

Dec. 17, 1929.

G. W. ELMEN

1,739,752

MAGNETIC MATERIAL AND APPLIANCE

Filed Dec. 28, 1927

4 Sheets-Sheet 1

FIG. 1.

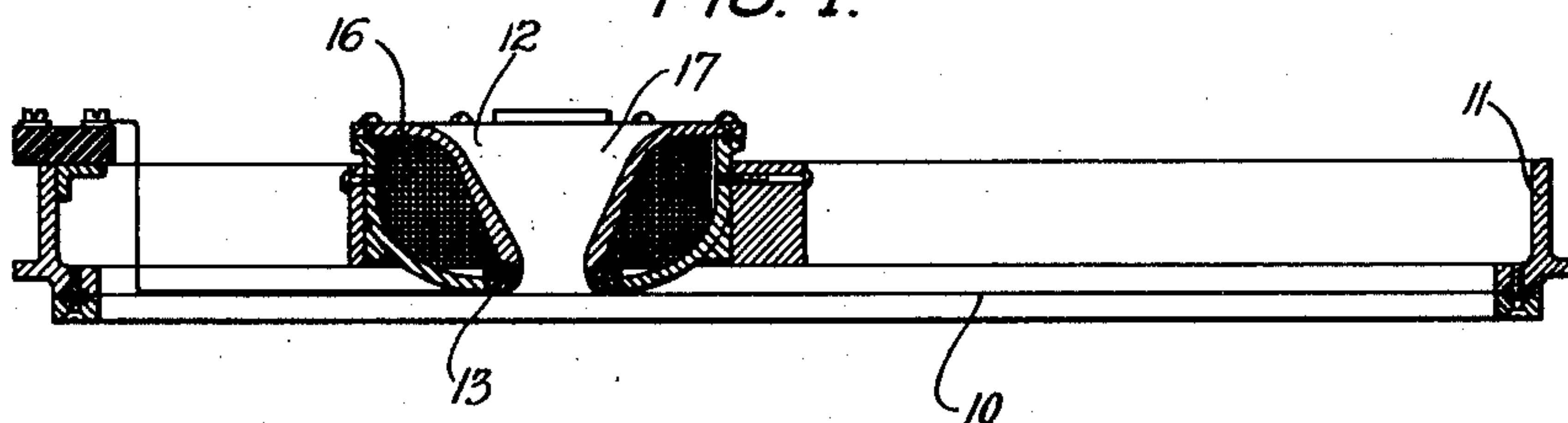


FIG. 2.

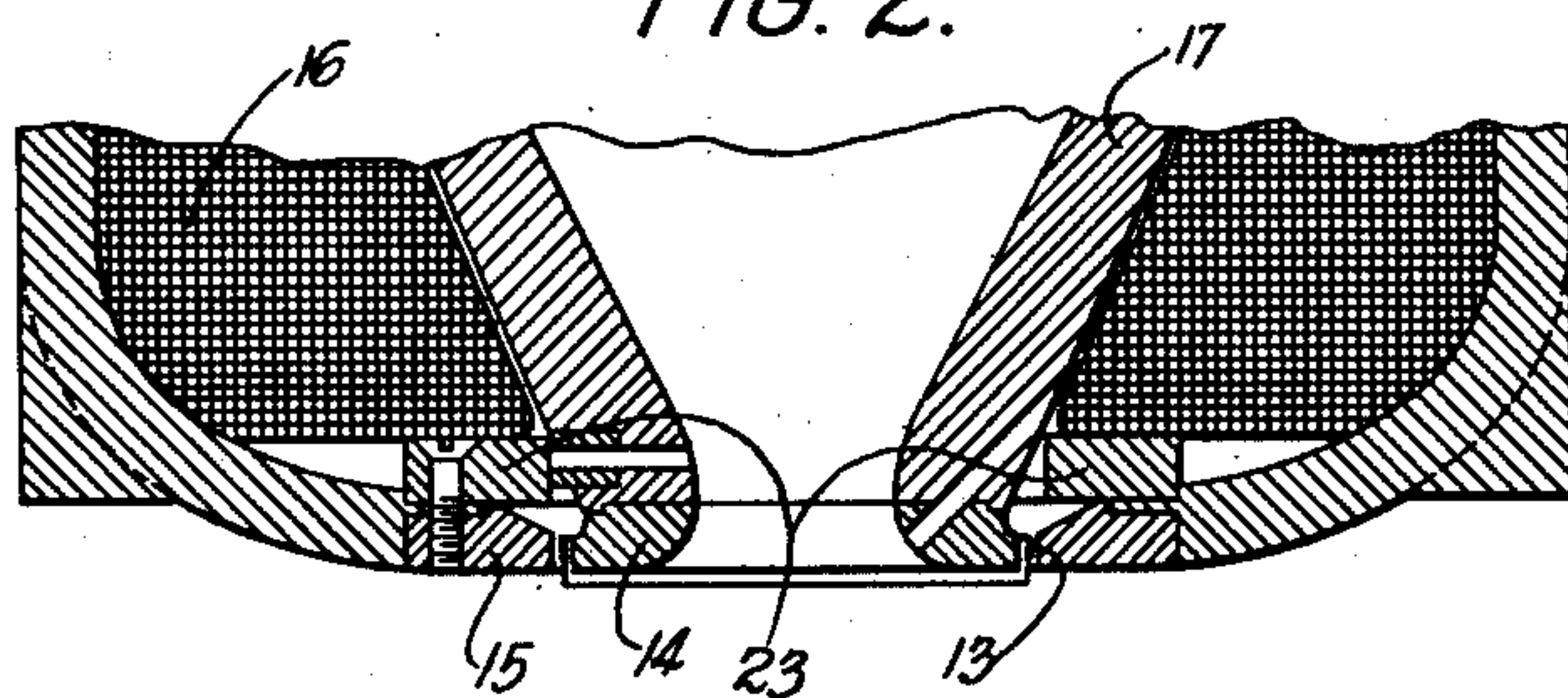


FIG. 3.

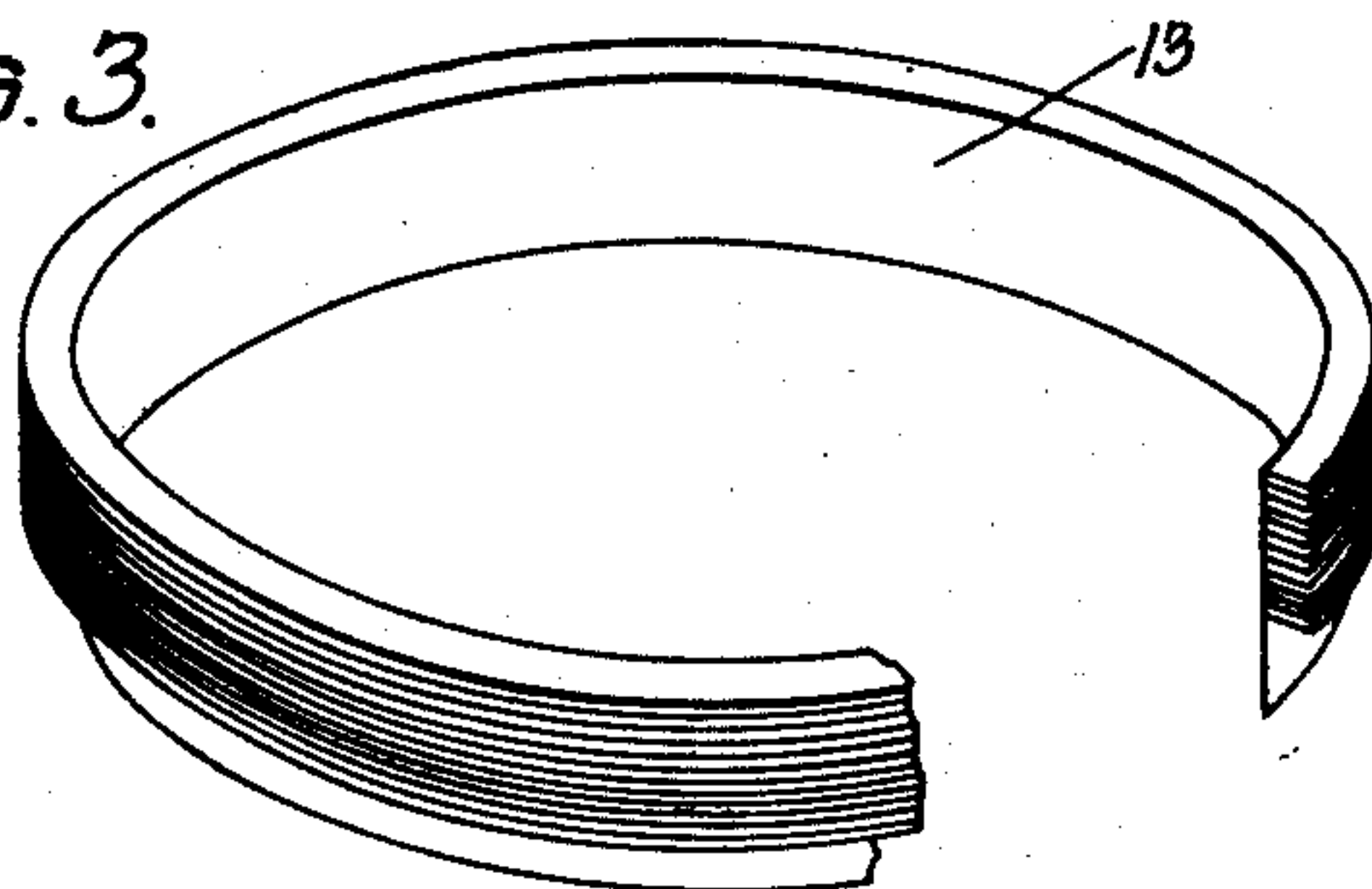


FIG. 4.

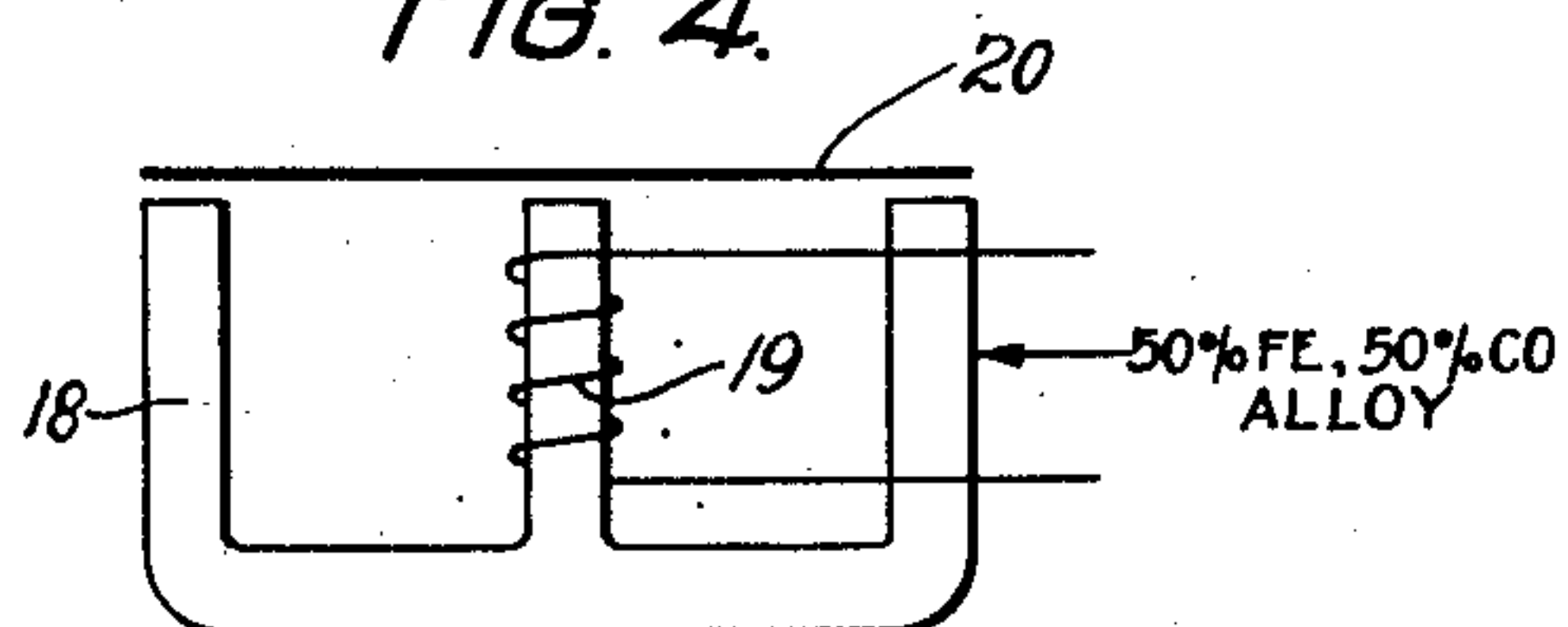
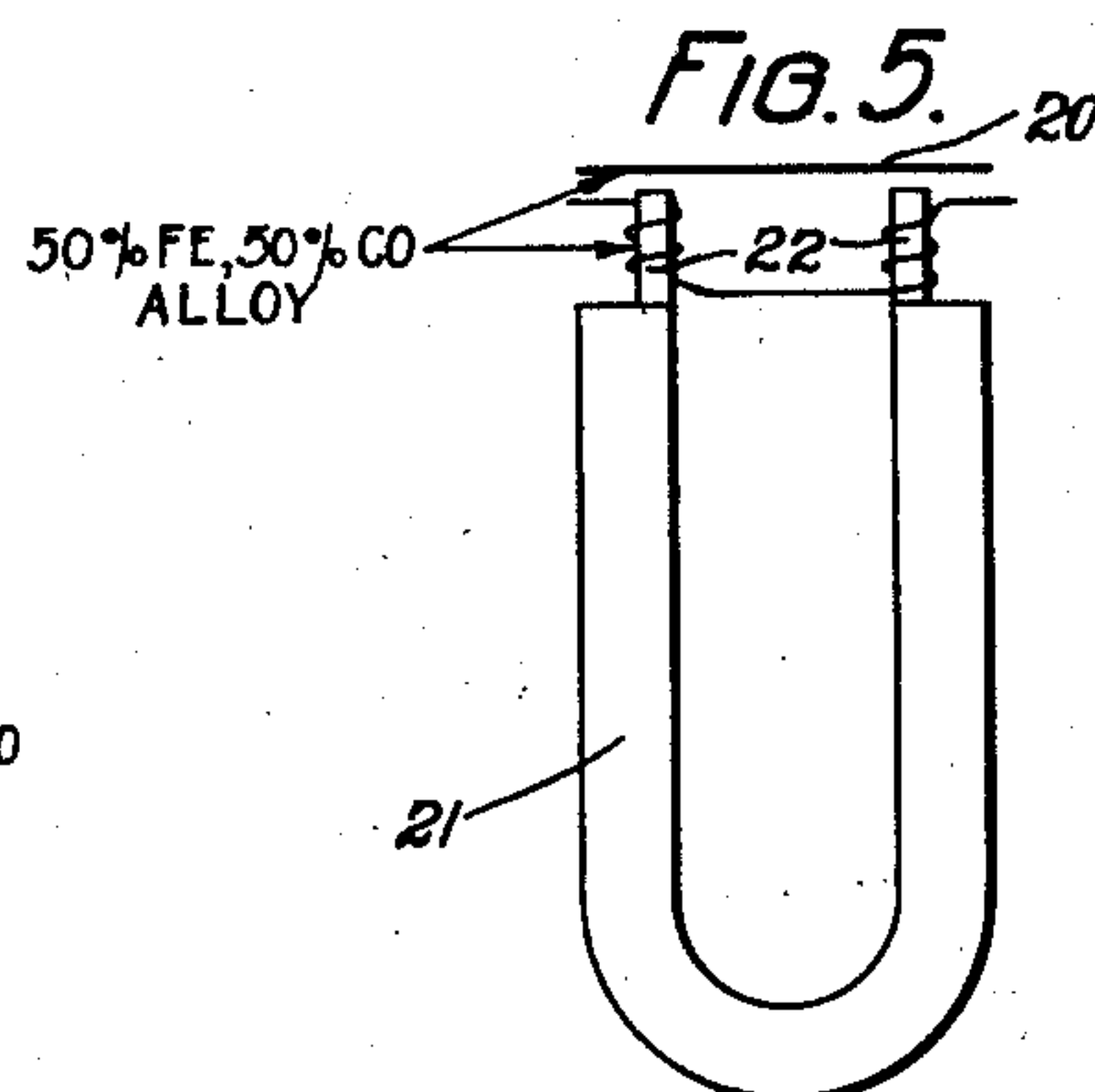


FIG. 5.



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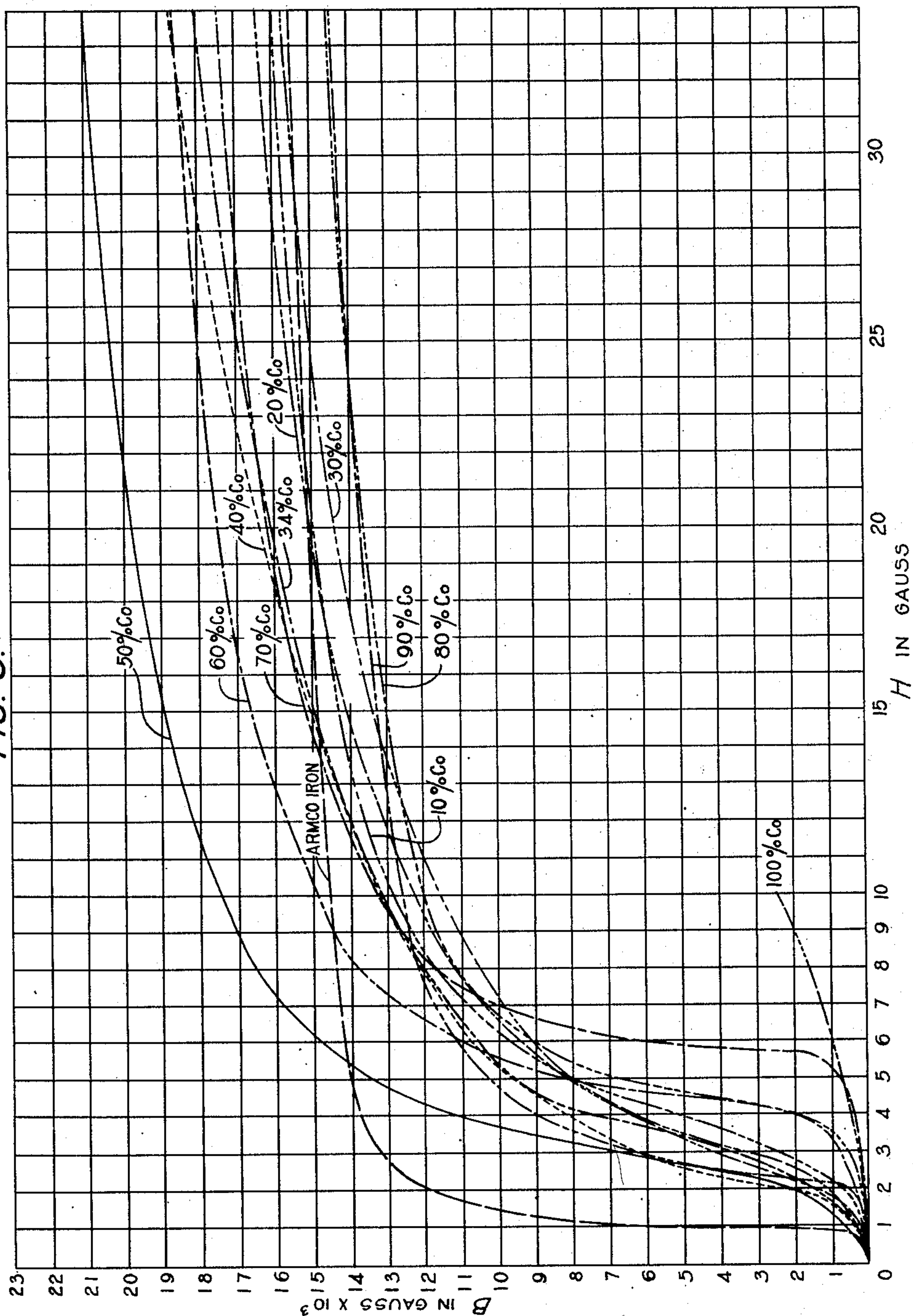
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4 Sheets-Sheet 2

FIG. 6.



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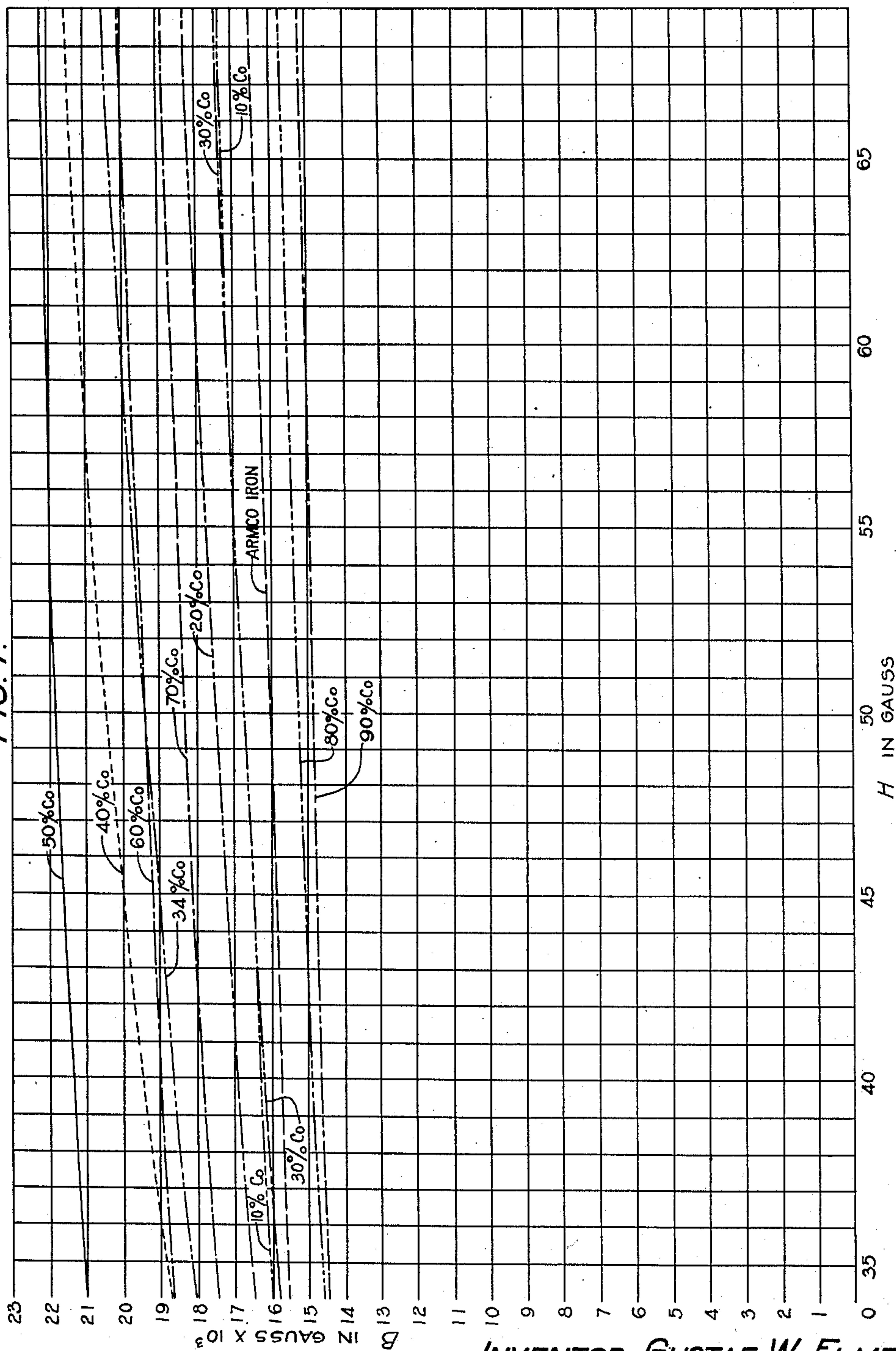
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MAGNETIC MATERIAL AND APPLIANCE

Filed Dec. 28, 1927

4 Sheets-Sheet 3

FIG. 7.



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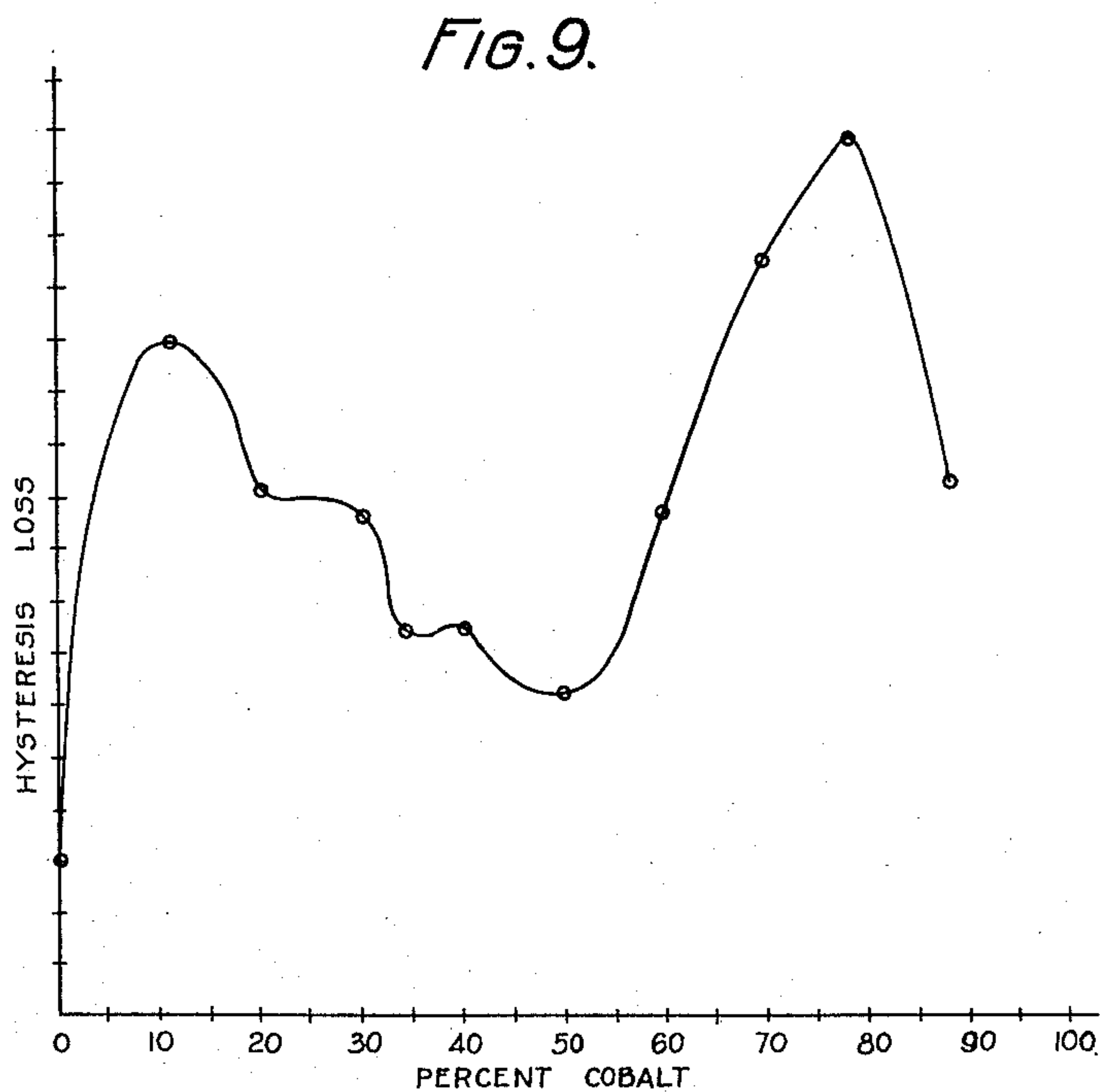
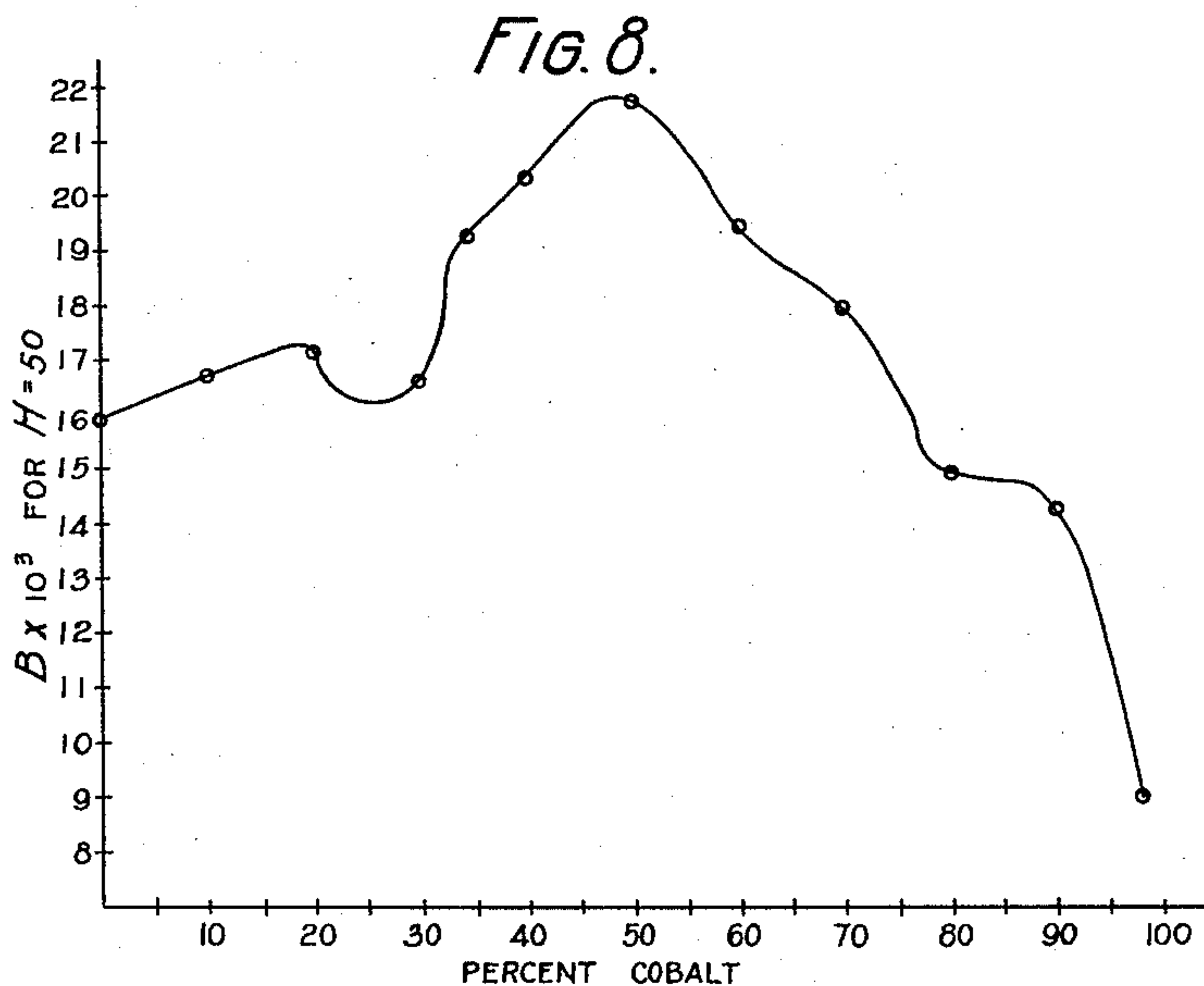
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MAGNETIC MATERIAL AND APPLIANCE

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4 Sheets-Sheet 4



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UNITED STATES PATENT OFFICE

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MAGNETIC MATERIAL AND APPLIANCE

Application filed December 28, 1927, Serial No. 243,008, and in Great Britain August 29, 1927.

This invention relates to magnetic alloys and has particular reference to magnetic alloys of high permeability.

A usual assumption is that among the magnetic alloys of iron and cobalt, those compositions having the approximate proportions of iron and cobalt represented by the chemical formula Fe_2Co , have the highest permeabilities in the range of magnetizing forces commonly described as moderate magnetizing forces, i. e., from 5 to 75 c. g. s. units. It has been found that alloys of iron and cobalt, having the proportions of 50% iron and 50% cobalt, have a permeability extremely high in the range of magnetizing forces from 5 to 75 c. g. s. units. Such alloys also exhibit very high flux densities at saturation. Alloys having from 40% to 60% iron and the rest cobalt exhibit similar properties.

In order to develop such properties the compositions are heat treated. A suitable heat treatment consists in maintaining the alloy at about 1100°C . for from two to three hours, followed by fairly slow cooling in the furnace. However, the heat treatment is not extremely critical and may be varied considerably with satisfactory results.

Magnetic compositions made from ordinary commercially pure iron and cobalt in the proportions of 50% iron and 50% cobalt heat treated at atmospheric pressure and in ordinary air have been prepared and found to have a flux density of about 17,400, 21,700, and 22,000 gauss at magnetizing forces of 10, 50 and 70 gauss respectively. Furthermore, at low magnetizing forces up to $H=.7$, such a composition is found to have a higher permeability than Armco iron. In the range of magnetizing forces above about 5 gauss, the flux density is considerably greater than that of Armco iron and also considerably greater than that of magnetic compositions corresponding to the formula CoFe_2 . Although the flux densities herein given for compositions of approximately 50% iron and 50% cobalt are not much greater than those given in prior publications relating to the alloy CoFe_2 , it has been found that the high values of flux density published by others for the alloy CoFe_2 do not apply to ordinary com-

mercial materials heat treated without special precautions. With commercial materials and ordinary methods of heat treating the flux densities of compositions of 50% iron and 50% cobalt have been found to be considerably higher than those obtainable with compositions approximating the formula CoFe_2 . Tests also indicate that the maximum permeability, for any magnetizing force, of the iron-cobalt series has a peak at about 50% cobalt although, of course, this peak is lower than the maximum permeability of pure or almost pure iron. The flux density B for $H=50$ also reaches an absolute maximum for the iron-cobalt series at about 50% iron. Careful measurements also indicate that the initial permeability of iron and cobalt alloys is high at about 45 to 50% cobalt. By careful measurement, values of over 600 for the initial permeability, have been determined. An interesting fact also is that the hysteresis loss for $B=5000$ reaches a minimum for the iron-cobalt series at about 50% iron.

These discoveries meet with practical application in pole pieces for loud speaker magnets. In certain types of such apparatus it is desirable to produce very high flux densities across narrow gaps. By employing pole pieces consisting of 50% iron and 50% cobalt flux densities of the order of 27,000 gauss at the pole faces have been produced. These flux densities were produced by practically saturating the material. At magnetizing forces below those required for saturation, however, the flux densities produced are exceedingly high.

The magnetic compositions just described are also useful for electromagnetic receivers. In receivers employing permanent magnets the pole pieces alone may be made of iron-cobalt compositions such as herein described. When non-permanent electromagnets are employed the entire core structure may be made of the iron-cobalt magnetic composition. The diaphragm also may advantageously be made of iron-cobalt alloys of high permeability having between 40 and 60% iron.

These materials are of general utility in heavy duty relays, and similar apparatus,

particularly in cases where excessively high magnetizing forces are not desirable. Such relays, for example, are commonly employed in dial or machine switching telephone systems.

The mode of application of high permeability cobalt-iron alloys to structures such as described above is indicated more definitely by reference to the accompanying drawings in which:

Fig. 1 is a cross-section of a loud speaker diaphragm and its driving magnet;

Fig. 2 is a detailed cross-section of a part of the magnet structure;

Fig. 3 illustrates the coil which is to be attached to the diaphragm on an enlarged scale;

Fig. 4 represents an electromagnetic receiver;

Fig. 5 represents a permanent magnet receiver; and

Fig. 6 is a graph of flux density B against magnetizing force H of a number of iron-cobalt alloys for flux densities from zero to 34 gauss, the percentage of cobalt being indicated on each curve;

Fig. 7 is an extension to $H=69$ of the curves of Fig. 6;

Fig. 8 is a smooth curve drawn through various points determined by plotting flux densities B , for $H=50$, gauss of various iron-cobalt alloys; and

Fig. 9 is a similar smooth curve in which hysteresis losses in ergs per cu. cm. per cycle at a maximum induction of $B=5000$ are plotted for various iron-cobalt alloys.

Referring particularly to Fig. 1, the diaphragm 10 is supported under tension by the frame 11. The electrodynamic unit 12 is supported by the cross members of the frame. The coil 13 of the electrodynamic unit is secured to the diaphragm to drive it. The coil 13 is positioned between the annular pole faces 14 and 15 of the magnetic structure. The polarizing winding 16 is positioned within and substantially fills the hollow magnetic structure. The brass ring 23 serves to support the winding. The main body 17 of the magnet structure may consist of any suitable magnetic material. The pole pieces 14 and 15, more particularly illustrated in Fig. 2, are annular and are constructed of high permeability cobalt-iron alloy having about 50% iron. The annular gap between the pole pieces is made very small. The coil 13 is made of a thin ribbon conductor preferably of copper and of the order of .002" thick and .014" wide, wound so that the plane of the ribbon is perpendicular to the axis of the coil. The adjacent turns of the ribbon conductor are insulated from each other by "bakelite". This is applied by dissolving the bakelite in acetone and then drying the coil after the conductor is applied.

The coil 13 with a part broken away is illustrated in Fig. 3 on a still more enlarged scale.

In such arrangements, flux densities of the order of 27,000 gauss have been observed at the pole faces. Such high flux densities exceed those which it has been found possible to produce in such apparatus with previously used magnetic materials and hence increase the effectiveness of the loud speaker device. Flux densities of 22,000 are attained at a magnetizing force of $H=60$. This latter represents a practical operating condition.

Fig. 4 represents an electromagnetic receiver in which the magnetic core 18 consists of a body of material having about 50% iron and 50% cobalt heat treated to have high permeability. The winding 19 is applied in the usual manner. The diaphragm 20 may also advantageously be constructed of a magnetic material of 50% iron and 50% cobalt.

In Fig. 5, which represents a receiver having a permanent magnet, the permanent magnet 21 may consist of any suitable magnetic material. The core portions 22 to which the magnetizing windings are applied consist of high permeability cobalt-iron alloys attached to the permanent magnet in any suitable manner. The diaphragm 20 may also advantageously be composed of an alloy similar to that of the cores 22.

The data given hereinafter is taken from tests on specimens all of which were given approximately the heat treatment mentioned in the early part of this specification although no unusual precautions were taken to make the treatments identical.

Figs. 6 and 7 are graphs based upon carefully compiled experimental data. It will be seen that an alloy of as nearly 50% iron-50% cobalt as was practicable to prepare had a flux density above 34% cobalt over practically the entire range of magnetizing forces for which measurements are indicated. At $H=10$ the flux for the 50% composition is about 30% higher than for the 34% cobalt composition. At $H=5.5$ to above $H=69$ the 50% composition has a greater flux density than iron. The same statements apply for compositions in the immediate region of 50% cobalt. At 60% cobalt and 40% cobalt it will be seen that the superiority of the compositions with respect to both 34% Co-66% Fe and pure iron is less marked and applies to a lesser portion of the range of magnetizing forces. The magnetizing curve of 50% Co-50% Fe remains above those of pure iron and 34% Co-66% Fe until magnetizing forces of several hundred gauss are reached.

Fig. 8 serves to show graphically that the flux density for $H=50$ is decidedly greater for 50% Co-50% Fe than for any other tested member of the iron-cobalt series from pure iron to almost pure cobalt.

Fig. 9 indicates a decided hysteresis minimum in the iron-cobalt series at 50% Fe-50% Co for a flux density of 5,000 gauss. On this curve a few points were calculated by means

of Steinmetz' formula, from hysteresis cycles taken at slightly greater flux densities. The results are no doubt quite close to those which would be obtained by using the same maximum flux density in each instance.

The following figures on initial permeabilities of the iron-cobalt series were determined experimentally:

Composition % Co	μ
0	250
10	170
20	190
30	250
34	300
40	450
50	635
60	135
69	75
78	100
88	90

A decided peak at 50% cobalt is evident. This indicates that the material may be better than iron for technical applications involving the employment of magnetizing forces of very low value, i. e. in the neighborhood of $H=0$, for example, in continuous loading of signaling conductors.

What is claimed is:

1. A magnetic composition comprising between 40 and 60% cobalt and the balance iron having a permeability above that of Armco iron at a corresponding magnetizing force.
2. A magnetic composition comprising approximately 50% iron and approximately 50% cobalt heat treated to have a permeability higher than that of Armco iron at a corresponding magnetizing force.
3. An electromagnetic apparatus such as a loud speaker, telephone receiver or heavy duty relay, having a magnetic circuit consisting in whole or part, and preferably in a part adjacent an air-gap, of a magnetic composition consisting of 40 to 60% cobalt and the balance iron.

In witness whereof, I hereunto subscribe my name this 21st day of December, 1927.

GUSTAF W. ELMEN.

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