The Lenkurt Demodulator

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CARBONYL IRON CORES

For Miniaturized Carrier Components

Miniaturized carrier equipment requires small yet highly efficient components. Of particular importance are the magnetic cores on which miniature coils and transformers are wound. At Lenkurt these cores are normally formed from carbonyl powdered iron which provides the desired electrical characteristics over the wide frequency bands used in carrier systems.

This article includes a brief discussion of magnetic principles and a description of the manufacture of carbonyl iron cores and of their use in telephone and telegraph carrier equipment.

Magnetic components of telephone and telegraph carrier systems can be divided into three broad classifications. These are:

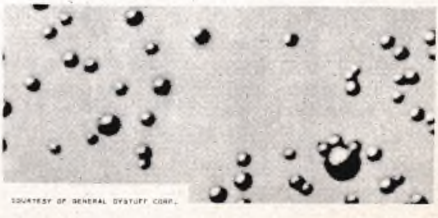
1. Electrical - mechanical devices such as relays or indicating meters.
2. Inductive elements such as toroidal coils.
3. Energy transfer devices such as transformers, hybrids, or repeating coils.

Relays and meters are usually direct current or low frequency devices which use the physical forces acting between magnetic fields or between a magnetic field and an iron member. Toroidal coils, transformers, etc. are more often high frequency devices whose operation depends upon the relationships between rapidly changing electric currents and magnetic fields. The use of the proper type and kind of iron core in these devices can often greatly improve their operation.

Hysteresis and Eddy Currents

Although the addition of an iron core to a coil of wire reduces the size of the coil and the number of turns required for a specific inductance, it also creates certain effects which are not present in air-cored coils. Two of the most important are hysteresis and eddy currents.

FIGURE 1. Photomicrograph of carbonyl powdered iron particles magnified about 10,000 times.



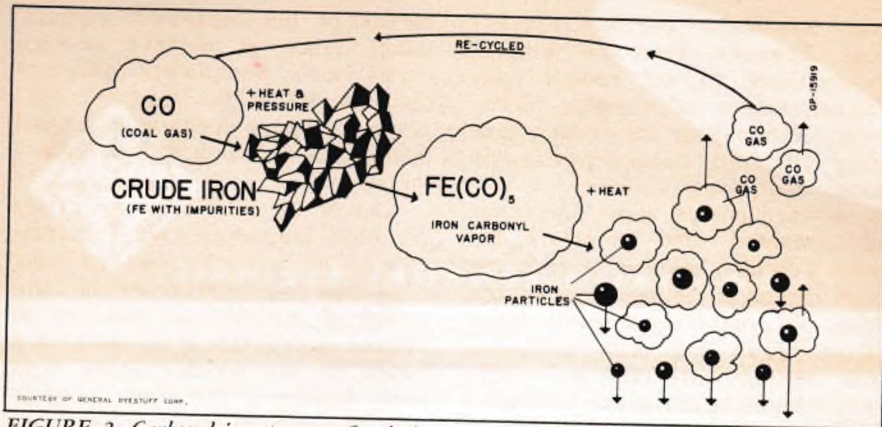


FIGURE 2. Carbonyl iron process. Crude iron is reacted with carbon monoxide to form iron pentacarbonyl. Upon further heating, the iron pentacarbonyl is decomposed forming minute spheres of almost pure iron.

When direct current flows in an iron cored coil, the iron is magnetized in the direction of the magnetic field. If the direction of the current is reversed, the magnetic field is reversed and the magnetization of the iron core is also reversed. However, the iron core will not reverse its magnetism without the expenditure of some energy. As the current in the coil changes, the magnetism of the iron lags somewhat behind the current. This lagging effect is called hysteresis and the energy expended in reversing the magnetism of the core is called hysteresis loss. At low frequencies, hysteresis loss is small in most core materials. It increases directly with frequency, however, and would become quite large at voice and carrier frequencies if special measures were not taken to reduce it.

A second effect, experienced with iron cored coils, is eddy current loss. Pure iron and most iron alloys are relatively good conductors of electricity. When they are used as the core materials for magnetic devices, currents are induced in them in the same manner as in the wire conductors. These currents circulate in the iron and dissipate energy in the form of heat. Eddy current losses increase with frequency at an even greater rate than hysteresis loss. Doubling the frequency multiplies the eddy current loss by four.

Reduction of Core Losses

An analysis of hysteresis and eddy currents will show that the losses from both sources can be reduced by the use of special core materials or by special core construction. In general, hysteresis loss can best be reduced by diluting a high permeability iron with a non-magnetic substance such as air or plastic. Eddy current losses can best be reduced by increasing the resistance of the eddy current paths.

A common method of diluting high permeability iron is the introduction of an air-gap into the magnetic path. The air-gap reduces hysteresis loss, but has very little effect on the eddy current losses. Eddy current losses are more effectively reduced by laminating the core with thin insulated sheets of iron. The sheets are oriented such that the eddy currents are forced to flow perpendicular to the long dimension of the sheet. Laminated cores can be made suitable for frequencies of several thousand cycles per second. For higher carrier frequencies, however, even the thinnest laminations do not reduce eddy current losses sufficiently. Moreover, laminating the core does very little to reduce hysteresis loss.

At frequencies above the range of laminated core materials, the most common method of reducing core losses is the use of powdered iron. By combining different types of powdered iron with insulating and binding materials, many different types of cores can be manufactured by simple cold pressure molding. Powdered iron cores offer the best solution for hysteresis and eddy current losses at high frequencies. By combining the powdered iron with insulating and binding materials, a core is produced that has many thousands of tiny air-gaps. These air-gaps, though reducing the permeability, also reduce the hysteresis loss. In addition, each of the particles of iron in the core is surrounded with a coating of insulation that impedes the flow of eddy currents and reduces loss from this source.

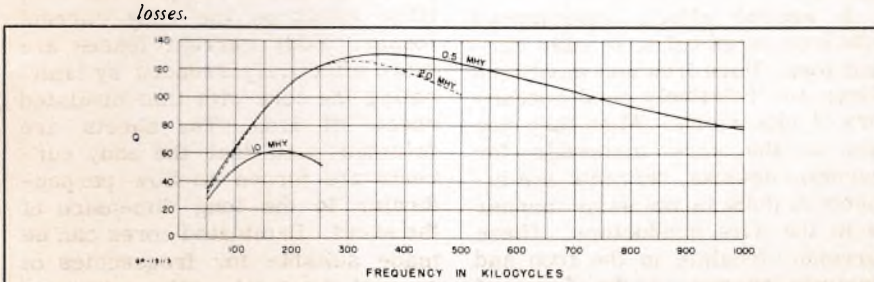
Carbonyl Powdered Iron

The type of iron powder used in different cores depends on the particular use of the magnetic device. Transformers and inductors for use over wide ranges of frequencies require a core that has low hysteresis and eddy current losses and does not cause distortion of the impressed signals. Other types of devices require cores with completely different characteristics; i.e., magnetic amplifiers require cores with special hysteresis and saturation characteristics.

One of the best core materials for high frequency carrier applications is carbonyl powered iron. This type of powdered iron is composed of microscopic spheres of almost pure iron. It is made in a range of six powder types with each having a different particle size or purity of iron. Three types have been selected for use in Lenkurt carrier. These three provide a wide range of characteristics suitable for most of the applications of powdered iron in carrier equipment. Figure 1 is a photomicrograph of particles of the carbonyl iron used in Lenkurt Type A powder. The average particle diameter of this particular type is 3 microns (millionths of an inch).

Carbonyl iron powders have been produced and used in the United States since about 1941. They are made by a unique process in which crude iron is heated in the presence of carbon monoxide gas. The iron and gas react to form another gaseous compound, iron pentacarbonyl. Further heating causes the iron pentacarbonyl to decompose forming almost pure iron and carbon monoxide gas. The iron precipitates from the cloud of gas in much the same

FIGURE 3. Typical Q curves of a Lenkurt miniature toroidal coil with carbonyl iron core. The decrease in Q with increase in inductance is caused by increased winding losses.



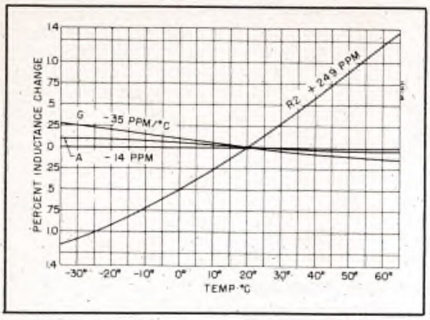


FIGURE 4. Lenkurt Type A and Type G powders are very stable over a wide range of temperatures. Type R2 exchanges some temperature stability for higher permeability.

manner as rain falls from a cloud of water vapor. The spherical droplets of iron are microscopic, ranging from about one-half to 40 microns in diameter. Size is controlled by variations in the manufacturing process. Normally, the particles contain from one to two percent carbon. For higher purity, the powder is heated in an atmosphere of hydrogen gas which reduces the carbon content to less than 0.2 percent. Figure 2 illustrates the process of producing carbonyl iron powder.

Properties

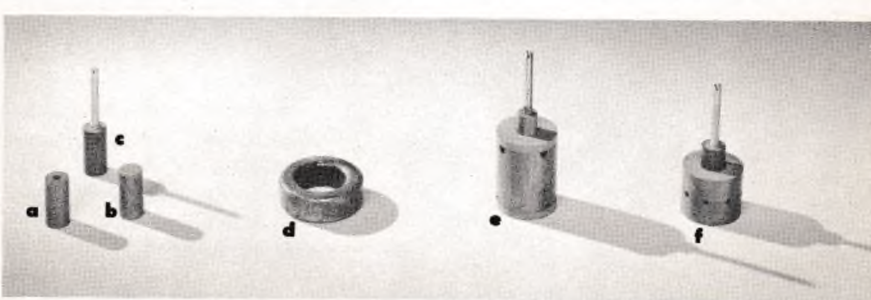
Cores made from carbonyl iron have several properties that make them desirable for high frequency carrier applications. These include: (1) low hysteresis and eddy current losses, (2) high "Q", and (3) excellent temperature and magnetic stability.

The exceptionally low hysteresis and eddy current losses of carbonyl iron cores can be attributed to the very small size of the individual iron particles and to their spherical shape. The small particle size creates many tiny air gaps that reduce hysteresis and interrupt the flow of eddy currents. The spherical shape of the particles contributes to a more uniform layer of insulating material than is likely on the irregular particles of most other types of powdered iron. The lack of sharp edges also permits greater molding pressures without insulation rupture and short circuiting between particles.

The principle effect of hysteresis and eddy current losses in an iron core is a reduction of the "Q" of the coil surrounding the core. "Q" is a figure of merit used to determine the behavior of a coil in a resonant circuit. In general, coils with higher "Q" are better for sharply resonant circuits such as filters and oscillators. Figure 3 is a graph of the values of "Q" obtainable with a miniature Lenkurt toroidal carbonyl powdered iron core of less than 0.7-inch outside diameter.

Temperature changes, humidity, magnetic shock, and aging have little effect on the characteristics of carbonyl iron. Figure 4 shows

FIGURE 5. Typical carbonyl iron cores manufactured for Lenkurt carrier equipment: (a) bob core, (b) plain core, (c) tuning core, (d) toroidal core, (e) pot core, and (f) cup core.



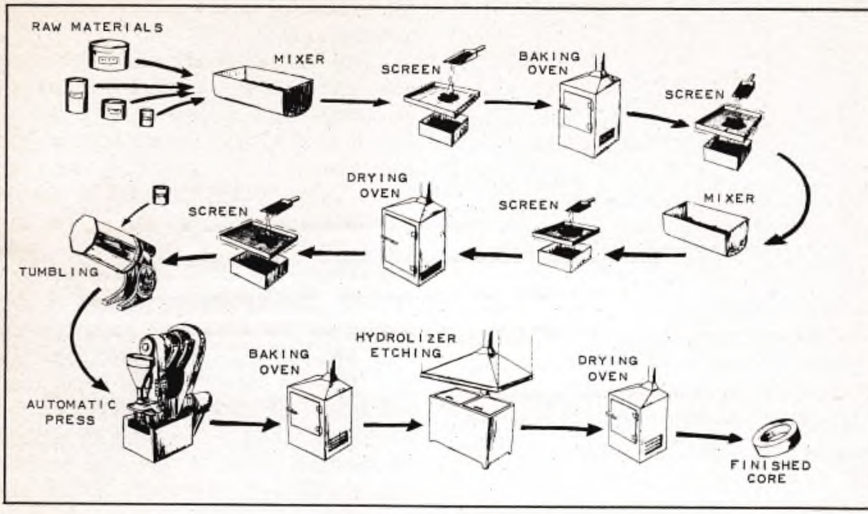


FIGURE 6. Basic process of manufacturing powdered iron cores. Each step is carefully controlled to insure unformity and peak performance.

the effect of temperature change on inductance for several different powder types.

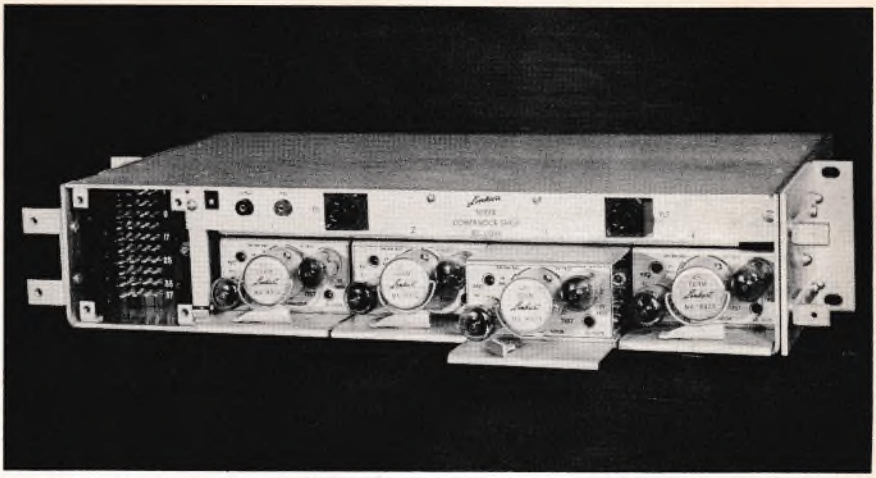
Lenkurt carbonyl iron cores are made in a wide variety of types and sizes for many different applications. Figure 5 shows several different kinds used in Lenkurt carrier equipment or made by Lenkurt for other manufacturers. Each kind is available in several different sizes and three different powder types. The three powder types are designated Type A, Type G, and Type R2.

Type A has the smallest particle size (3 microns average) and is suitable for use up to 200 megacycles. It is especially stable and causes very little modulation distortion. Type G is almost as good as Type A. It has slightly larger particles (8 microns) and is excellent for frequencies up to about 5 megacycles. It is less expensive than Type A. For low frequency applications up to 200 kc and where some loss can be tolerated, Type R2 core material is ideal. Type R2 powder is a hydrogen treated (reduced) powder of exceptional purity. It has very high permeability which permits large values of inductance with few turns and small core size.

Almost as important as the type of powder used in a core is the care and technique used in the core manufacture. At Lenkurt, carbonyl iron cores are made under carefully controlled conditions so that they will be uniform within each lot and so that cores from different lots will be essentially identical. Figure 6 illustrates schematically the process of making carbonyl iron cores.

Conclusions

The use of carbonyl powdered iron cores to obtain wide frequency response has been of great value in the design and manufacture of Lenkurt's modern carrier equipment. In a comparison made between equivalent air-cored and carbonyl iron-cored coils, the iron-cored coils generally weighed one-third less than the air-cored coils, occupied less than 20 percent of their volume, and required 60 percent less wire. In addition, the "Q" of the iron-cored coils was 170 percent greater.



New Type 5090B compandors in improved Type 5083B shelf assembly.

AN IMPROVED COMPANDOR

For General Purpose Use

Several recent articles in the Lenkurt Demodulator have pointed out the value of the compandor for the economical control of noise and crosstalk. Recently, a new model of Lenkurt's compandor unit and an improved mounting shelf have been designed to make the application of compandors even simpler and more practical than in the past. Several new features have been added to simplify installation and maintenance, and to improve operation under certain adverse operating conditions. Compandors are used to improve the signal-to-noise ratio of both physical and carrier derived circuits.

Basically, the compandor is a two-unit device consisting of a volume compressor at the transmitting end of a circuit and a volume expandor at the receiving end. The compressor reduces the intensity range of speech signals by a fixed ratio and the expandor expands the received signals by the same ratio to restore the speech to normal. Both the compressor and expandor are nonlinear devices with gain or loss at any time dependant on the intensity of the input signal. Figure 1 is a block diagram of a complete compandor circuit. (A complete discussion of compandor principles was in the March 1953 issue of the Demodulator.)

A compandor does two things to reduce the effect of noise and crosstalk. First, it raises the average level of transmitted speech by several decibels. This produces some signal-to-noise ratio improvement, depending on the volume and intensity range of the talker. Second, it greatly reduces the gain of the circuit when signals are not present; i.e., between syllables and words of speech. This action silences noise between syllables and words, thus improving articulation. The combination of these two actions reduces the interfering effect of noise and crosstalk by about 22 db for the average circuit and talker.

Application

Application of the compandor is not limited to carrier systems. Other types of speech transmission can also make effective use of this device. To facilitate the application of compandors under many different conditions, the new models of Lenkurt compandors have been designed so that any one of three d-c voltages can be used for the plate voltage supply. A simple strapping arrangement on the compandor shelf permits office voltages of 130, 154, or 200 volts to be used by any compandor shelf.

In addition to a new arrangement for connecting the compandor shelf to different battery voltages, other improvements in the new model compandor and mounting shelf include an electrically balanced output circuit, a better arrangement of fuses, and a more accessible filament voltage adjustment. In the previous model compandor, the circuits on the carrier or line side were electrically unbalanced.

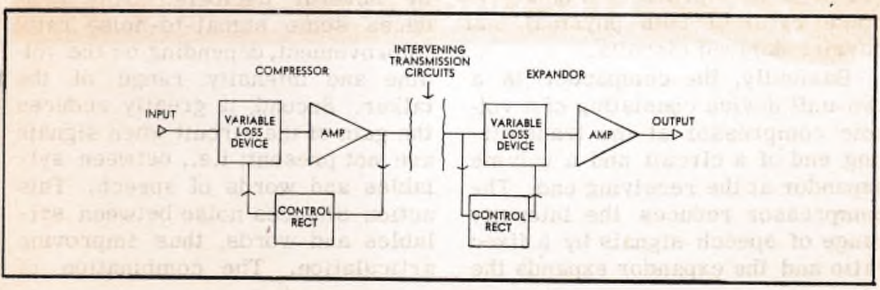
When the compandor was located a considerable distance from the carrier terminal, it was necessary to use external repeating coils in the wire pairs from the compressor and expandor to the carrier terminal to avoid crosstalk. This crosstalk was caused by coupling between ground current loops of the compandor circuit and other intra-office wiring. In the new model, an improved output transformer for the compressor and an improved input transformer arrangement for the expandor provide good electrical balance that eliminates ground current loops.

The fusing arrangement of the new mounting shelf uses Western Electric 70-Type plug-in fuses that can be replaced more quickly and easily than the previous 'grasshopper' type which required a screwdriver.

An improved filament voltage adjustment consists of a potentiometer and two test jacks mounted on the front of the compandor shelf. Previous models of the compandor shelf provided an adjustable slidewire resistor which, though adequate, was not readily accessible.

The new model compandor provides the same large improvement in signal-to-noise ratio as its predecessor. It permits the operation of carrier channels over facilities that would otherwise be unsuitable. With the several physical and electrical improvements that have been incorporated in the new model compandor unit and new mounting shelf, installation and maintenance have been simplified and operation of the compandor remote from the carrier equipment has been greatly improved.

FIGURE 1. Block diagram of a compandor. Both compressor and expandor consist of a variable loss device, an amplifier, and a control rectifier.



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Factory Service Available

The facilities of the Lenkurt Factory Service Departments at both San Carlos, California and Vancouver, British Columbia are available to users of Lenkurt carrier and radio equipment. These new departments have been established to provide (1) fast repair service for all Lenkurt carrier and radio equipment and (2) rapid replacement of the various plug-in units of Lenkurt's miniaturized 45-class carrier equipment. Replacement units will normally be shipped within 24 hours after receipt of an order.

More detailed information on Lenkurt's new repair and replacement services is contained in **Product Information Letter No. 15.** Copies are available from your distributor.

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