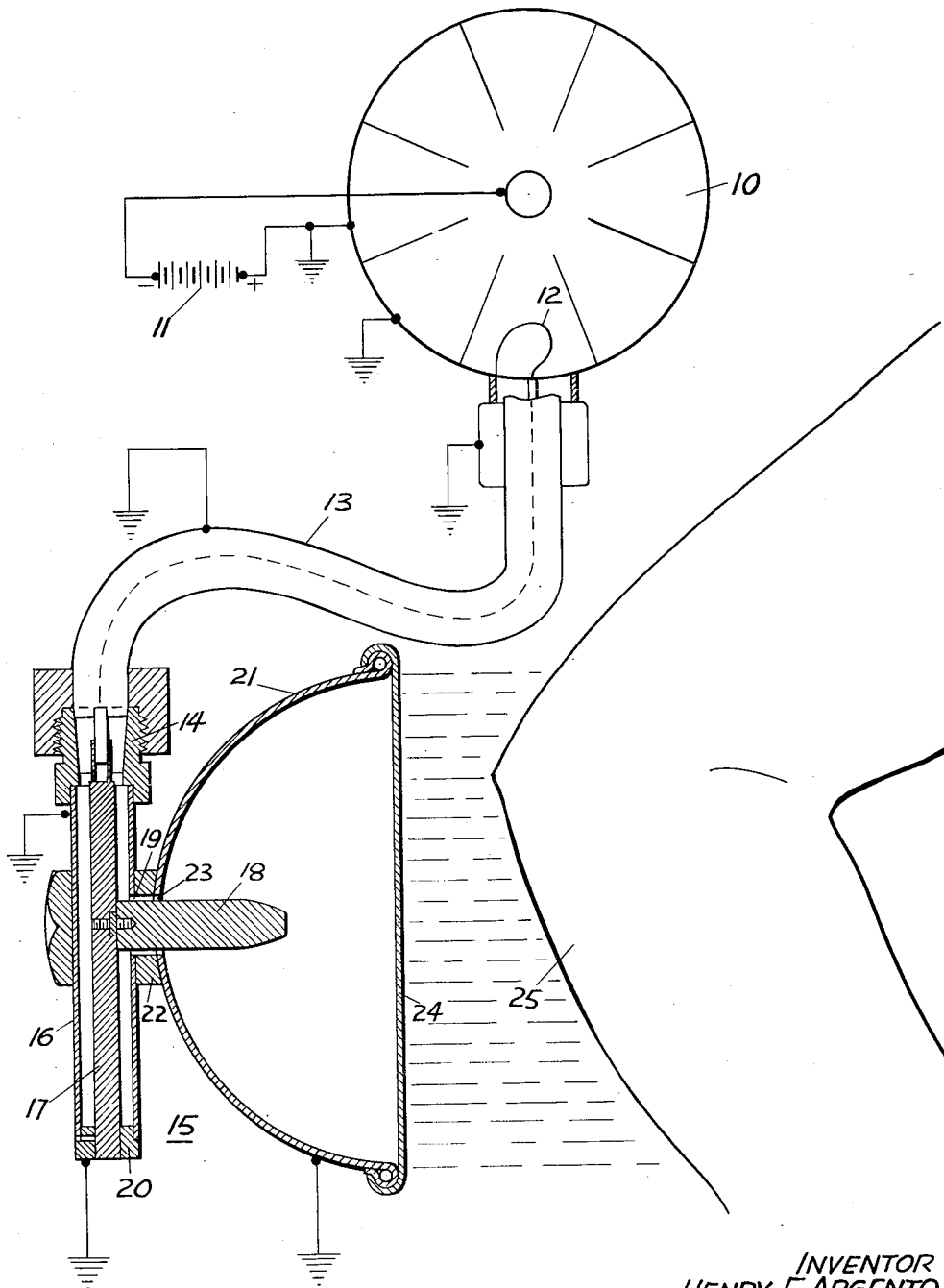


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THERAPEUTIC DEVICE

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THERAPEUTIC DEVICE

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This invention relates to a therapeutic device for applying a penetrating heat to a localized area of a body to be treated.

It is an important object of this invention to provide an improved therapeutic apparatus of the character described and utilizing the heating effects of electromagnetic radiations in the microwave spectrum having a frequency which may be in the range of 2300 to 3300 megacycles per second, the apparatus providing for a radiating element having a predetermined total impedance such as to produce a condition of impedance match to a body representing the average body to be treated at an average distance from the radiating element in order that the radiating element may be subsequently used without further adjustment to assure a maximum of advantageous match of the impedance of the radiating element to the impedance of any expected condition of body being treated and to thus obtain the desired heating effect with maximum efficiency.

It is a further object of this invention to provide a therapeutic device utilizing the heating effects of electromagnetic radiations in the microwave spectrum specified and having fixed-tuned means for generating such radiations together with broadly tuned means for radiating and focusing the radiations towards the object to be treated in such manner that a predetermined amount of radiations is obtained for therapeutic application regardless of the tendencies of the generator to shift in frequency for variations of loading as determined by the area and location of the tissues being treated and the amount of power for the radiations to be applied. Additional objects and advantages of this invention will be apparent with reference to the following specification and drawing in which the single figure illustrates a preferred embodiment of the invention employing a magnetron oscillator combined with a broadly tuned radiator and director, the director being shown in half-section along the axis of the matching stub.

The heating effects by electromagnetic radiations in the frequency range, commonly known as the microwave spectrum, may be observed in various types of microwave apparatus. For example, a hand held in front of the radiating horn of a conventional radar machine will, under certain favorable conditions, become heated. A careful analysis and study of such heating effects, as applied to therapeutic apparatus, has not been made prior to this invention. As a result of an analysis and study leading to this

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invention, it has been found that a conventional radar system generator and radiating horn may not be effectively and practically used in the therapeutic applications, hereinafter to be referred to as microwave diathermy, in view of the many special conditions peculiar to such diathermic application which would make a conventional radar system ineffective to produce the desired results.

One of the principal considerations presenting a difficulty to be overcome, peculiar to the use of microwave radiations in a therapeutic application as distinguished from a mere adaptation of a conventional radar system for such purpose, is the fact that the variable loading and conditions of impedance match represented by the energy absorption in the tissues being treated are physically close to the radiating element and reflector so that a special condition of average impedance matching between the radiating element and the body being treated must be had in order to assure that the radiations will not be reflected from the surface of different bodies being treated. It has also been determined that a conventional radar type of sharply tuned radiator is not effective to supply a requisite amount of energy when the radiation generator is pushed or pulled off frequency due to the effects of the variable loading and variable impedance matching represented by the closely adjacent energy absorbing body to be treated. This invention provides for a novel combination with a generator of microwave radiations of a broadly tuned radiating element and reflector, hereinafter referred to as a director, which is designed for a predetermined impedance condition to produce a desired no-load standing wave ratio to assure a maximum condition of impedance matching when a load such as any average body to be treated is brought into operating range of the apparatus under all average conditions of treatment and which is effective to maintain substantial resonance of the director to the frequency of the generator, regardless of a generator frequency shift due to variable loading effects in response to the variable conditions of therapeutic applications.

In the following detailed description of the invention, reference is made to the single figure of the drawing wherein a continuous wave magnetron oscillator 10 is shown to be energized from a source of direct current 14 in a conventional manner with the positive terminal of the source and the anode of the magnetron grounded. The magnetron is shown in schematic out-

line and it will be understood that a suitable filament supply for heating the cathode (not shown) is provided. The magnetron 10 is of the fixed-tuned variety manufactured to oscillate at a selected frequency for its principal mode of operation. The frequency of operation for the magnetron 10, when used in the therapeutic apparatus being described, may be selected to be within the range of 2300 megacycles per second to 3300 megacycles per second. Instead of the magnetron type of oscillator 10, it should be understood that other generators of microwave electromagnetic radiations within the frequency range specified may be used where suitable.

The pickup loop 12 of the magnetron oscillator 10 is connected by conventional coupling means to the flexible coaxial cable 13 whose outer sheath is connected to the magnetron anode and grounded as shown. The other end of the flexible coaxial cable 13 is connected by the threaded coupling 14 to the combined radiating element and reflector herein known as the director 15. Thus the director may be easily moved into a cooperating position with a body to be treated.

The director 15 has a cylindrical matching sleeve 16 of brass or other suitable metal enclosing the inner metal conducting rod 17 also of brass which is insulated therefrom except at the grounded end 20. The outer metal sleeve 16 is electrically connected and grounded to the outer conductor of the flexible coaxial cable 13, while the inner metal conductor 17 is connected to the inner conductor of the flexible coaxial cable 13. Fastened at right angles to the inner metal conductor 17 is the radiating element 18 which is adapted to extend through an opening 19 in the metal sleeve 16. The radiating element 18 is fastened to the inner conductor 17 at a point approximately one-quarter wave length from the end of the conductor 17 that is grounded at 20 to the outer metal sleeve 16. The radiating element 18 is approximately one-quarter wave length in length and is of comparatively large diameter in order to assure a high capacity to ground and a consequent broad band of frequency response. Surrounding the radiating element 18 is a hemispheric metal reflector 21 fastened by a metal bushing 22 to the grounded metal sleeve 16. It will be noted that the radiating element 18 extends through the opening 23 without contacting the reflecting element 21. A protective cover 24 of plicofilm is placed over the opening of hemispheric reflector 21 in order to prevent accidental body contact between the radiating element 18 and the reflector 21 such as would produce an arc and injure the body. The cover of plicofilm or other suitable material is, of course, transparent to the passage of the radiations emanated.

The director 15, constructed as described, provides in some manner not well understood a beam of radiations having a pattern or beam width equal to the width of the opening of the reflector 21 upon an object placed within a distance not greater than a wave length from the reflector opening. Thus, in employing the therapeutic apparatus of this invention, the reflector 21 may advantageously be positioned at a distance preferably not greater than a wave length from the body to be treated (shown as human elbow 25) thus providing a desired focusing of the radiations.

As previously mentioned, it has been found, as a result of careful study, that the director 15

comprising the radiating element 18 and reflector 21 must be properly matched in impedance to the terminating impedance of the body being treated in order to prevent undesired reflection of the radiations from the surface of the body, thus obtaining maximum efficiency of operation. Methods of matching microwave radiating devices to various impedances representative of the intended loading of the antennae are well known and it is a common feature of all such known methods that the radiating elements and reflectors must be cut and tried until the desired results are obtained. For example, the reactance of the radiating element and reflector may be varied by changing the capacitance to ground of the radiating element or by changing its position with respect to a grounded reflecting element or by changing its inductance. In the specific example of one form of director which has been described, the diameter, length and position of the radiating element 18 with respect to the matching stub 17 and the reflector 21, may be determinant of the total impedance of the antenna. There may be other factors contributing to the total impedance such as the coaxial cable and the magnetron oscillator. However, it has been discovered by this invention that the total impedance of the director must produce a no-load standing wave ratio within the range of 1.2 to 1 and 1.6 to 1 in order to obtain the correct loaded impedance matching, and, therefore, a minimum standing wave ratio when the surface of an average body to be treated is brought within operating range of the director. In other words, if the director is designed in accordance with the teachings of this invention, it appears that inherently a reactive component is present in the director which is effective to cancel the reactive component in the body being treated to thus assure an optimum of impedance matching with the body being treated under average conditions of therapeutic applications. Testing of the director constructed in accordance with the above considerations, by observing the heat effects produced in various bodies of flesh representative of the various bodies which may be treated in therapeutic applications, has disclosed that, with the director positioned approximately one-half wave length from the body under test, and the impedance of the director adjusted to produce a no-load standing wave ratio within the range specified, an optimum impedance matching with any of the bodies under test is obtained. Therefore, a total impedance for the director element, resulting in a no-load standing wave ratio of approximately 1.2 to 1 and 1.6 to 1, will assure an optimum of impedance matching for all expected conditions of therapeutic applications so that once having adjusted the director to such impedance matched condition, it is not necessary to subsequently adjust the apparatus when using it in therapeutic applications.

In using the apparatus of this invention for therapeutic applications in which the body of flesh absorbing the energy radiated is relatively close to the director, it has been found that a director having a band width of resonant frequency response less than ten megacycles per second is not effective to assure consistent results with all bodies being treated, in view of an apparent change or reduction of radiated power when applied to certain types of bodies being treated under certain conditions. If a director element having a broad band width of frequency response of at least 10 megacycles per second and prefer-

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ably more is employed, it is found that there is substantially no variation in the power and amount of radiations emanated for all average variations of bodies to be treated under different conditions of therapeutic applications. In the specific form of director shown at 15, the radiating element 18 is of relatively large diameter to provide the broad band width of frequency response sufficient to obtain the desired results. It should, of course, be understood that other forms of broad band radiating elements may be employed in combination with other shapes of reflector elements to obtain a broad band director unit for combination with a source of microwave radiations to produce the therapeutic apparatus of this invention.

One of the advantages of the therapeutic apparatus of this invention, in addition to its extreme portability, is its ease of operation due to the fact that it is not necessary to manually adjust the high frequency oscillator 10 or the director 15 to resonance in a given band of operation. Neither is it necessary to adjust the matching of the impedance of the director 15 to the terminating impedance of all average bodies to be treated under average conditions. It is assumed that a desired frequency band and band width within the range of 2300 to 3300 megacycles per second will be provided for operation of the microwave diathermy apparatus of this invention. Thus to operate the apparatus of this invention, it is only necessary to connect the magnetron oscillator 10, factory designed to operate in the middle of the provided frequency band, to a source of energizing current which may be a conventional rectifying system (not shown). It should also be understood that various sizes and shapes of director units 15 can be used provided their total impedance is initially adjusted in accordance with the teachings of this invention to provide the correct impedance matching with bodies to be treated, and that they will further have the broad band frequency response characteristic, so that they may be interchangeably used without the requirement of manually adjusting or cutting of the radiating element to the frequency of the oscillator.

It should be understood that the invention is

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not limited to the specific elements shown in the combination since substituted elements having the same characteristics will readily suggest themselves to those skilled in the art.

What is claimed is:

1. Therapeutic apparatus comprising a source of electrical oscillations having a frequency within the microwave spectrum, and means connected to said source and resonant to the frequency of said source for radiating said oscillations in a predetermined direction, said means for radiating having a total impedance such as to produce a no-load standing wave ratio within the range of 1.2 to 1 and 1.6 to 1, said means for radiating further having a band width of frequency response of not less than 10 megacycles per second.

2. Therapeutic apparatus comprising a source of electrical oscillations having a frequency within the microwave spectrum, and means including a radiating element and a reflector connected to said source for radiating said oscillations in a predetermined direction, said means for radiating being resonant to the frequency of said source and having a total impedance such as to produce a no-load standing wave ratio within the range of 1.2 to 1 and 1.6 to 1, said means for radiating further having a band width of frequency response of not less than 10 megacycles per second.

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