE 334 Variable Air Condensers (double-spaced) for high voltage use have been too conservatively rated. When they were first produced, it was recommended that the voltage across them be limited to 2000 volts, but continued tests under actual operating conditions permits this rating to be increased to 2500 volts, root mean square, or 3500 volts, peak.

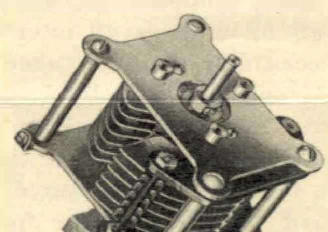

FIGURE 3. TYPE 334 DOUBLE-SPACED VARIABLE CONDENSERS

The TYPE 334 Condensers are of the metal-end-plate-type. They are of the low-loss construction having soldered rotor and stator plates. Until now they have been available only in maximum capacitances of 50 and 100 micromicrofarads, but on June 15 a 250 micromicrofarad size will become available. Its voltage rating is the same as that mentioned above for others of the same type.

Prices

TYPE 334-R 250 mmf.	$5.50
TYPE 334-T 100 mmf.	2.75
TYPE 334-V 50 mmf.	2.50

A Capacity Unbalance Bridge For Cable Testing

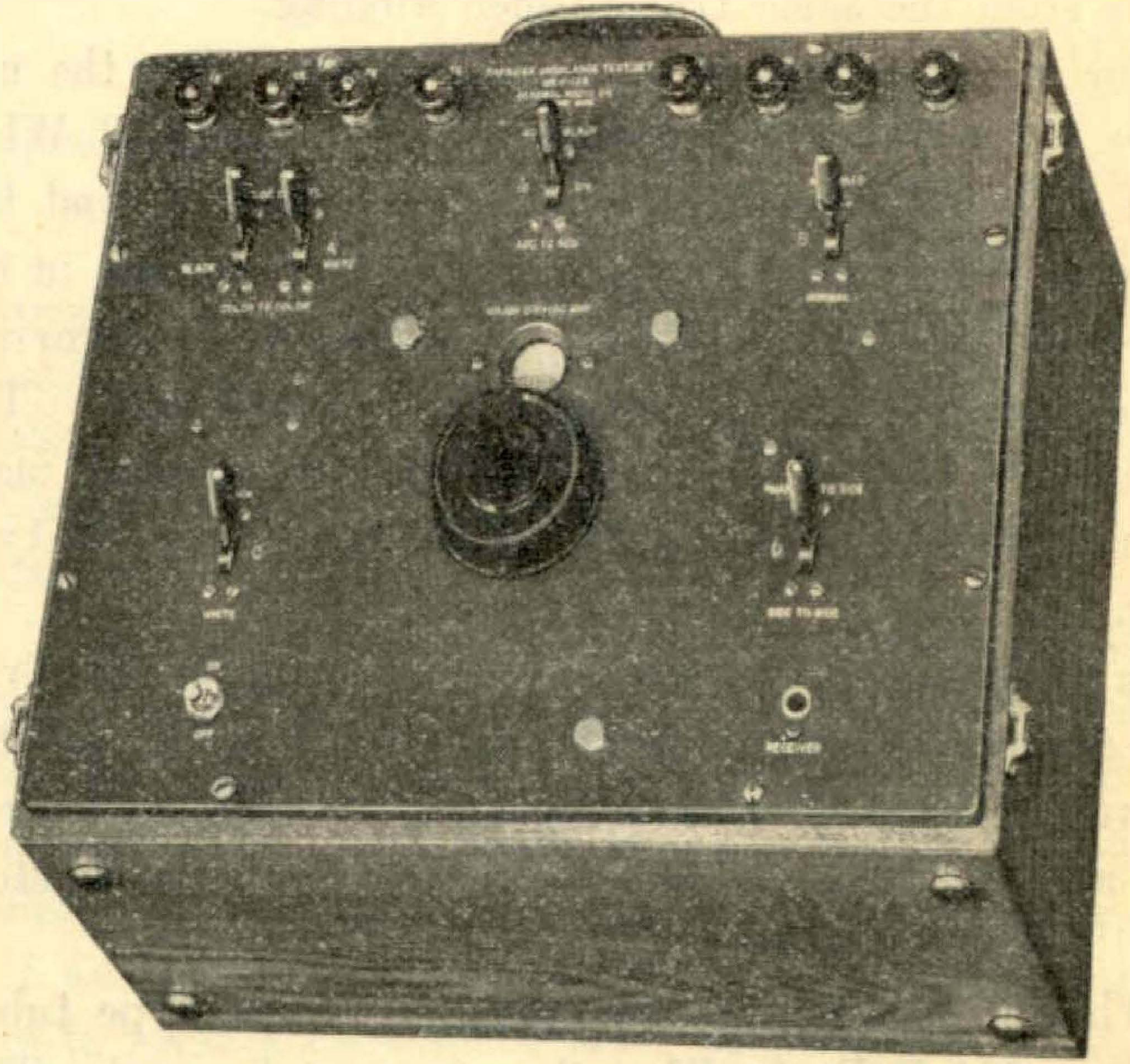

FIGURE 4. CAPACITY UNBALANCE TEST SET

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Permalloy

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for audio transformer cores because they saturate at much lower values of current than silicon steel. Therefore, they must be used in plate circuits drawing only comparatively small currents unless special precautions are taken in the design. Amplifier transformer cores made of permalloy also have the disadvantage of being subject to damage by mechanical shocks which cause them to lose their permeability.

Acknowledgment for certain information contained in the foregoing article is made to papers published by H. D. Arnold and G. W. Elman in *The Bell System Technical Journal* and by L. W. McKeehan in *The Journal of the Franklin Institute.*

A Capacity Unbalance Bridge For Cable Testing

SOME time ago the engineers of a large organization engaged in the operation of long telegraph and telephone cables needed a bridge for measuring the capacity unbalances between the conductors in each group of four wires (or quad). Knowing that the General Radio Company has for many years been specializing in the design and manufacture of bridges, precision air condensers, and other apparatus for the measurement of capacity, they called upon this company to build a suitable instrument. The following is a brief description of it with an explanation of the problem involved.

The important limiting factor in the operation of long cables, especially when phantom circuits are used, is the amount of cross-talk or inter-circuit interference that can be tolerated. Precautions must be taken to minimize it by balancing the circuits as carefully as possible with respect to resistance, inductance, leakage, and capacity. In general, capacity unbalances cause the most trouble.

When the cable is being manufactured, each group of four wires or quad (which provides for two channels operated in the usual way as well as one phantom channel) are continuously transposed by twisting together the two wires for each physical or side circuit. Then the two twisted pairs are twisted together, and the result is a cable unit in which the capacity of any wire to any other wire is supposedly the same. Actually, however, small unbalances almost always exist.

When two long cables are to be joined together, the problem confronting the lineman is to determine how he shall connect the two quads together. There are eight possible ways of connecting the two pairs of a quad, some will give a large amount of unbalance, others will give less. It is, of course, necessary that he shall choose that combination which has the least, and it was for the selection of the best combination that General Radio built the capacity unbalance bridge.

Figure 3 shows the instrument, at the back of which are two sets of four binding posts for making connections to the two quads which are to be joined. By means of the switches on the panel, the lineman can connect the two together in every possible combination and measure the capacity unbalance for each with the bridge.

For any combination there are, of course, four terminals, which form the four corner points of a bridge network. The four capacity arms of the bridge are the capacities between conductors in the quad. Across one diagonal of the bridge corresponding to one pair of the quad is connected a small buzzer operating at about 400 cycles, and across the other is connected the telephone headset for indicating balance.

When the circuit capacities are not balanced, a means of measuring the degree of unbalance is provided. This consists of a double-stator variable air condenser having the stator plates connected to opposite bridge points and

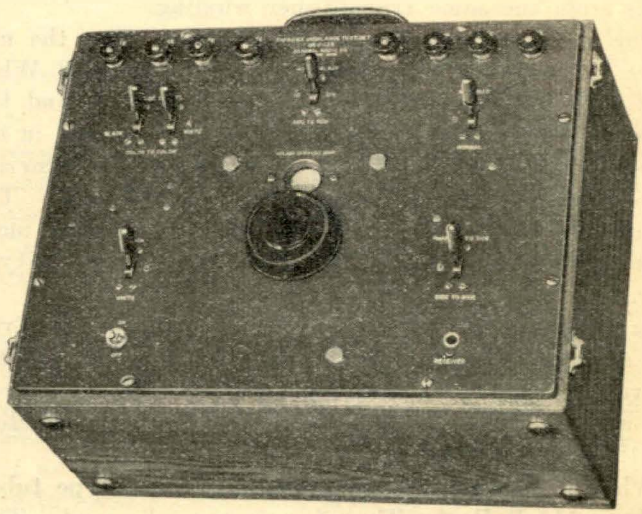

FIGURE 4. CAPACITY UNBALANCE TEST SET

the rotor connected to one of the remaining ones. By adjusting the condenser, it is possible to increase the capacity of either side of the bridge and reduce that of the other until a balance is secured. The setting of the condenser then gives directly a measure of the unbalance capacity.

The complete instrument is self-contained. It is light in weight and is equipped with an oak case and a weather-proof canvas cover. It is therefore, adapted for use by the lineman in the field.

Since the above described instrument was built, a new model has been prepared in which the unbalance is determined in only one quad at a time. The unit is smaller, more compact, and lighter than the larger one. In using this instrument the lineman measures unbalance in each of the quads which are to be joined. Then by knowing the magnitude and sign of the unbalance in each he can determine the best method of making the connection.