United States Patent [19]

Reid

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[54] **METHOD OF MAKING MAGNETS**

[75] Inventor: **William R. Reid,** Wollaston, Mass.

[73] Assignee: **Raytheon Company,** Lexington, Mass.

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[52] **U.S. Cl.** **148/108;** 29/608; 148/105; 264/24; 264/319

[51] **Int. Cl.²** **C21D 1/04**

[58] **Field of Search** .... 148/101, 103, 105, 108; 264/24, 319, DIG. 58; 29/608, 604, 580, 530, DIG. 31

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Primary Examiner—Walter R. Satterfield
Attorney, Agent, or Firm—Harold A. Murphy; Joseph D. Pannone; John T. Meaney

[57] **ABSTRACT**

A method of making magnets of small size which comprises depositing magnet material in apertures of controlled size in a sheet of material of desired thickness, applying electromagnetic forces to magnetically orient the particles of magnet material, applying pressure to the deposits of magnet material to produce densification thereof, and sintering.

1 Claim, 7 Drawing Figures

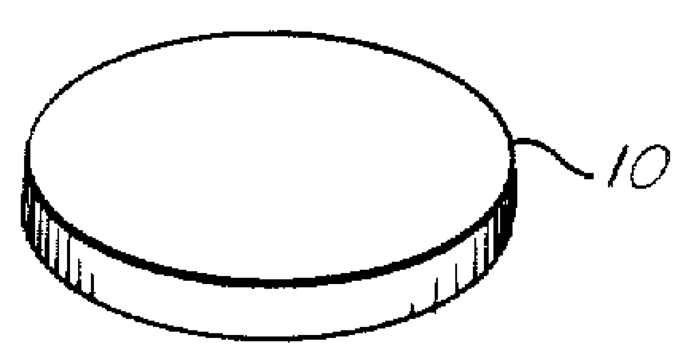

FIG. 1

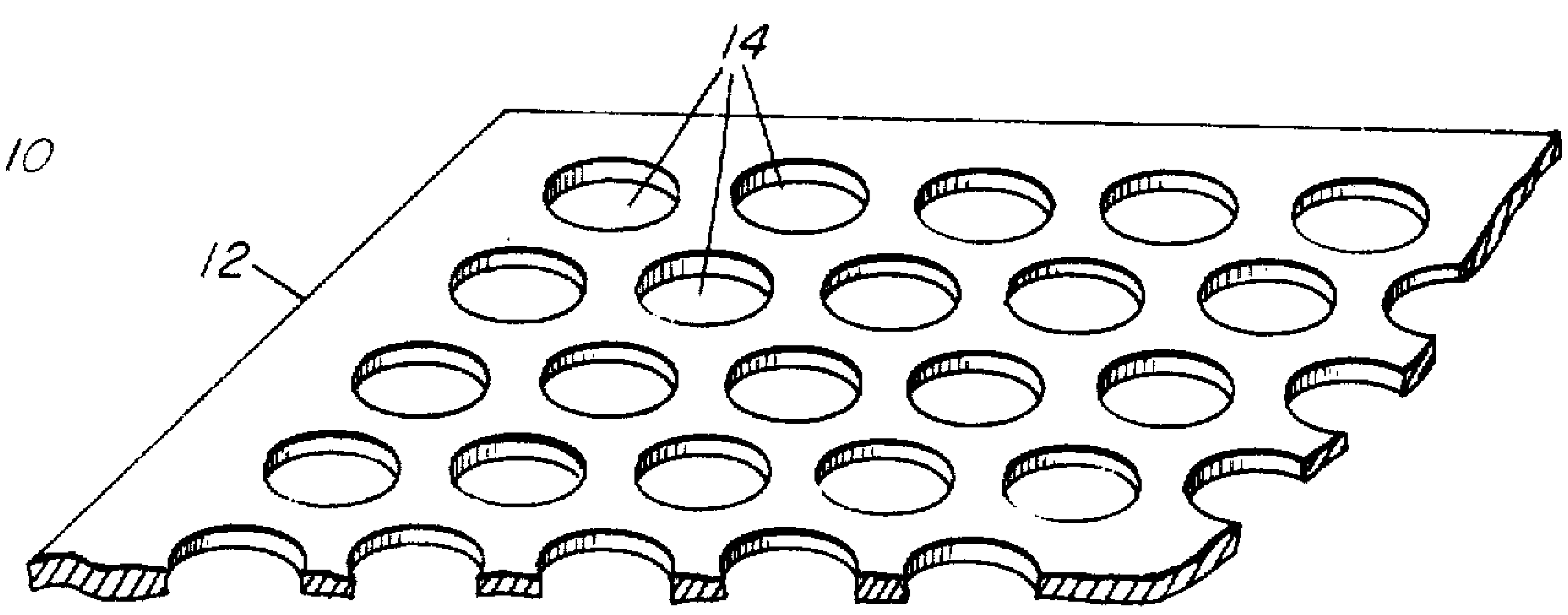

FIG. 2

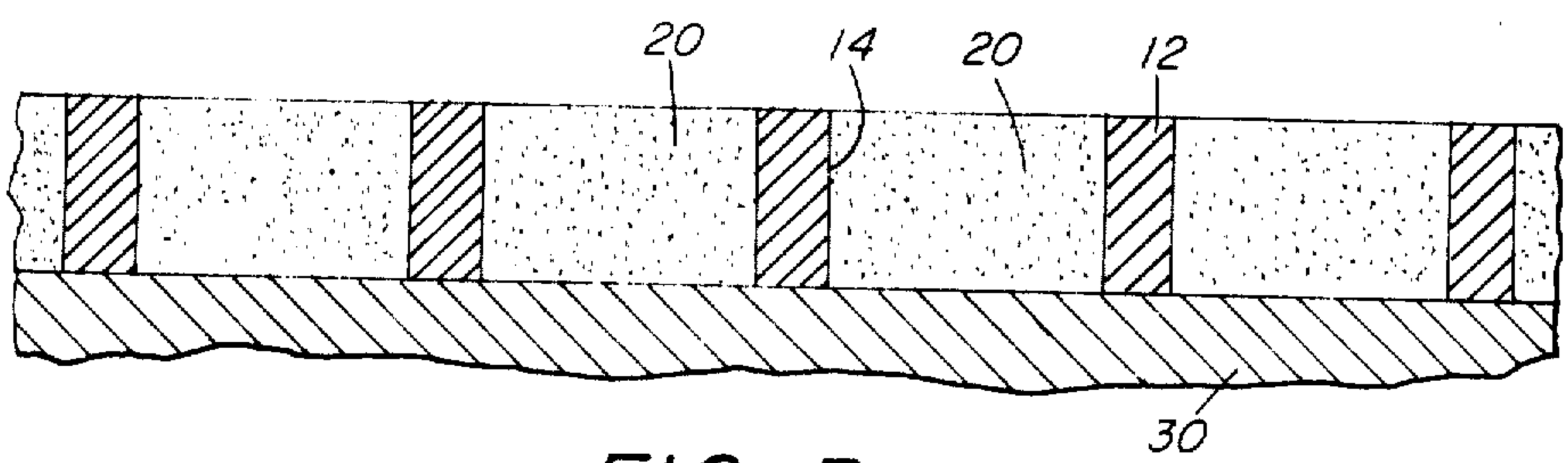

FIG. 3

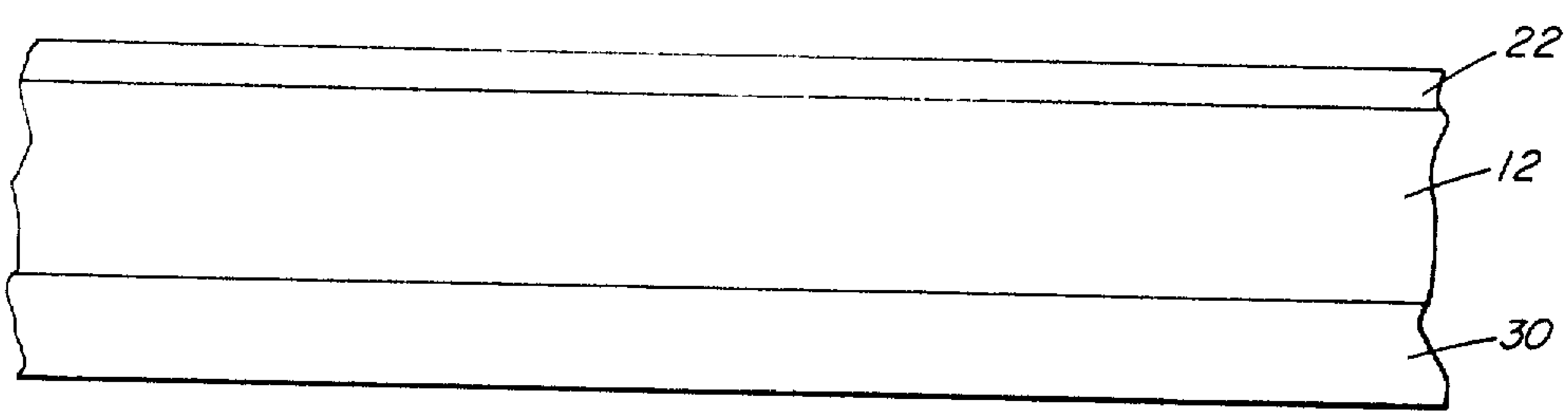

FIG. 4

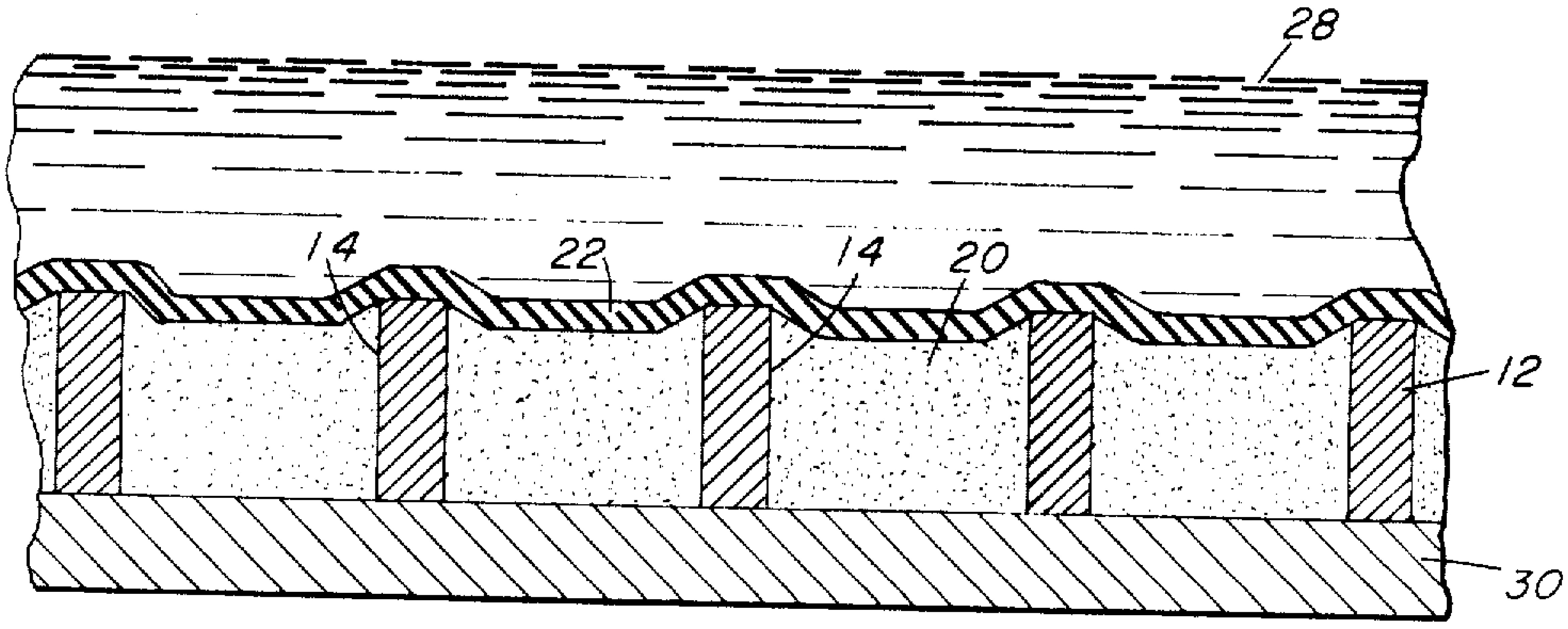

FIG. 5

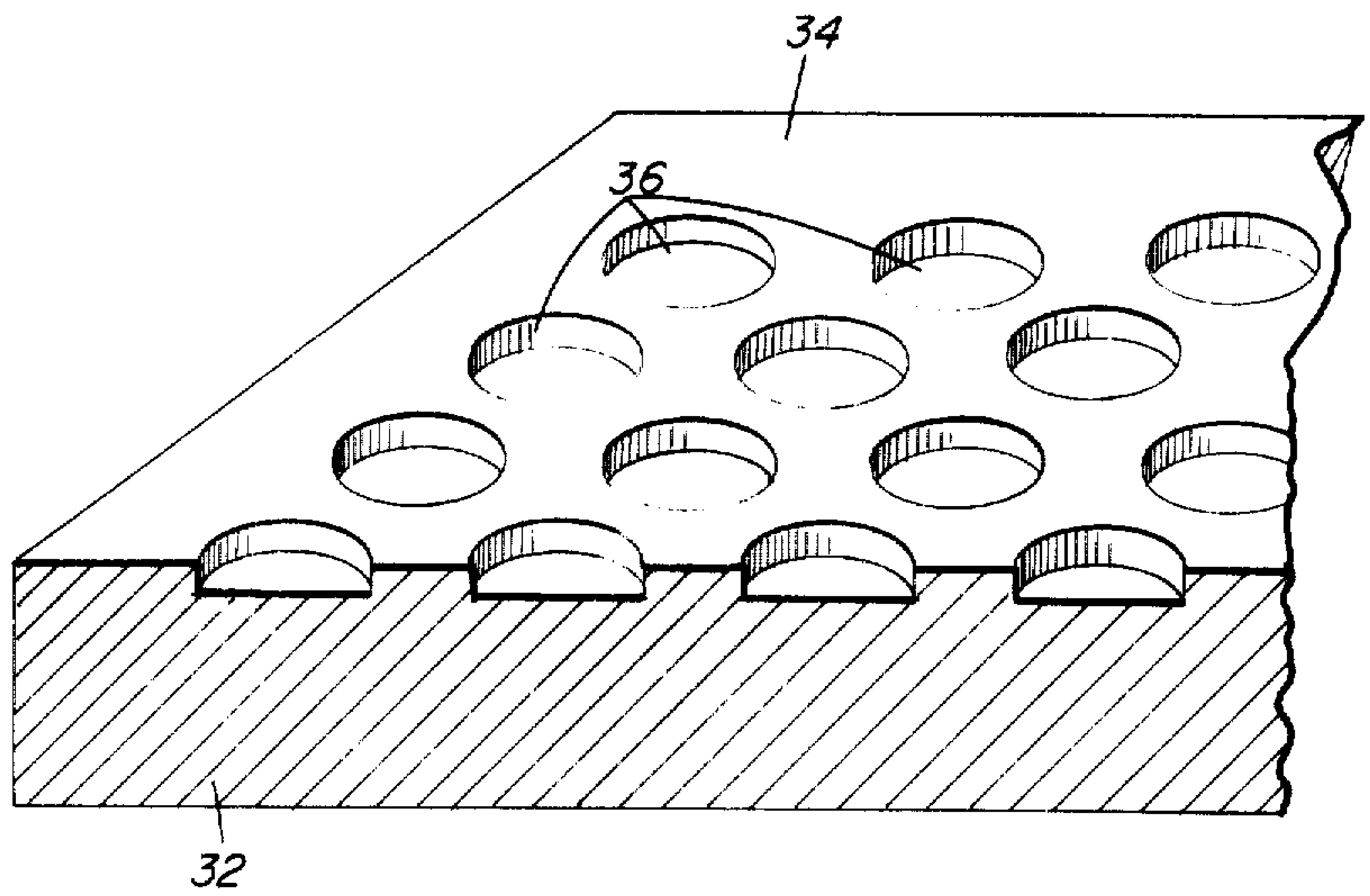

FIG. 7

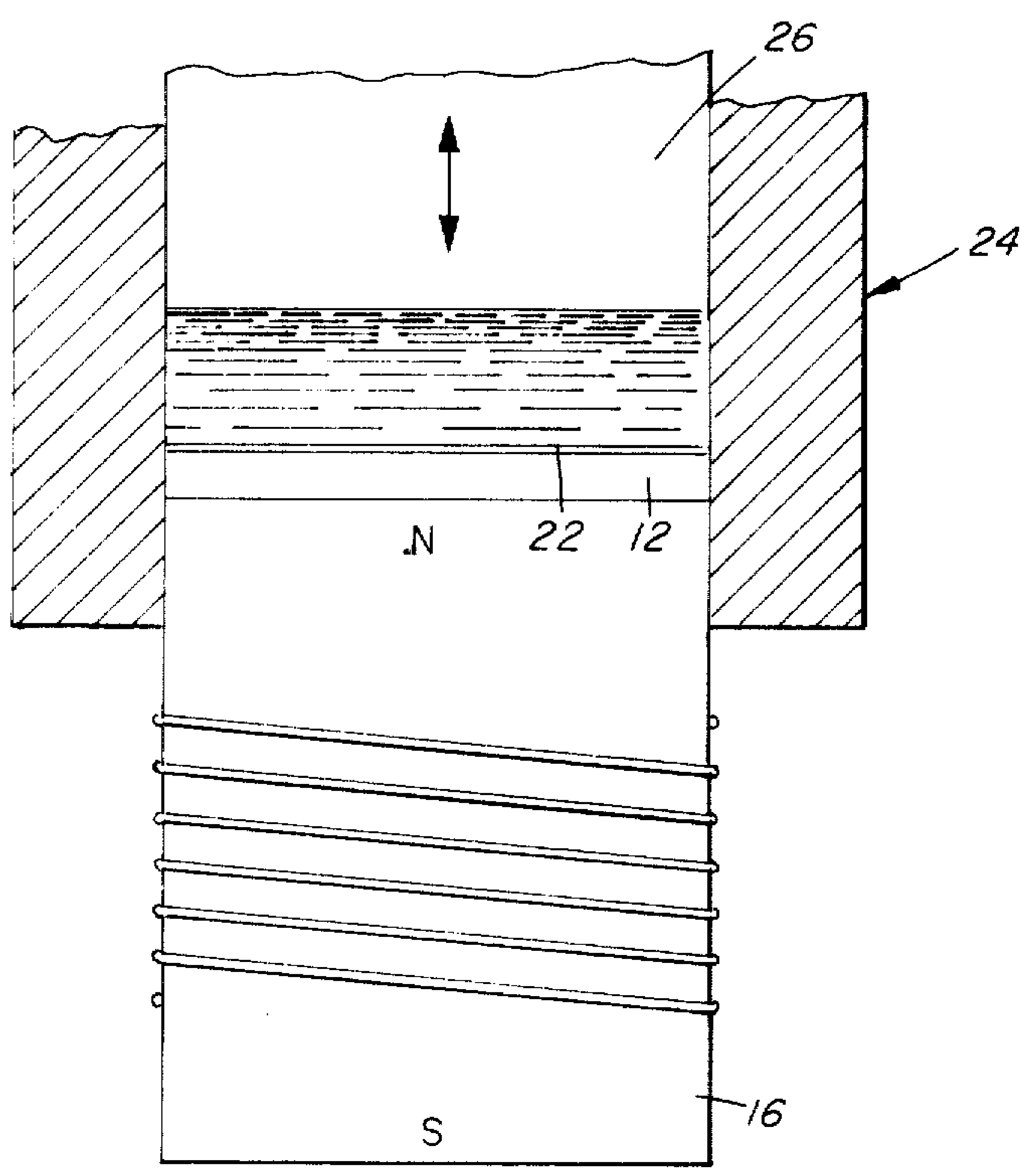

FIG. 6

METHOD OF MAKING MAGNETS

BACKGROUND OF THE INVENTION

In the production of magnets, it has been found very difficult and expensive to produce small magnets or micromagnets in large quantities and of relatively uniform size. It will be understood that in the manufacture of devices such as hearing aids, timepieces, reed switches and magnetic pickups, for example, that the magnets in the devices should be not only of satisfactory quality but also should be consistently of desired relatively uniform sizes and shapes. In many cases it has been the practice to produce small magnets by first making large magnets by conventional methods and subsequently cutting or breaking up the large magnets into the micromagnets of desired sizes and shapes. In addition to the initial fabrication expense and effort involved in initially making the large magnets, there also is incurred the added expense and effort in reducing the large magnets to micro sizes, thereby increasing the overall production costs to unwarranted levels. Furthermore, such methods often preclude the possibility of producing large quantities of micromagnets which are relatively uniform in size and shape.

SUMMARY OF THE INVENTION

The above and other disadvantages of prior art methods or processes for making small magnets are overcome in the method of the present invention by the hereinafter described process steps which include first the production of a support having therein a relatively large number of apertures or cavities of a size and shape conforming substantially to the diameter and shape of the magnets to be produced. The support is of a material which will be compatible with the magnet materials to be subsequently utilized, that is, it should be of a material which will not contaminate the magnet materials during subsequent heat cycles.

This support is disposed upon a suitable flat surface such as one end surface of an electromagnet. At this time the apertures or cavities in the support are filled with particles of the selected magnet powder. With the electromagnet on, the powder particles will become automatically magnetically oriented. The deposits of powder are then compacted and densified in any appropriate manner. If relatively low density is required such compaction may be achieved by means such as squeegee pressure. For high density magnets compaction may be achieved as by, for example, covering the surface or surfaces of the support with a selected thin sheet or film of flexible material such as rubber or plastic and then applying fluid to the film under pressure in a suitable device such as a hydraulic, hydrostatic or isostatic apparatus. Pressure upon the film will be translated to the magnet powder deposits whereupon they will be compacted and densified as desired.

The support may then be transferred into a sintering furnace where heat is applied in the known manner. After sintering the resultant magnets will be easily removable from the support. Such magnets produced in this manner have been found to be relatively uniform in size, shape and other characteristics.

BRIEF DESCRIPTION OF THE DRAWINGS

Other objects and advantages of the invention will become apparent from the following description taken in connection with the accompanying drawings, wherein:

FIG. 1 is an isometric view of a magnet produced by the method of this invention;

FIG. 2 is an enlarged fragmentary isometric view partly in section of one type of magnet support utilized in this invention;

FIG. 3 is an enlarged sectional view of the support shown in FIG. 2 with associated elements used during a process of magnet manufacture;

FIG. 4 is an enlarged fragmentary side view of assembled elements of the apparatus;

FIG. 5 is an enlarged fragmentary sectional view illustrating a step in the method of the invention;

FIG. 6 is a diagrammatic illustration of one form of magnet powder compaction apparatus; and

FIG. 7 is an enlarged fragmentary view partly in section of a modified support utilizable in the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring more particularly to the drawings wherein like characters of reference designate like parts throughout the several views, there is shown in FIG. 1 a magnet **10** of a type which may be made by the method of this invention. Magnet **10** is of extremely small size such as will permit its use in relatively small devices such as hearing aids, watches, magnetic pickups, reed switches, meters or fuses, for example, and may be of any selected configuration. Magnet **10** in FIG. 1 for convenience is shown as disc shaped and is of a diameter and thickness which is conducive to the terminology "micromagnet." As an example, magnet **10** may be less than .078 inch in diameter and less than .020 inch in thickness. Obviously, making such micromagnets in large production quantities in an economical manner by conventional magnet making methods is undesirable for reasons of economy. Furthermore, it is also difficult to make such desired production quantities wherein the micromagnets will be substantially uniform from magnet to magnet as well as from batch to batch.

In accordance with this invention a magnet-supporting matrix **12** (FIG. 2) is provided in the form of a sheet or block of rigid material which will not contaminate the magnet materials during processing. The support **12** may be, for example, in the form of a sheet of molybdenum or iron, for example, having any selected length and width suitable for use in the processing equipment. The thickness of the support sheet **12** is substantially equal to or slightly greater than the thickness desired of the magnets being produced. For example, a moly sheet about .020 inch thick, 7 inches wide and 22 inches long has been found to be particularly suitable for making approximately 15,000 magnets having a diameter of slightly less than .078 inch and a thickness of slightly less than .020 inches.

The support is provided with a large number of holes, apertures or perforations **14** which, in the production of micromagnets of the examplary size referred to above, are 15,000 in number and about .078 inch in diameter.

The sheet support **12** is placed on the flat negatively polarized end of an electromagnet **16** as illustrated in FIG. 6 and the electromagnet coil **18** is electrically energized. At this time the apertures or holes **14** in the support are filled with powdered magnet material 20 as shown in FIG. 3.

Since the magnets to be produced by the method of this invention may be permanent magnets comprised of any selected materials, the particular materials comprising the powder 20 are not in themselves a part of this invention. However, a particularly good magnet material comprises a powder mixture containing cobalt and a rare earth such as samarium alone or mixed with praseodymium, lanthanum or cerium where the samarium represents one-half or more of the total rare earth ingredient. Such a magnet composition is described in U.S. Pat. application Ser. No. 131,777 filed Apr. 6, 1971 and assigned to the assignee of the present invention.

With the electromagnet 16 energized, the powder or domains of the deposits 20 will become magnetically oriented so that the deposits will be magnetically anisotropic, that is, they will have a preferred direction of magnetization.

After any loose powder has been skimmed or brushed off the support 12 the deposits 20 are compacted to the desired density. If relatively low density is satisfactory, compaction may be achieved by rolling a squeegee over the deposits. This may be done with or without the interposition of a thin, flexible membrane, film or the like 22 over the support 12. Pressure should be at least in the order of 250 lbs., however, to render the deposits self-supporting during subsequent transport of the support to other apparatus, as will be described.

When relatively high density is desired of the deposits 20, it becomes necessary to apply greater pressures. This is done by laying a film 22 over the support and deposits, inserting the assembly in a hydraulic or hydrostatic (isostatic) press 24, and operating the press so that its piston 26 will urge a supply of water 28 or other selected fluid toward the deposits 20. This pressure of fluid upon the film 22 will cause the film to assume the shape shown in FIG. 5 as the deposits become compacted and densified. Such apparatus will apply pressures of as much as about five tons per square inch.

It is to be understood that the film 22 may be any suitable thin flexible material such as rubber or plastic, and that beneath the support 12 there may be interposed, if desired, a separate removable sheet 30 of rigid material as shown in FIGS. 3–5 to aid in supporting the deposits 22 during transport of the support 12 and to aid in keeping the surface of the electromagnet 16 clean.

After the compaction step the support 12 and compacted deposits 20 are placed in a sintering furnace (not shown) where the deposits 20 are sintered. Any suitable sintering furnace and method may be employed. For example, temperatures in the vicinity of about 1,100°C may be applied after which the deposits, which are now small magnets, may be easily cooled and removed from the apertures 14 in the support 12. The magnets generally need no further processing but, if desired, may be further formed or machined. They may also be again magnetized in the same magnet direction as employed during the initial compaction step, with or without reversing the magnetic poles.

It is to be understood that although a thin apertured sheetlike support 12 has been described for use in supporting the deposits 22, a block 32 of suitable benign material such as molybdenum or cast iron, for example, may be provided in one surface 34 with a large number of shallow recesses or depressions 36 having the sizes and shapes desired of the magnets to be produced. The recesses 36 function just as the apertures 14 in the support 12.

It is also to be understood that other modifications and changes may be made by those skilled in the art without departing from the spirit of the invention as expressed in the accompanying claims. Therefore, all matter shown and described is to be interpreted as illustrative and not in a limiting sense.

I claim:

1. A method of making magnets of a size less than about .078 inch in diameter and less than about .020 inch in thickness comprising the steps of

forming a multitude of perforations of a size and shape corresponding to the size and shape of the magnets to be produced in a rigid sheet of material which will not contaminate the material of the magnets during fabrication;

placing the perforated sheet on the negatively polarized end of an electromagnet and electrically energizing the coil of the electromagnet;

filling said perforations with deposits of a powder mixture containing cobalt and samarium;

laying a flexible film over the sheet and deposits;

inserting the assembled sheet, deposits and film in a press;

applying fluid under pressure of up to 5 tons per square inch to the film to compact the deposits thereunder while continuing to electrically energize the electromagnet;

placing the sheet and compacted deposits in a sintering furnace;

applying heat of about 1,100°C to the compacted deposits to sinter same;

and removing the resultant individual magnets from the sheet.

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