FORM 1

COMMONWEALTH OF AUSTRALIA

PATENTS ACT 1952 **598042**

APPLICATION FOR A STANDARD PATENT

I\We,

KLOCKNER-HUMBOLDT-DEUTZ
AKTIENGESELLSCHAFT

of DEUTZ-MULHEIMER STR. 111
5000 KOLN 80
FEDERAL REPUBLIC OF GERMANY

hereby apply for the grant of a standard patent for an invention entitled:

MAGNETIC SEPARATOR

which is described in the accompanying complete specification

Details of basic application(s):

Number of basic application	Name of Convention country in which basic application was filed	Date of basic application
P3637200.5	DE	OCT 86

LODGED AT SUB-OFFICE
19 OCT 1987
Melbourne

My/our address for service is care ~~of CLEMENT HACK & CO.~~, Patent Attorneys, 601 St. Kilda Road, Melbourne 3004, Victoria, Australia.

DATED this 19th day of October 1987

KLOCKNER-HUMBOLDT-DEUTZ
AKTIENGESELLSCHAFT

APPLICATION ACCEPTED AND AMENDMENTS
ALLOWED 27.3.90

CLEMENT HACK & CO.

TO: The Commissioner of Patents.

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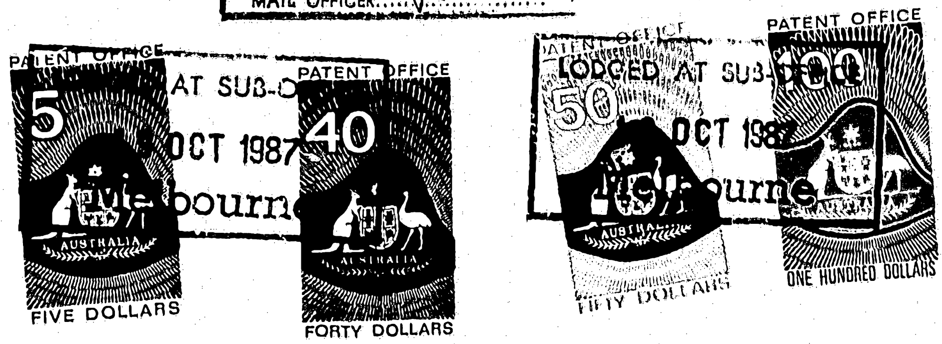

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Australia Patent Declaration Form

Forms 7 and 8

AUSTRALIA

Patents Act 1952

DECLARATION IN SUPPORT OF A CONVENTION OR NON-CONVENTION APPLICATION FOR A PATENT OR PATENT OF ADDITION

Name(s) of Applicant(s)	In support of the application made by Klöckner-Humboldt-Deutz Aktiengesellschaft
Title	for a patent for an invention entitled Magnetic Separator
Name(s) and address(es) of person(s) making declaration	I/We, Hermann Christl, Pohlhausenstr. 4o, 53o3 Bornheim; Ekkehard Valentin, Wipperfürther Str. 52, 5o6o Bergisch Gladbach 1

do solemnly and sincerely declare as follows:-

1. I am/we are the applicant(s) for the patent, or am/are authorised by the abovementioned applicant to make this declaration on its behalf.

2. The basic application(s) as defined by Section 141 of the Act was/were made in the following country or countries on the following date(s) by the following applicant(s) namely:-

Country, filing date and name of Applicant(s) for the or each basic application

in West Germany on 31. Oktober 1986
by Klöckner-Humboldt-Deutz Aktiengesellschaft
in ______ on ______ 19__
by ______

3. The said basic application(s) was/were the first application(s) made in a Convention country in respect of the invention the subject of the application.

Name(s) and address(es) of the or each actual inventor

4. The actual inventor(s) of the said invention is/are
Hans Georg Schnabel, Hanrathstr. 37, 53o3 Bornheim 3;
Dr. Karl-Heinz Unkelbach, Hauptstr. 71, 5ooo Köln 5o;
Dr. Marlene Marinescu, Mailänder Str. 19, 6ooo Frankfurt 7o;
Dr. Nicolae Marinescu, MailänderStr. 19, 6ooo Frankfurt 7o

See reverse side of this form for guidance in completing this part

5. The facts upon which the applicant(s) is/are entitled to make this application are as follows:-
The said Klöckner-Humboldt-Deutz AG is the assignee of the inventors named in paragraph 4. above.

DECLARED at Cologne this 1st day of October 1987

Klöckner-Humboldt-Deutz Aktiengesellschaft

i.V. Christl i.V. Valentin

This form may be completed and filed after the filing of a patent

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(54) Title
MAGNETIC SEPARATOR

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(71) Applicant(s)
KLOCKNER-HUMBOLDT-DEUTZ AKTIENGESELLSCHAFT

(72) Inventor(s)
HANS GEORG SCHNABEL; Dr. KARL-HEINZ UNKELBACH; Dr. MARLENE MARINESCU; Dr. NICOLAE MARINESCU

(74) Attorney or Agent
GRIFFITH HACK & CO. MELBOURNE

(56) Prior Art Documents
DE 3238052
US 4199455
US 3737822

(57) Claim

1. A magnetic separator, comprising:

a rotatable drum including an axis of rotation and a periphery comprising a plurality of magnetic blocks, each magnetic block having a center of gravity, the magnetic blocks being mounted and arranged as circular rings about said axis of rotation;

wherein i^{th} magnetic block being magnetized in a predetermined direction $\psi_i = -n\phi_i$, where n is a positive number and ϕ_i is an angle described by a line from the center of gravity of the i^{th} block to said axis of rotation and a predetermined radius vector, and ψ_i is counted in the same rotation sense proceeding from the predetermined radius vector; and

the spacing between neighboring centers of gravity of said magnetic blocks, expressed as a sector angle, is smaller than or equal to $\pi/2(n + 1)$.

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Form 10

COMPLETE SPECIFICATION

(ORIGINAL)

FOR OFFICE USE

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Int. Cl:

Application Number:
Lodged:

This document contains the amendments made under Section 49 and is correct for printing.

Complete Specification Lodged:
Accepted:
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Related Art:

TO BE COMPLETED BY APPLICANT

Name of Applicant: KLOCKNER-HUMBOLDT-DEUTZ AKTIENGESELLSCHAFT

Address of Applicant: DEUTZ-MULHEIMER STR. 111
5000 KOLN 80
FEDERAL REPUBLIC OF GERMANY

Actual Inventor:

Address for Service: CLEMENT HACK & CO.,
601 St. Kilda Road,
Melbourne, Victoria 3004,
Australia.

Complete Specification for the invention entitled:
MAGNETIC SEPARATOR

The following statement is a full description of this invention including the best method of performing it known to me:-

The present invention relates to a magnetic separator, containing homogeneous magnetic blocks, arranged perpendicular to the axis of the magnetic separator, inside a drum.

This type of magnetic separator is very widely used for dry- or wet-field separation where the field produced by a permanent magnet is sufficient for the purpose. In the case of drum magnetic separators the magnetic field is stationary and the material to be separated is passed over a region of the drum (DE 32 38 052 A1, DE-AS 28 32 275).

The force for the separation of magnetic from non-magnetic particles in the dry- or wet-field separation process depends upon the absolute value and the gradient of the magnetic field strength. The highest possible field strength of the highest possible uniformity is generally a desirable prerequisite. However, the decisive factor for the performance of a magnetic separator is its range which fundamentally depends upon the gradient of the magnetic field and which, amongst other things, has an influence on the maximum particle size of the material to be separated.

It has been proposed in the US Patent ~~32 65 599~~ 3,365,599 that the magnetic flux in the exterior space around a magnetic drum may be improved by the bridging over of the intermediate spaces of radially magnetized segments (the north and south poles of the magnetic separator) partly by magnetic blocks which are magnetized in the peripheral direction. This would make it possible to exploit the magnetism "dissipated" by the reciprocal de-magnetization. However, it is not correct, as is occasionally asserted, that the "total magnetism is thereby conducted into the working range of the drum".

The object of the present invention is to maximize the field strength in the external region of drum magnetic separators, in which instance there must be adaptability to the mineralogical composition and the particle-size distribution of the mixture of particles to be separated, thus making it possible to achieve an optimum field-strength distribution in the external region around the drum with the number of poles required at that particular time.

According to the present invention there is provided a magnetic separator, comprising: a rotatable drum including an axis of rotation and a periphery comprising a plurality of magnetic blocks, each magnetic block having a center of gravity, the magnetic blocks being mounted and arranged as circular rings about said axis of rotation; wherein i^{th} magnetic block being magnetized in a predetermined direction $\psi_i = -n\phi_i$, where n is a positive number and ϕ_i is an angle described by a line from the center of gravity of the i^{th} block to said axis of rotation and a predetermined radius vector, and ψ_i is counted in the same rotation sense proceeding from the predetermined radius vector; and the spacing between neighboring centers of gravity of said magnetic blocks, expressed as a sector angle, is smaller than or equal to $\pi/2(n + 1)$.

The teachings of the invention apply to all magnetic blocks which are arranged in an annular manner around the axis of the magnetic separator, where 'n' is any arbitrary positive number, preferably a whole number, provided that the magnetic blocks are not distributed over the whole of the circumference. In this latter instance the restriction that 'n' must be a whole number applies. In one variation of the invention, the direction of magnetization of all the magnetic blocks is the same in the assembled state. In this case it can be considered that n = 0.

Because no forces should act in the axial direction of the magnetic separator if at all possible, this simplifies the description of the field strength to a planar configuration perpendicular to the axis of the magnetic separator. In what follows it is intended that the magnetic field components should always be in such a plane.

The term radial vector is understood to be any arbitrary direction (perpendicular to the axis of the magnetic separator). Using the clock face as an example, the hour hand could be in the 12 o'clock position for example. Once the arbitrary radial vector has been established , then the angle φ_i and the angle ψ_i for every 'i' is always in relation to this radial vector in the same direction of rotation (clockwise or anti-clockwise as the case may be) and starts out from the same zero position (for example, 12 o'clock).

The determination of the angle ψ_i is based upon the centre of gravity of the i^{th} block. This is the sensible thing to do because the magnetic blocks are magnetized as homogeneously as possible and in any case they have a very high degree of radial symmetry. Here it is not a matter of the diameter of the drum but solely of the direction towards the centre of gravity. The radius to each of the centres of gravity of the 'i' blocks should preferably be the same in every case. It has been found that, even when the condition of $\psi_i = -n\,\varphi_i$ is not strictly adhered to, when the angle ψ_i deviates from the nominal position by 3 - 5° for example in the case of individual blocks, then the field distribution in the external region around the magnetic separator in accordance with the present invention is always substantially better than that achieved with known devices.

In the magnetization of the i^{th} block it must naturally be quite precisely known how this block is to be installed in the magnetic separator. Otherwise the direction ψ_i is independent of how large the magnetic block itself is, of whether there is an adjacent block in contact with it or whether there are spaces between the magnetic blocks, how much magnetic material is contained in a block, how wide (sector-wise) or how long (radially) the block is, which naturally has an influence on the de-magnetization of this block and which must be taken into consideration in the construction of a magnetic separator. However, despite the possibilities of adaptation to the desired number of poles or the remanence (residual magnetization) of the working material and other magnetic separator characteristic parameters, the magnetization of the magnetic block must fundamentally be effected in accordance with the afore-named condition, namely that $\psi_i = - n \varphi_i$.

It is primarily for reasons involved in the manufacture of the individual magnetic blocks that a high degree of symmetry of the forms of embodiment is called for. It is generally highly expedient for the magnetic blocks to all be of the same size. In this circumstance, the cross section can preferably be rectangular, trapezoidal or even the sector of an annulus. The radial elongation of a magnetic block influences the maximum field strength and this becomes all the greater as the amount of magnetic material which is present in a suitable form is increased. For economic reasons it is seldom that the magnetically best, but at the same time the most expensive, solution of the problem will be chosen. Thus, for example, it is expedient to fabricate the magnetic blocks as sectors extending to the axis of the magnetic separator. The improvement which is brought about by the sectoral filling of the inner space of the magnetic separator is however not compensated for by the increased cost of the magnetic material when compared with a magnetic block which is fabricated as only a portion of an annulus which may be wide or narrow sector.

It is also frequently necessary that the magnetic blocks should butt against one another. It is true that the magnetic field becomes weaker if there are spaces between the magnetic blocks in the circumferential direction but, despite this, an adequate field may frequently be obtained and the magnetic material which is possibly saved with this arrangement provides an economic advantage when compared with known magnetic separators which do not have these intermediate spaces. The gaps between the blocks (as sector angle or annular surface) should not be any greater than 30%

of the size of the actual magnetic blocks themselves.

The number of poles is established by the choice of 'n' and the sectoral extent of the magnetic system. If the magnetic blocks are distributed uniformly around the entire circumference, then 'n' must be a whole number. The result of this is that there are $N = 2(n + 1)$ magnetic poles (north and south poles). When the magnetic blocks extend over a sector 'α', then $\alpha/(180(n + 1))$ poles are present, under which conditions, depending upon the choice of 'α', magnetic poles do not unconditionally have to lie on the borders of the magnetic blocks.

The rule that $\psi_i = - n \varphi_i$ can be satisfactorily adhered to for every drum radius and for every type of material to be separated because, in the establishment of the magnetic field gradient, it is true that a weakening of the magnetic field due to unavoidable de-magnetization must be accepted as part of the bargain but, none the less, in spite of this, the field strength will still attain the highest possible value. Even in the establishment of the number i_{max}, that is to say, the number of magnetic blocks (in the case of a desired number of poles), there exists a degree of freedom : the greater the number i_{max} is, the greater will be the uniformity of the magnetic field in the space around the outside of the magnetic separator. The magnetization of the magnetic blocks is, however, determined by the formula given above and cannot be further improved. The width of a magnetic block should preferably not be greater than $\pi/(2(n + 1))$ (as sector angle). In relation to a quadrant of the magnetic separator, a range from 4 to 8 is preferred for the value of i_{max}. The range for the value of 'n' is preferably from 3 to 5.

In the case of known magnetic separators, the individual magnetic blocks are mounted on a support made from soft iron which is intended to achieve the effect that the magnetic field from the interior of the drum will be forced more towards the outside. In the case of the magnetic separator in accordance with the invention, however, there are practically no magnetic field lines present in the interior of the magnetic separator but, none the less, it is also expedient here to mount the magnetic blocks on a ring made from soft iron, especially if intermediate spaces are provided between the blocks, because such an arrangement facilitates the assembling operations.

Two types of arrangement of the magnetic blocks are especially preferred : firstly, the sectoral arrangement over a sector of angle α , preferably from 70° up to 160°, and secondly, the annular arrangement. The first-named configuration is utilized in "conventional" drum magnetic separators, where a rotating drum is rotated around a stationary magnetic field and several different methods are known for the supply and removal of the material. The second configuration, the "entire annulus magnetization", can be utilized, for example, in conjunction with conveyor belts, where the belt passes over a drum and a sorting effect is achieved at the dumping point, depending upon the magnetizability of the material transported on the conveyor belt. In this case 'n' must be a whole number.

A special case of the desired field distribution in accordance with the invention will be arrived at when the direction of magnetization of the magnetic blocks (in their installed positions) is the same for all of them. It is not a decisive factor whether the magnetic system is distributed over the entire circumference of the drum or whether it only fills up a sectoral region. It should occupy a sectoral width of at least $\pi/2$. Under these conditions there will be only one north pole and one south pole exactly opposite to each other. For this special case of magnetization the value of zero could be allocated to 'n' ($n = 0$).

The invention is described by way of example in what follows, with reference to the accompanying drawings.

There is shown in :

Fig. 1 the sectoral arrangement of 10 magnetic blocks with n = 4, without intermediate spaces;

Fig. 2 the sectoral arrangement of 10 magnetic blocks with n = 3.5, without intermediate spaces;

Fig. 3 double the number of magnetic blocks, without intermediate spaces but with the same number of poles as in Fig. 1;

Fig. 4 the flux density over the peripheral angle in the case of the arrangements shown in Figs. 1 and 3;

Fig. 5 the sectoral arrangement of 10 magnetic blocks with intermediate spaces and with the same number of poles as in Fig. 1 or Fig. 3;

Fig. 6 the field distribution for 10 magnetic blocks with n = 4 (5 poles) without internal soft iron support;

Fig. 7 the field distribution as shown in Fig. 6 with internal soft iron support;

Fig. 8 the arrangement of 24 magnetic blocks with n = 3 (8 poles) without intermediate spaces in a full circle;

Fig. 9 the field distribution with equal magnetization of all magnetic blocks (n = 0).

In all the examples, the problem is solved, under the given circumstances (number of poles, type of magnetic material, amount), as to how the magnetic field may be displaced as far as physically possible in the external space around the drum. In Figs. 1, 2, 3, 5, 6 and 7, five poles should be present within a sectoral region of $\alpha = 150°$.

Fig. 1 illustrates how the i^{th} magnetic block is to be magnetized (shown by bold arrows), under which conditions the direction ψ_i is naturally related to the installed situation. If at all possible the field should have no components at right angle to the plane of the drawing. Here the 12 o'clock position is assumed as the radial vector which is primarily freely selectable but to which all angles must then bear reference. Here the positive counting direction is clockwise.

Another possible magnetization of the ten magnetic blocks in accordance with the invention, distributed over an angle α of 150° is illustrated in Fig. 2. In this instance the value of 'n' selected was 3.5 and thus not a whole number. At the border of this magnetic system there is no such pronounced pole as there is in Fig. 1. However, despite this, with the magnetization as shown, the most suitable field distribution is achieved under these circumstances.

For the same angular spread and for the same number of poles (n = 4) as shown in Fig. 1, the number of magnetic blocks was doubled to give the arrangement shown in Fig. 3.

Because of the doubling of the number of blocks (magnetized in accordance with the invention) as shown in Fig. 3 as compared with Fig. 1, the radial magnetic field distribution which is depicted in Fig. 4 becomes more uniform. The distance of the magnetic system from the axis is not of any importance here. For the sake of comparability the only stipulation to be made is that two magnetic blocks in the configuration shown in Fig. 3 should consist of the exactly the same amount of magnetic material as one block shown in Fig. 1, and they should have comparable geometries.

If ten magnetic blocks with n = 4 and with intermediate spaces between them are arranged as shown in Fig. 5, then the magnetic field distribution is fundamentally like that in Fig. 1 and Fig. 3, the only difference being that the maximum field strength and the homogeneity thereof are less. However, because of the high field strength in the external space, such a magnetic separator is comparable to the known magnetic separators in which considerably more magnetic material must be used for their magnetic systems. In practice, the intermediate spaces should be smaller than the magnetic blocks themselves. Preferably, the angle of the "free" space should be at most only 30% of that of a magnetic block.

The field has been calculated for an arrangement of magnetic blocks as shown in Fig. 1 and this is depicted in Fig. 6. Three north poles and two south poles may be recognized in the external space around the drum. The internal space within the drum is practically free from a magnetic field.

If the same magnetic blocks as shown in Fig. 1 are affixed to a soft iron support, there is no substantial improvement in relation to the field lines (Fig. 7). Such an arrangement is preferred primarily for manufacturing reasons.

If the magnetic blocks of a magnetic separator are to be distributed right around the entire circumference of the drum, then 'n' must be a whole number. In Fig. 8, there are 24 magnetic blocks shown uniformly distributed around the entire circumference without any intermediate spaces; with n = 3, there are 8 poles. In the case of a magnetic separator with such a system of magnets, the conveyor belt passes over two deflection rollers, where one of the deflection rollers contains the magnetic system which rotates with it at the same time and, disposed beneath these rollers there are devices for receiving the particles which have different degrees of magnetization.

A limiting case with two poles also falls within the scope of the invention; this may be characterized by the value of n = 0. In this case, each block 'i' of the magnetic separator has the same direction of magnetization (in relation to a fixed direction in space). Each individual block 'i' is therefore magnetized to a different extent, depending upon its different location in the magnetic separator.

The calculated field distribution for two "tubular half-shells" is depicted in Fig. 9. Similarly to the situation shown in Fig. 5 and Fig. 6, because of the de-magnetization, the actual course of the flux deviates from the "nominal course" as indicated by the bold arrows. Independently of the fact whether the system of magnets consists of two tubular half-shells or of eight "tubular one-eighth shells" magnetized in accordance with the invention, the desired effect is invariably obtained, namely a practically field-free interior with maximum field distribution in the external space around the drum.

THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. A magnetic separator, comprising:

a rotatable drum including an axis of rotation and a periphery comprising a plurality of magnetic blocks, each magnetic block having a center of gravity, the magnetic blocks being mounted and arranged as circular rings about said axis of rotation;

wherein i^{th} magnetic block being magnetized in a predetermined direction $\psi_i = -n\phi_i$, where n is a positive number and ϕ_i is an angle described by a line from the center of gravity of the i^{th} block to said axis of rotation and a predetermined radius vector, and ψ_i is counted in the same rotation sense proceeding from the predetermined radius vector; and

the spacing between neighboring centers of gravity of said magnetic blocks, expressed as a sector angle, is smaller than or equal to $\pi/2(n + 1)$.

2. The magnetic separator of claim 1, wherein said magnetic blocks are of identical size.

3. The magnetic separator of claim 1, wherein a cross section of a magnetic block has the shape of a sectorial segment of a circular ring.

4. The magnetic separator of claim 1, wherein said magnetic blocks each have a trapezoidal cross section.

5. The magnetic separator of claim 1, wherein each of said magnetic blocks comprises a sectorial segment having a width, expressed as a sector angle, which is smaller than or equal to $\pi/2(n + 1)$.

6. The magnetic separator of claim 1, wherein said magnetic blocks are arranged as said circular ring abutting one another and without spacing therebetween.

7. The magnetic separator of claim 1, wherein the individual magnetic blocks are arranged as said circular ring spaced apart so as to have interspaces therebetween, whereby said interspace has a width of less than half of the width of a magnetic block.

8. The magnetic separator of claim 1, wherein said rotatable drum comprises a soft iron portion and said magnetic blocks are arranged on said soft iron portion.

9. The magnetic separator of claim 1, wherein all of said magnetic blocks are arranged within a sector and the sector angle of α for all magnetic blocks lies between 60° and 240°.

10. The magnetic separator of claim 9, wherein said sector angle is between 90° and 160°.

11. The magnetic separator of claim 1, wherein the magnetic blocks are uniformly distributed over the overall circumference of the circle and in that the number n is a whole number.

12. The magnetic separator of claim 1, wherein each of said magnetic blocks comprises the magnetization direction which is identical among all of said magnetic blocks and the magnetic system formed by said magnetic blocks covers at least an overall sector range of at least $\pi/2$.

13. The magnetic separator of claim 12, wherein said magnetic blocks are distributed over the full circumference of the circle.

14. The magnetic separator of claim 12, wherein said magnetic blocks are distributed over at least a quadrant of the circle.

Dated this 14th day of March, 1990

KLOCKNER-HUMBOLDT-DEUTZ AKTIENGESELLSCHAFT
By Its Patent Attorneys

GRIFFITH HACK & CO.
Fellows Institute of Patent
Attorneys of Australia.

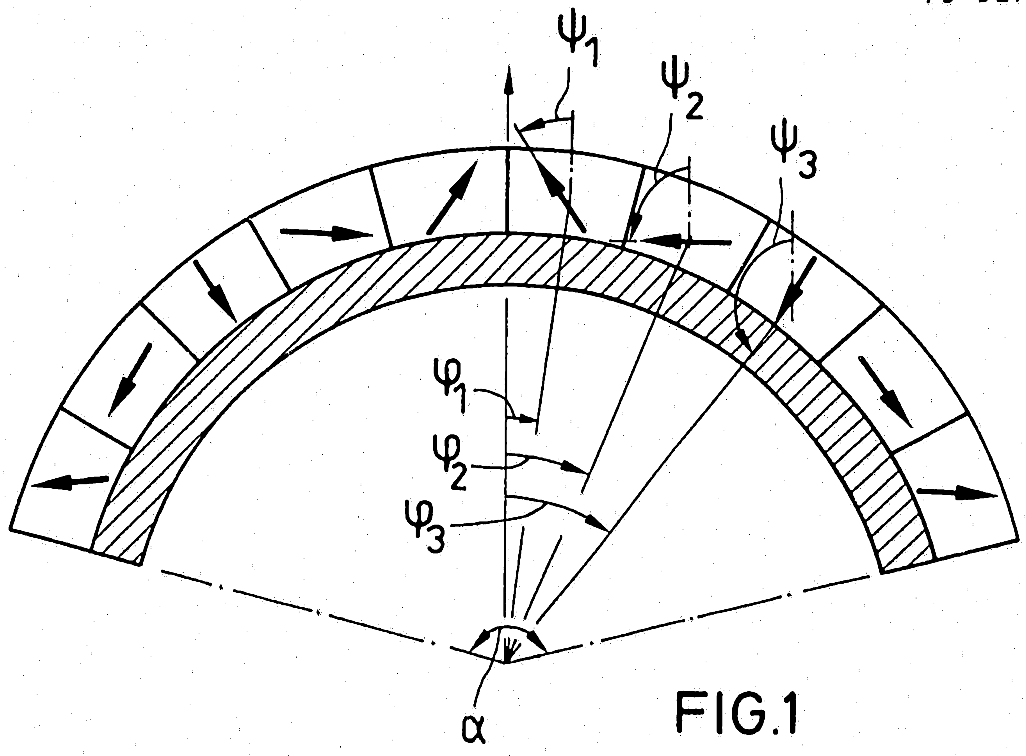

FIG.1

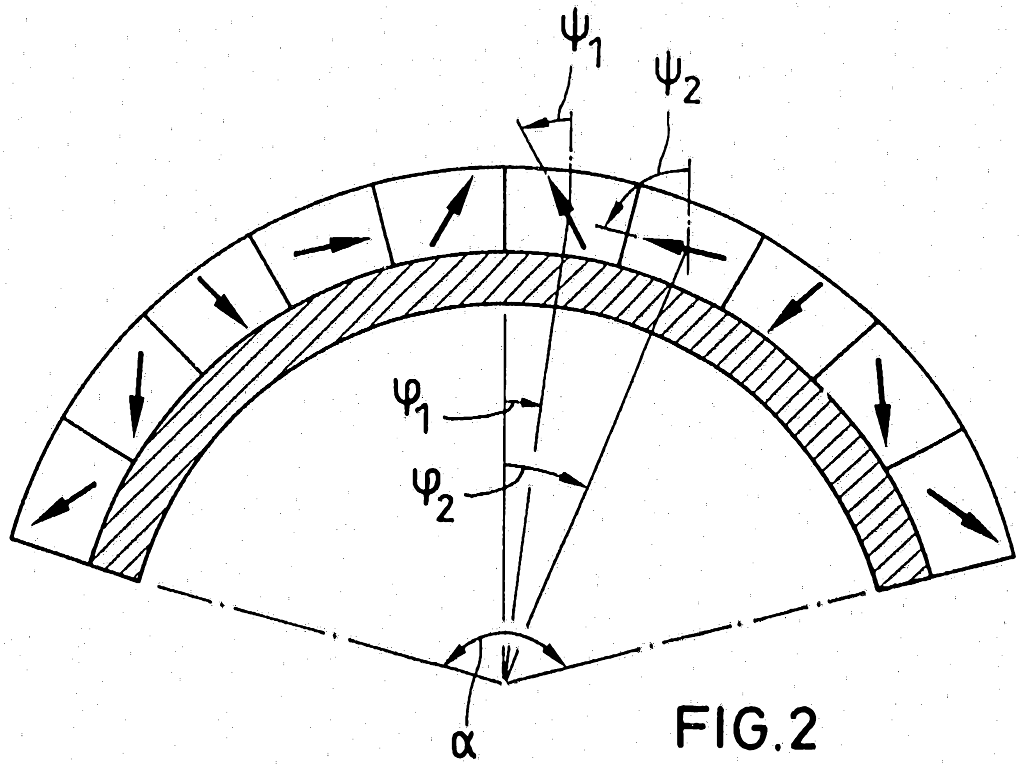

FIG.2

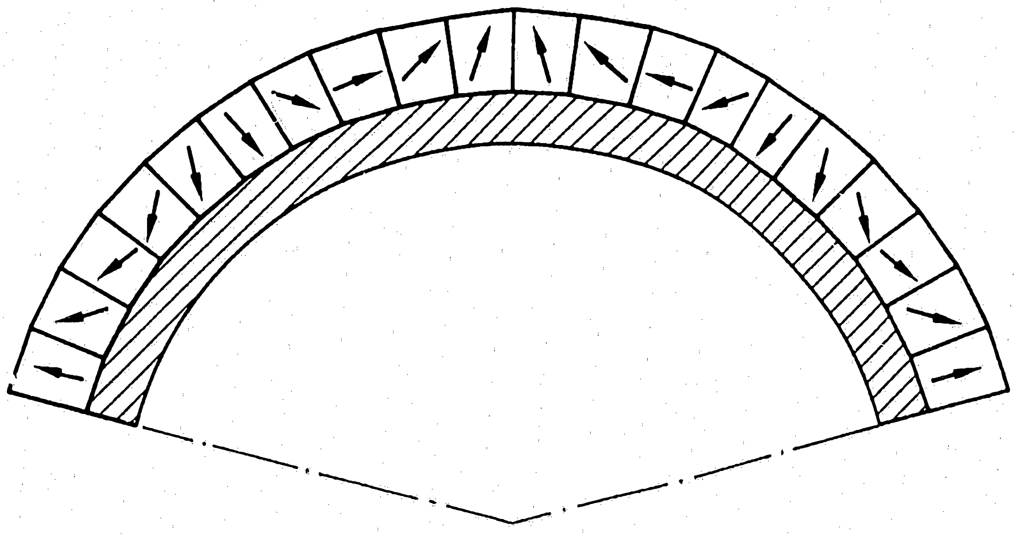

FIG.3

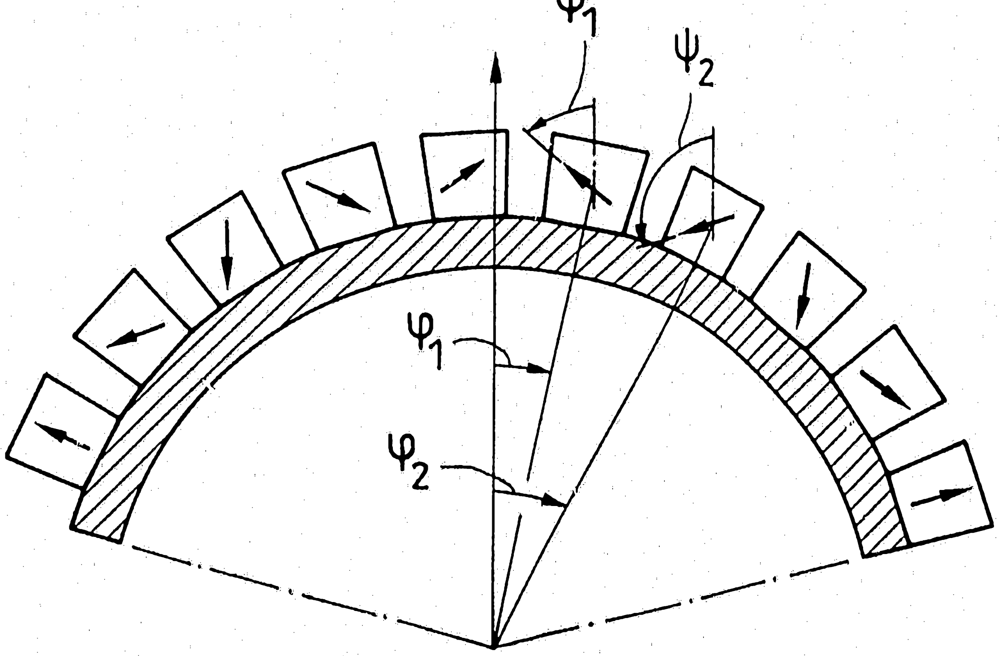

FIG.5

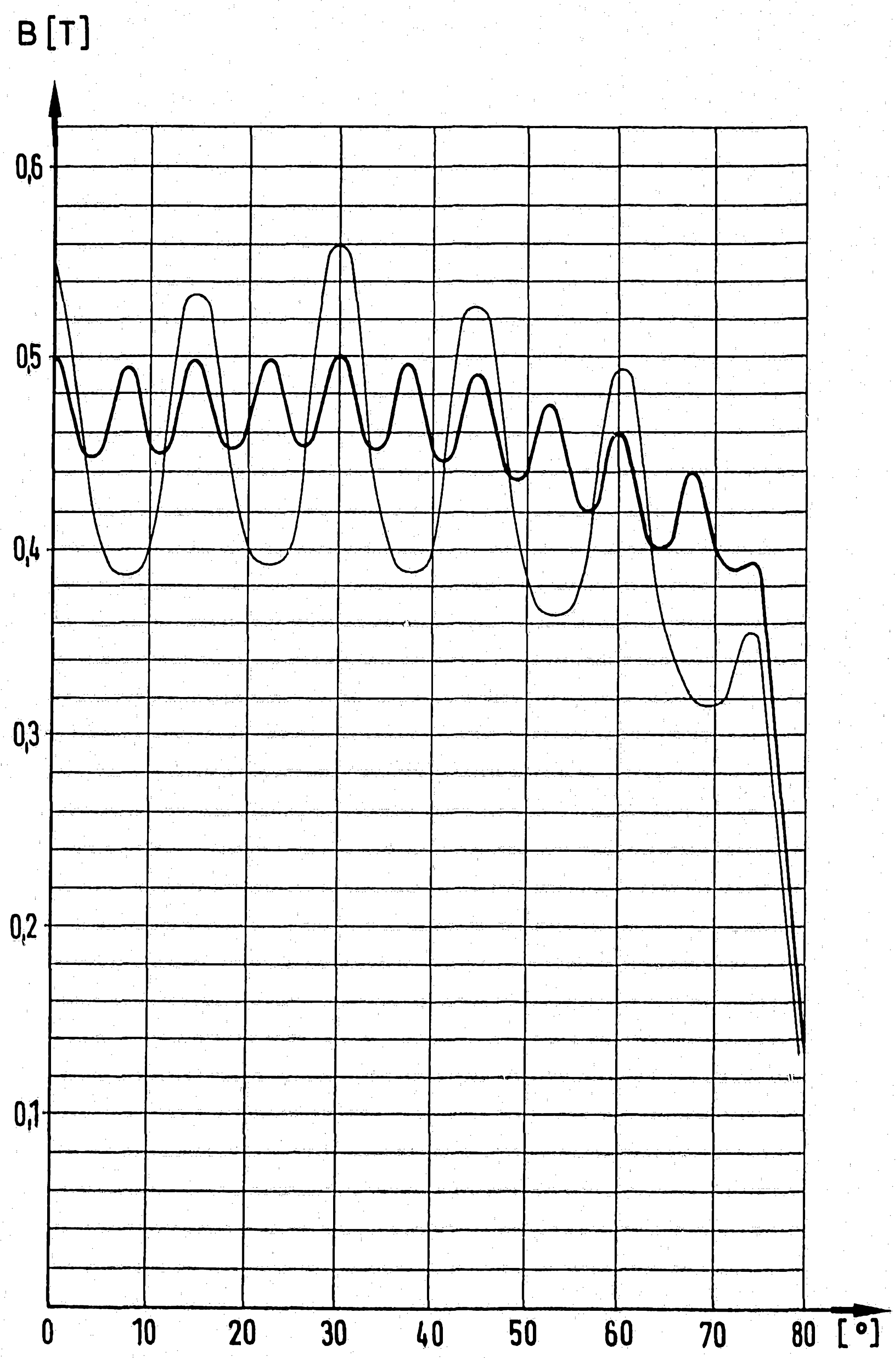

FIG.4

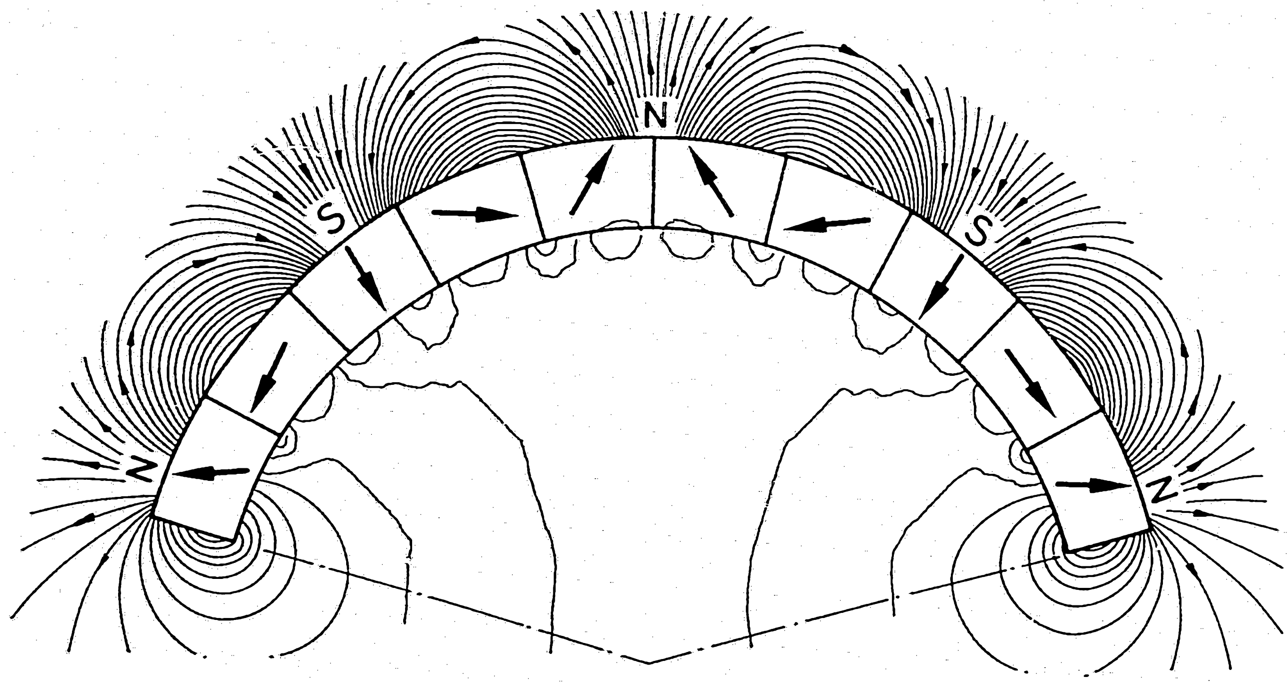

FIG.6

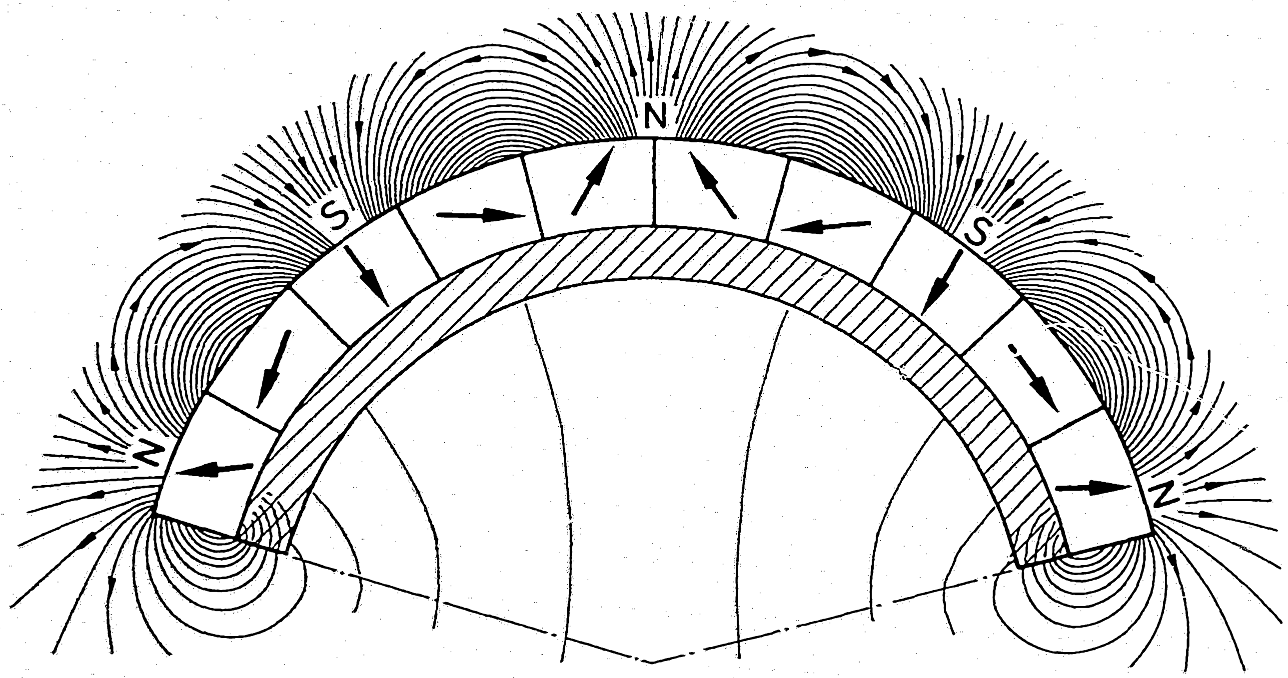

FIG.7

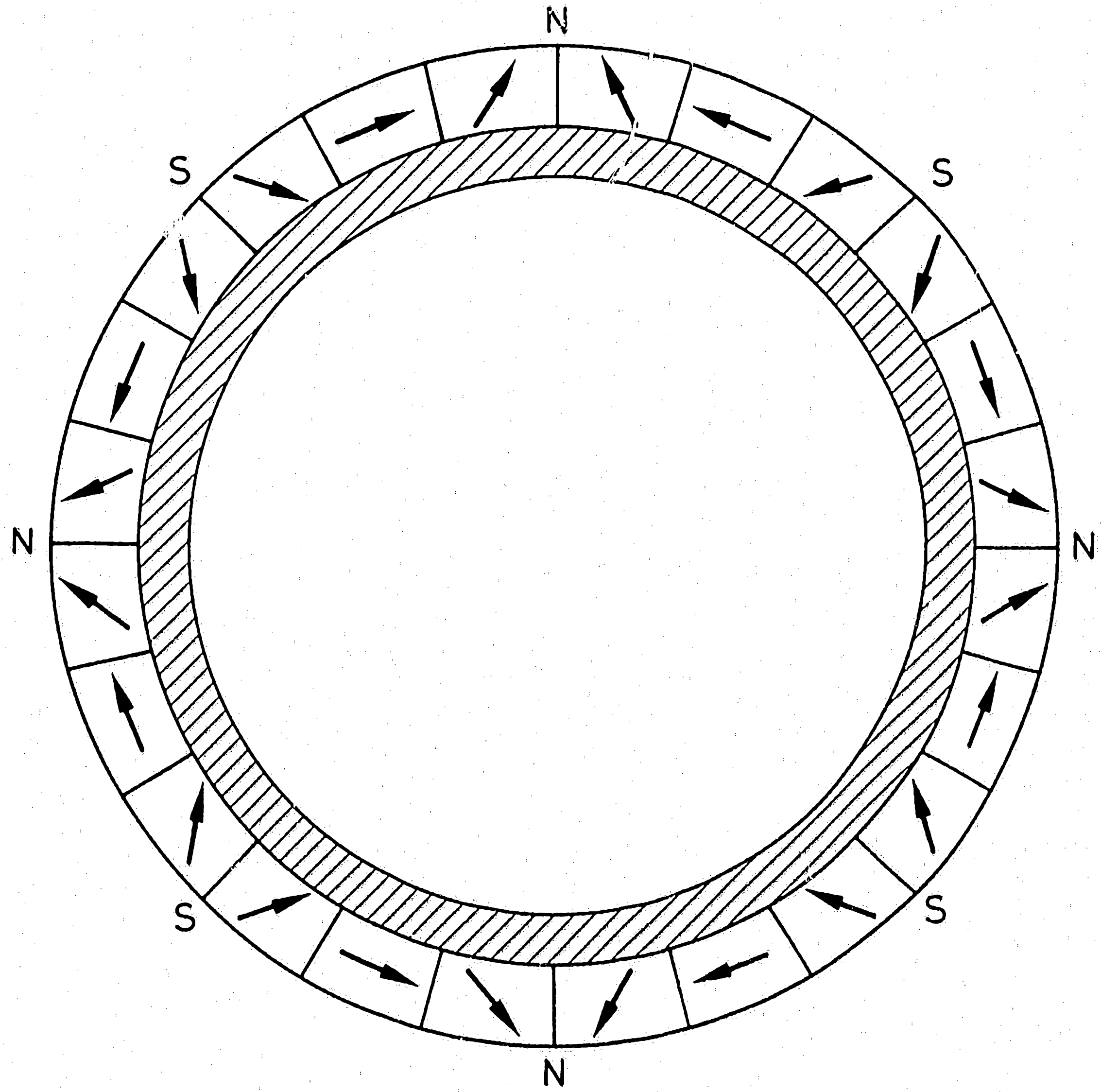

FIG.8

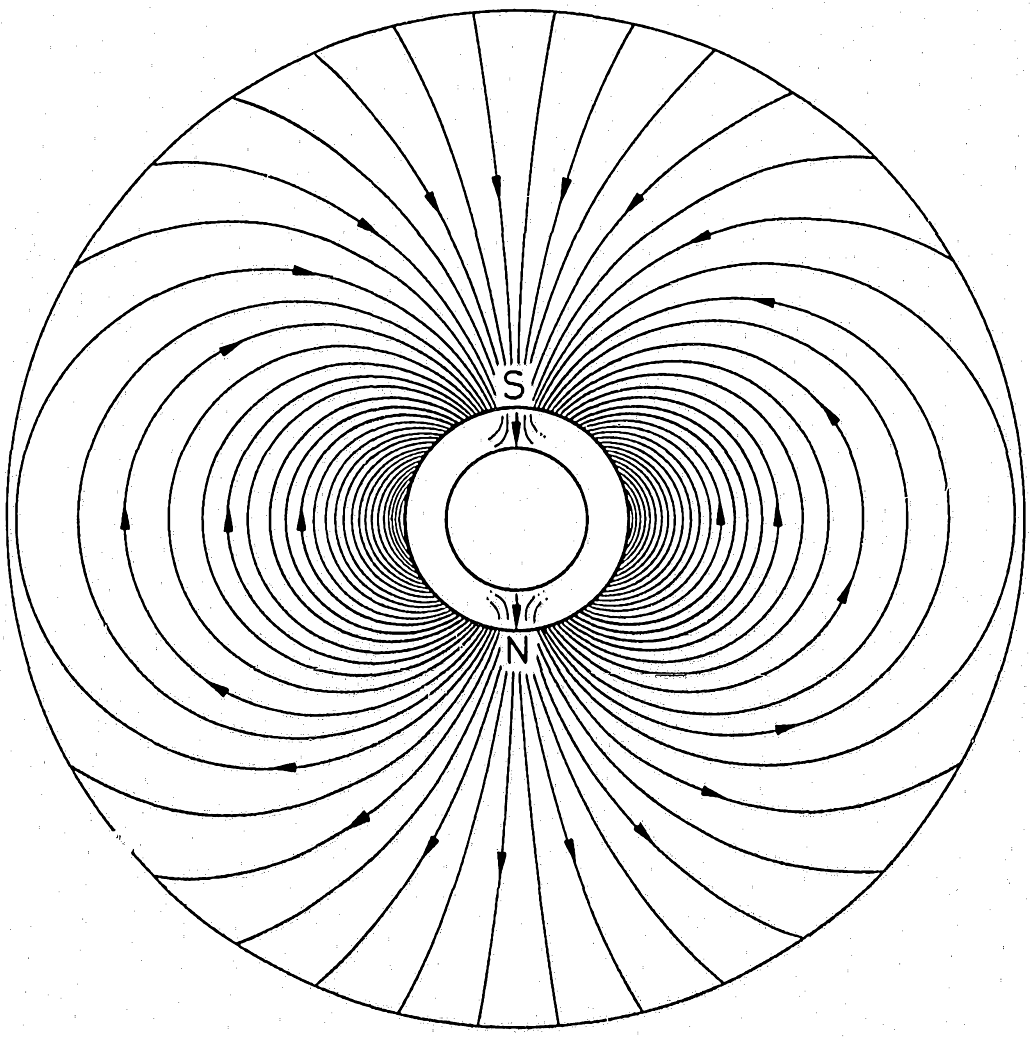

FIG.9