United States Patent [19]

Peterson

[11] **3,927,291**

[45] **Dec. 16, 1975**

[54] **REDUCED SPEED COMPENSATOR FOR MICROWAVE HEATING APPLICATOR**

[75] Inventor: **Robert A. Peterson,** Canton, Mass.

[73] Assignee: **Raytheon Company,** Lexington, Mass.

[22] Filed: **June 19, 1974**

[21] Appl. No.: **480,657**

Related U.S. Application Data

[63] Continuation of Ser. No. 374,832, June 29, 1973, abandoned.

[52] **U.S. Cl.** ..... **219/10.55 R;** 219/10.55 B

[51] **Int. Cl.**[2] **H05B 9/06**

[58] **Field of Search** ..... 219/10.55 B, 10.55 R, 219/10.55 A, 10.55 M, 10.69, 219/10.77, 10.67

[56] **References Cited**

UNITED STATES PATENTS

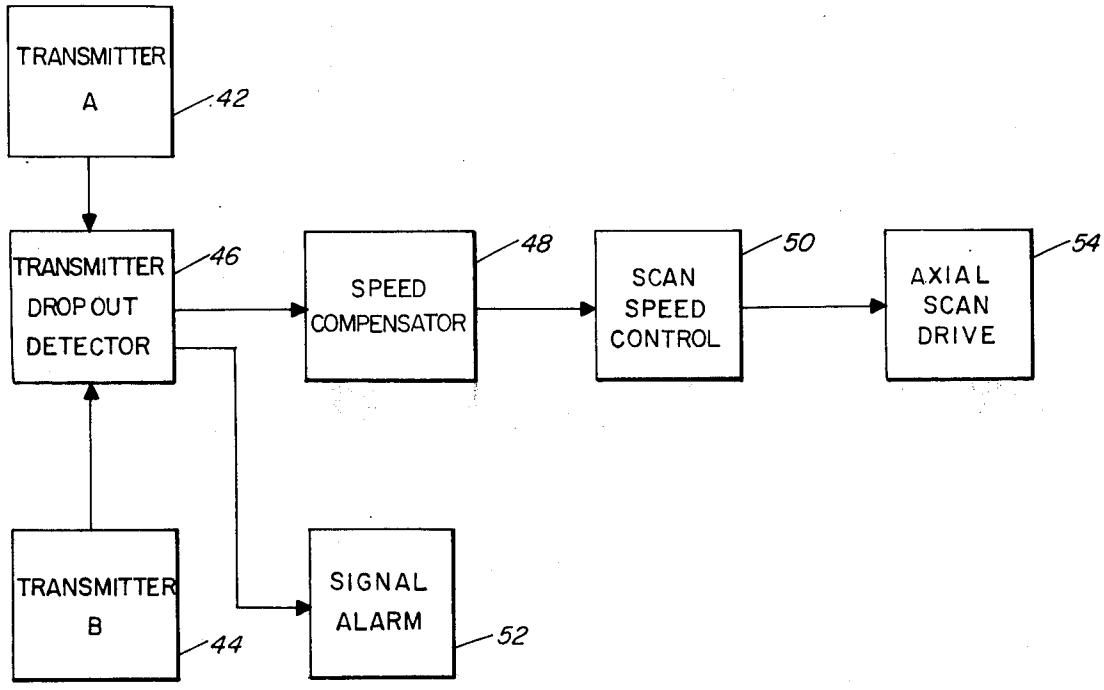
2,637,091	3/1953	Hagopian	219/10.69
3,182,166	5/1965	Bohm et al.	219/10.55 M
3,436,506	4/1969	Smith	219/10.55 R
3,500,012	3/1970	Hilton	219/10.55 B
3,541,289	11/1970	Smith	219/10.55 A
3,584,389	6/1971	Hilton et al.	219/10.55 A
3,614,366	10/1971	Huchok	219/10.69
3,691,459	9/1972	Anderson	219/10.55 R
3,745,291	7/1973	Peterson et al.	219/10.55 R

Primary Examiner—Bruce A. Reynolds
Attorney, Agent, or Firm—Edgar O. Rost; Joseph D. Pannone; Harold A. Murphy

[57] **ABSTRACT**

A control circuit is disclosed for apparatus utilized in processing with microwave energy, such articles as pneumatic type rubber tires having nonuniform shaped bodies for pre-heating prior to vulcanizing or recapping. The articles to be heated are rotatably and axially moved within a microwave heating applicator and the energy is radiated by means such as horn antennas. Any loss of power in the microwave energy transmitter is automatically compensated for by reducing the programmed speed of movement by a factor commensurate with the loss of power to equalize the heating profile. Hence, if one of two 25KW transmitters were to fail, the speed of movement of the article being heated would be reduced by one-half. Means are also provided, such as an alarm, to alert the operator of the equipment failure.

4 Claims, 3 Drawing Figures



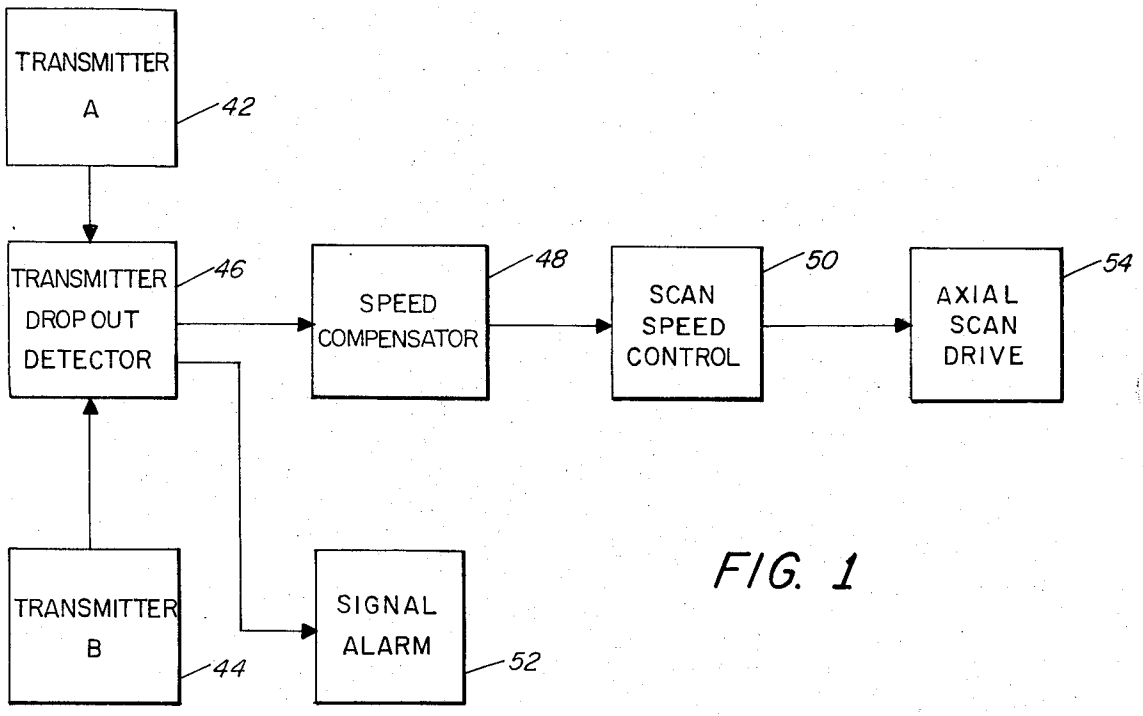

TRANSMITTER A
42
TRANSMITTER DROP OUT DETECTOR
46
SPEED COMPENSATOR
48
SCAN SPEED CONTROL
50
AXIAL SCAN DRIVE
54
TRANSMITTER B
44
SIGNAL ALARM
52

FIG. 1

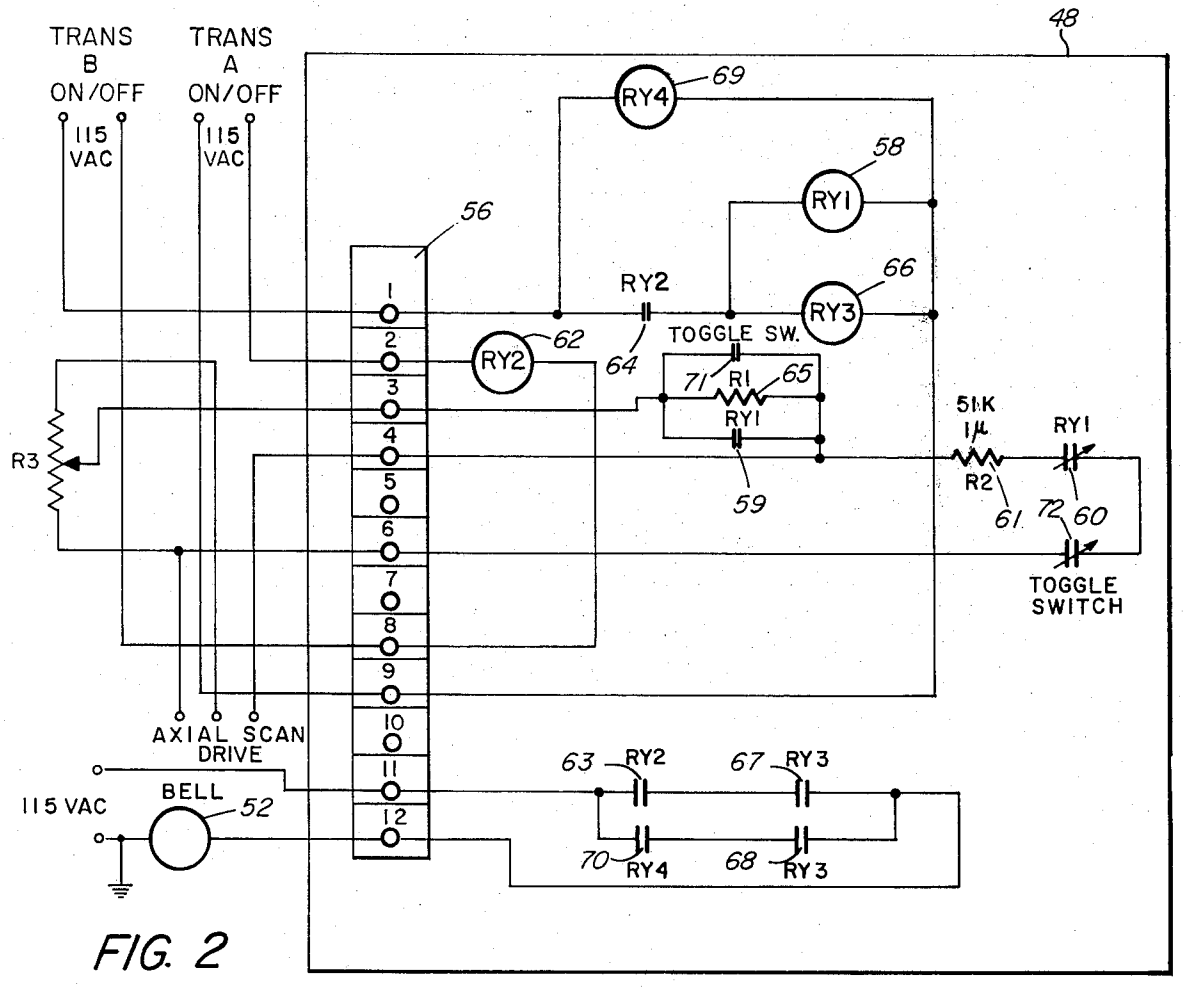

48
TRANS B ON/OFF
115 VAC
TRANS A ON/OFF
115 VAC
RY4
69
58
RY1
56
RY2
66
RY3
62
RY2
64
TOGGLE SW.
71
R1
65
RY1
59
R3
51K
1μ
R2
61
RY1
72
60
TOGGLE SWITCH
1
2
3
4
5
6
7
8
9
10
11
12
AXIAL SCAN DRIVE
115 VAC
BELL
52
63
RY2
67
RY3
70
RY4
68
RY3

FIG. 2

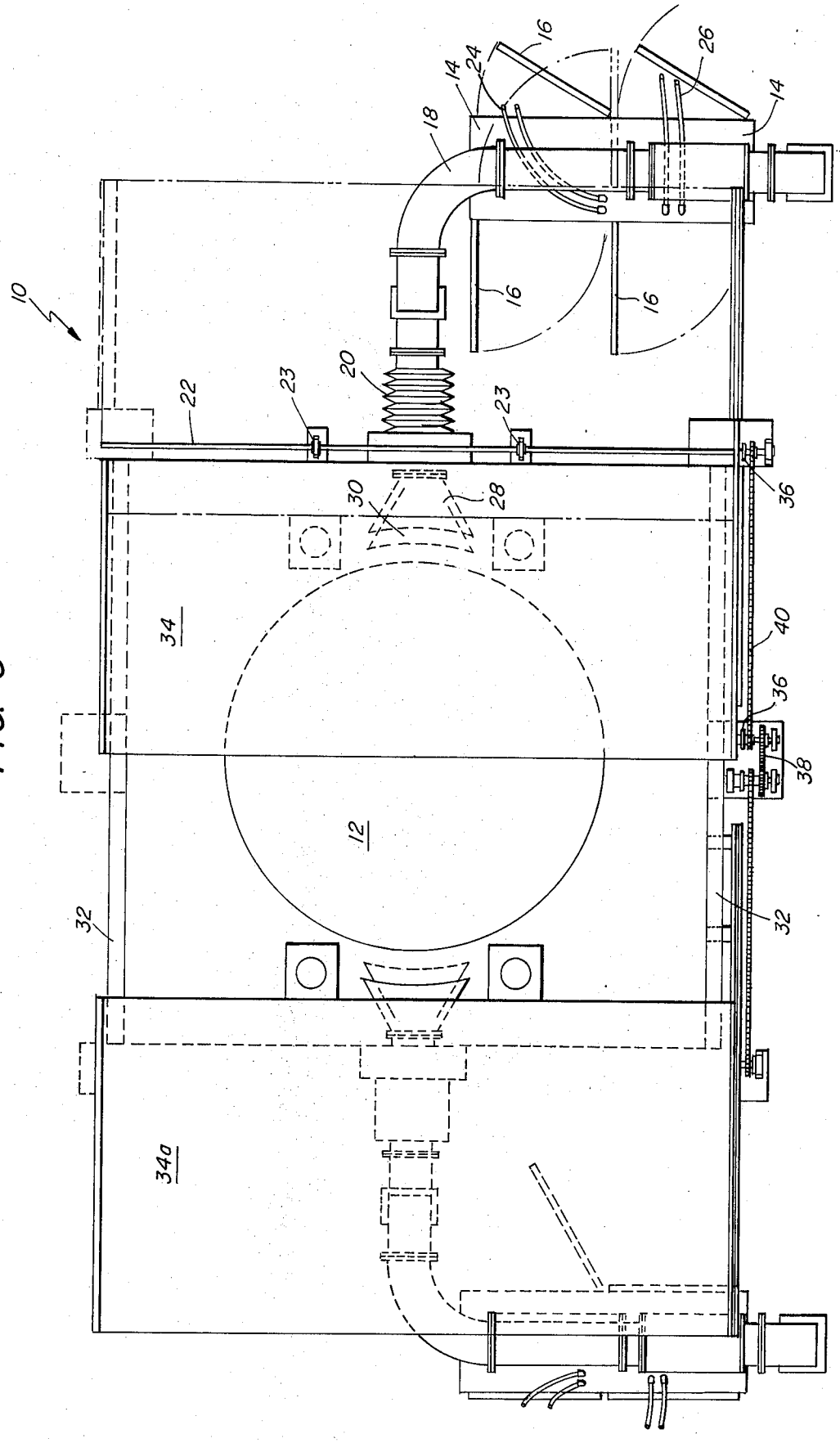


FIG. 3

REDUCED SPEED COMPENSATOR FOR MICROWAVE HEATING APPLICATOR

CROSS-REFERENCE TO RELATED CASES

This is a continuation of application Ser. No. 374,832, filed June 29, 1973, abandoned.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention relates to an electrical control circuit for microwave heating applicators wherein articles of large mass are moved continuously during processing to establish a predetermined heating profile.

2. Description of the Prior Art

In the rubber industry vulcanizing and molding, as well as, recapping of pneumatic type tires has been time consuming due to the inherent poor thermal conductivity of rubber material. Such articles are generally heated from the outside and in many instances it may take hours to reach the required working temperature. The materials used in the applicable articles incorporate both natural as well as synthetic rubber along with other ingredients including carbon-derived products. The compounded material has an inherent ability for being treated with electromagnetic energy to thereby provide for more rapid generation of heat by absorption. Carbon-derived products, such as carbon black, are ideal electromagnetic energy absorbing materials to aid in the microwave heating process.

Microwave heating applicators are now widely utilized in the processing of nonconductive or poor thermally conductive materials such as foods, paper, wood, leather, plastics and the like. The high frequency energy at microwave frequencies are generated by such devices as the magnetron oscillator which is well known and described in the text "Microwave Magnetrons", Vol. 6, Radiation Laboratory Series, by G. B. Collins, McGraw-Hill Book Company, Inc., 1948. The operating frequencies for such applicators are allocated by governmental regulatory bodies and, typically are 915 ± 13MHz and 2450 ± 50MHz or the so-called industrial scientific medical band. In the present application the term "microwave" is defined as electromagnetic energy radiation having wavelengths in the order of 1 meter to 1 millimeter and frequencies in the order of 300 MHz to 300 GHz.

An example of prior art microwave heating applicators for preheating rubber tires is disclosed in U.S. Pat. No. 3,566,066, issued Feb. 23, 1971, to J. Borthwick and E. Searle. In this reference a chamber of a substantially circular, elliptical or smooth curved cross-sectional configuration is provided with an assymmetrically located waveguide feed disposed in the base. Multimode distribution means comprising a motor driven vane-type mode stirrer is disposed adjacent to the waveguide feeding means. A rotatable disc within the chamber carries the article to be heated and is energized by a shaft and motor.

Another example of the prior art teachings is found in copending application Ser. No. 227,547, filed Feb. 18, 1972, by R. A. Peterson and C. L. Gilliatt, and assigned to the assignee of the present invention. This apparatus provides for processing very large diameter pneumatic type rubber tires with a heating applicator including an enclosure having at least one flared horn antenna radiator heating specific areas of the tire. The ends of the radiator surrounding the open mouth are

shaped to have a contour substantially conforming to that of the article being processed and path of travel. A supporting structure is positioned within the heating applicator and such support means are vertically, as well as rotatably, displaced by suitable gearing means to provide for the uniform application of the microwave energy across the entire surface of the article being processed. Since the articles being heated have substantially nonuniform cross-sectional areas with the thicker region in the central area of the tread varying heating times are required to substantially equalize the overall temperature of the article prior to subsequent processing operations which may be either vulcanizing or recapping. Tires having a diameter of up to 15 feet are easily accommodated by the enclosure having movable sidewalls. To heat such articles the microwave power is of such a substantial nature and numerous transmitters are required to operate numerous individual microwave energy sources. As the article to be heated is continuously rotated and moved axially past the energy radiating means the speed of movement is programmed to obtain the desired temperature profile across the entire article. Hence, in the areas of thicker or the tread sections much higher heat concentration is required while lower heat is required for the sidewalls.

In the overall processing of articles by microwave energy involving rotation as well as axial displacement and a rather large mass required to be heated, the failure of one or all of the power sources could result in considerable damage to the product by failure to achieve the desired temperature profile. This could be quite costly in view of the great expense of the articles such as the giant tires which may cost many thousands of dollars. A need arises therefore, for rapid and automatic control of the programmed movement of an article being heated with microwave energy or the complete shutdown of the apparatus to compensate for diminution of power due to source failures.

SUMMARY OF THE INVENTION

In accordance with the present invention an electrical control circuit is disclosed for microwave heating applicators having rotatable and axially displaceable product-carrying means to automatically compensate for any loss of power from the energy source means by reducing the speed of movement of the product-carrying means by a factor commensurate with overall loss of power. The temperature profile across the article, such as a pneumatic type rubber tire, having a nonuniform cross-sectional area is thereby temporarily adjusted to provide for substantially uniform heating until full power is restored. Additionally, means are disclosed to alert the operator at the time of the equipment failure in order that suitable repairs may be instituted.

BRIEF DESCRIPTION OF THE DRAWINGS

Details of the illustrative embodiment of the invention will now be described with reference being directed to the accompanying drawings, wherein:

FIG. 1 is a diagrammatic representation of the embodiment of the invention;

FIG. 2 is a schematic circuit diagram of the illustrative embodiment of the invention; and

FIG. 3 is a detailed plan view of a microwave heating applicator embodying the invention with the top wall partially displaced to disclose internal structure.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Before proceeding to a description of the illustrative embodiment, the applicable apparatus **10** shown in FIG. **3** will be described. In this embodiment a large sized rubber tire is mounted on turntable **12** which is adapted to both rotate and vertically displaced at a programmed rate of movement by such structure as that disclosed in the referenced pending patent application which provides for the rotation of the tire at speed illustratively 4 rpm. While the tire casing is rotated, vertical displacement of the article will provide for heating to temperatures at approximately 200°F in the center sections of the tire while the sidewalls remain at approximately 100°F or below. Numerous differential gear structures are disclosed in the referenced pending application and need not be further elaborated on for the purpose of describing the present invention.

The microwave heating applicator comprises a plurality of high voltage power supplies **14** shown with doors **16** open and are of the conventional power supplies employed for electromagnetic energy generators of the magnetron type. The high power electromagnetic energy is coupled by means of rectangular waveguides **18** including energy sealing bellows arrangements **20** secured to movable walls **22.** Electrical power cables **24** and coolant circulation conduit means **26** are coupled to each of the power supplies.

Plural horn antenna radiator means **28** are contoured at the open ends **30** to substantially conform to the shape of the article being processed. The radiator means **28** being carried on the inside of the movable walls **22** can be disposed at any desired position as indicated by the dashed lines. The movable walls are carried along with the high voltage power supplies by means of wheels **23.** Parallel sidewalls **32** are fixed and provided with access means such as a door. The top wall of the overall microwave heating applicator **10** is formed by sliding sections **34** supported by wheels **36** which are actuated by gears **38** and chains **40.** In the view shown the left-hand portion illustrates the sliding wall section in the open position and has been designated **34***a*. The right-hand portion of the view indicates the closed position of the top wall section **34.** In normal operating conditions the sliding wall sections open and close simultaneously and a crane or other suitable elevating means is utilized to position the article to be heated on the turntable **12.** The dashed lines in FIG. **3** indicate the movable positions of the described components as well as underlying structures.

In accordance with the invention means are provided for compensating for any power failure in the overall high voltage transmitters or the energy sources. In the disclosed embodiment four such transmitters have been shown and while only oppositely disposed radiator means **28** are shown it is possible, in accordance with the teachings of the referenced copending application, to provide four such radiators to radiate all quadrants of the rotating article being heated. It is also permissible to provide for a staggering of the individual radiators at different levels to all selectively heat different regions of the rotating article.

Referring next to FIGS. **1** and **2** the electrical circuit for reflecting changes in the power levels of the energy being radiated within the enclosure will now be described. The illustrative circuit provides for reduced speed compensation in a microwave heating applicator with transmitters **42, 44** including the high voltage supplies and energy sources which are interconnected by a drop-out detector circuit **46.** If one of the transmitters should fail during the heating process, the article being heated would then be subjected to less power during the remainder of the cycle since the axial speed of the article is programmed to obtain the desired temperature profile across the overall cross section. A signal from the drop-out detector causes a resistance voltage divider compensator circuit, to be described in greater detail in reference to FIG. **2** designated by the block **48,** to be energized in the motor speed control circuit which reduces the speed of the scan control **50.** Simultaneously, the signal from the drop-out detector alerts the operator for the condition by means of the actuation of any suitable signal alarm **52.** The scan speed control **50** regulates the movement of the article being heated so that the speed is cut back in appropriate proportion commensurate with the amount of the power loss. If one of two transmitters should fail, the speed is reduced to one-half; if one of five transmitters fail, the speed would be four-fifths of normal; etc. Should all the transmitters fail to result in a total loss of power, the entire process would stop until at least one of the transmitters is turned on.

In FIG. **2** an exemplary schematic of a speed compensator electrical circuit **48** is disclosed. A set of relays designated RY **1–4** inclusive is shown to reduce the motor control speed by a factor determined by the overall loss of heating power. Terminal board **56** provides for the interconnection of the electrical components of the overall circuit. Each relay is shown with the solenoid coil designated by a circle, the contacts by the parallel disposed lines and the resistor which is cut into the circuit at the appropriate time by the standard resistor electrical designation. Hence coil **58,** contacts **59** and **60** and resistor **61** comprise the first relay designated RY-**1.** Similarly, relay RY-2 comprises coil **62,** contacts **63** and **64** as well as resistor **65.** The alarm means **52** are also energized by the relay RY-**2.** Another relay RY-3 includes coil **66** and contacts **67** and **68** interconnected to the alarm system **52.** Finally, relay RY-4 includes coil **69** and contacts **70.** Toggle switch contacts **71** and **72** provide for the energizing of the control circuit.

A source of voltage, illustratively, 115VAC, for transmitter **42** appears across terminals **1** and **9** when it is operative and the similar voltage value from transmitter **44** across terminals **2** and **8.** When transmitter **44** is on RY-2 is energized and when transmitter **42** is on RY-4 is energized. Relays RY-1 and RY-3 are energized when both transmitters are on. The toggle switch provides for on or off control of the Automatic Circuit means. Resistors R**165** and R**261** provide a voltage divider circuit which is connected between the speed control **50,** potentiometer R3 and the axial scan drive control **54.** When switch contacts **71** are closed, series resistor R**165** is shorted to open the circuit to shunt resistor R**261** thereby eliminating the divider from the control circuit. A similar result occurs with relay RY-1 being energized by contacts **60.** This provides for a reduction of speed when a transmitter fails. The alarm signal **52** is actuated when either relays RY-2 or RY-4 are energized and when relay RY-3 is not energized. Since RY-2 energizes only when transmitter **44** is on and relay RY-4 energizes when transmitter **42** is on, the alarm bell will ring when only one transmitter is generating power. Relay RY-3 energizes when both transmit-

ters are on closing contacts **67** and **68** therefore, the alarm circuit will only be energized when there is a failure to alert the operator.

There is thus disclosed means for automatically compensating for any loss in power in a microwave heating applicator, particularly, useful where articles of high cost and programmed temperature profiles are involved. Numerous modifications, variations and alterations will be evident to those skilled in the art. The foregoing description of the embodiment, therefore, is intended to be interpreted broadly rather than in a limiting sense.

I claim:

1. Microwave heating apparatus comprising:

an enclosure;

plural interconnected sources of electromagnetic energy;

means for radiating said energy within said enclosure;

means for positioning an article to be heated within said enclosure;

said positioning means having a programmed rate of movement controlled by a speed control electrical circuit to heat said article to obtain a desired temperature profile; and

electrical circuit means including a drop-out detector circuit to detect the failure of at least one of said sources to operate and generate an output signal and a speed compensator circuit energized by said output signal interconnected to said speed control circuit to reduce movement of said article positioning means by a factor commensurate with the reduction of power resulting from said source failure.

2. The apparatus according to claim **1** wherein said positioning means comprise means for rotating said article during heating.

3. The apparatus according to claim **1** wherein said positioning means comprise means for rotating and axially displacing said article during heating.

4. The apparatus according to claim **1** and alarm means energized by said drop-out detector circuit to alert the operator of the reduction of power condition of said apparatus.

* * * * *