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(54) Through passing heater.

(57) A cylindrical microwave applicator for heating appliances has adjusting means for varying the heating intensity in the cross section of a cylindrical load (1) conveyed through the applicator (2) in the longitudinal direction thereof, said means constituted of a metal wall structure (6) positioned in the applicator parallell with the axis thereof and adjustable from the outside and making contact, in a microwave manner, with the cylindrical and plane inner surface of the applicator.

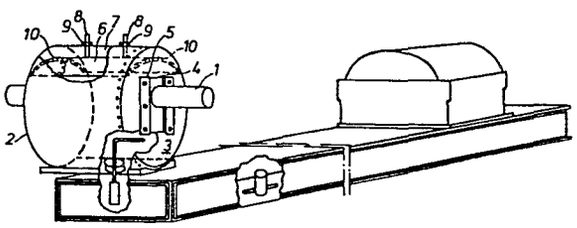

Fig.1

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Through Passing Heater

The present invention relates to a cylindrical microwave applicator for heating purposes with special arrangements for adjusting the heating density in a section through the cylindrical load, which is conveyed through the applicator along or parallelly with its longitudinal direction.

Microwave applicators in which the load stuff is conveyed through a heating zone and heated to a predetermined temperature are known. If the stuff is in the form of a liquid it is conveyed through a microwave transparent tube through the zone. Such a device is known from the Swedish Patent Specification No. 363 462. In this one a TM021-applicator of a cylindrical shape is used for creating a heating zone in a rod-like load extended along the longitudinal direction of the applicator. As a flow in a tube, owing to friction, does not have the same flow velocity at the periphery of the cross section area as in the center, the heating must be more effective in the center than at the periphery. In order to achieve such a distribution of the heating effect in the cross section it is used in a known applicator a TM021-type of field which has a maximum effect in the center and a minimum at the periphery. By such a distribution of the effect over the cross section area of the load it is possible to avoid more heating of some parts than others and over-heating of the peripherial parts. It is shown in the said patent specification that the TM021-resonator has properties which solve the problem of overheating of some parts of the load cross section and allows greater load diameters than priorly known types of applicators.

However, if the load is conveyed through the applicator in contact with a conveying tube, band or the like it is desirable that the heating at the periphery of the load shall not, proportionally, be so small, as in the above said type of applicator. In fact, the applicator diameter for a given diameter and dielectric constant of the load can be calculated by an exact solution of the transcendental equations of the zero order of Bessel- and Neumann-functions and their first derivatives. However, it may be successful to use approximative calculation methods. As the field in the load is not homogenous it is necessary to use an integral function. This one is approximately proportional to $J_0^2(kr) \cdot kr$, where k is so estimated that the peripheral field (in a loss-free case) is zero, when k.r = 2,405.

The microwave heating in an applicator with modified measures according to the above-said but otherwise according to the Swedish Patent Specification No. 363 462 eminates substantially from the resonance amplification of the dominating TM020 field, if the length of the applicator in the axial direction is about the same

as its diameter. However, also other oscillation modes can arise. Among several oscillation modes are just such ones of the TM-type possible in practice, first for the reason that the introduction of microwave energy to the applicator is effected by a loop connected to the magnetic field and then for the reason that the major part of connection of the field to the load is effected when the electric field vector is substantially parallell to the surface of the load.

The resonance field patterns which can generally prevail during the above given circumstances are TM011, TM012, TM110 and TM111. These notations for modes are generally accepted and are explained as follows: The first index after "TM" means the number of hole cycles in the angular direction during one revolution around the axis, the second index states the number of minima of the E-field in a radial direction from the axis to the periphery, the third and last index is the number of half wave lengths in the axial direction of a standing wave in the applicator. The two first said modes have no field variation in the angular direction in the cylindrical applicator, but the two others have an angular function ($\cos\varphi$) and another radial function J_1 (kr) of the radial field component which is zero on the axis and has a maximum at a somewhat less value of r than the zero point of the J_0-function. The two first said resonances have a radial function of the radial field component according to the J_0 (kr) function, i.e. the same as the "basic mode" TM020 - yet another value of k which will be different owing to the different connection to the rod-like load. All four "distorsion modes" have variations in the axial direction (z-) bringing about a tendency of an increase of the heating at the periphery of the load.

By the arrangement described in the Swedish Patent Specification No. 7801280-4 a possibility is introduced to displace the load parallelly with the cylinder axis in a radial direction, whereby a certain change in the connection of the basic oscillation in the applicator is achieved. This change can easily be compensated as known per se by a so called stub in the wave guide feeding the applicator.

In consequence of the useful changes of the applicator and the load positioning therein in relation to the theoretical basic principles the appearance of the composite field pattern will be difficult to calculate. It is therefore suggested also to change the diameter of the applicator and in an empirical way achieve an improvement of the applicator. In principle, this change brings about a diplacement of all resonances of the system - thus, in practice, a possibility to change the balance between the basic mode and other modes. As all the above said other modes make an amplification of the electric field of the periphery of the load they contributes to an equalization of the composite field strength and thus also of the heating velocity over the hole cross section area of the load. As only the two added

modes TM110 and TM111 have variations in the angular direction but locked in one and the same position in relation to the antenna member a field adjustment is possible to achieve just by making the changes of the tube in the radial direction and the diameter of the applicator. Such an adjustment involves in general that the operating frequency of the microwave generator does not correspond to any of the considered resonance frequency peaks. However, it is stated in the Swedish Patent Specification No. 363 462 that the Q-value is proportionally small and thus the band width, where a good efficiency is obtained, so great that just by a matching adjustment with the aforesaid stub it is possible to reach a sufficiently good microwave matching within a necessary generator frequency range.

The purpose of the invention consists of an embodiment of an applicator with variable inner cross section dimensions. The arrangement for enabling this feature is stated in detail in the characterizing clause of Claim 1.

An embodiment of the applicator according to the invention is described in the following with references to the accompanying drawing which shows in Fig. 1 a perspective view of the applicator, wave guide and generator, Fig. 2 a cross section through the applicator.

An apparatus of a through passing type and microwave heating based on the theory of the microwave field according to the foregoing is shown in Fig. 1. The load is conducted in a tube 1 through a cylindrical applicator 2 provided with end walls 3 penetrated by the tube. This one can be displaced in a radial direction and by such a displacement the field pattern can be located to the axial center of the load. In the shown embodiment of the applicator the displacement of the load has been carried out by means of a flange 4 on the tube 1 at each end wall, where the tube pass through in a rather big hole. The tube can then be displaced laterally in this hole and fixed in an adjusted position by means of a couple of retainers 5, which by means of screws keep the flange pressed against the end wall. The position of the tube at the one end can be adjusted independent of its position at the other end.

The technical embodiment of the arrangement for adjustment of the diameter of the applicator is shown on the drawing in the shape of a flexible sheet 6, which resiliently abuts the cylindrical surface 7 of the applicator and the inner surfaces of the end walls. The sheet is kept in this position by a couple of adjusting screws 8 each one penetrating a hole in the cylindrical wall and having a nut 9 on its end. The length of the screws determines how far the position of the sheet can be changed and thus how much the cross section of the applicator cavity can be decreased. As it is designed for TM-modes the surface currents on its inside will have components in the axial direction but not in the angular direction. This will mean that special arrangements for achieving a good contact between the sheet 6 and the cylindrical surface 7 need not be used. A higher demand for a good contact

is put on the abutment of the sheet against the inside of the end walls 3, where the edge of the sheet is slitted so that thus produced contact tongues 10 can slide against the inside of the end wall making a good contact when the sheet edge is moved over the inside.

This now added feature to change the cross section of the applicator offers a greater liberty to dimension the cross section of the load which no longer needs to follow the formula from the Patent Specification 363 462 strictly, i.e. the radius of the cross section of the load = the first minimum in the function $J_o(\Gamma r).J_o^*(\Gamma r)$ where

$$\Gamma = \frac{\omega}{c}\left(\sqrt{\frac{\varepsilon'_r}{2}}\left(\sqrt{1+\left(\frac{\varepsilon''_r}{\varepsilon'_r}\right)^2}+1\right) - j\sqrt{\frac{\varepsilon'_r}{2}}\left(\sqrt{1+\left(\frac{\varepsilon''_r}{\varepsilon'_r}\right)^2}-1\right)\right)$$

In many practical cases the cross section of the load is predetermined as the stuff to be heated has a determined thickness. By assuming that the applicator shall be, e.g. a TM020-resonator, the designer choses a somewhat great value of the diameter of the applicator casing than what is chosen according to an ordinary dimensioning of a TM020-resonator. By way of experimental measuring and adjustments the position of the load in the applicator is adjusted empirically (by means of the flanges 4) and the cross section of the applicator cavity (adjustments of the sheet) so that the heating density in the load in the cross section thereof will be symmetrical, i.e. constant in the angular direction. As said in the introduction a matching adjustment can be carried out by a stub in the wave guide so that a sufficiently good microwave matching of the applicator to the microwave generator is achieved.

The described embodiment may be regarded as example of the invention with a reservation for other possible applicator apparatus for a variable determining of the cross section, which in fact need not have the illustrated circular shape but, for instance, a polygon.

Claims

1. Microwave heater of the through passing type including a cylindrical microwave applicator, a microwave transmission line with an input arrangement, a microwave generator and a conveying means for a through-passing rod-like object positioned near to the axial center of the applicator, and adjusting means at each end wall of the applicator for positioning of the object in the applicator, c h a r a c t e r i z e d in that the applicator is provided with at least one wall structure (6) extended between the end walls (3) which wall structure is adjustable in the radial direction thereby making the inner cross sectional area of the applicator variable.

2. A microwave heater of the through passing type according to Claim 1, c h a r a c t e r i z e d in that the adjustable wall-structure is positioned substantially diametrically in the applicator in relation to the input arrangement.

3. A microwave heater of the through passing type according to Claim 1, c h a r a c t e r i z e d in that the direction of adjustment of the wall structure is substantially coordinated with the direction of adjustment of the load position at the two end walls.

4. A microwave heater of the through passing type according to Claim 1, c h a r a c t e r i z e d in that the edges of the adjustable wall structure turned to the end walls are slitted in order to give a good galvanic contact between the wall structure and the end walls.

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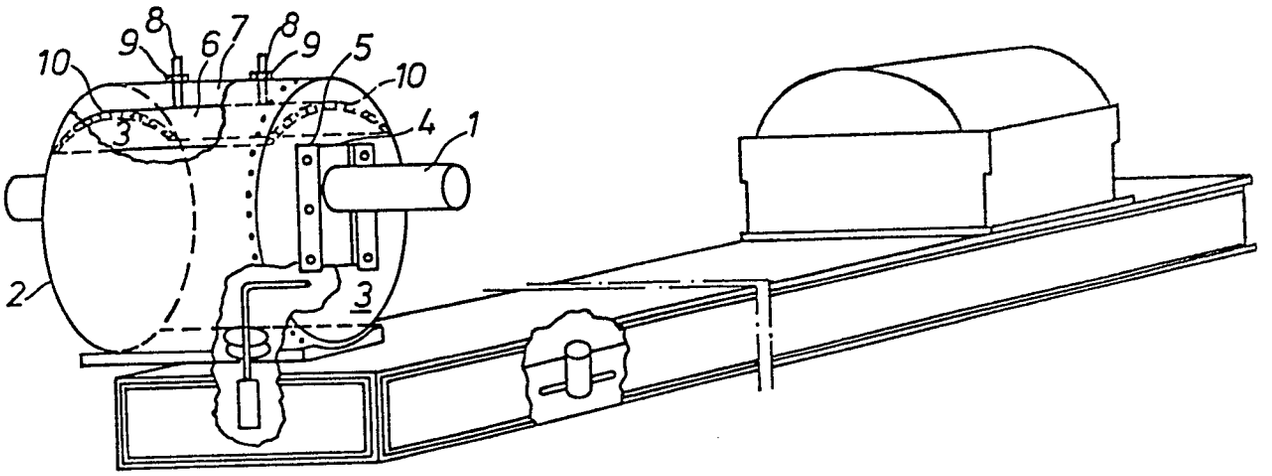

Fig.1

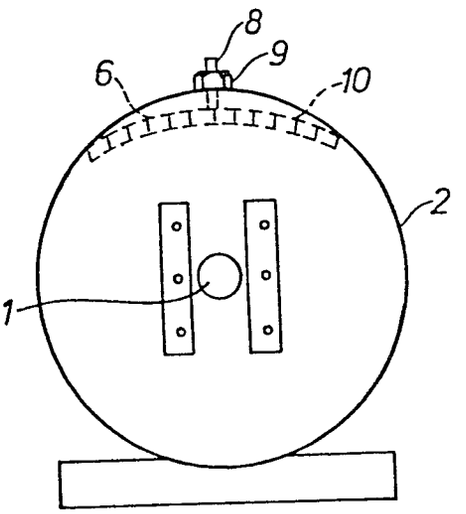

Fig. 2

European Patent Office

EUROPEAN SEARCH REPORT

Application number
EP 80 85 0191.0

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim
	DE - A - 2 162 851 (SOULIER) * fig. 1 * --	1
	US - A - 3 344 254 (MANWARING) * column 3, line 42 to column 4, line 26 * --	1
	DE - B2 - 1 907 448 (FRITZ) * column 2, lines 22 to 47 * --	1
A	DE - B2 - 2 345 706 (HUSQVARNA AB) * complete document * --	1
A	DE - A1 - 2 903 984 (HUSQVARNA AB) * complete document * ----	1

CLASSIFICATION OF THE APPLICATION (Int. Cl.³)

F 24 C 7/02
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TECHNICAL FIELDS SEARCHED (Int. Cl.³)

F 24 C 7/00
F 24 C 9/00
F 24 H 1/00
H 05 B 6/00

CATEGORY OF CITED DOCUMENTS

X: particularly relevant
A: technological background
O: non-written disclosure
P: intermediate document
T: theory or principle underlying the invention
E: conflicting application
D: document cited in the application
L: citation for other reasons

&: member of the same patent family, corresponding document

X The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Berlin	12-03-1981	PIEPER