United States Patent

[11] **3,590,202**

[72] Inventors **John D. A. Day**
Berkeley;
Edward J. Hunt, San Francisco, both of, Calif.

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[73] Assignee **Bechtel Corporation**

[54] **CONSTRUCTION FOR TUNING MICROWAVE HEATING APPLICATOR**
6 Claims, 5 Drawing Figs.

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[51] Int. Cl. **H05b 9/06** H05b/5/00
[50] Field of Search 219/10.55, 10.61; 333/83

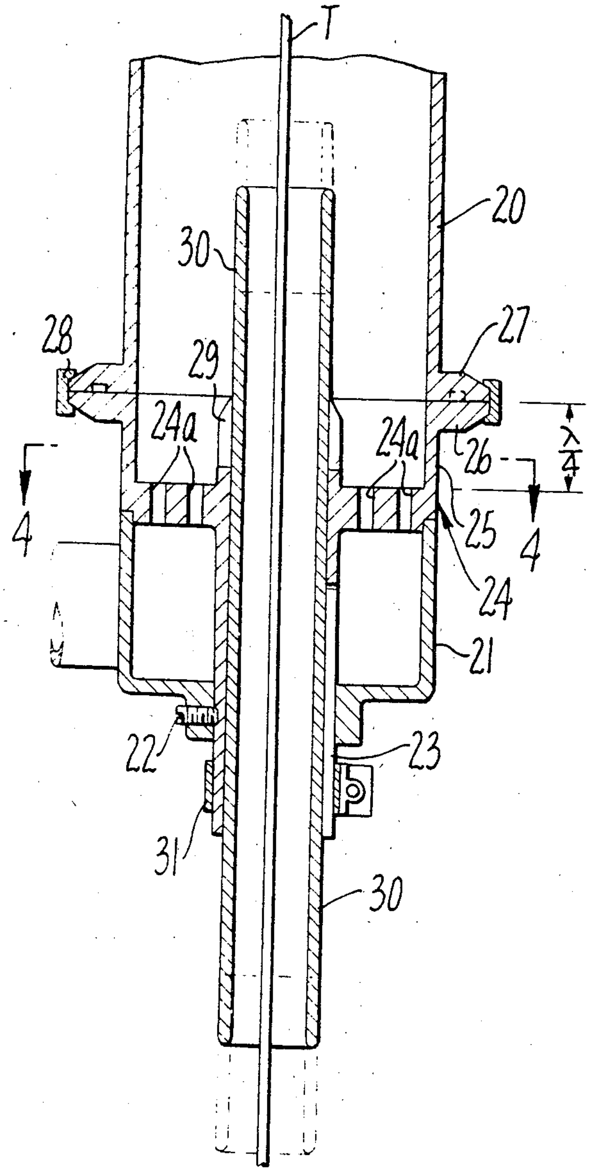
[56] **References Cited**

UNITED STATES PATENTS

2,640,142	5/1953	Kinn	219/10.61 X
3,235,702	2/1966	Timmermans et al.	219/10.61
3,449,836	6/1969	Schreiber et al.	219/10.55 X
3,457,385	7/1969	Cumming	219/10.55
3,461,261	8/1969	Lewis et al.	219/10.55
3,465,114	9/1969	Bleachly	219/10.55

Primary Examiner—J. V. Truhe
Assistant Examiner—L. H. Bender
Attorney—Eckhoff and Hoppe

ABSTRACT: A microwave heating applicator that operates in the TM modes having a substantially cylindrical resonant cavity in which elongate material is heated while being processed therethrough. A microwave heating applicator having a perforated end cap on one end, said end cap having perforations for admitting heated air into the cavity, the size of each perforation being sufficiently small relative to its length to attenuate the transmission of microwave energy, a manifold for receiving heated air and guiding the air toward the perforations in the end cap; and a cylindrical metal sleeve mounted in openings through the end cap and manifold, one end of said sleeve projecting into the resonant cavity and the other end being accessible for adjusting its axial position as to tune the cavity.



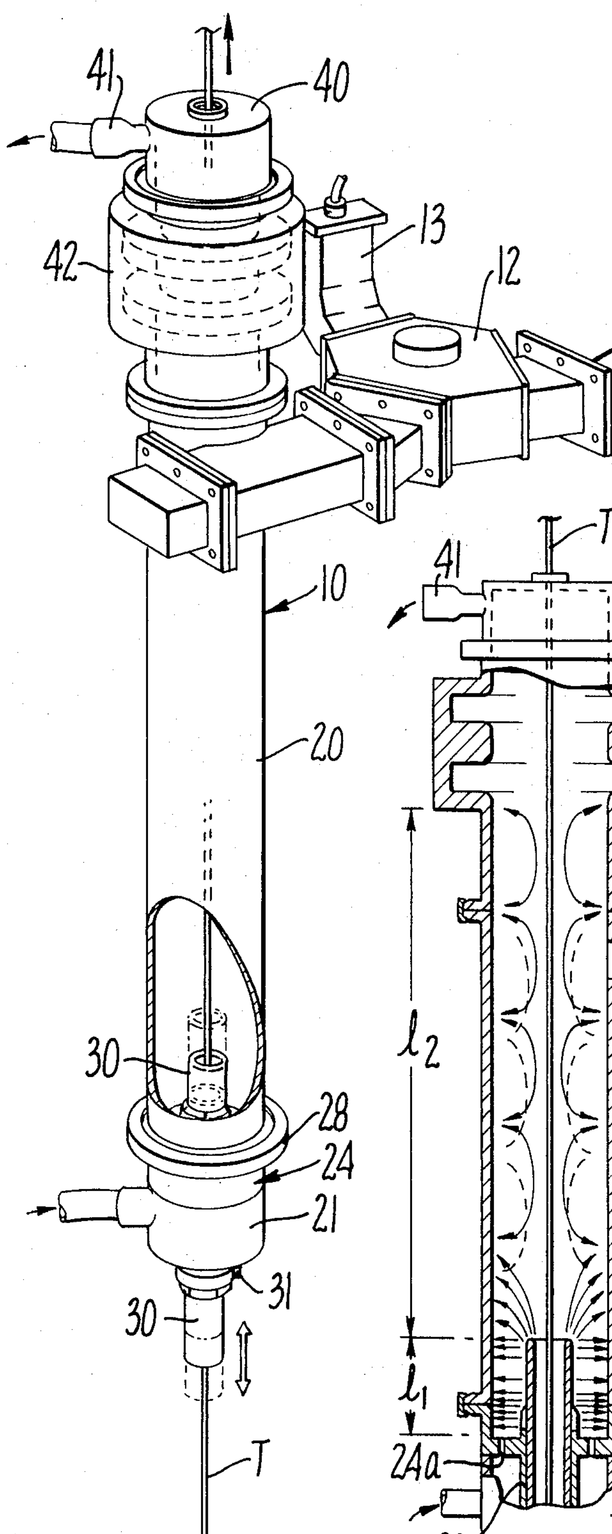


FIG. 1.

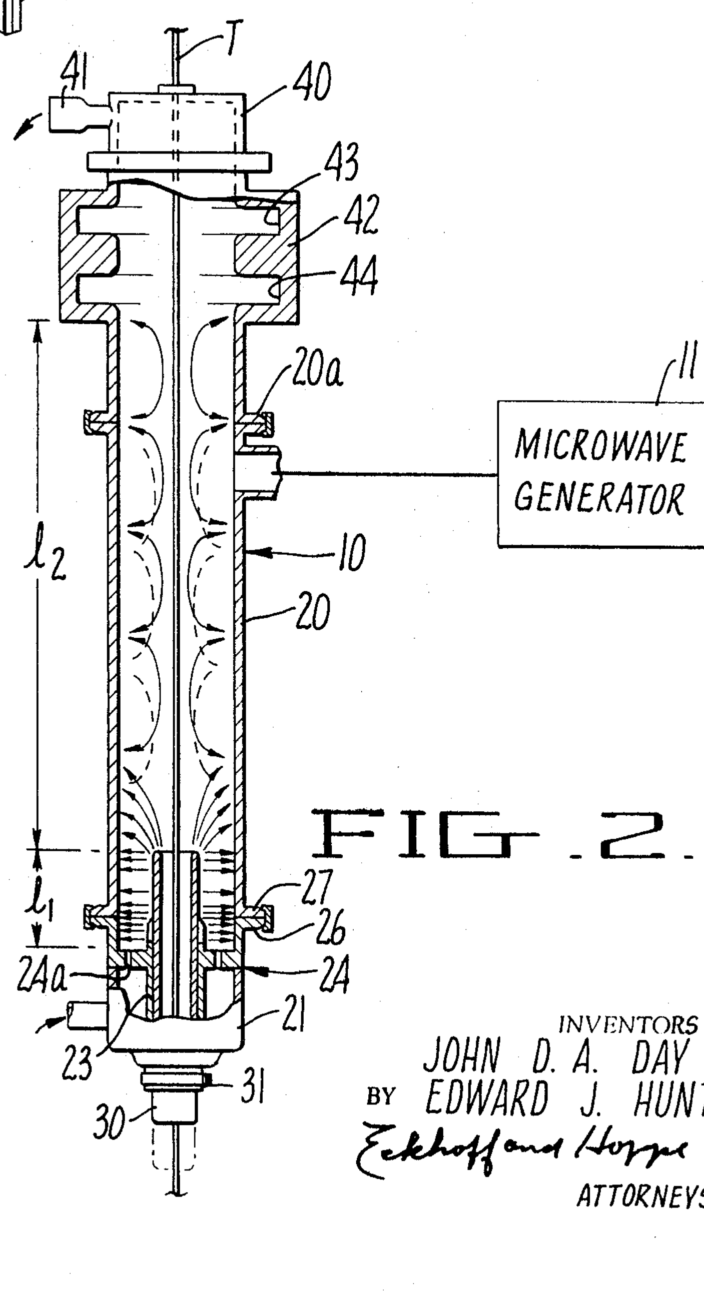


FIG. 2.

INVENTORS
JOHN D. A. DAY
BY EDWARD J. HUNT
Eckhoff and Hoppe
ATTORNEYS

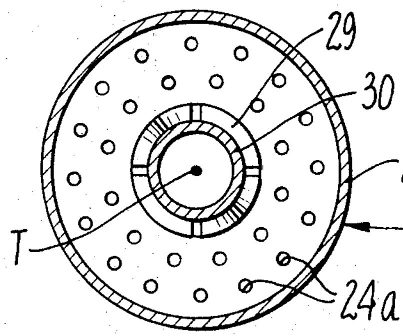


FIG. 4.

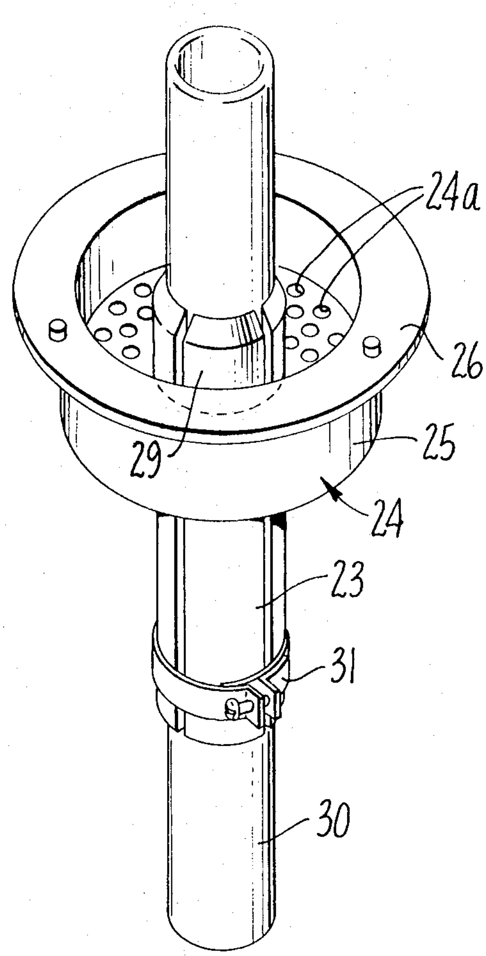


FIG. 5.

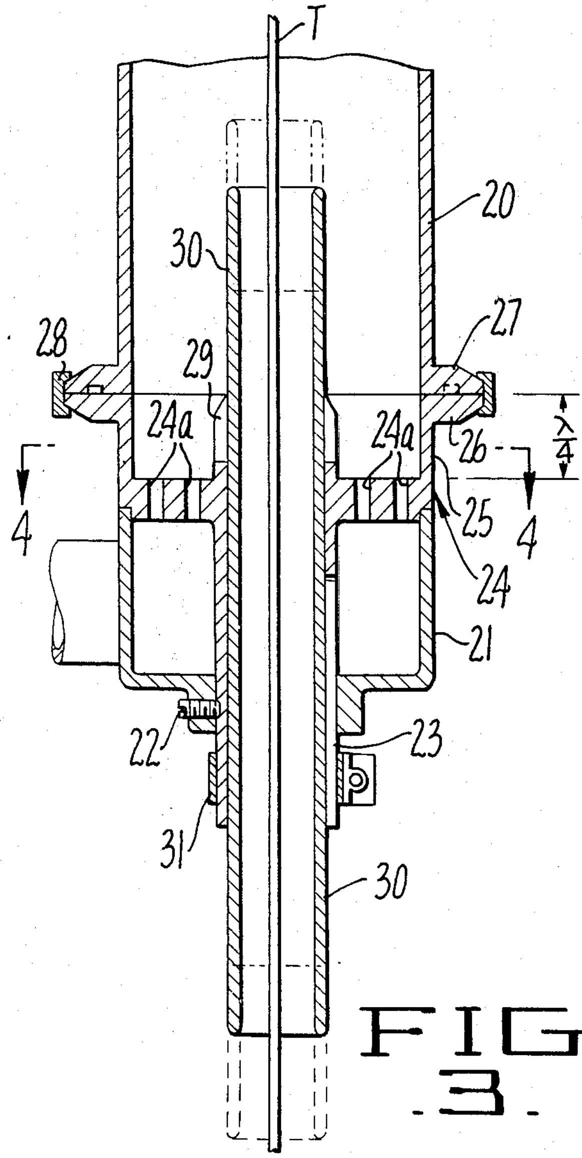


FIG. 3.

INVENTORS
JOHN D. A. DAY
BY EDWARD J. HUNT
Eckhoff and Hoppe
ATTORNEYS

CONSTRUCTION FOR TUNING MICROWAVE HEATING APPLICATOR

This invention generally relates to microwave heating applicators and more particularly to applicators for continuously processing and heating a threadlike substance. The invention particularly relates to applicators which operate in the TM modes and which may be tuned while in use.

Various microwave heating applicators are known which provide means for continuously processing a threadlike substance and which also have the capacity for being tuned while in operation. An exemplary teaching of this type is described in U.S. Pat. No. 3,461,261 in which tuning is accomplished by partially loading the cavity using a quartz sleeve mounted in one end of the applicator. However, none of the previously known microwave applicators are capable of being operated in the TM modes and tuned while simultaneously passing an airstream through a resonant cavity. In brief, the present invention comprises a microwave heating applicator having a cylindrical resonant cavity which is tuned with a metallic sleeve, the axial position and portion of the sleeve within the resonant cavity determining the effective electrical length of the applicator as a whole as determined by the formula

$$\theta=2\pi l_1/\lambda g_1+2\pi l_2/\lambda g_2$$

Where

θ = effective electrical length of applicator

l_1 = physical length of that portion of resonant cavity which is occupied by the metallic sleeve.

l_2 = physical length of the remaining portion of resonant cavity not occupied by the metallic sleeve.

Λg_1 = wavelength in coaxial section of resonant cavity occupied by the metallic sleeve.

Λg_2 = wavelength in remaining portion of resonant cavity not occupied by metallic sleeve.

In addition, a further feature of the present invention is in providing an applicator construction which allows a stream of heated air to be passed through the resonant cavity while also allowing the cavity to be tuned.

It is to be understood, therefore, that one object of the present invention is to provide a microwave heating applicator with means for tuning a cylindrical resonant cavity by changing its effective electrical length and while simultaneously processing a threadlike substance through the applicator in a heated airstream.

Another object is to provide a microwave heating applicator of the kind described which may be disassembled for cleaning and then reassembled with a minimum of down time and labor.

Other objects of this invention will become apparent in view of the following detailed description and the accompanying drawings.

In the drawings forming a part of this application and in which like parts are identified by like reference numerals throughout the same.

FIG. 1 is a perspective view of a preferred embodiment of this invention in a microwave heating applicator, a portion of the applicator being broken away;

FIG. 2 is a vertical section of a portion of the applicator shown in FIG. 1;

FIG. 3 is an enlarged vertical section of the lower end of the applicator;

FIG. 4 is a section taken on lines 4—4 of FIG. 3; and

FIG. 5 is a perspective view of the tuning sleeve mounted in the perforated end cap forming part of the applicator.

Referring to FIG. 1 in particular, there is shown a preferred embodiment in a microwave applicator **10** connected to a source of microwave energy **11** through a three-port circulator **12**. One port of the circulator connects with a water load **13** which absorbs reflected energy, the other two ports connecting the applicator with the source of microwave energy, all in a manner well known in this art.

The present invention is directed more especially to those structural details of applicator **10** which allow tuning while elongated, threadlike material T is being processed. In general, applicator **10** comprises a cylindrical waveguide **20** that operates in the TM modes for heating the material T as it is drawn through the waveguide. Heated air is introduced into the waveguide through a bottom manifold **21** secured by set screw **22** to an axially segmented sleeve **23**, said sleeve forming an integral part of a perforated end cap **24** having a plurality of openings **24*a*** for admitting heated air into the resonant cavity. The cross section or size of each opening **24*a*** is restricted by design so that microwave energy is not lost through the openings. This involves a selection and design of opening size and length as required to attenuate microwave energy of predetermined wavelength. In effect, the perforated end cap serves as a conducting screen in which openings **24*a*** are too small to permit radiation leakage but offer only slight restriction to the flow of heated air.

End cap **24** provides a cylindrical wall section **25** that defines a portion of the resonant cavity, a relatively large flange **26** being provided at the end of the wall section for attaching the end cap to the bottom flange **27** of wave guide **20**. The two flanges are joined together by a rapid disconnect coupling **28** of conventional design.

It will be especially noted that the end cap is designed as a component part of the applicator so that the interface between flanges **26** and **27** is a quarter wavelength from the end of the resonant cavity. This construction creates a condition such that the E field between flanges is at a minimum. Also, the relatively large and flat surfaces of contact between flanges makes the joint relatively insensitive to frequency variations.

End cap **24** further comprises an inner segmented sleeve **29** that extends into the resonant cavity a distance of approximately one quarter wavelength, and the ends of the sleeve are preferably tapered to avoid arcing. The tapered ends also aid in preventing dust or other materials introduced into the waveguide from collecting in a region of high E field intensity.

Inner segmented sleeve **29**, as well as exterior sleeve **23**, define an inner opening and mounting for a metallic tuning sleeve **30**. The segments of sleeve **29** are particularly formed so that their tapered ends contact the tuning sleeve with a resilient gripping force. This force is sufficient to support the sleeve itself but allows the sleeve to be moved coaxially of the resonant cavity into various positions of adjustment. Once the resonant cavity has been properly tuned, sleeve **30** is clamped in a fixed axial position by means of an expansible band **31** mounted around a segmented portion of sleeve **23**.

Applicator **10** further comprises an upper end cap **40** having a lateral connection **41** that communicates with a vacuum source, not shown. In addition, a choke device **42** having a pair of quarter wave recesses **43** and **44** spaced approximately one-half wavelength apart is employed to attenuate microwaves and prevent energy losses through the upper end of the waveguide.

In operation, applicator **10** provides a cylindrical resonant cavity that operates in essentially the TM modes for drying a threadlike material. The moisture and other gases which is expelled from the threadlike material is removed by a stream of heated air. This air is introduced through bottom manifold **21**, passed into the resonant through openings **24*a*** of end cap **24** and then removed from the cavity through the upper end cap **40**. Unlike conventional microwave heating applicators, the resonant cavity of applicator **10** may be tuned during normal processing of the threadlike material by simply adjusting the axial position of tuning sleeve **30**.

Although a preferred embodiment of this invention is illustrated and described, various modifications and changes may be made in the applicator construction without departing from the spirit of the invention or the scope of the attached claims, and each of such modifications and changes is contemplated.

What we claim is:

1. In a microwave heating applicator having a substantially cylindrical resonant cavity, a perforated end cap mounted to one end of said applicator, said end cap having perforations for admitting heated air into the cavity, the size of each perforation being sufficiently small relative to its length to inhibit the transmission of microwave energy therethrough, means defining a central opening through said end cap and coaxial relative to said cavity; means defining a plenum at the one end of said applicator for receiving heated air and guiding the air through the perforations in said end cap, said plenum means having an opening coaxial with the opening of said end cap; and a cylindrical tuning sleeve mounted in the openings through said end cap and plenum means, one end of said cylindrical sleeve extending into said cavity, the other end of said sleeve projecting out from said plenum means.

2. The microwave heating applicator of claim 1, the opening through said end cap being defined by a substantially cylindrical mounting sleeve having a segmented end that extends into said cavity and terminates at a distance approximately one-fourth wavelength from the near end of the cavity.

3. The microwave heating applicator of claim 2, said segmented end comprising a plurality of fingers that taper axially inward and provide resiliency for griping said tuning sleeve.

4. The microwave heating applicator of claim 1, said end cap comprising a cylindrical wall section that defines a portion of the resonant cavity and having a connecting flange for attachment to the applicator, the axial length of said wall portion being approximately one-fourth wavelength.

5. A microwave heating applicator having a resonant cavity adapted to operate in the TM modes and comprising: a cylindrical waveguide; an end cap mounted at one end of said waveguide, said end cap being perforated and having a central opening coaxial of said waveguide the size of each perforation being sufficiently small relative to its length to inhibit the transmission of microwave energy therethrough; a plenum in communication with said perforations and having an opening therethrough and a cylindrical metal tuning sleeve extending through the opening of said end cap and axially adjustable therein, one end of said sleeve projecting into the resonant cavity and the other end being accessible to adjust the axial position of the sleeve and tune the cavity.

6. The microwave heating applicator of claim 5, said end cap comprising a substantially cylindrical mounting sleeve for supporting said metal tuning sleeve, and further comprising a mainfold mounted to said end cap for receiving heated air and guiding the air through the perforated end cap into the resonant cavity, said manifold having an opening therethrough coaxial with the mounting sleeve and the central opening of said end cap, said mounting sleeve extending through the opening of said manifold.