Optimum Use of Nickel Alloy Steels in Low-Level Transformers

L. W. HOWARD*

A statement of the problems involved in making a line of high-quality transformers, and a useful bibliography on transformer design.

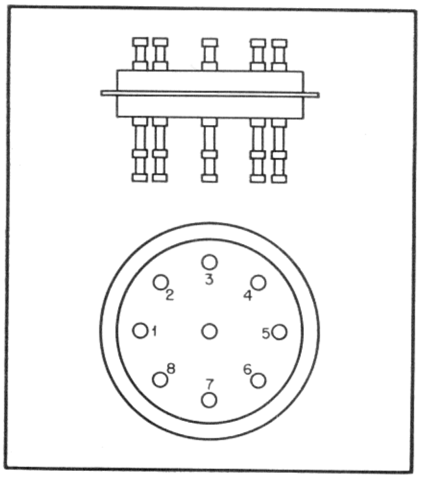

Fig. 1. Terminal arrangement which permits an adequate number of connections for multilead transformers.

THE PROPERTIES OF THE NICKEL ALLOY series of lamination steels which make them desirable for use as core materials and as a shielding material for low-level transformers have been known and commercially applied for a good many years. By a series of relatively small gains in the design techniques, the engineers in the industry have attained results which, when accumulated over a long period of time, represent major advancement in performance. Application of all of these new developments in any given application is frequently limited by economic considerations, the necessity for making use of expensive dies already purchased, the losses involved in obsoleting stocks on hand, etc. It is all too infrequent that any group of engineers has the opportunity to review all advances in technique, select the most adaptable to the problem under consideration, and to tool from scratch with no limitations due to use of dies already on hand. Such a development program is described in this article.

Since new tooling was involved, it became desirable to review all possible uses for such tooling and to make each die serve a purpose in each of several possible lines.

A tentative series of designs was developed for each of three fields of application in which the properties of the nickel alloy series afford promise of improved operation. A group of dies were then laid out to adapt themselves best to these designs. The groups of transformers around which this development grew were as follows:

A. Low-level wide-range transformers.

The high permeability of the nickel alloy steels at very low levels makes them particularly desirable for use in wide-range designs. High inductance values are obtainable without excessive leakage inductance or capacitance being developed, even when such transformers show relatively high gain. If full advantage is taken of this feature, a wide-range low-level transformer can be built into a very small space.

B. Transformers for geophysical prospecting equipment.

Geophysical equipment involves a different series of objectives in that only very low frequencies need to be considered, but low phase shift, high inductance, high gain, and above all, exact reproduction of characteristics, are of major importance. The equipment is portable in application, and as more and more channels are crowed into a typical prospecting truck, small size and weight become secondary in importance only to the electrical performance. A very high degree of shielding is required because of the high gain and sensitivity at line frequencies. All of these requirements are best met by use of properties of the nickel alloy steels.

C. Miniature components.

Using the high permeability of the nickel alloy steels to attain a reasonable amount of inductance in a small space permits the manufacture of transformers for practically all low-level applications with sizes which are only a fraction of that required for normal transformers designed for the same purpose. Since most of the equipment is battery operated and response at line frequencies is greatly attenuated, the shielding problem is not acute.

Common Problems

Problems which were common to the three groups were as follows:

A. SIZE: In all of the types of equipment for which these transformers are designed, extreme portability where obtainable without sacrifice in performance is desirable. Tooling was set up to reduce size and weight to the absolute minimum in all types. External cases were also to be shielding cases, to eliminate even one thickness of electrically inactive material.

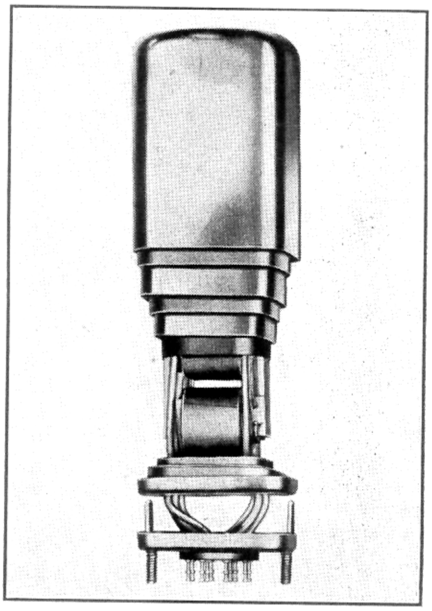

Fig. 2. Transformer case composed of nested alternate layers of nickel-alloy and copper shields.

B. MOISTURE PROTECTION: It was felt that wartime developments in hermetic sealing, as exemplified in the JAN-T-27 specifications, provided a good standard. Satisfactory terminals of molded, mineral-filled, low-loss phenolic were available but did not provide an adequate number of terminals in the small area available in the new miniature series of cases. Two new types were therefore

* *Triad Transformer Mfg. Co., 2254 Sepulveda Blvd., Los Angeles 64, Calif.*

developed, providing, respectively, nine terminals in 23/32 in. diameter and twelve terminals in 7/8 in. diameter. These seals use sturdy turret-type studs molded into the plastic and with their identifying number molded nearby as shown in *Fig.* 1. Soldering techniques and vacuum apparatus for impregnation and filling of the transformers were already included in the production equipment available.

C. MAGNETIC SHIELDING: The problems of shielding against stray fields and of the external case must be considered together when minimum size is to be maintained. Previous experience had indicated that a maximum of three high-permeability nickel alloy shields, interleaved with heavy copper shading rings, would be necessary to provide the reduction in pickup of stray fields needed for the lowest level transformers. Due to the wide range in transformer size and handling capacity, it was necessary to provide seven sets of case dies, each usable either as an external case or as an interior shield. These cases were designed so that the smaller cans nest within the larger with room between for the heavy copper shading rings, as shown in *Fig. 2*.

The equipment used in checking shielding efficiency is also of interest. As illustrated in *Fig.* 3, the transformer is positioned on the platform in the center of the Helmholtz coil, the large diameter of the coil ensuring a weak and uniform field for testing. Standard procedure is to check the transformer in two planes at right angles to each other, the results being strictly comparative with a similar unshielded unit.

D. FREQUENCY RANGE: The transformers involved in this problem are divided into three groups:

1. *Wide-range components.* It was felt that a minimum standard of 20 to 20000 cps ± 1 db should be maintained. Where wider range could be attained without increase in size or weight, this was done.
2. *Geophysical components:* Depending upon portability in the particular piece of equipment to be designed, 5 to 500, 10 to 500, or 20 to 500 cps, ± 1 db were determined as standards. Several designs were to be available for each standard function. Where possible without sacrifice of other desirable characteristics, frequencies above 1000 cps were to be attenuated.
3. *Miniature components:* Nickel alloy cores were used to attain minimum size rather than wide frequency range. The voice frequency range of 250 to 5000 cps, ± 1 db, is all that is considered necessary.

E. HANDLING CAPACITY: The nickel alloys are not too useful in the larger transformers due to their low saturation point. High-quality silicon steels are therefore more adaptable to high-level output transformer designs. Generally speaking, transformers in the groups described in this article were in the operating range below 20 VU.

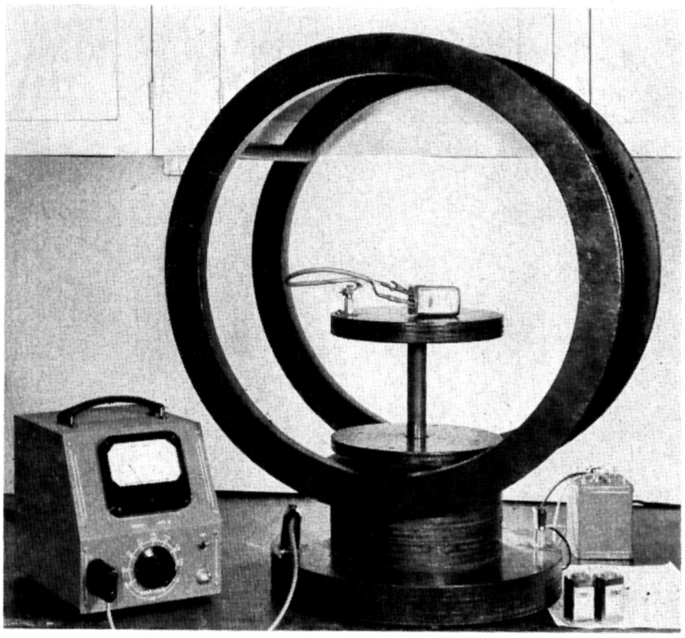

Fig. 3. Equipment used for testing efficiency of transformer shielding.

Conclusions

Since it is important that size be held to a minimum in all types, extremely accurate winding equipment and great skill in winding are necessary to handle the fine wire sizes which must be used. Such fine wire coils open up easily under moist conditions or mechanical movement. Therefore it is urgent that the windings be completely dried and all voids filled with non-hygroscopic and non-acid material. Only the most highly developed of vacuum-treating equipment is satisfactory. We have also found it almost imperative that the transformers be hermetically sealed and filled with compound under vacuum.

Fig. 4. Complete line of transformer cases for units of various sizes.

Possibly the emphasis placed on minimum size in this article seems overdone; however, not only is size important in the applications where these transformers are used, but keeping physical dimensions to a minimum permits reduction in leakage inductance and in capacity, thus permitting a more extended frequency range. *Figure* 4 shows a series of transformers made in a variety of case sizes.

The attached bibliography covers a number of articles which have appeared in the Proceedings of the Institute of Radio Engineers. The audio design chapters in Dr. Terman's "Radio Engineering" and "Radio Engineers Handbook" are also particularly helpful.

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[*Continued on page 50*]