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Kuhlmann-Schäfer

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[54] **PROCESS FOR THE PRODUCTION OF PERMANENT MAGNETS**

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[51] **Int. Cl.** **B22d 27/02**

[58] **Field of Search** 164/49, 51, 250, 251

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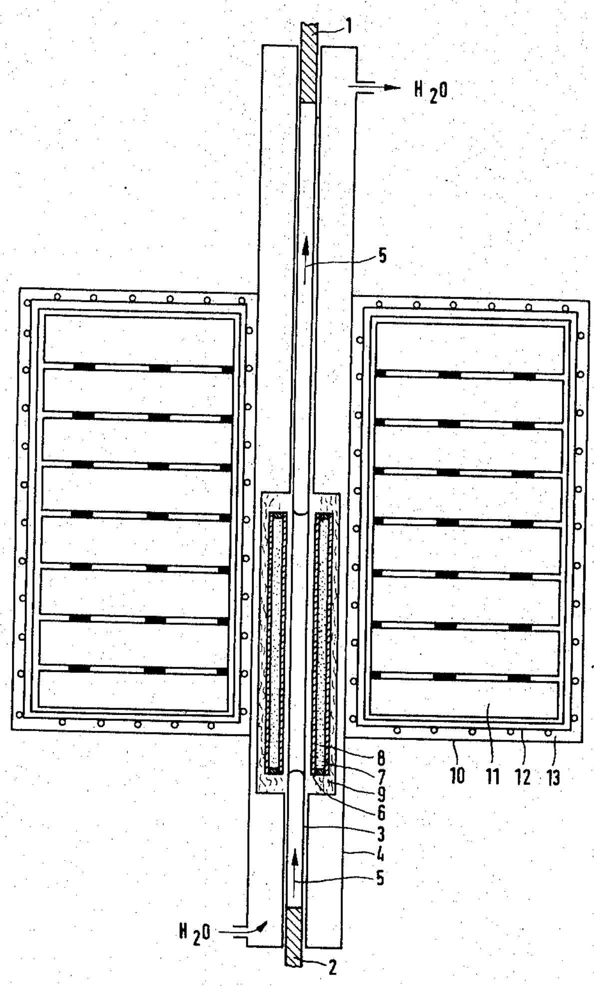
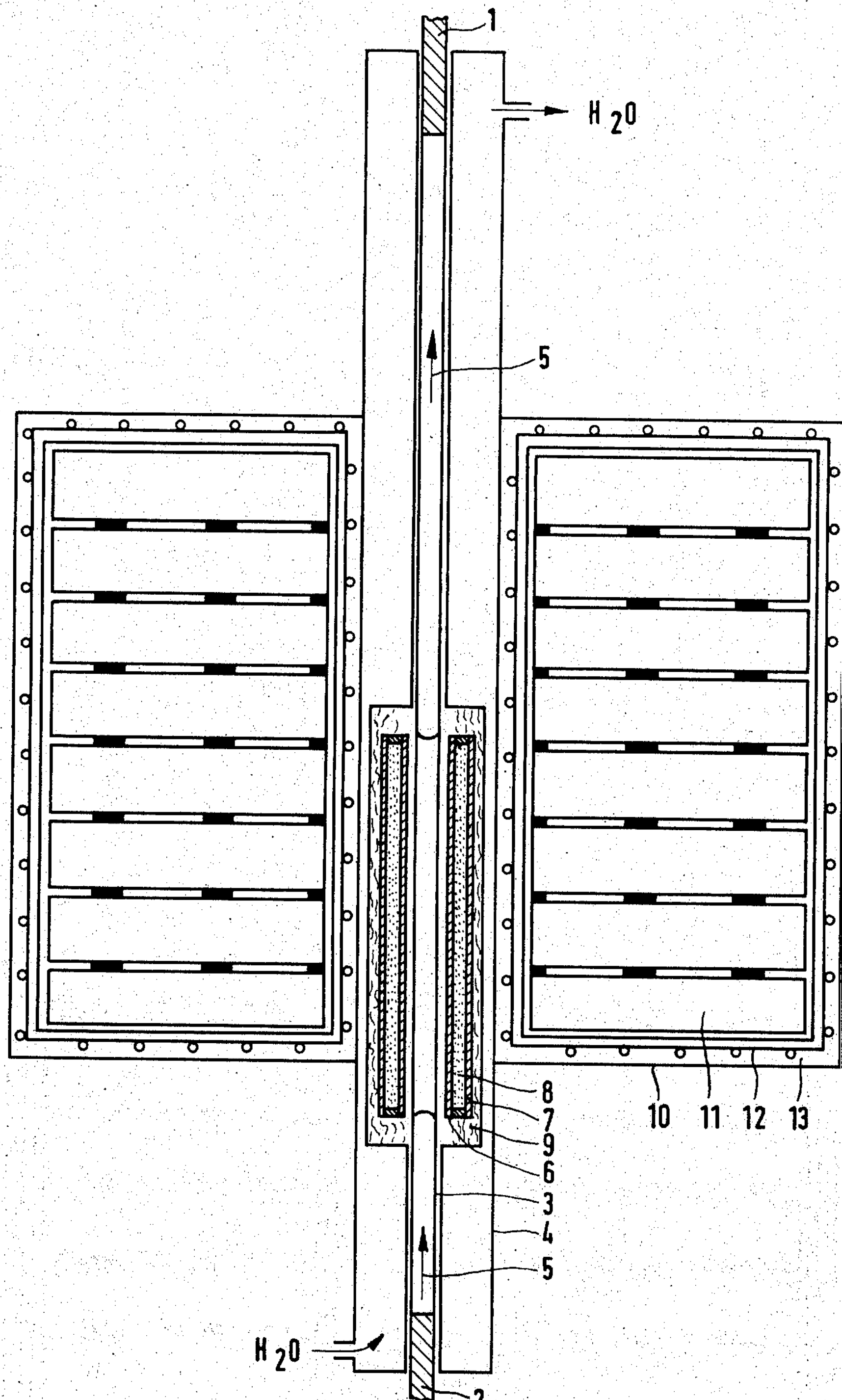
[57] **ABSTRACT**

Permanent magnets having high coercivity forces and remanence are produced by melting and cooling a charge of magnetic material in a strong magnetic field.

9 Claims, 1 Drawing Figure

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PROCESS FOR THE PRODUCTION OF PERMANENT MAGNETS

BACKGROUND OF THE INVENTION

The invention relates to a process for the production of permanent magnets.

It is known to sinter Co_5R magnets from fine particles of magnetic material in the production of these materials. This production is carried out in various stages, namely, the mixing of the raw materials in a fluid, and filtering, drying, pre-sintering, grinding, pressing, final sintering, and forming the resultant product. This sintering process is relatively complicated.

When carrying out the sintering process, it is known to produce a magnetic field in the charge during the pressing part of the operation in order to obtain more favorable magnetic properties. The purpose of said magnetic field is to substantially align the axes of easiest magnetizability of individual powder particles with the magnetic field. In order to permit this, the powder must be introduced into the mold either in a very dry state or in a suspension in water, which further increases the production costs involved. It is also known that optimum values can be achieved when using a sintering process in a magnetic field if each powder particle is a single crystal of suitable size. Therefore, extremely fine grinding is a prerequisite if optimum values are to be achieved. (See A. I. Stuijts et al., Phil. Tech. Rev. 16, page 141, 1954, the teachings of which are incorporated herein by reference.)

To improve the magnetic properties, and particularly to produce a preferred direction of magnetization, it is known in the case of ferrites containing Co additives to cool the charge after final sintering in a magnetic field between the Curie temperature and about 150°C. (See M. Kornetzki et al., Siemens-Zeitung 29, page 434, 1955, the teachings of which are incorporated herein by reference.)

It is also known to grow monocrystals in order to improve magnetic properties. But, in fact, the Weiss domains usually have no specific association with the geometry of the monocrystal, so that an effective improvement in magnetic properties cannot be achieved thereby.

SUMMARY OF THE INVENTION

The object of the invention is to provide a simple process for the production of permanent magnets having improved magnetic properties, particularly, magnets having high coercivity forces or high remanences.

The object of this invention is achieved by a process for the production of permanent magnets wherein a charge of magnet material is melted and cooled in a strong magnetic field. It is particularly convenient and preferred to effect the melting of the charge in a migrating zone, the transition from the liquid phase to the rigid phase occurring in the center of the strong magnetic field.

With the process of the present invention, the aligning of the Weiss zones is effected by a magnetic field when the individual molecules of the magnet material exhibit their maximum mobility, i.e., when the material is in the melted, fluid state. After cooling and consolidation of the material, the material is given a preferred direction of magnetization in the direction of the lines of flux of the applied magnetic field, so that the magnetic properties are substantially improved. At worst,

the Weiss domains are at a small angle relative to one another and are usually uniformly aligned. As a result, the magnetic properties are at an optimum.

A further development in the process of this invention is that there is conducted through the charge a current of such intensity that it is capable of heating the charge to a temperature above the melting point. The charge is then cooled, after passing through the melting zone, to a temperature below the melting point. Thus, because of the effectiveness of the cooling of the charge, the envelope about the charge can be kept particularly thin so that the inner diameter of an electromagnet, preferably a superconductive magnet, can be correspondingly small and the field intensity in the charge particularly great. Preferably, the charge is surrounded in the region before the melting zone by a heat-insulating envelope.

Prior to this invention, high coercivity forces of the order of magnitude of 200 kilogauss have been only sporadically found with small particles of Co_5R (R is a radical). With particles of larger dimension, it has been impossible to produce permanent magnets from Co_5R. The process of the present invention facilitates the transformation of large Co_5R particles into permanent magnets, thus providing an economical means of producing large magnets with coercivity forces of the order of magnitude of 200 kilogauss and with high remanences. These properties afford considerable advantages in electric motors, frictionless suspensions, magnetic pads, magnetic separators, elementary particle accelerators, quadripole systems and the like.

Since, depending on the type of magnet material used, a reaction may take place with the gas of the surrounding atmosphere, it is expedient to conduct the melting and particularly the zone melting operation under an inert gas atmosphere. Naturally, the process also permits the production of magnetic monocrystals.

DESCRIPTION OF PREFERRED EMBODIMENT

The invention will be explained in detail with reference to the attached drawing.

The drawing shows, in principle, a device for carrying out zone melting. Between two electrodes 1 and 2, there is a charge 3 which is, for example, in the form of a Co_5R rod which is to be subjected to zone melting. The electrodes 1 and 2 can move with the charge 3 in the direction of arrows 5 through an envelope 4 cooled with water. In the drawing, the direction of movement is vertical and the other parts are arranged correspondingly. It is possible to have this direction with crucible-free zone melting, wherein the charge is brought to a liquid state only over a short region, and is held together by the surface tension of the liquid. However, the charge may also be held in a concentric ceramic tube 6 made of, for example, Y_2O_3 in the case of Co_5R, so that it can be brought to the liquid state over a longer region. In the device shown in the drawing, the ceramic tube 6 is surrounded by a second ceramic tube 7. The intervening space between the two ceramic tubes 6 and 7 is filled with heat-insulating ceramic powder 8. Between the ceramic tube 7 and the envelope 4, there is ceramic wool 9 for further heat insulation. It will be noted that the envelope 4 is widened internally in the region of the ceramic tubes 6 and 7 to provide space for the ceramic tubes.

The envelope 4 is surrounded by a superconductive magnet **10**, the center of which is in the region of the transition from the liquid phase to the solid phase, said region lying in the direction of movement of the charge 3 as it moves in the direction of the arrows **5**, and between the ends of the ceramic tubes 6 and 7 and the casing **4**. Subsequently, the casing **4** is again narrowed. This means that the center of the superconductive magnet is situated in the transition region between heat insulation and heat dissipation.

The superconductive magnet **10** consists of a plurality of superconductors **11** (so-called pan cakes), consisting, for example, of Nb_3Sn or VGa_3, which are cooled by a radiation shield **12** and a helium bath **13.**

To carry out the process of the present invention, an electric current of sufficient intensity is sent through the charge so that the charge 3 is liquefied within the heat-insulated zone, represented substantially by the ceramic tubes 6 and **7.** The amount of charge required is dependent upon the exact material and/or amount treated and is readily determined by those trained in the art. In the aforesaid heat-insulated zone, the strong magnetic field of the superconductive magnet **10** effects substantial alignment of the Weiss domains, or gives them a parallel form. Since this alignment is particularly important when the re-solidification is effected in the region between the downstream end of the ceramic tubes 6 and 7 and the beginning of the narrowed portion of the envelope used for cooling, this region is located in the center of the superconductive magnet **10.** After solidification, the permanent magnet thus produced is given a preferred direction of magnetization in the direction of the lines of flux of the superconductive magnet **10.** Therefore, the magnetic properties obtained are good, with especially high coercivity force and remanence.

As used herein, R in Co_5R refers to a rare earth. See for example, 1971 Intermag Conference; IEE Transactions on Magnetics, The Preparation of RCo_5 Permanent Magnet Alloys, page 423 (1971) the teachings of which are incorporated by reference herein. Further, the strong magnetic field used in producing

the permanent magnets is held at a value of about 50–250 kilogauss and is maintained at that value until solidification occurs.

I claim:

1. A process for production of a permanent magnet from a charge of magnetic material comprising the steps of:

heating said charge to provide a melting zone along a portion of the length of said charge, said melting zone having a liquid-to-solid interface;

causing said melting zone to pass through said charge; and

continuously subjecting said interface of said melting zone to a magnetic field.

2. A process as claimed in claim **1** wherein said liquid-to-solid interface is positioned in the center of said magnetic field.

3. A process as claimed in claim **1** wherein said heating step includes passing a current through said charge to heat said charge to a temperature above the melting point of said magnetic material and cooling a portion of said charge to a temperature below the melting point.

4. A process as claimed in claim **3** wherein said heating step further includes insulating a second portion of said charge with a heat-insulating envelope, said melting zone substantially aligning with said heat-insulating envelope.

5. A process as claimed in claim **4** wherein said causing step includes moving said charge relative to said envelope.

6. A process as caimed in claim **1** further comprising the steps of placing said charge in an air-tight container and filling said container with an inert gas.

7. A process as claimed in claim **1** wherein said magnetic material of said charge is Co_5R, wherein R is a rare earth metal.

8. A process as claimed in claim **1** wherein said charge is contained in a crucible of Y_2O_3 and said magnetic material is Co_5R.

9. A process as claimed in claim **1** where the strength of said magnetic field is at least 50 kilograms.

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