

TRANSLATOR'S DECLARATION

I, Christa Schaertel, declare and say:

1. That I reside at 250 South Reynolds Street, Alexandria, Virginia 22304;

2. That I am thoroughly familiar with the German and English languages;

3. And that I have prepared the attached English-language translation of the PCT/CH97/00114 Patent Application with the title TARGET, MAGNETRON SOURCE WITH SAID TARGET AND PROCESS FOR PRODUCING SAID TARGET, International Preliminary Office Action and Amended Pages, written in the German language; and

4. That all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true, and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Christa Schaertel
Christa Schaertel

Date: October 6, 1998

SP 3193/00

LW

TARGET, MAGNETRON SOURCE WITH SAID TARGET, AND PROCESS FOR
PRODUCING SAID TARGET

The present invention relates to a target made of a ferromagnetic material, a magnetron source, a magnetron sputtering system and to a process for producing a target made of a ferromagnetic material.

It is known that magnetron sputtering sources have a target as well as a magnet arrangement situated underneath. This magnet arrangement generates above the sputtering surface of the target a tunnel-shaped stray field which is normally looped in itself and which is decisive for the effect of the sputtering source as the magnetron sputtering source. During the magnetron sputtering of targets made of a ferromagnetic material, the latter act as a magnetic short circuit. Therefore, a sufficient tunnel-shaped stray field can be implemented only in the case of relatively thin target plates or very strong magnets must be used. Nevertheless, the service life of the target and its yield of material remain low because, as soon as the formation of the erosion trough starts at the target, the stray field intensity in the trough area will increase which, in the sense of a regenerative system, results in an increasing contraction of the erosion trough with a correspondingly poorer yield of target

material and a high rate loss by the sputtering deposit on the target.

It is known from U.S. Patent Documents US-4 401 546, US-4 412 907 and German Patent Document DE-A-32 23 245 to solve this problem in that the target plate bonded onto a carrier plate is segmented to the carrier plate by means of slots. The division of the target plate into individual components requires extremely high expenditures. In addition, it must be ensured by the appropriate design of the intermediate spaces that the contamination of the sputtering process by the carrier plate material is minimized.

U.S. Patent Document US-4 299 678 teaches that the above-addressed problem can be counteracted in such a manner that grooves are machined into the target plate which do not extend through it, but instead the ferromagnetic target material is heated above Curie temperature.

In addition to the working-in of the surrounding groove pattern, in this case, the heating of the target, in particular, also requires extremely high expenditures; since, for example, for a nickel target, this requires a heating to above 350°C.

Finally, from European Patent Document EP-0 210 858, targets are known which have a blind hole pattern. They are used for

non-magnetron high-frequency sputtering and consist, for example, of Mo, Cu, C or SiO₂. Other metallic and dielectric materials can also be used. In this case, the blind holes are dimensioned such that one cylindrical cathode charge respectively burns therein, whereby a particularly high plasma density is to be achieved. In this case, an alternative approach is used for the high-frequency sputtering for the magnetron sputtering which is rare in the case of high-frequency applications.

It is an object of the present invention to provide a target made of a ferromagnetic material, a magnetron source with such a target; further, a magnetron sputtering system with such a source, on which high service lives are achieved with respect to the target, while the material is utilized well. In this case, the targets preferably are to have a rectangular or circular-plate shape. Furthermore, it is an object of the present invention to suggest a manufacturing process for such targets.

On the mentioned target, the above-mentioned object is achieved in that a pattern of blind holes is provided along its sputtering surface.

In the following, the invention will be explained in the manner of an example by means of figures.

Figures 1a to 1f are one cutout respectively of a target

according to the invention, in each case, with an embodiment of the blind hole bores according to the invention;

Figure 2 is a schematic cutout of a magnetron source according to the invention having a target according to the invention, also for defining the quantities used in the description;

Figure 3 is a view of a preferred embodiment of a round target according to the invention with a minimal hole pattern;

Figure 4 is a top view of a rectangular target according to the invention with an improved hole pattern;

Figure 5 is a view of a calculated stray field elevation on an offset individual blind hole on the target of the source according to Claim 2;

Figure 6 is a view of the comparison of the stray field elevation calculated according to Figure 5 with the measured one in the x-direction of an x/y/z -system of coordinates (see definitions);

Figure 7 is a representation analogous to Figure 6, viewed in the y-direction;

Figure 8 is a view of the course of the maximal stray field elevation on three individual blind holes of different diameters in the case of a different offset (see definitions);

Figure 9 is a view of the course of the magnetic field caused by a superposition in the case of four blind holes situated side-by-side;

Figure 10 is a view of the course of the useful sputtering rate on a nickel target structured according to Figure 4 as a function of the service life of the target;

Figure 11 is a view of a function block / signal flow diagram of a target producing system according to the invention operating according to the process of the invention; and

Figure 12 is a view of a particularly preferred embodiment of a rectangular target according to the invention in a representation analogous to Figure 4.

According to Figure 1, a target according to the invention made of a ferromagnetic material, particularly of nickel or a nickel alloy, such as NiFe, has a pattern of blind holes on its sputtering surface. These may be worked into the target plate 1, as illustrated, for example, by means of Figure 1a to 1c, for example, by drilling. Preferably, the blind holes 3 are

rotationally symmetrical with respect to the axis L.

According to Figure 1d, the blind holes 3 provided according to the invention, as illustrated at reference number 3', may also be worked in at an oblique angle with respect to the new sputtering surface 7 of the target.

Further, according to Figure 1e, in the case of a construction of the blind holes provided by the invention according to one or several embodiment(s) illustrated in Figures 1a to 1d, the thickness dimension of the target 1 may be stepped, which also influences the course of the tunnel field.

According to Figure 1f, the target, which is again provided with blind holes according to one of Figures 1a to 1d, is constructed in two parts - of an upper plate 1a and of a lower plate 1b -, preferably made of the same materials. The upper plate 1a is drilled through for establishing the blind holes 3". This may result, for example, in important manufacturing advantages.

The terms used in the following are defined by means of Figure 2.

Figure 2 is a schematic view of a cutout of a magnetron source according to the invention with a target according to the

invention. The broken line indicates one of the several blind holes 3 provided according to the invention. The magnet arrangement 5 produces the tunnel-shaped stray field $\bar{B}$.

Definitions:

- Tunnel Field: The total field pattern of the magnetic stray field $\bar{B}$ of the magnetron source which emerges from the target sputtering field and returns into it, with the component B_z perpendicularly to the new sputtering surface 7 and the component B_x in parallel to the new surface 7. The lines $\bar{B}$ of electric flux extend in respective planes E perpendicularly to the new surface 7.
- Tunnel Axis y: Corresponding to the coordinate axis y: Location on the new surface 7, above which B_x is maximal and B_z is vanishing.
- x-Coordinate With the origin on the tunnel axis y,
x/y/z System: perpendicular to y in the new surface 7. This results in the x/y/z system.
- Erosion Trough 9: The increasingly deep area of sputtered-off material which extends essentially under

the area T of the tunnel field $\bar{B}$.

- New Surface 7: Non-sputtered target sputtering surface.
- Field Intensity B_{ox} : Field intensity component in the x-direction which, when the new surface is not perforated, occurs directly on its surface.
- $B_{\ell x}$: The field intensity in the x-direction which occurs in the area of a blind hole provided according to the invention.
- $B_{\ell x \max}$: Its maximal value.
- ΔB_x : Stray field elevation. The difference between field $B_{\ell x}$ measured at the same location in the area of a blind hole provided according to the invention and field B_{ox} measured at the same location.
- B_{rx} : The course of the field in the x-direction occurring when several blind holes are provided.
- Hole Offset V: The offset of the central axis L of a blind

hole provided according to the invention
perpendicularly to the tunnel axis y.

- Useful Sputtering Rate NZ: The amount of material in grams sputtered per kWh and usable over the target.
- Degree of Utilization N: The percentage of the proportion of the sputtered material which can be used above the eroded target surface, relative to the new weight of the target.

According to the invention, the distribution of the provided blind holes 3 in the target sputtering surface influences the tunnel field in a targeted manner in order to design in a targeted manner, on the one hand, the useful sputtering-off rate distribution - the useful sputtering-off rate per se - and on the other hand, the forming erosion profile.

Figure 3 illustrates a simple embodiment of the round target according to the invention. According to the invention, a pattern of blind holes 3 is provided in the area T, preferably defining a loop which is closed in itself, preferably also a circular loop in T. By means of the selective design of the hole spacing in the y-direction, of the offset V and of the hole diameters as well as of the hole profiling (see, for example, Figure 1c), further of the alignment of the hole axes L (see, for

example, Figure 1d), and/or of the thickness profiling (see, for example, Figure 1e), the resulting field B_{rx} can be designed as desired within wide limits.

Figure 4 is a top view of an end section of a rectangular target. As illustrated, four loops of blind holes 3 are provided here; an outermost loop 11_a and an innermost loop 11_i with blind holes having a larger diameter. In-between, two loop patterns 13_a and 13_i of blind holes are situated which have smaller diameters. By means of an arrangement with several loop patterns in the or close to the T, it becomes possible to implement above it, for example, an optimally homogeneous field B_{rx} .

In Figure 5, ΔB_x is received at a height of 5 mm above a 4mm individual hole in a Ni target of a thickness of 11 mm, with a magnet system, as used on the magnetron source AK 517, which is sold by the applicant.

By means of point markings K, Figure 6 illustrates values of ΔB_x , measured on a 4 mm individual blind hole in the 11 mm nickel target with the above-mentioned magnet system as well as the adapted course calculated by means of a Gauss function. The match is clearly demonstrated.

While Figure 6 shows the course of the magnetic field elevation ΔB_x similar to the Gauss function in a z/x plane,

Figure 7 shows the above-mentioned comparison on the same individual blind hole, viewed in the z/y plane, in each case through L.

Figure 8 shows, as a function of V , for individual blind holes of the diameters 4 mm (a), 5 mm (b), 6 mm (c) in a 11 mm Ni target, when the above-mentioned magnet system is used, the maximum magnetic field elevation $\Delta B_{x\max}$, measured over 5 mm of the new surface and the respective hole center L.

Figure 9 shows the resulting magnetic field B_{rx} if, with the corresponding offset V_1 to V_4 in T and centered with respect to the y -tunnel axis, four pocket bores are provided, each of a diameter of 4 mm, again in an Ni target of a thickness of 11 mm and with the above-mentioned magnet arrangement. This demonstrates that B_{rx} can be determined; here, measured or calculated at a height of 5 mm over the sputtering surface, by the additive superposition of the Gauss-type distributions of $B_{\ell x}$ and ΔB_x of the individual blind holes.

By means of a function block signal flow diagram, Figure 11 shows the production process according to the invention, on the one hand, and the construction of a system for its implementation, on the other hand. By a given number of n individual bore holes, with a given magnetic field $B_{x0}(x,y)$ distribution, with one given offset V_{1-n} respectively, a given

diameter ϕ_{1-n} , and the given y-position y_{1-n} , further, in the case of a given hole profile and a given inclined position and in the case of a given target thickness, the measured or calculated individual hole magnetic fields $B_{\ell_{x1-n}}$ are fed into a computer 20. These are additively superimposed on the computer unit 22. This results in the course of the magnetic field $B_{rx}(x, y)$; corresponding to the summation of the individual-hole magnetic-field courses, for example, according to Figure 5, in the resulting magnetic field course, for example, according to Figure 9.

In a comparison unit 24, the calculated resulting course $B_{xr}(x,y)$ is compared with a given DESIRED course $B_{\ell_{x}DESIRED}(x,y)$. By means of the resulting deviation course Δ , an automatic change takes place on the defining unit for the $B_{\ell_x}(x,y)$ 26, of the hole offsets V_{1-n} and/or the diameters ϕ_{1-n} and/or the hole positions x, y and/or the hole profiles and/or the diagonal hole positions and/or the target thickness until the resulting field course $B_{rx}(x,y)$ corresponds with the required precision to the DESIRED course $B_{rxDESIRED}(x,y)$. Then, as schematically illustrated by means of the comparator unit 28, the iterative feedback process Δ is interrupted; the then determined geometrical data for the position, the profile, the inclined position, the thickness and the hole diameter, as schematically illustrated with the switching unit 30, are illustrated; and, optionally by way of an intermediate storage, are transmitted to an automatic tool 32 for

the target perforation.

With the defining of the DESIRED course $B_{rxDESIRED}(x,y)$, a stray field intensity is endeavored which is as high as possible, as well as a stray field profile over the new target surface which is as broad as possible. Furthermore, on the defining unit 26, preferably not only the above-mentioned hole parameters, specifically the geometrical position, the profile, the inclined position, the local thickness of the target plate, are varied but also the used hole number n in order to implement the DESIRED course with the required approximation, specifically with a blind hole number which is as low as possible. During the selection of the DESIRED field course, the experimental values over the corresponding course of the target erosion are taken into account.

In Figure 10, the measured NZ is listed on an Ni target which is structured according to the invention and has a thickness of 11 mm with the dimension 5" x 17", designed as illustrated in Figure 4, which shows that, as a function of the target operating time in kWh, the utilized sputtered-off material rate decreases only insignificantly and the loss rate therefore increases only insignificantly.

In the case of the target according to the invention, for example, according to Figure 4, N was measured in the case of Ni

targets according to the invention at 18%, in contrast to only 13% in the case of unstructured Ni targets.

By means of the targets according to the invention made of a ferromagnetic material, it is possible to use significantly thicker target plates and thus to clearly lengthen the service life of the target. The providing of a carrier plate for the target is often not necessary. Compared to the non-blind-hole-profiled targets made of the same ferromagnetic material, the erosion troughs have little contraction. This results in a significant increase of N.

Furthermore, an improvement of NZ is determined with respect to the local homogeneity, which is explained by, among other things, the widening of the erosion trough. This demonstrates that, by means of a targeted distribution of the blind hole pattern, the distribution of NZ can also be influenced in a targeted manner.

The establishment of a hole pattern in the target is extremely reasonable in cost, and, by means of the production process according to the invention, desired field courses of the tunnel field can be implemented in a targeted manner.

Finally, Figure 12 shows a particularly preferred pattern on a rectangular target. It comprises rows of holes 40 which, along

the longitudinal sides of the target, are arranged toward the inside in a zig-zag-shape. The outer holes 3a - preferably two respectively - and the inner holes 3i - again preferably two - are larger than the central holes 3m - again preferably two. In this case, the diameter of holes 3a, 3i is preferably 5 mm; that of holes 3m is 4 mm. The holes 3 are again arranged in loop legs 11c. Along the broad sides of the target, the pattern essentially has a circular-segment shape, as illustrated at reference number 4, and is preferably spread out by rows of holes 3m, 3a in parallel to the target broad side. This pattern results in a particularly flat erosion trough which is independent of the target thickness.



CLAIMS:

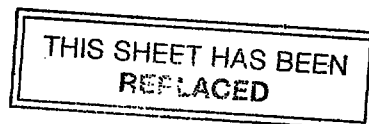
1. Target made of a ferromagnetic material, characterized in that, distributed along its sputtering surface, it has a pattern of blind holes 3.

2. Target according to Claim 1, characterized in that the blind holes are arranged essentially along at least one loop, which is closed in itself, preferably in a centered manner with respect to the target surface center and/or at least one target surface axis of symmetry, preferably in at least two of the above-mentioned loops which are closed in themselves.

3. Target according to Claim 2, characterized in that, between two loops, which are closed in themselves, at least one additional loop is provided, the diameters of the blind holes along the additional loop preferably being smaller than those along the two outer loops.

4. Target according to one of Claims 1 to 3, characterized in that the pattern comprises rows of blind holes which extend in a zig-zag shape from the target surface edge toward their center.

5. Target according to Claim 4, characterized in that it is rectangular, extends in a zig-zag pattern transversely to and along the longitudinal sides and in that, along the broad sides,





the pattern, at least approximately in the form of a circular-segment surface, connects the zig-zag patterns.

6. Target according to Claim 4 or 5, characterized in that the rows consist of pocket bores whose outer bores have a larger diameter than whose inner bores.

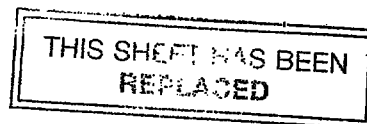
7. Target according to one of Claims 1 to 6, characterized in that it consists of nickel or of a nickel alloy, preferably, in the case of the latter, of NiFe.

8. Target according to one of Claims 1 to 7, characterized in that the blind hole diameters are situated in the area of from 3 mm to 6 mm (both limits are included).

9. Magnetron source having a target according to one of Claims 1 to 8, characterized in that the blind hole distribution extends along that target area above which the tunnel field of the source is situated.

10. Magnetron source according to Claim 9, characterized in that the blind hole distribution is essentially symmetrical to the location of the vanishing magnetic field intensity component (B_z) perpendicular to the new target surface 7 of the tunnel field.

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11. Magnetron sputtering system having a magnetron source according to one of Claims 9 or 10, characterized in that the diameters of the blind holes are dimensioned such that no cylindrical cathode discharge occurs at operating conditions of the system.

12, Process for producing a target made of ferromagnetic material for a given magnetron source with a given tunnel field, characterized in that

- the tunnel field course is measured or calculated, when individual blind holes are provided in the new target surface, as a function of hole diameters and/or their relative position to the tunnel field and/or of the hole profile and/or of the hole axis inclination with respect to the new target surface and/or of the target thickness profiling, and is stored,

- these tunnel field courses of several individual blind holes, in the case of given relative positions between the holes and with respect to the tunnel field and the hole diameters, as initial conditions, are additively superimposed for obtaining a resulting tunnel field course,

- the resulting tunnel field course is compared with a DESIRED tunnel field course,

- as a function of the comparison result, the relative parameter position of the individual blind holes and/or their diameters and/or their position with respect to the tunnel field and/or their profile and/or their inclination and/or the target





thickness profiling and/or the number of holes are changed until the resulting field corresponds to the DESIRED field course with a given approximation,

- by means of the found parameters, the working of blind holes into the plane target sputtering surface is controlled.

13, Arrangement for producing a target from a ferromagnetic material for a given magnetron source with a given tunnel field, characterized in that it comprises

- an input unit with several outputs, at which field distribution curves can be retrieved and at which, by way of adjusting inputs, curve parameters can be adjusted,

- a course addition unit which is operatively connected on the input side with the input unit and which, on the output side, leads to one input of a course comparison unit, at whose second input a desired course can be fed and whose output feeds back to the adjusting inputs at the input unit, the adjusting inputs being operatively connected with an output for the triggering of a blind hole production device for the target.

14. Arrangement according to Claim 13, characterized in that the number (n) of activated outputs can be adjusted at the input unit by way of adjusting inputs.



FIG.1a

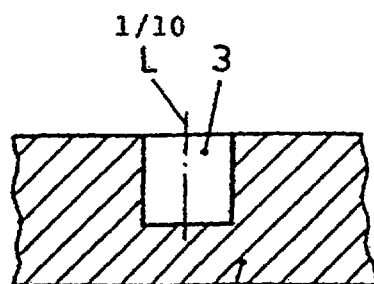


FIG.1b

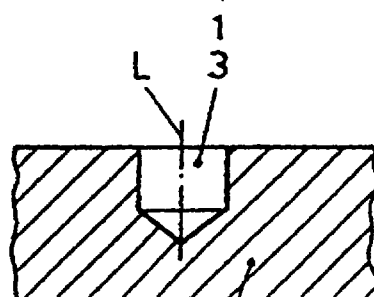


FIG.1c

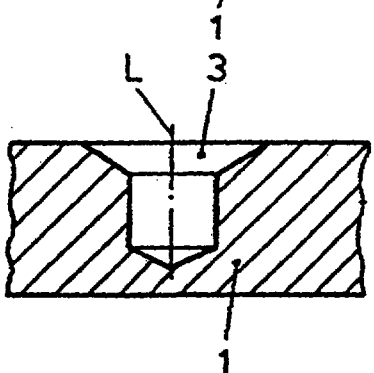


FIG.1d

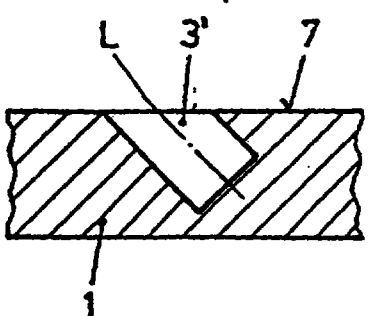


FIG.1e

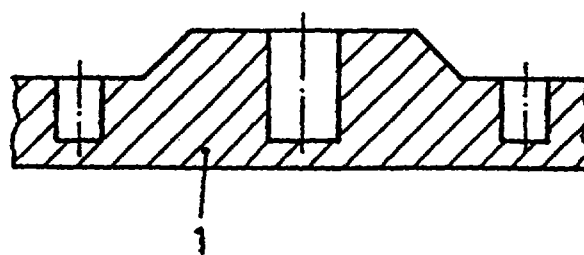
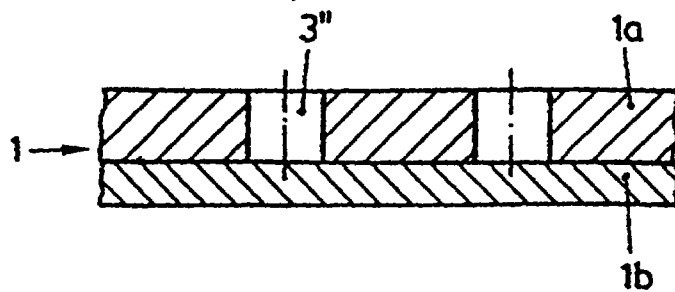


FIG.1f



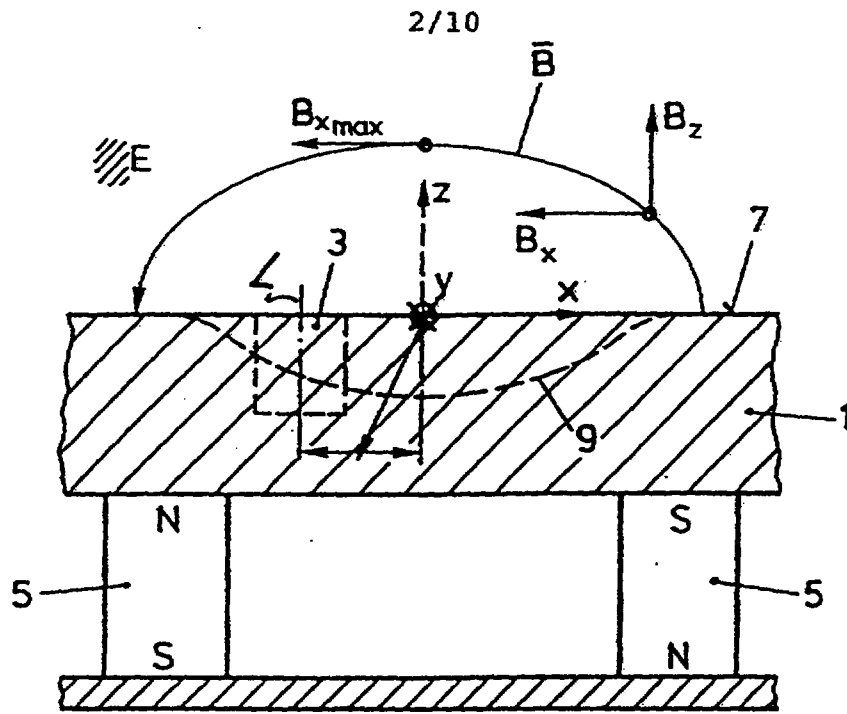


FIG. 2

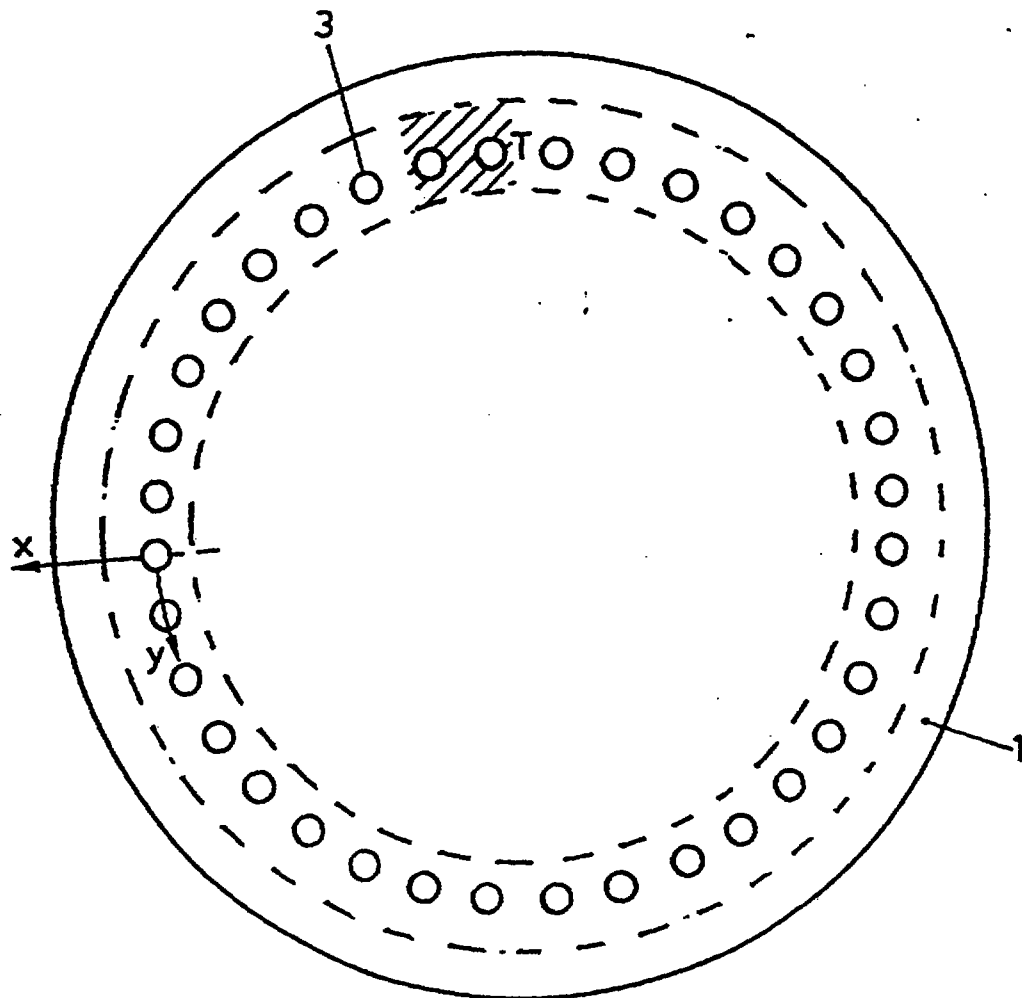


FIG. 3

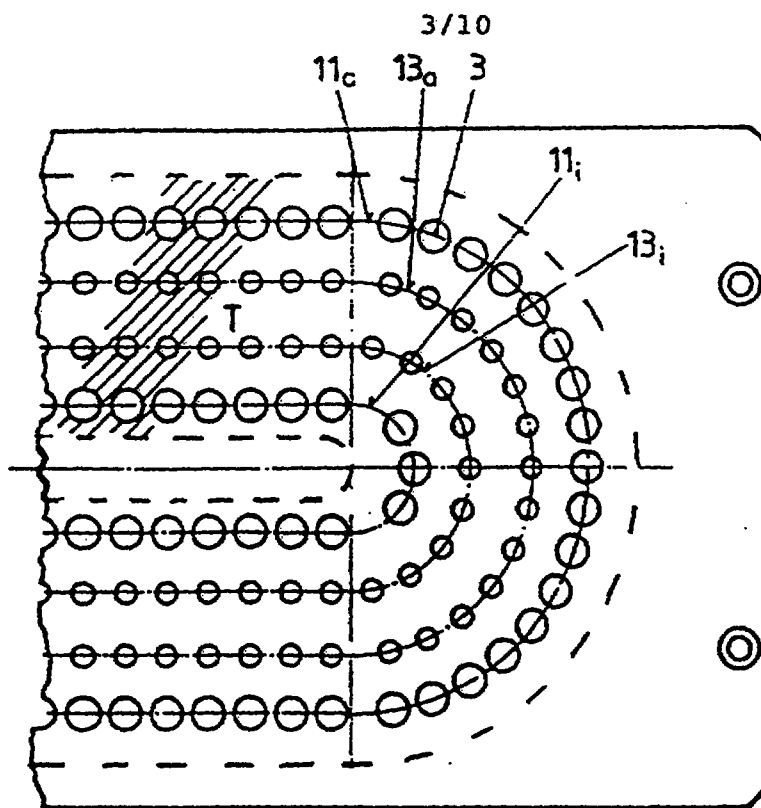


FIG.4

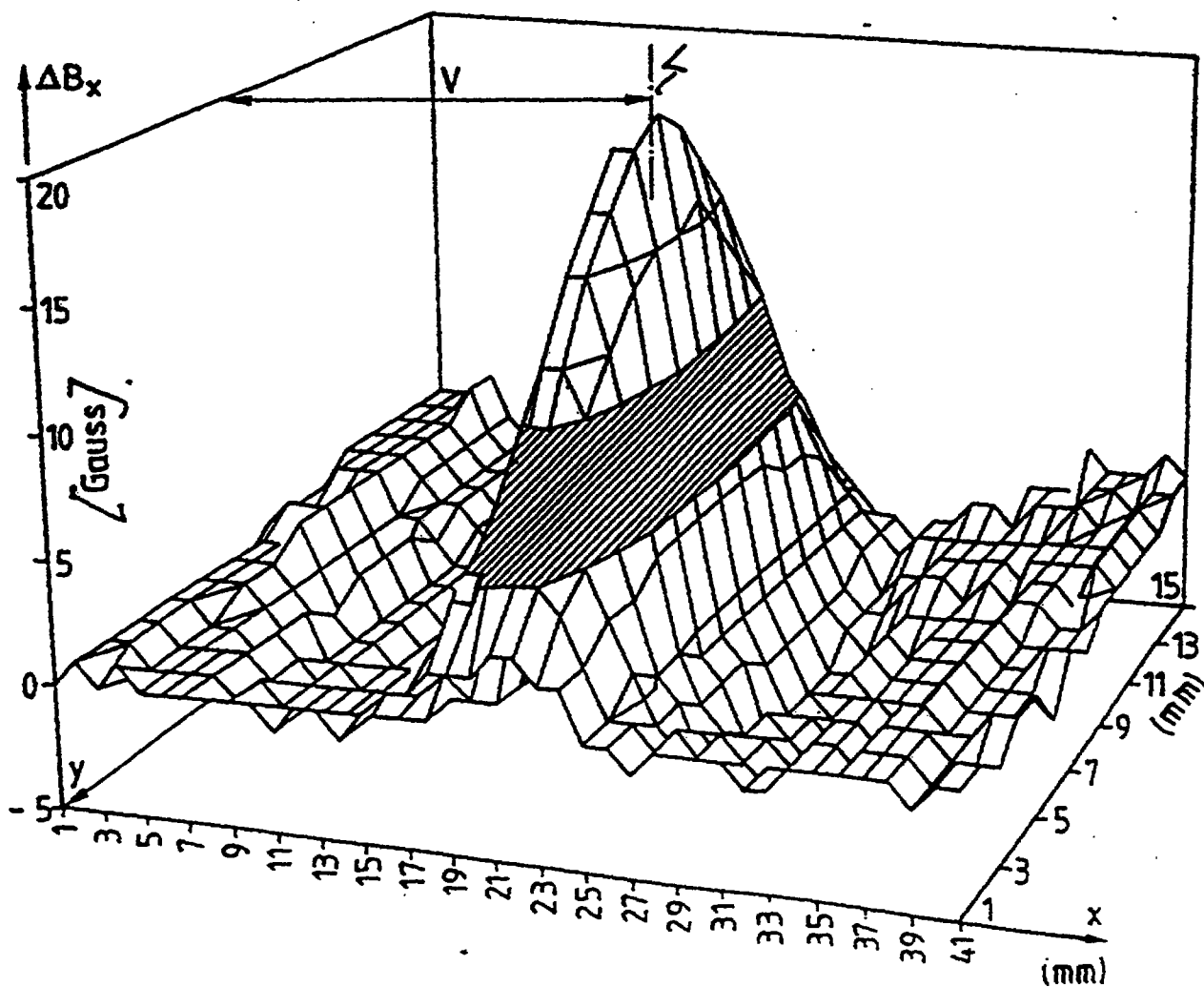


FIG.5

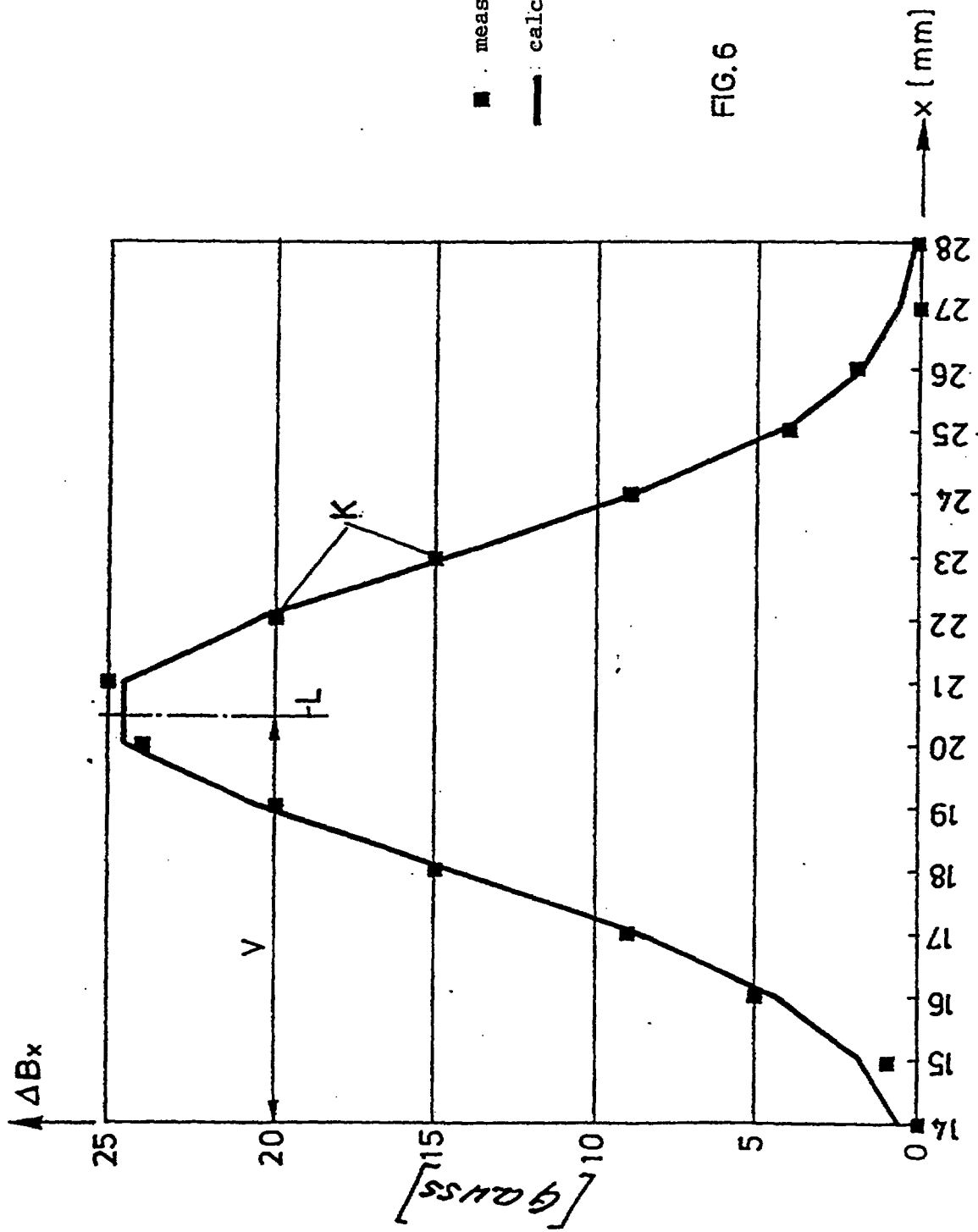


FIG. 6

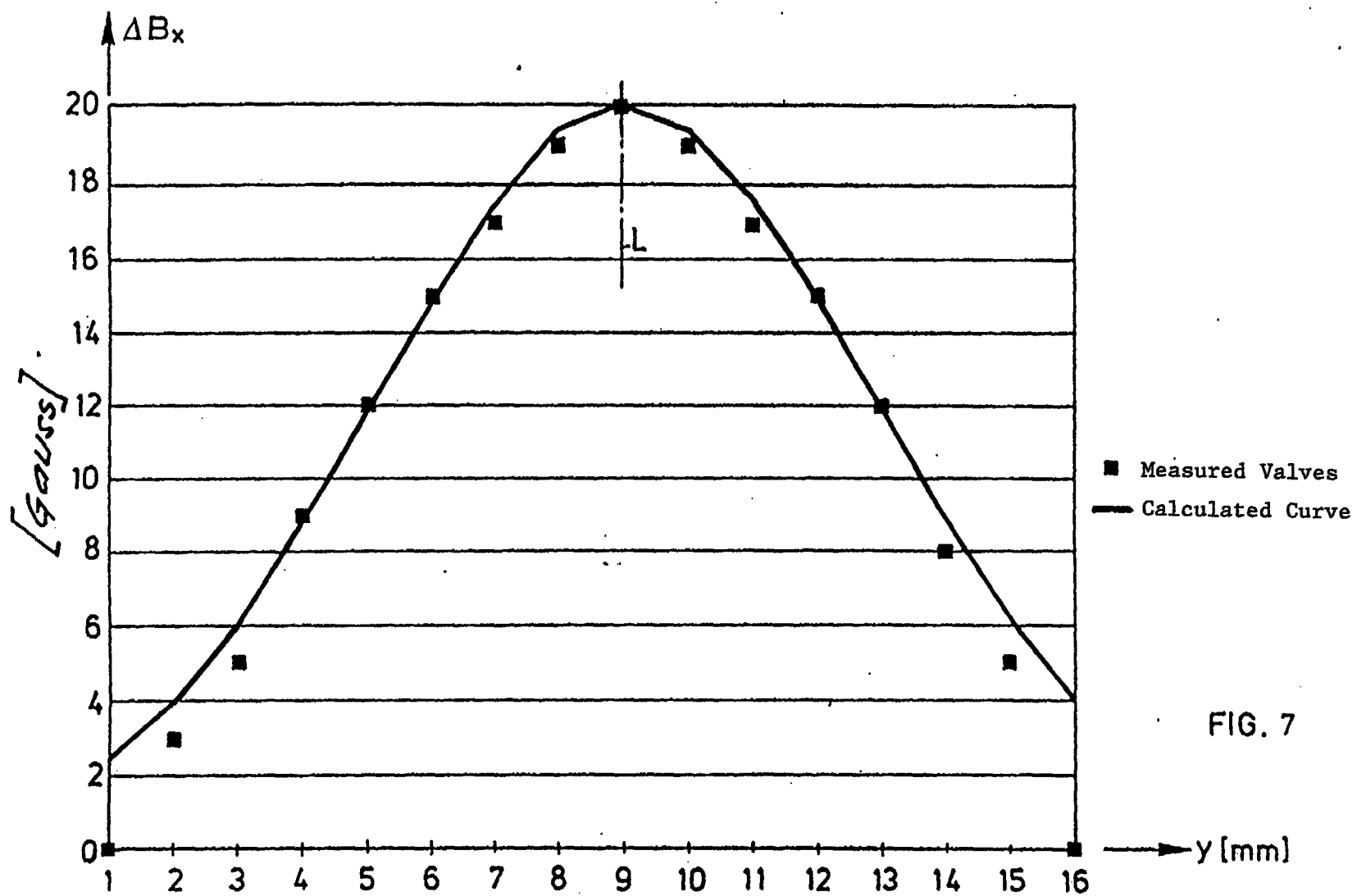


FIG. 7

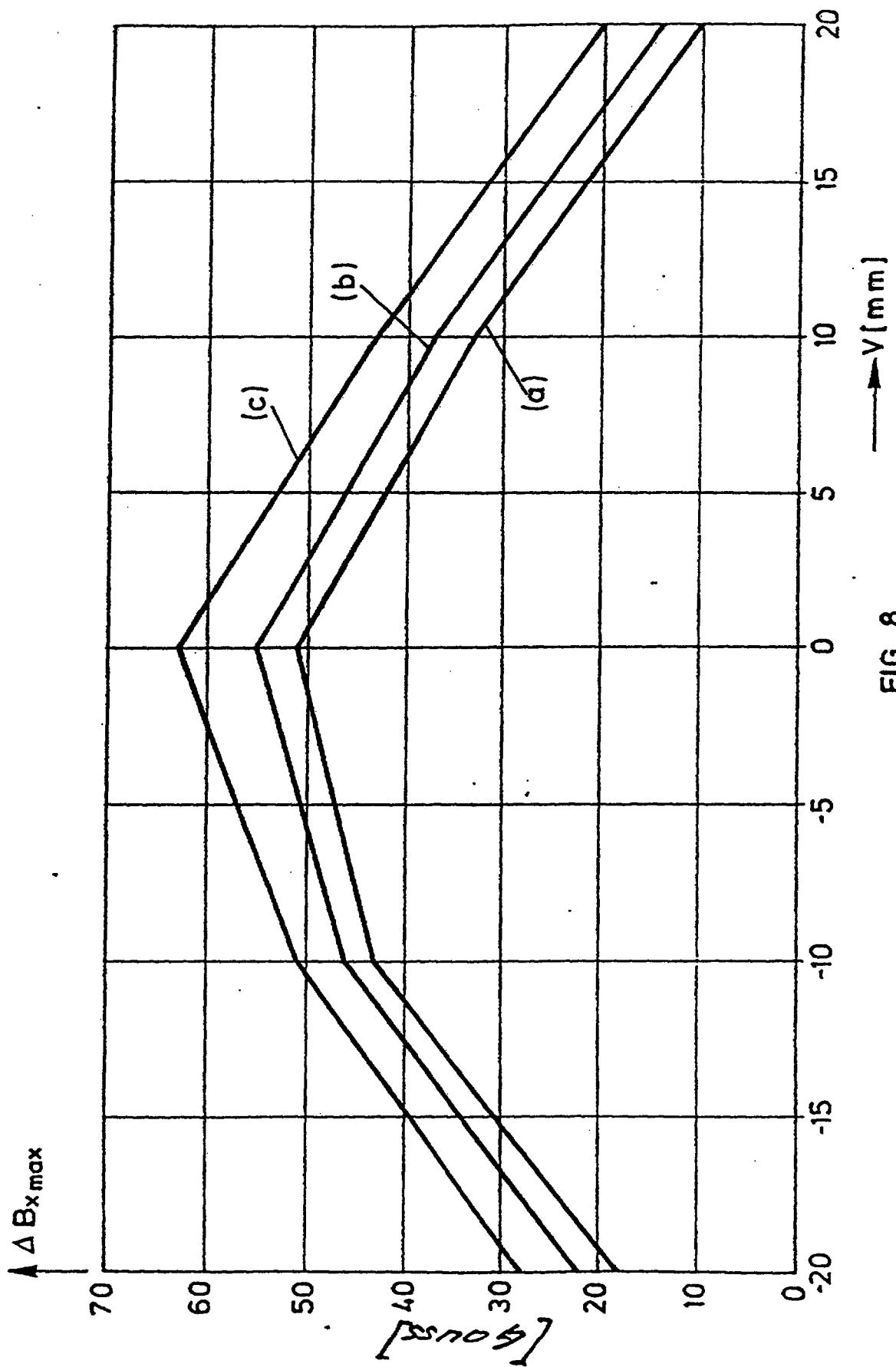


FIG. 8

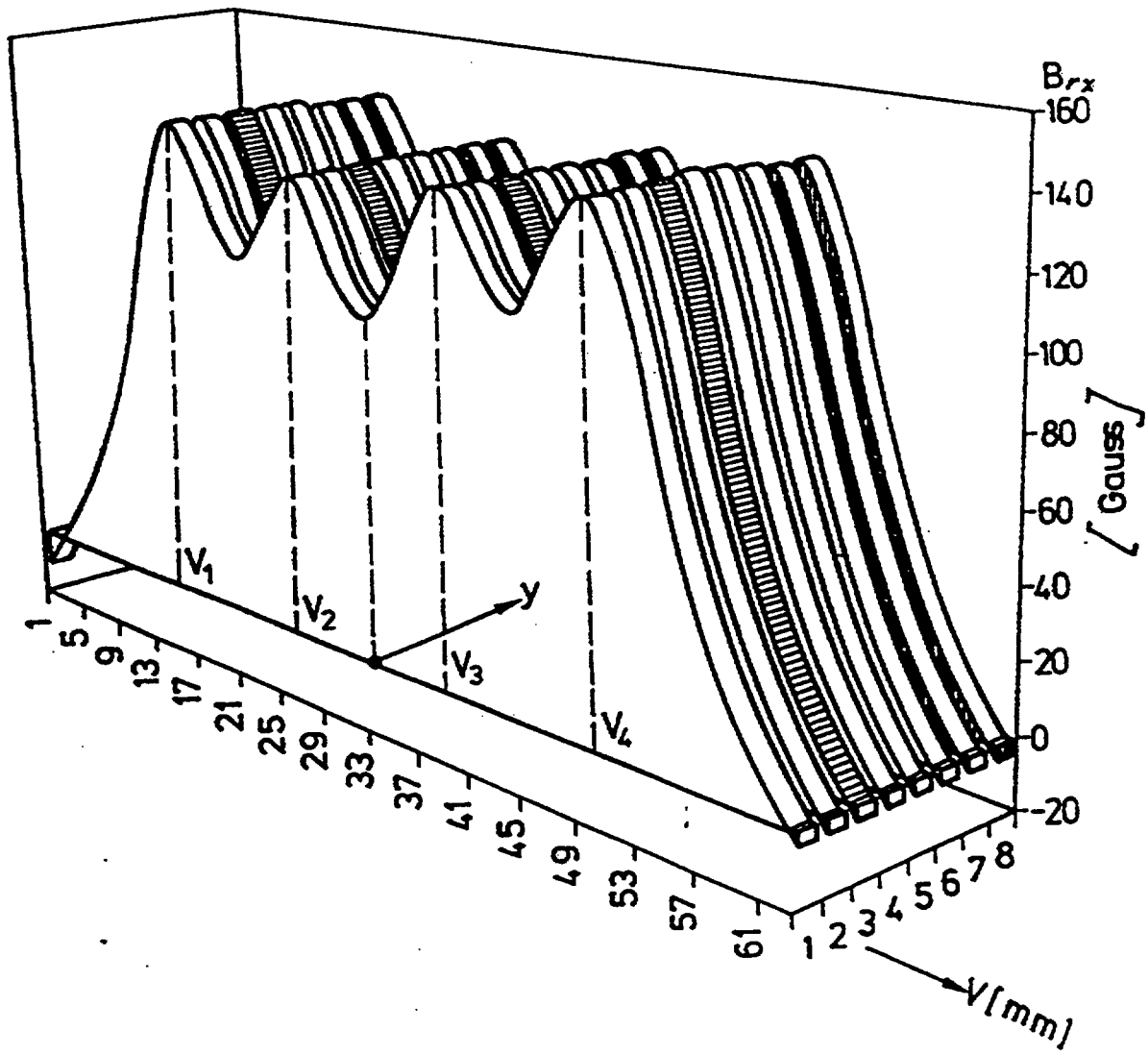


FIG. 9

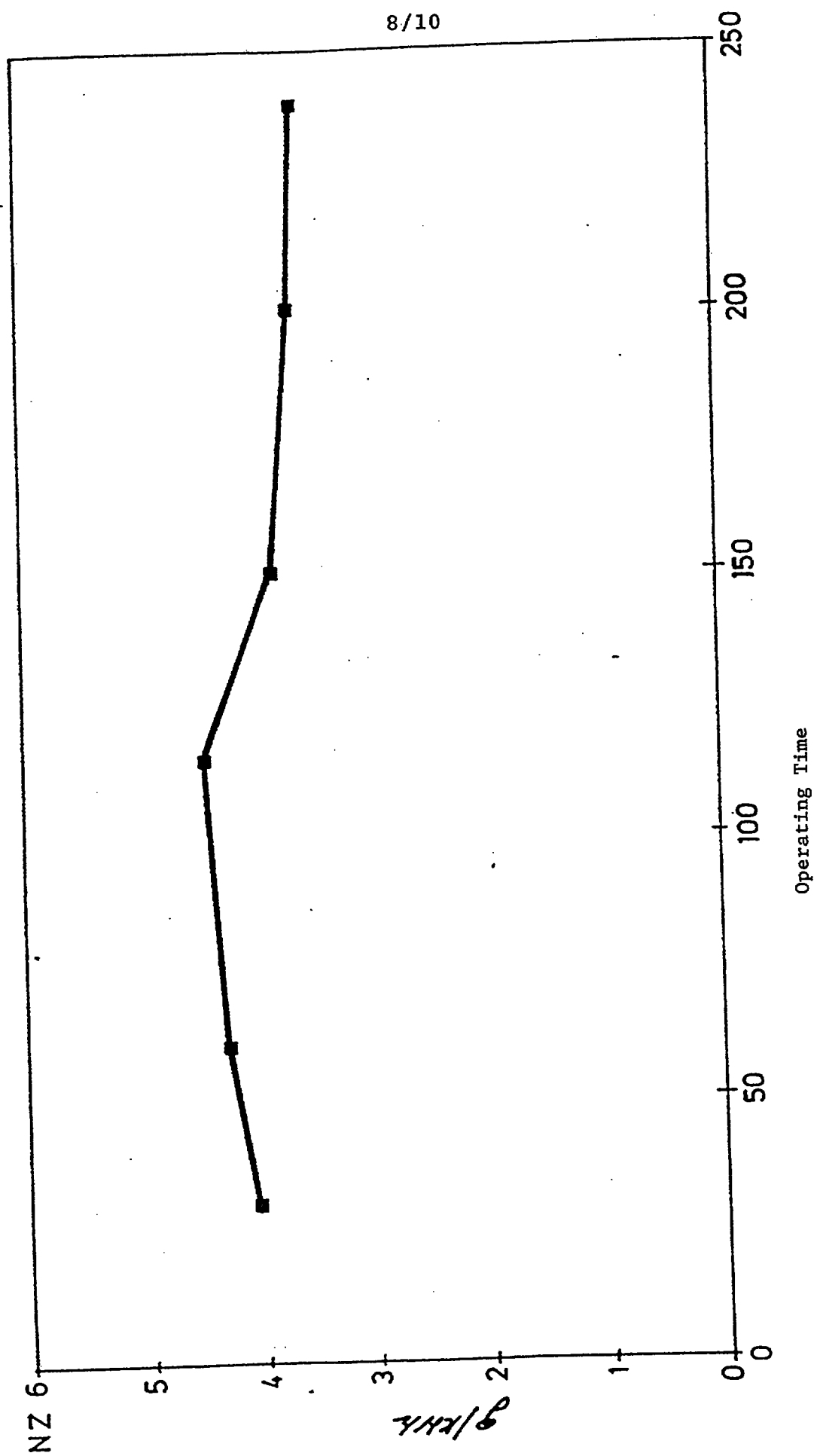


FIG. 10

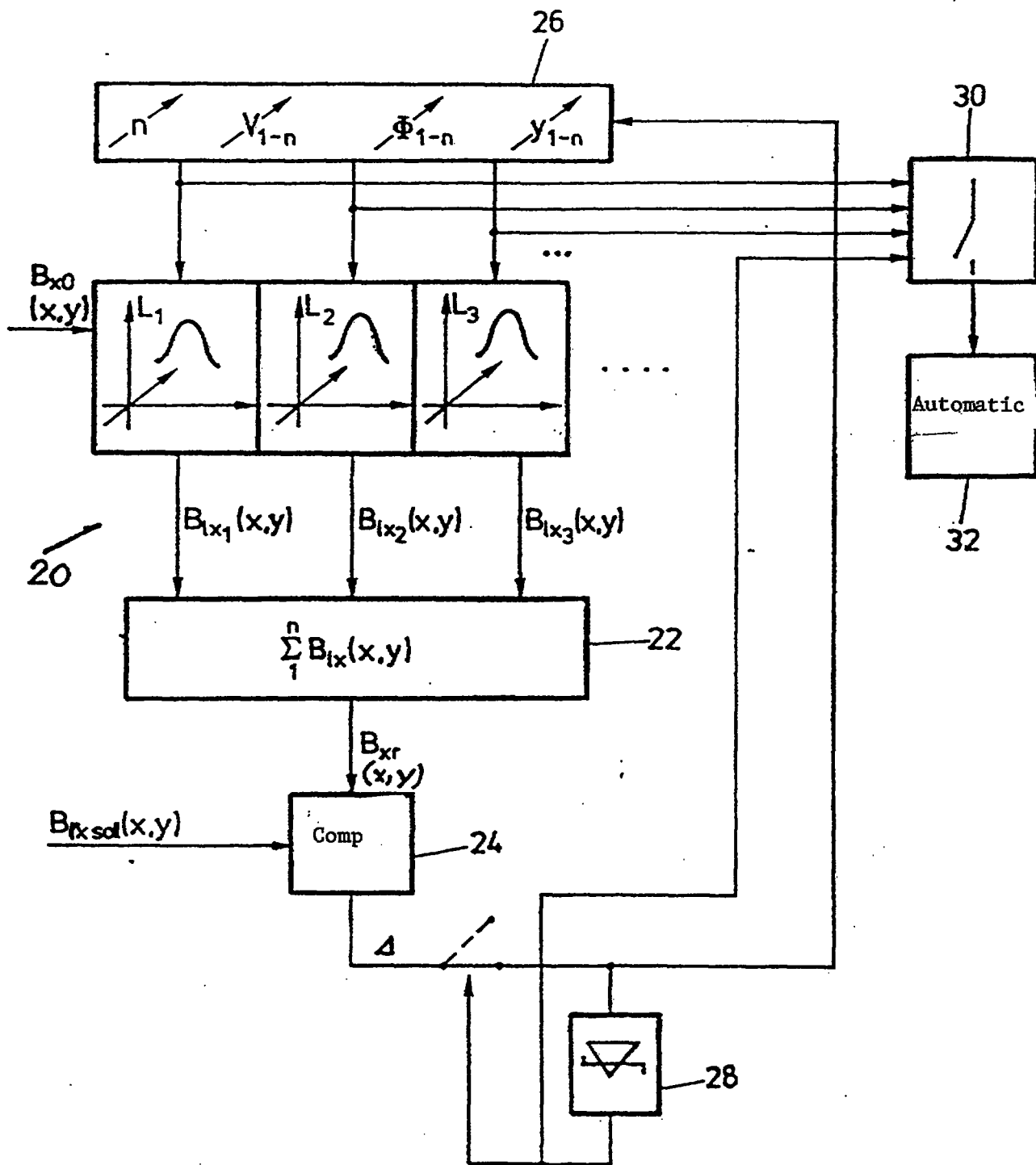


FIG. 11

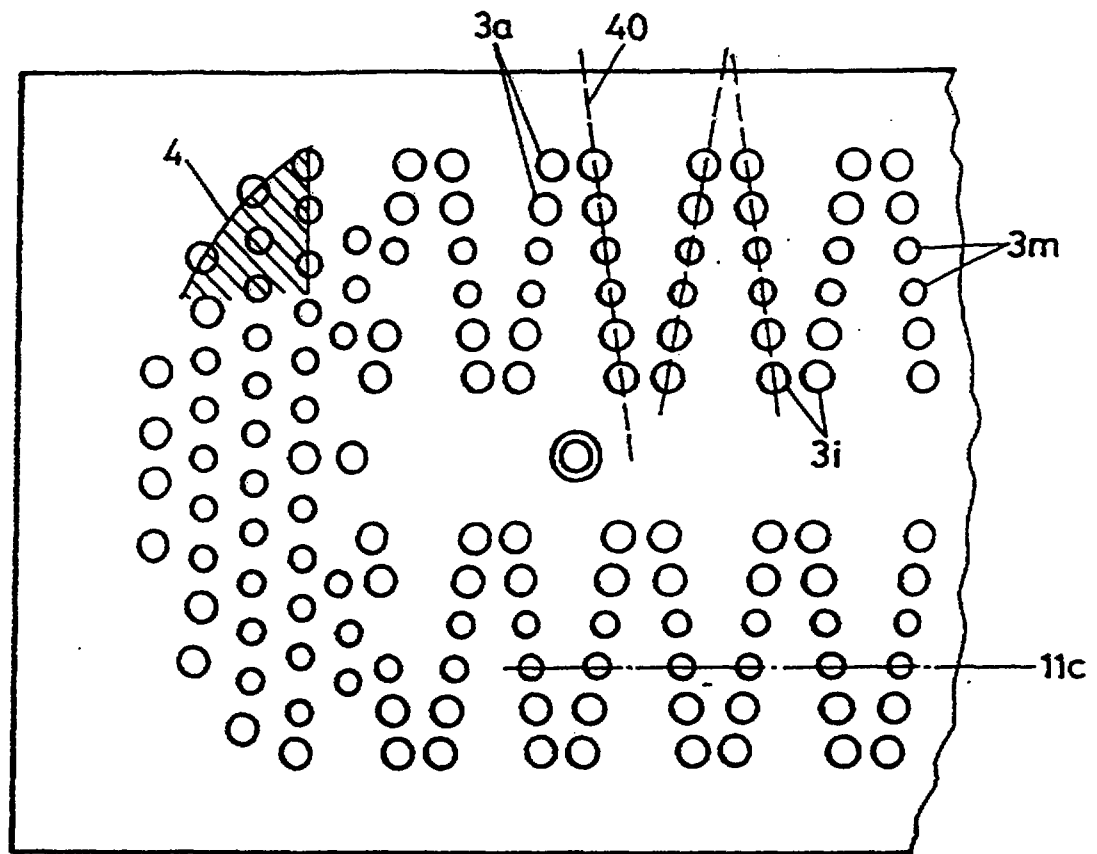


FIG.12



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CLAIMS:

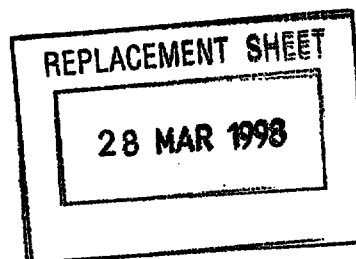
1. Magnetron target made of a ferromagnetic material, characterized in that, distributed along its sputtering surface, it has a pattern of blind holes 3 with a circular cross-section.

2. Magnetron target according to Claim 1, characterized in that the blind holes 3 are arranged essentially along at least one loop 11, 13, which is closed in itself, preferably in a centered manner with respect to the target surface center and/or at least one target surface axis of symmetry, preferably in at least two of the above-mentioned loops which are closed in themselves.

3. Target according to Claim 2, characterized in that, between two loops 11a, 11i, which are closed in themselves, at least one additional loop 13a, 13i is provided, the diameters of the blind holes 3 along the additional loop preferably being smaller than those along the two outer loops 11a, 11i.

4. Target according to one of Claims 1 to 3, characterized in that the pattern comprises rows 40 of blind holes 3 which extend in a zig-zag shape from the target surface edge toward their center.

AMENDED PAGE





Continuation of Amended Page 13 of Claims

5. Target according to Claim 4, characterized in that it is rectangular, extends in a zig-zag pattern transversely to and along the longitudinal sides and in that, along the broad sides, the pattern, at least approximately in the form of a circular-segment surface 4, connects the zig-zag patterns.

REPLACEMENT SHEET

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6. Target according to Claim 4 or 5, characterized in that the rows consist of pocket bores whose outer bores 3a have a larger diameter than whose inner bores 3m.

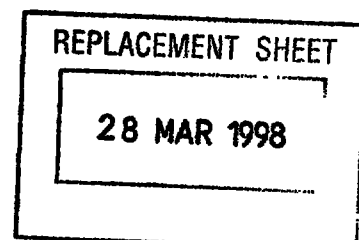
7. Target according to one of Claims 1 to 6, characterized in that it consists of nickel or of a nickel alloy, preferably, in the case of the latter, of NiFe.

8. Target according to one of Claims 1 to 7, characterized in that the blind hole diameters are situated in the area of from 3 mm to 6 mm (both limits are included).

9. Magnetron source having a target according to one of Claims 1 to 8, characterized in that the blind hole distribution extends along that target area above which the tunnel field ($\bar{B}$) of the source is situated.

10. Magnetron source according to Claim 9, characterized in that the blind hole distribution is essentially symmetrical to the location of the vanishing magnetic field intensity component (B_z) perpendicular to the new target surface 7 of the tunnel field.

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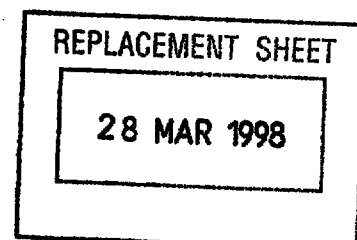




Continuation of Amended Page 14 of Claims

11. Magnetron sputtering system having a magnetron source according to one of Claims 9 or 10, characterized in that the diameters of the blind holes are dimensioned such that no cylindrical cathode discharge occurs at operating conditions of the system.

12. Process for producing a target made of ferromagnetic material for a given magnetron source with a given tunnel field, characterized in that





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- the tunnel field course is measured or calculated, when individual blind holes are provided in the new target surface, as a function of hole diameters and/or their relative position to the tunnel field and/or of the hole profile and/or of the hole axis inclination with respect to the new target surface and/or of the target thickness profiling, and is stored,

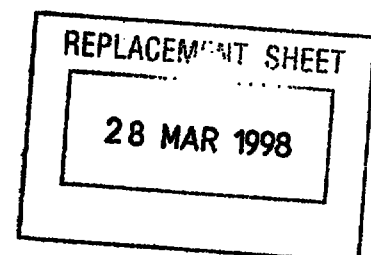
- these tunnel field courses of several individual blind holes, in the case of given relative positions between the holes and with respect to the tunnel field and the hole diameters, as initial conditions, are additively superimposed for obtaining a resulting tunnel field course,

- the resulting tunnel field course is compared with a DESIRED tunnel field course,

- as a function of the comparison result, the relative parameter position of the individual blind holes and/or their diameters and/or their position with respect to the tunnel field and/or their profile and/or their inclination and/or the target thickness profiling and/or the number of holes are changed until the resulting field corresponds to the DESIRED field course with a given approximation,

- by means of the found parameters, the working of blind holes into the plane target sputtering surface is controlled.

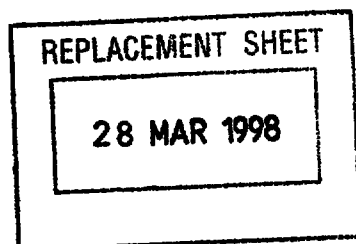
AMENDED PAGE





Continuation of Amended Page 15 of the Claims

13, Arrangement for producing a target from a ferromagnetic material for a given magnetron source with a given tunnel field, characterized in that it comprises





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- an input unit with several outputs, at which field distribution curves can be retrieved and at which 26, by way of adjusting inputs, curve parameters (n , v , Φ , y) can be adjusted,

- a course addition unit 22 which is operatively connected on the input side with the input unit and which, on the output side, leads to one input of a course comparison unit 24, at whose second input a desired course can be fed and whose output feeds back to the adjusting inputs at the input unit 26, the adjusting inputs being operatively connected with an output 30, 32 for the triggering of a blind hole production device for the target.

14. Arrangement according to Claim 13, characterized in that the number (n) of activated outputs can be adjusted at the input unit by way of adjusting inputs.

AMENDED PAGE