

- [54] **ELECTRICAL APPARATUS GENERATING A LOW FREQUENCY, ALTERNATING MAGNETIC FIELD FOR PROMOTING THE GROWTH OF BONE AND OTHER BODY TISSUES**

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- [30] **Foreign Application Priority Data**

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- [52] **U.S. Cl.**..... **128/1.5; 128/82.1; 128/419 F**

[51] **Int. Cl.**..... **A61n 1/42**

[58] **Field of Search**..... **128/1 R, 1.3, 1.5, 82.1, 128/404, 405, 411, 418, 419 R, 422**
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[57] **ABSTRACT**

The growth or repair of fractured bones or the growth of other body tissues is promoted by means of a coil which is applied to produce a magnetic field at the site in which growth is to be encouraged. The coil is supplied with a low frequency alternating voltage below 50 Hz. A device is applied to the body or implanted in the body in order to concentrate the magnetic field produced by the coil.

5 Claims, 8 Drawing Figures

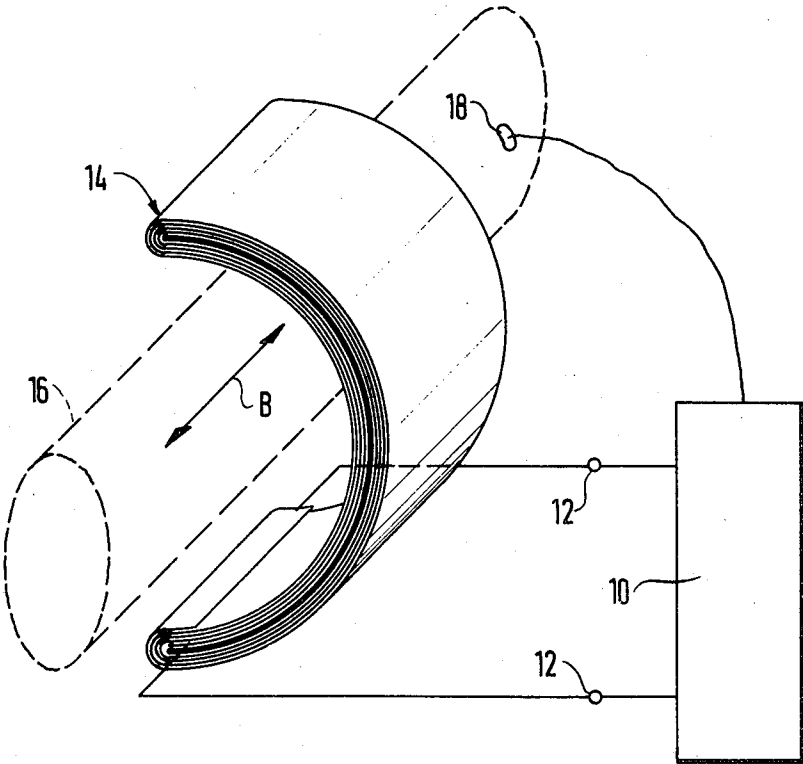


Fig. 1

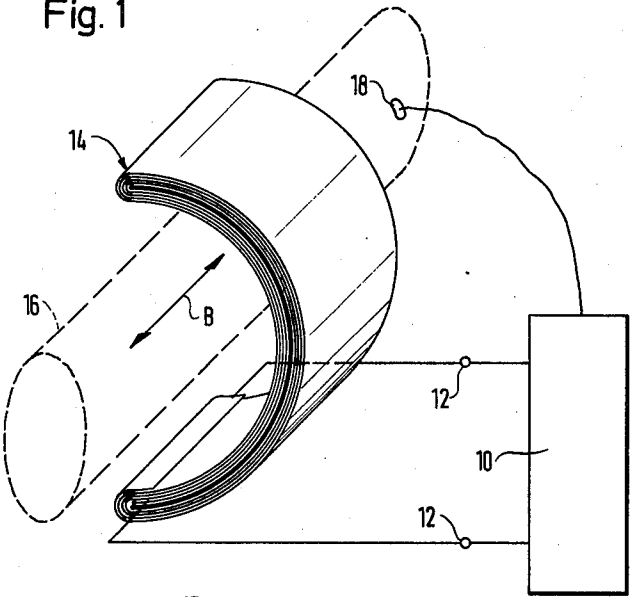


Fig. 2

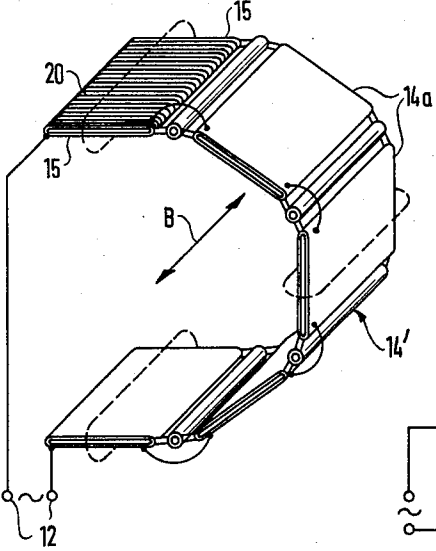


Fig. 3

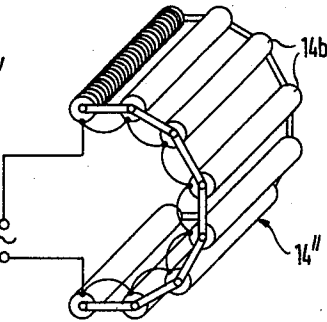


Fig. 4

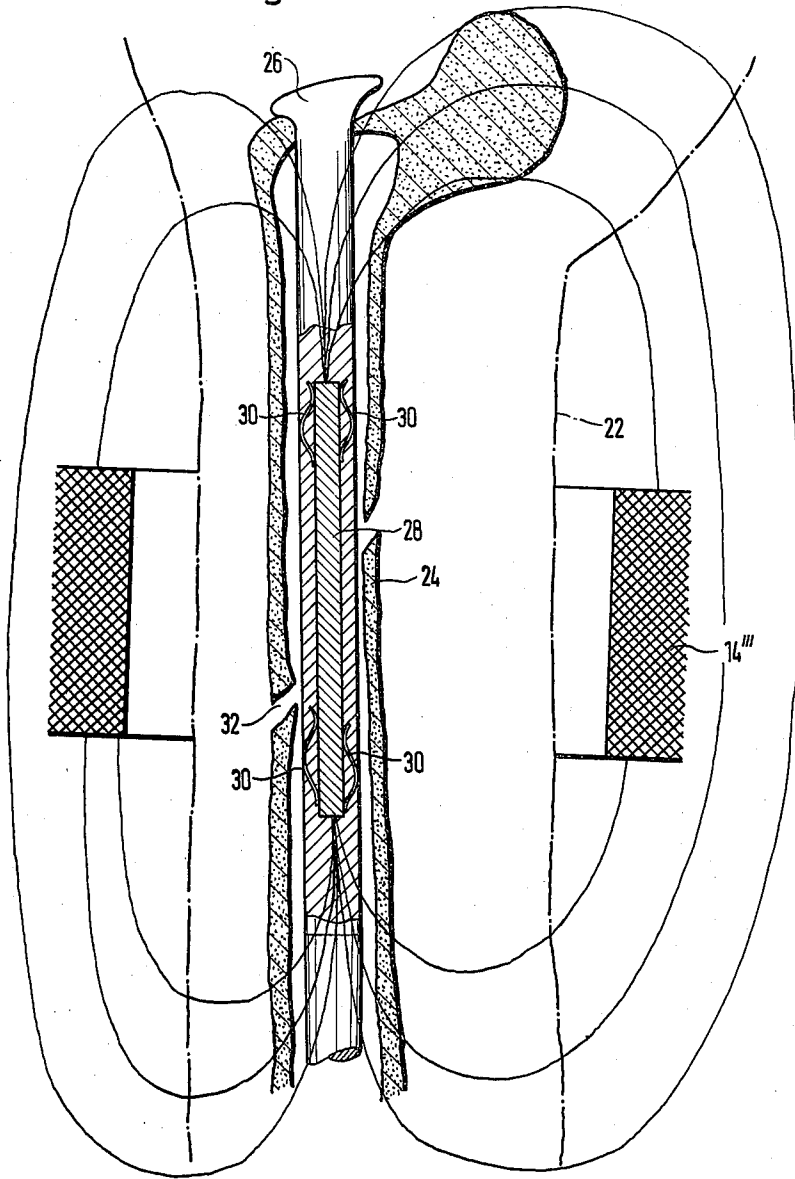


Fig. 5

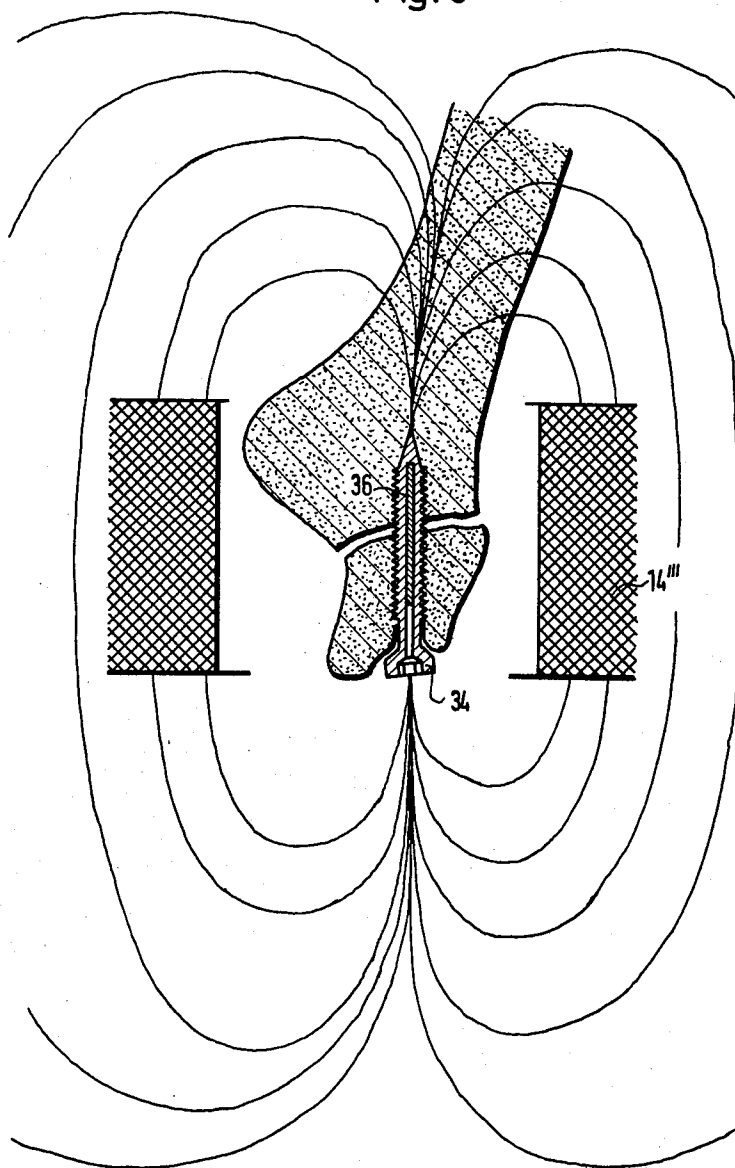


Fig. 6

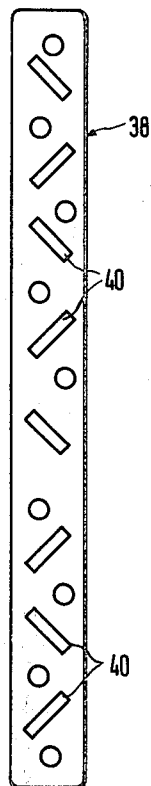


Fig. 7

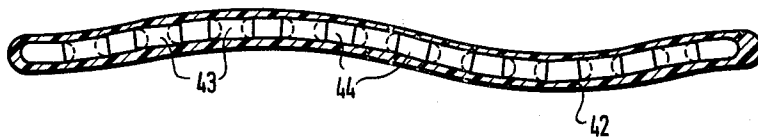
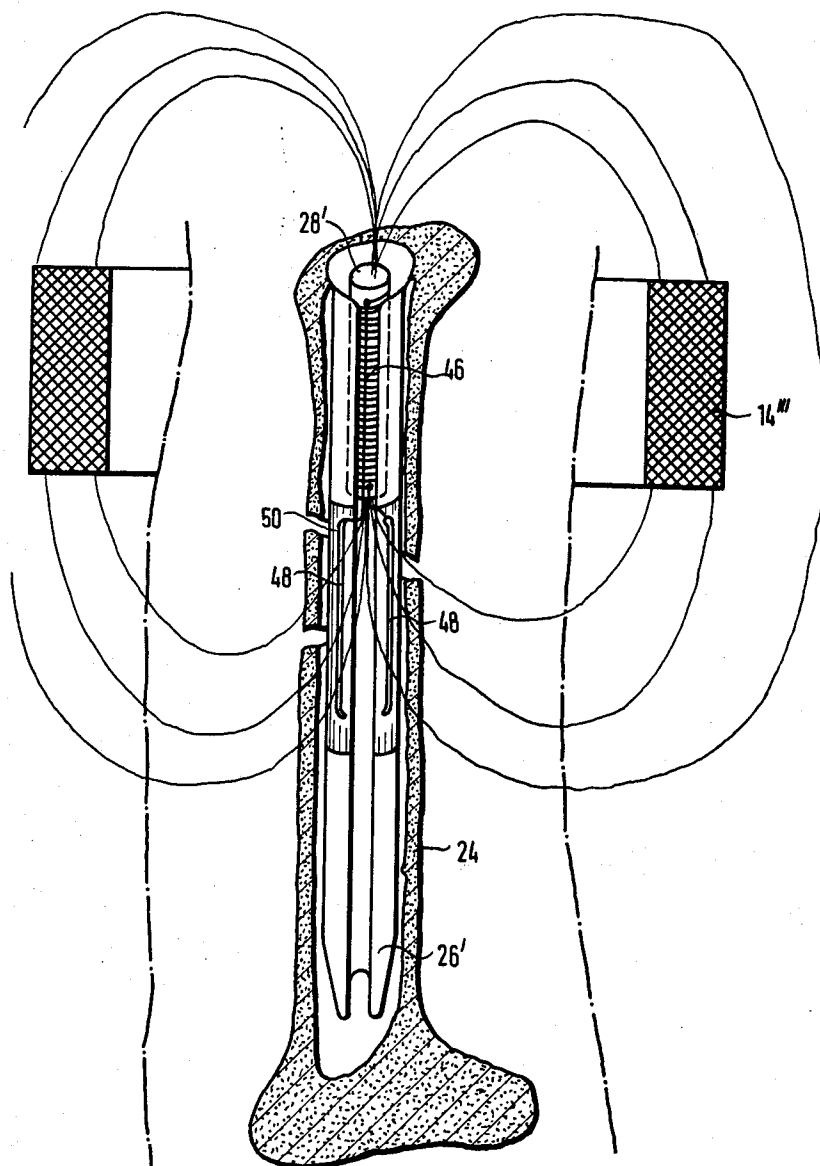


Fig. 8



ELECTRICAL APPARATUS GENERATING A LOW FREQUENCY, ALTERNATING MAGNETIC FIELD FOR PROMOTING THE GROWTH OF BONE AND OTHER BODY TISSUES

BACKGROUND OF INVENTION

1. Field to which Invention Relates

The present invention relates to an apparatus for promoting the growth of bone and other body tissues.

It is known that the shifting of an electrochemical equilibrium existing in a living organism can lead to a change in a mechanical state in the organism. Processes of this type are continually taking place in muscle tissue. Furthermore the contraction and expansion of fibers of collagen, that is to say the connective tissue substance, has been observed to take place following a change in the concentration of a salt solution surrounding the fibers.

One example of the reversability of this principle is offered by the piezoelectric behavior of bone: In this case electrical deformation potentials, which arise owing to mechanical loading of bone fiber, regulate the dynamic equilibrium between the free calcium and phosphate ions in the blood, on the one hand, and the bound calcium and phosphate ions in the crystal lattice of the hydroxyl apatite on the other.

The changes in state occurring are thus due to the disturbance of an existing mechanical-chemical equilibrium between free and bound ions. The restoration of the original electro-neutrality is determined by the speed of diffusion of the free ions and the statistical distribution in the vicinity of the bound ions.

2. The Prior Art

In accordance with a previous proposal the reunion of fractured bones was to be encouraged by alternating electric currents, which were produced by means of a pick-up coil which was attached to a splint (induction splint) serving for holding the bone in place. The splint had electrodes which extended into the gap of the fracture and the like.

In the case of clinical application of "induction splints" of the proposed type effects were observed which cannot be completely explained on the basis of the galvanic action of the induced currents. On the basis of the above-mentioned considerations the idea then arose that electro-dynamical occurrences — and such occurrences are involved in the case of the above-described mechanical-chemical changes in equilibrium — must be accompanied by corresponding magnetic fields and that it should, however, also be possible to produce corresponding chemical and physical reactions by the action of electromagnetic fields in biological systems. Experiments carried out along these lines, which were aimed at distinguishing the biological actions of the electric field and that of the magnetic field, proved this assumption to be correct. It was found in this respect that the application at certain times and at certain locations of electromagnetic fields led to growth of bone and other body tissues. As a consequence of the action of the magnetic field a formation of new vessels occurring as a primary factor was detected.

SUMMARY OF INVENTION

On the basis of these discoveries one aim of the present invention is to provide an electrical apparatus for promoting the growth of bone and other body tissues.

The present invention resides in an electrical apparatus for promoting the growth of bone and other body tissues comprising a generator for the supply of low frequency alternating current with a frequency below 150 Hz, a coil which can be connected with the output of the generator and whose shape is adapted to the shape of the body part in which the growth of tissue is to be promoted and to the structure of the tissue to be grown, and a device which can be applied to the body part for concentration of the field produced by the coil on to the zone of the body in which the tissue is to be grown. The device which can be applied to the body part can if necessary be implanted in the body.

With the apparatus in accordance with the invention substantial successes in healing have already been obtained in practice. For example in the case of severe accident casualties involving fractures, the time for repair of the fracture was reduced to half the normal time required for healing. Furthermore, the healing of bed sores could be brought about or substantially accelerated.

LIST OF FIGURES OF DRAWINGS

Further development of the invention are defined in the subclaims.

In what follows embodiments of the invention will be described with reference to the accompanying drawings in detail.

FIG. 1 is a diagrammatic representation of a generator and a field coil of an apparatus in accordance with one embodiment of the invention.

FIGS. 2 and 3 show in perspective other types of field coils for a device in accordance with the invention.

FIG. 4 is a sectional view of a fractured thigh bone with a marrow or Kuntscher nail or pin, which comprises a field-concentrating device in accordance with one embodiment of the invention.

FIG. 5 is a diagrammatic representation of an applied compression screw, which also comprises a fieldconcentrating device in accordance with the invention.

FIG. 6 shows a splint with embedded or inserted magnetic cores for the purpose of field concentration.

FIG. 7 shows a device for field concentration which can be implanted.

FIG. 8 shows a Kuntscher nail or pin, which comprises a magnetic core serving both for field concentration and also the inductive production of a galvanic current in the bone region.

DESCRIPTION OF PREFERRED EMBODIMENTS

The apparatus shown diagrammatically in FIG. 1 comprises a AC generator 10, which supplies low frequency AC at the output terminals 12. The frequency of the AC lies below 150 Hz, for instance between 1 and 50 or 65 Hz. It has been found particularly favorable to use a frequency range between 5 or 10 and 30 Hz, for example 25 Hz. The half cycles of the alternating current should have comparatively gently sloping leading and trailing flanks (rise and fall times of the half cycles being for example in the order of magnitude of a quarter to an eighth of the length of a cycle); the AC can thus be a sinusoidal current with a low non-linear distortion, for example less than 20 percent, or preferably less than 10 percent, or a triangular wave current.

The rise and decay times of the cycles can be in the order of one quarter to one eighth of the cycle.

It is also possible for the current to consist of sinusoidal or triangular pulses with alternating polarity, which alternate either individually or in pairs with pulse intervals. It is clearly important in all cases that the front and trailing flanks of the current pulses or AC half cycles should slope relatively slightly. The rise and fall times are preferably substantially greater than 5 ms (corresponding to a sinusoidal current of 50 Hz), and preferably at least approximately 8 to 10 ms, for example up to 80 ms.

On the AC signal it is possible to superimpose a DC component and/or an AC component with a higher frequency by means of a modulating device contained in the generator 10. The frequency of the component with the higher frequency can amount, for example, to three to 10 times the basic frequency of the AC signal. It is also possible for a DC component to be superimposed on the AC signal so that the latter is asymmetric with respect to the zero line.

The output terminals 12 of the generator 10 are connected with a field coil 14, which in the case of the embodiment shown comprises an insulated copper ribbon in the form of an U-shaped flat coil on a flexible flat core. The windings of the coil thus comprise two respective bends of 180° between which long relatively adjacently running longitudinal parts lie, which are bent in a U-shape. The particular shape of the coil is selected for producing a magnetic field B, whose direction is adapted to the structure of the bone or other body tissue whose growth is to be promoted. If, for example, an extremity 16, as indicated in broken lines, for example a thigh with a fractured femur is to be treated, the magnetic field B preferably runs in the direction in which the thigh bone is loaded during normal use, and the function of the blood vessels is encouraged.

Preferably, however, it is not only the spatial orientation of the magnetic field which is adapted to the circumstances present in the living organism, but also the timing. In addition to known spatial structures of bone and other body tissues, the timing of the effect is also of significance. The most important change with time of the mechanical influences acting on the substance of the organism from the inside follows the heart beat. The rhythm and form of the spread of the pressure wave of the blood in the organism determine the metabolic events with their biochemical and biophysical reactions to a substantial extent. For this reason actuation and/or control of the generator 10, and thus of the electromagnetic fields produced, is provided for by the systolic pressure wave in the zone of application. This can be carried out in particular with a pulse pressure wave detector 18, which is applied adjacent to the treatment zone between the latter and the heart on the body part to be treated.

The actuating pulse produced at the pulse detecting device 18 in accordance with the systolic pressure wave can be used in a generator 10 for initiating an individual oscillation cycle or for the synchronisation of a continuous oscillation of the output current.

In accordance with a further possibility the systolic pressure change detected by the pulse detector 18 directly controls the variation in the output current of the generator 10.

A further possibility resides in that the pulse produced from the pulse detector 18 initiates an output current oscillation produced by a function generator, for example a magnetic tape device, with the shape of

the function corresponding to the systolic pulse pressure wave of a healthy person with blood vessels which are still elastic, more particularly a young person.

FIG. 2 shows another embodiment of a field coil which can be used for the present device. The field coil in accordance with FIG. 2 consists of a number of flat coils 14a, the shape of whose windings is indicated in the case of the uppermost coil by solid lines 20. The flat coils 14a can comprise ferromagnetic laminations and are connected at the sides corresponding to bends in the windings in a hinged manner so that the field coil 14', consisting of the flat coils connected in parallel or in series, can be applied as desired about a body part in order to induce in the latter a magnetic field, whose direction is indicated by the double arrow B, the paths of fields of the individual coils being indicated by broken-line loops.

The flat coils 14a can on the other hand be connected at the end faces 15 in a hinging manner with each other, if the field coil is required for treating the spinal column for example.

The field coil 14'' in accordance with FIG. 3 corresponds in principle with the field coil in accordance with FIG. 2 with the exception that the coils 14b, which are connected together in a hinged manner, have a circular cross-section.

Instead of flat coils 14a or coils 14b with a circular cross-section it is naturally also possible to use other suitable coil forms, for example coils with an elliptical cross-section.

As a coil a cylindrical or solenoid coil 40''' is to be used, as indicated in FIG. 4.

If desired the distribution of windings on the field coils can be uneven in order to obtain a field concentration. For example the winding density in the case of the coils 14', -'' and 14''' can increase from the outside in an inward direction or it is possible to connect additional narrower coils which can be slid on in order to achieve the desired field distribution.

The solenoid coil 14''' in FIG. 4 has such a large internal diameter that it can be slid over an extremity to be treated, for example a thigh 22, for example when the healing of the fractured femur 24 is to be promoted. The bone 24 is pinned in a conventional manner with a Küntscher nail 26 or pin, in whose interior a field concentrating device of a rod-shaped body 28 of ferromagnetic material with a high initial magnetic permeability and a low remanence is used, that is to say a magnetically "soft" material. The body 28 is fixed by staples 30 in the desired position. It brings about a concentration of the magnetic field at the site of the fracture 32. The core is coated with an inert polytetrafluoroethylene layer. In a manner similar to the arrangement to be described with reference to FIG. 7, it is also possible to provide several cores with a spacing between them in the nail or pin and between the cores a relatively strong leak field occurs which promotes growth. This leak field extends into the gap in the fracture or the site of the fracture.

FIG. 5 shows a so-called compression screw 34, which is provided with an axial hole, in which a ferromagnetic body 36, serving for field concentration, is located, which preferably is also made of a magnetically soft material.

FIG. 6 shows a splint which can be implanted or support plate as is conventional in principle for fixing fractured bones, with which it is connected by screw

means. In the construction shown in FIG. 6 there is, however, the novel feature that it comprises embedded or inserted bodies 40 of ferromagnetic material in order to bring about a concentration of the magnetic field produced by the field coil adjacent to the fractured bone.

Since with the invention a comparatively rapid restoration of the bone and other body tissue can be achieved it is possible to make the splint 38 and other corresponding support structures (pins etc.) so as to be substantially lighter than has been the case to date. For example the splint 38 can be made of plastics material and can be used only for fixing the bone fracture parts, since the bone will be rapidly repaired to such an extent that it can carry the load itself.

Preferably such support structures are made of organic material, for example cut or milled from animal bone. This material, which must be freed of protein, may then possibly be absorbed by the living body, can then possibly be absorbed or taken up by the body, so that subsequent treatment is substantially simplified. The production of bone fracture support parts such as pins or nails, plates, half-shells and screws of bone substance or synthetically produced molded parts, which are treated with calcium and orthophosphates and can be taken up by the body, offers advantages not only with the present purpose.

FIG. 7 shows a further apparatus for producing a field concentration. It comprises a flexible tube 42 of an inert material such as polyethylene, in which rod-shaped bodies 44 of a metnetically soft material with a high permeability are embedded. The flexible tube 42 can be shrunk after the insertion of the bodies in order to fix the bodies 44 with a spacing between them. The flexible tube with the bodies 44 can then be embedded in the tissue to be regenerated.

The position of the magnetic core 44, see FIG. 7, in the flexible tube 42 can also be fixed by means of distance pieces 43, such as pieces of polytetrafluoroethylene, which are arranged between the cores.

The marrow or Küntscher nail 26' or pin shown in FIG. 8 comprises, as is the case with the nail 26 in accordance with FIG. 4, a magnetic core 28', which serves for field concentration at the site of fracture. Furthermore the core carries at least one winding 46, in which the low frequency magnetic field produces an alternating voltage. The ends of the winding are connected with bare platinum-iridium electrodes 48, which may be in the form of wires or metal sheet. The electrodes are arranged on an insulated section 50 of the outside of the nail or they can be embedded in an insulated manner in the outside of the nail. The alternating current flowing between the electrodes 48 through the fracture site also encourages the healing process and callus formation, as has already been proposed in connection with the splint.

Instead of using magnetically soft material, it is also possible to use a ferromagnetic material with a relatively low remanence, which is so selected that a certain premagnetisation can be set and this premagnetisation has superimposed on it the alternating magnetisa-

tion as produced by the field coil. The same effect can be achieved by superimposing a DC component on the AC supply to the field coil.

It is naturally possible for other coil and magnetic core arrangements to be used in order to concentrate the low frequency alternating magnetic field adjacent to the organism, in which the growth or regeneration of tissue is to be promoted. The direction of the magnetic field lines then preferably runs parallel to that of the fiber or vessel structure.

All parts coming into contact with the body substance consist of a physiologically compatible material, at least on their surface.

What is claimed is:

1. In an electrical apparatus for promoting the growth of bone and other body tissues by the application thereto of a low frequency alternating magnetic field, such apparatus having current generating means and field applicator means, the improvement wherein the applicator means comprises a flat solenoid coil having an axis about which the coil is wound and composed of a plurality of parallel and flexible windings, each said winding having two adjacent elongate portions and two 180° coil bends joining said elongate portions together, said coil being flexible in the coil plane in the region of said elongate portion for being bent into a U-shape, said coil being bent into such U-shape about an axis parallel to the coil axis and adapted for connection to a source of low frequency alternating current.

2. In an electrical apparatus for promoting the growth of bone and other body tissues by the application thereto of a low frequency alternating magnetic field, such apparatus having current generating means and field applicator means, the improvement wherein the applicator means comprises a U-shaped flat solenoid coil having an axis about which the coil is wound and composed of a plurality of parallel windings, each said winding having two adjacent, elongate U-shaped portions and two 180° coil bends joining the ends of said elongate portions together, the coil being curved in such U-shape about an axis parallel to the coil axis and adapted for connection to a source of low frequency alternating current.

3. In an electrical apparatus for promoting the growth of bone and other body tissues by the application thereto of a low frequency alternating magnetic field, such apparatus having current generating means and field applicator means, the improvement wherein the applicator means comprises: a plurality of solenoid coils each having an axis about which such coil is wound and disposed adjacent one another with their axes parallel and adapted for connection to a source of low frequency alternating current, and hinge means connecting adjacent coils together for pivotal movement about axes parallel to the axes of said coils.

4. An arrangement as defined in claim 3 wherein said coils having a cylindrical cross section.

5. An arrangement as defined in claim 3 wherein said coils have an elliptical cross section.

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