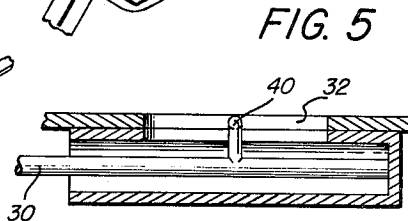
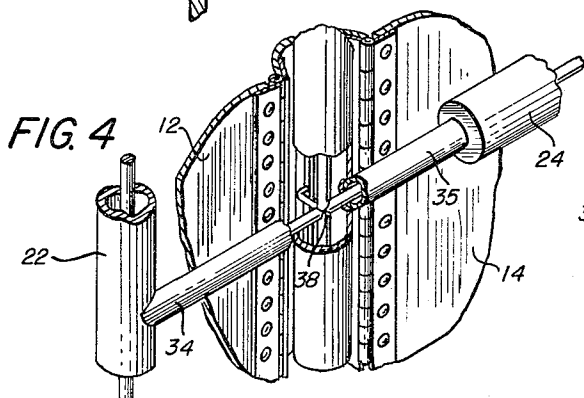
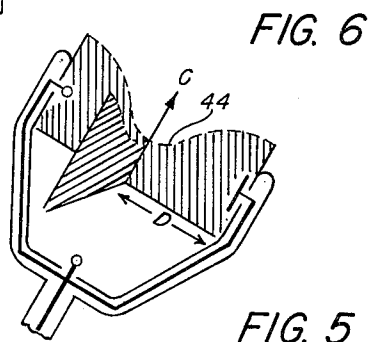
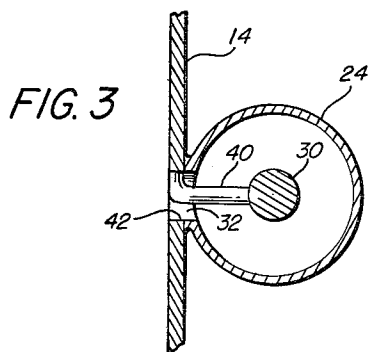
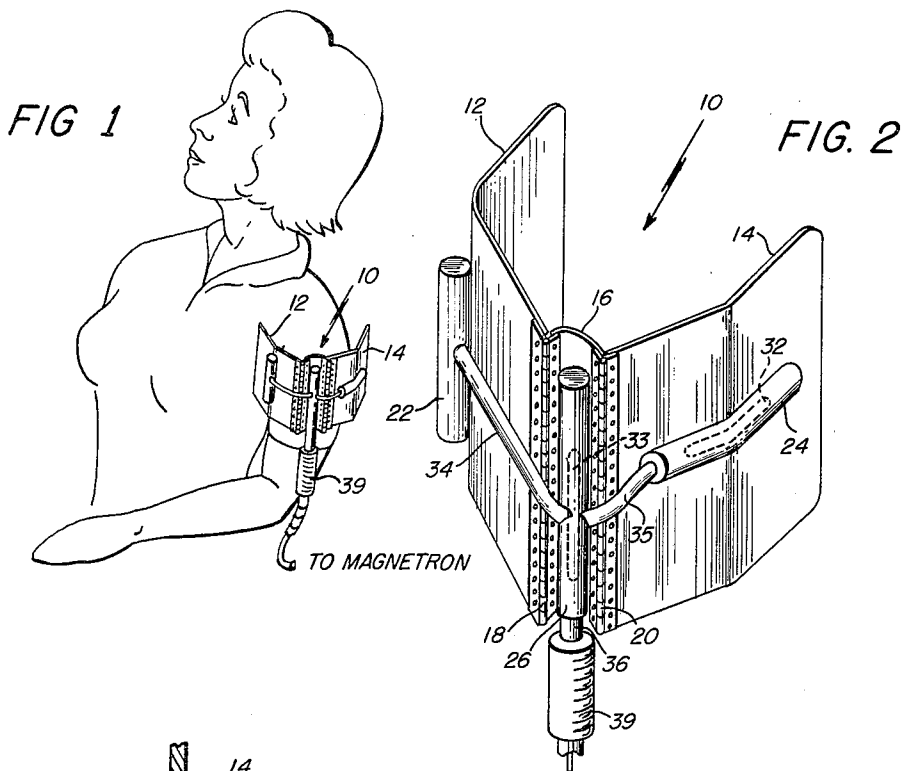


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DIATHERMY APPLICATORS

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DIATHERMY APPLICATORS

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This invention relates to a diathermy applicator and, more particularly, to a diathermy applicator which is capable of directing microwave energy into a body from a plurality of directions in order to obtain a relatively uniform heat field necessary for proper diathermy treatment of said body.

In therapeutic apparatus for radiating and directing energy upon an accurately defined area of a body to be treated, it is desirable to produce uniform heating of the tissue placed in the vicinity of the energy radiating means. When conventional diathermy apparatus employs a single reflector element to direct radiation toward the body, the field strength declines as the wave travels into the body, and, consequently, the deep tissues develop less heat than those which are near the surface. It is, therefore, desirable to reduce this heat differential and to provide substantially uniform radiation of internal areas of the body which are relatively remote from the heat radiating source.

In accordance with the diathermy applicator of this invention, substantially uniform heating of specific internal tissue is provided by feeding energy directly to the part of the body under treatment from a multiplicity of peripheral radiating elements positioned substantially opposite to each other. These radiating elements are positioned in this manner in order to irradiate the desired body area simultaneously from a plurality of directions and, at the same time, to prevent the escape of unabsorbed energy passing through the desired area. Each radiating element which, in effect, is a coaxial waveguide, is capable of adjustment to various bodily contours, concave or convex, and is positioned on a conductive plate or arm provided with a corresponding energy radiating slot resonant at the operating frequency. In order to excite each resonant slot in the conductive plate with microwave energy a waveguide comprising a hollow metallic cylinder is provided with a conductor which passes through the inside of the cylinder parallel to the axis thereof and is connected to one end of said cylinder. The wall of the cylinder which forms the outer conductor is provided with an energy radiating slot which is supported in register with a corresponding radiating slot in the applicator plate. A feeder pin or stub is connected to the inner conducting rod of the metallic cylinder and projects radially outward therefrom to contact the wall of the corresponding radiating slot in the plate. A coaxial line couples energy from a microwave source to each of the excitation cylinders.

In order to prevent undesirable cross coupling of energy between the radiating elements, the resonant slots are oriented to produce a multiplicity of incident wave polarizations. In this manner, substantially uniform heating of a desired area is achieved without the escape of microwave energy and without an undesirable heat differential due to field strength decay about relatively deep areas of the body.

Other and further advantages of this invention will be apparent as the description thereof progresses, reference being had to the accompanying drawing wherein:

FIG. 1 is a pictorial view of the applicator in accordance with the invention;

FIG. 2 is an isometric view of the applicator;

FIG. 3 is a cross-sectional view of the energy radiating portion of the applicator;

FIG. 4 is a detail of the coaxial feed line partially cut away;

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FIG. 5 is a longitudinal sectional view of one radiating element of the applicator; and

FIG. 6 is a schematic diagram of the energy field produced in the body by the three radiating elements.

Referring to FIGS. 1 and 2, an applicator 10 comprises a pair of arms or conductive plates 12 and 14 connected to a back plate 16 by means of hinges 18 and 20. The conductive plates are bent along their mid portion and hinged to provide a simple arrangement permitting adjustment for treatment of bodily contours. Each conductive plate is provided with a radiating element 22 and 24. The back plate 16 is also provided with a radiating element 26. The outer cylindrical conductor of radiating elements 24 and 26 is closed at one end and the outer cylindrical conductor of radiating element 22 is closed at both ends. Each element has a maximum transverse dimension less than one-half its free space wavelength. In a typical element, as shown in FIGS. 3 and 5, a metal inner conductor 30 extends coaxially within the outer conductor, and is connected to the closed end thereof, to produce an electrical short circuit. Extending in the wall of each outer conductor is a resonant or substantially resonant slot 32. Each slot is approximately one-half wavelength long at the operating frequency. Preferably, the configuration of each slot is substantially rectangular and is provided with either a straight end or a rounded end, as shown in FIG. 5 of the drawing. In addition, the slots in the outer conductor are arranged with their longitudinal axes parallel to the longitudinal axis of the coaxial line.

It should be noted, that the length, width and spacing of the slots depends on the microwave operating frequency and the type of radiation pattern desired. In the present application, in which the operating frequency is approximately 2450 megacycles, each slot is approximately 6.1 centimeters long or approximately one-half wavelength.

Microwave energy is fed into the open end of each radiating element by means of coaxial lines 34, 35 and 36. The inner conductor of each coaxial line is connected at a common junction point 38 as shown in FIG. 4. The common coaxial line 36 is coupled by way of a well-known coaxial connector 39 to a source of microwave energy such as a magnetron oscillator, not shown. It should be understood that while a magnetron is used in the present therapeutic apparatus, other generators of microwave energy can be used where suitable.

The energy fed in to each radiating element from a microwave source, as shown in FIGS. 1 and 2, is coupled to slots 32, 33 and a slot, not shown, in element 22 through a conducting metallic stub 40 which is attached to the inner conducting rod 30 at a location equidistant from the ends of the slots. The stub 40, as shown in FIGS. 3 and 5, projects radially outward to make electrical contact with the edge of the corresponding slots in each conductive plate at a point equidistant from the ends thereof. This distance is approximately one-half the wavelength of the operating frequency from the shorted end of the radiating element. The stub 40 is bent to contact the wall 42 of the corresponding longitudinal slot in each conductive plate. This connection is shown in detail in FIG. 3 with reference to the conductive plate 14. The stub consists of a metal rod, one end of which is bonded to the inner conductor 30, as shown. The other end is connected to the conductive plate 14. However, the stub can consist of a threaded pin inserted into holes bored into the inner conductor at the proper location and threaded to receive the pin.

In accordance with the invention, the oppositely disposed radiating elements 22 and 24 are oriented at approximately ninety degrees to each other to produce cross-polarized energy fields. With this arrangement, undesirable coupling of energy from one radiating element to the

oppositely disposed radiating element is prevented. At the same time, a third source of energy from radiating element 26 provides a third field which is directed toward the area of the body to be treated.

The heat pattern produced by the applicator 10 in a body is approximately circular in area and extends outward from each radiating slot. FIG. 6 shows the heat distribution in a selected body area for a given distance D from each radiating slot. As energy travels into the body from each radiating slot, the field strength decreases as shown at 44, and the corresponding heat developed, C, is lower at approximately the center of the pattern of heat. The cold spot thus obtained in an energy absorbing body enables the applicator to be used to treat specific internal areas of the body, or organs, that may present an irregular surface contour to the heating source. By providing a plurality of oppositely disposed radiating elements, the heat pattern is confined to a specific body area and microwave energy is prevented from escaping from that area. In addition, the multiplicity of incident wave polarizations prevent crossfeed of microwave energy between the microwave elements and provides a substantially uniform external heat pattern about the bodily contour.

It should be noted that the coaxial feed lines are by way of example only, and any desired structure for introducing energy into the radiating elements can be used. While it is possible to use the principles of this invention in the range of free space wavelengths of one to one hundred centimeters, preferably, the device is used to operate in the industrial, scientific and medical bands allocated for this purpose.

It should be understood that various modifications of this invention will be apparent to those skilled in the art within the scope of the invention. For example, the materials, contours and dimensions specified for the particular form of the invention being described can be varied to obtain the desired results when selecting various area sizes for the pattern of energy to be radiated at selected operating frequencies. Accordingly, it is desired that this invention be not limited by the embodiment described herein except as defined in the appended claims.

What is claimed is:

1. Apparatus for heating a body to be treated comprising a source of microwave energy, a waveguide applicator having a pair of conductive plates adapted to be positioned about the part of the body to be treated, each conductive plate containing an energy radiating aperture resonant at the operating frequency, a hollow metallic cylinder having an energy radiating slot resonant at the operating frequency and supported in register with the corresponding energy radiating aperture in each conductive plate, said energy radiating slots positioned in a manner to direct energy toward said body in cross-polarized planes, a conducting rod passing through the inside of each cylinder parallel to the axis thereof and attached to one end of said cylinder, a feeder stub connected to the inner conducting rod of each cylinder and projecting radially outward therefrom to contact the wall of the corresponding radiating aperture in each plate, and a coaxial transmission line adapted to couple energy from said microwave source to each of said cylinders.

2. A waveguide applicator for heating selected parts of a body simultaneously from a plurality of directions, said applicator comprising a plurality of oppositely disposed conductive plates, each conductive plate containing an energy radiating slot, said energy radiating slots positioned in a manner to direct energy toward said body in cross-polarized planes, a radiating element positioned adjacent to each of said radiating slots, each radiating ele-

ment having a hollow metallic cylinder provided with an energy radiating slot in register with the corresponding radiating slot in each conductive plate, a conducting rod passing through the inside of said cylinder parallel to the axis thereof and attached to one end of said cylinder, and a feeder pin connected to said inner conducting rod at a location equally distant from the ends of said radiating slot and projecting radially outward therefrom to contact the wall of the corresponding radiating slot in each conductive plate.

3. A waveguide applicator for the simultaneous heating of a selected part of a body from a plurality of directions, comprising a plurality of oppositely disposed radiating elements adapted to direct energy toward said body in cross-polarized planes, each of said elements including a microwave coaxial waveguide, the outer conductor of said waveguide having a slot resonant at the operating frequency and spaced longitudinally along said waveguide, means for supporting said inner conductor in fixed spatial relationship with respect to said outer conductor, a conductive plate containing an energy radiating slot in register with said longitudinal waveguide slot, and a feeder pin connected to the inner conductor of said waveguide, said pin projecting radially outward from said inner conductor to contact the wall of the corresponding radiating slot in said conductive plate.

4. Apparatus for heating selected portions of a body from a plurality of opposite directions comprising a source of microwave energy, an applicator comprising at least a pair of conductive plates adapted to be adjustably positioned about the part of the body to be treated, each of said plates provided with a radiating slot resonant at the operating frequency, said energy radiating slots positioned in a manner to direct energy toward said body in cross-polarized planes, a waveguide excitation element positioned adjacent to each of said radiating slots, each excitation element comprising a hollow metallic cylinder provided with an energy radiating aperture in register with the corresponding radiating slot in said conductive plate, a conducting rod passing through the inside of said cylinder parallel to the axis thereof and attached to one end of said cylinder, a feeder pin connected to said conducting rod, at said feeder pin projecting radially outward from said inner conductor to contact the wall of the corresponding radiating slot in each conductive plate, and a coaxial transmission line adapted to feed microwave energy to each excitation element.

5. An applicator for heating selected parts of a body from a plurality of directions comprising a multiplicity of radiating elements adapted to be adjustably positioned about the parts of the body to be treated, each radiating element comprising a conductive plate containing an energy radiating slot resonant at the operating frequency, said energy radiating slots positioned in a manner to direct energy toward said body in cross-polarized planes, a waveguide having a circular inner conductor and a circular outer conductor, said outer conductor containing an energy radiating slot, means for supporting said inner conductor in fixed spatial relationship with respect to said outer conductor, means for supporting said radiating slot in said outer conductor in register with said radiating slot in each of said conductive plates, and means for coupling energy from said inner conductor to the wall of said corresponding conductive plate.

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