

(19)



Europäisches Patentamt

European Patent Office

Office européen des brevets



(11)

EP 0 697 165 B1

(12)

EUROPEAN PATENT SPECIFICATION

(45) Date of publication and mention
of the grant of the patent:

03.09.1997 Bulletin 1997/36

(21) Application number: **94914465.3**

(22) Date of filing: **05.05.1994**

(51) Int Cl.⁶: **H05B 6/80, H05B 6/70**

(86) International application number:
PCT/GB94/00968

(87) International publication number:
WO 94/26078 (10.11.1994 Gazette 1994/25)

(54) **MICROWAVE OVENS**

MIKROWELLENHERD

FOURS A MICRO-ONDES

(84) Designated Contracting States:
BE DE DK ES FR GB IT SE

(30) Priority: **05.05.1993 GB 9309202**
20.08.1993 US 109350

(43) Date of publication of application:
21.02.1996 Bulletin 1996/08

(73) Proprietor: **APV UK Plc**
London SW1W OJR (GB)

(72) Inventors:
• **SHUTE, Martin Ralph**
Harpenden, Hertfordshire AL5 3BP (GB)

- **DAINES, Peter Nicholas**
Crowland, Peterborough PE6 0NA (GB)
- **MEREDITH, Roger John**
Rutland, Leicestershire LE15 7QA (GB)

(74) Representative: **Lomas, Geoffrey Michael et al**
Barker, Brettell & Boutland,
Medina Chambers,
Town Quay
Southampton SO14 7AQ (GB)

(56) References cited:
DE-A- 1 440 335 **DE-A- 4 032 496**
GB-A- 1 409 227 **GB-A- 1 471 016**

EP 0 697 165 B1

Note: Within nine months from the publication of the mention of the grant of the European patent, any person may give notice to the European Patent Office of opposition to the European patent granted. Notice of opposition shall be filed in a written reasoned statement. It shall not be deemed to have been filed until the opposition fee has been paid. (Art. 99(1) European Patent Convention).

Description

BACKGROUND OF THE INVENTION

This invention relates to microwave ovens particularly, but not exclusively, to industrial ovens for food products such as biscuits, snacks, chips, meat substitutes. The invention may however be applied to non-food products, such as to the heating of plastics.

Continuous ovens for food products such as biscuits can be designed to have a plurality of zones through which each food product travels in sequence. Such zones can be used to provide different heating and baking conditions. Multi-media ovens combine different means of heating a food product in the different zones, such as cyclotherm radiant heating, gas or electrically heated convection, near infrared radiant heat, and are well-known in the industry.

In addition to the usual methods of heating we have shown it to be advantageous to inject microwave energy into an oven at various positions along the oven length. Such an oven which employs microwave heating in addition to another form of heating is hereinafter referred to as a 'combined oven'.

Microwave heating provides means to induce a rapid transfer of energy to the product, the level of energy transfer being selected to provide a desired effect within the product. In a proposed combined microwave-biscuit oven, using four microwave zones, the first microwave zone induces a rapid rise in temperature within the product, the second microwave zone enhances development, and the third and fourth microwave zones reduce the moisture content of the product prior to leaving the oven.

Conventionally heated industrial ovens for food products generally use a metal band to support and convey the food products through the oven. The band may be a metal strip or a mesh band.

The use of a metal band in a multi-mode microwave oven, however, gives rise to serious problems. The microwave heating efficiency is found to be reduced to unacceptably low levels, especially with thin food products such as biscuits.

Industrial microwave units basically consist of a microwave generator and a microwave applicator.

We have appreciated that one of the reasons for the low efficiency of prior art combined ovens is that the conventional applicators operate in several modes, and that the use of substantially one or two modes only can provide advantages.

The terms 'band-parallel' and 'band-normal' used herein are intended to refer to directions which are parallel to and normal to, respectively, the plane of the oven band. Whilst the oven band will often be horizontal, it should be appreciated that the oven band need not always be horizontal since products can be conveyed on a sloping band.

SUMMARY OF THE INVENTION

We have previously proposed a microwave tunnel oven comprising a microwave applicator extending transversely of an electrically conductive oven band and intended to produce electric fields in the region above the band and adjacent thereto, with a plane of polarisation substantially perpendicular to said conductive oven band, and propagated in a direction substantially lengthwise of the band.

The various aspects of the present invention are concerned with practical arrangements to achieve such electric fields.

The band-parallel component (E_H) of the electric field is constrained by the conductive band to be small in the region closely adjacent to the band. The vertical component (E_V) of the electric field in the region occupied by the product is arranged to be sufficient to provide heating of the product carried on the conductive band.

The applicators in accordance with the present invention are essentially configured to create, in the absence of a product, radiation propagated lengthwise of the band in the (TEM) transverse electromagnetic mode, or TM_1 mode. The presence of a product will distort the radiation pattern.

Designs in accordance with the invention aimed at producing such an E-field take account of the conductive oven band in the overall design of the microwave applicator. If the head-space between the product and the applicator is small (such as 40 mm), the equivalent of a parallel-plate transmission line can be created, supporting the TEM mode. If the head space is greater than 60 mm, a higher order mode can be supported.

In experiments in which microwaves are simply fed from the sides of the parallel-plate transmission line formed by the conductive band and a vertically spaced horizontal plate, and in the presence of the product, there was found to be a high attenuation of the microwave energy propagating between the band and overlying plate and normal to the axis of travel of the band. This caused severe non-uniformity of heating of the product on oven bands of width greater than 100 mm.

We have designed applicator configurations which launch a quasi-plane wave longitudinally of the oven band, and thereby provide, in conjunction with the band, the equivalent of a parallel plate waveguide extending longitudinally of the oven.

Such an applicator configuration can provide improved heating uniformity across the oven width.

This requires a microwave applicator with substantially constant amplitude illumination in its aperture plane, and preferably utilising one or two modes only.

Means for broadcasting such a waveform will be described hereinafter, and relate to a microwave generator frequency of 2450 MHz. Other (lower) frequencies can be used but, due to the resultant longer wavelength, less uniform illumination will be achieved.

The microwave applicator preferably comprises an

elongate feeder waveguide extending substantially transversely of the band and positioned above the band, the waveguide being provided with a plurality of longitudinally spaced-apart radiation emitter means adapted to emit radiation with a substantially vertically polarised electrical component in the near vicinity of the band, and preferably substantially throughout the vertical thickness of the product.

A phased array of said emitter means is preferably employed to broadcast the waveform, that is there is a uniform phase difference between adjacent pairs of emitter means of the plurality of emitter means.

The feeder waveguide is preferably a rectangular section waveguide.

The emitter means may be slots in one wall of the waveguide or antenna associated with respective probes which extend inwardly of the waveguide from a wall of the waveguide.

The emitter means are preferably spaced-apart along the waveguide on a pitch of substantially half a guide wavelength.

When the emitter means are antennas the antennas may be carried on the underside of the waveguide. Alternatively the antennas could be connected to respective probes located in the waveguide by respective waveguide links, such as coaxial waveguide links.

When the emitter means are slots, each slot is preferably of a length substantially half a free-space wavelength.

Such slots are preferably provided in a broad side of the waveguide which is oriented substantially normal to the band.

US-A-4570045 (Jeppson) shows an oven comprising an endless band of metal caused to pass through an oven chamber, whereby coal carried by the band is subjected to microwaves existing within the treatment space, the microwaves being emitted from slots beneath aligned slots in waveguides extending transversely of the oven band.

However, this reference fails to teach the use of microwave launch means whereby a polarised waveform is caused to exist within the treatment space.

According to the invention we provide a microwave tunnel oven for subjecting products conveyed through the oven to microwave radiation comprising a tunnel oven casing the oven casing comprising spaced apart tunnel oven side-walls and an oven roof connecting the side-walls, an electrically conductive product-supporting conveyor band positioned between the side-walls and beneath the roof to extend lengthwise of the tunnel, band drive means operative to drive the band, a microwave generator means, a microwave applicator, positioned between the side-walls and above the band, microwave supply means connecting the generator means to the applicator, the applicator comprising an elongate microwave emitter assembly extending transversely of the oven band, the emitter assembly comprising a plurality of spaced-apart microwave emitter means charac-

terised by the provision of microwave launch means extending longitudinally of the oven and above the band from adjacent to the emitter assembly, the emitter assembly being operable to emit radiation into the oven generally in a longitudinal direction of the oven with a plane of polarisation substantially perpendicular to the oven band, at least a portion of the launch means and the band defining therebetween a microwave treatment space through which the products are conveyed in use for being subjected to microwave radiation, the launch means being configured to maintain the polarisation of the radiation in the treatment space substantially perpendicular to the oven band, and further characterised by a microwave containment assembly extending for substantially the full length of the applicator, in the longitudinal direction of the band, and comprising an electrically conductive floor extending beneath the band, and spaced-apart electrically conductive containment side-walls on either side of the band, and connecting the conductive floor with the applicator.

The emitter assembly may comprise a feeder waveguide extending transversely of the oven band, and a plurality of spaced-apart slots in the feeder waveguide, the slots facing longitudinally of the oven for emitting radiation into the oven generally in a longitudinal direction of the oven with a plane of polarisation substantially perpendicular to the oven band at least a portion of the launch means and the band defining therebetween a microwave treatment through which the products are conveyed in use for being subjected to microwave radiation, the launch means being configured to maintain the polarisation of the radiation in the treatment space substantially perpendicular to the oven band, and the microwave launch means may comprise, as viewed in longitudinal vertical section of the oven, a first stage positioned adjacent to the feeder waveguide and a second stage remote from the feeder waveguide, the first stage comprising upper and lower first stage plates disposed above and below respectively the slots and extending generally longitudinally of the oven from the feeder waveguide, the second stage comprising a panel extending closer to the band in proceeding away from the first stage, the upper first stage plate meeting the second stage panel at a junction therebetween, and the upper and lower first stage plates as viewed in longitudinal vertical section of the oven, being essentially mirror images of each other about a longitudinal plane that extends symmetrically through the plurality of slots and parallel to the band.

Preferably said upper and lower first stage plates are substantially flat plates, said upper first stage plate extending upwardly and longitudinally, with respect to the band, from said feeder waveguide, said lower first stage plate extending downwardly and longitudinally, with respect to the band, from said feeder waveguide, so as to define a cavity in the near field of the slots which expands in the direction proceeding away from said slots.

A parallel plate portion of the applicator may be provided, said parallel plate portion extending substantially parallel to the band and away from the launch section of the applicator, with which the parallel plate portion is continuous. Such a parallel plate portion effectively extends the length of the applicator in the longitudinal direction of the band, to retain the polarisation of the waveform when the products to be heated are low loss products which do not readily absorb the waveform and accordingly allow the waveform to travel further along the oven.

The launch means may be configured to maintain the polarisation of the radiation in the treatment space substantially perpendicular to the oven band characterised in that the arrangement is such that the mode of radiation in the treatment space is at least predominantly the TM_1 mode.

Alternatively, the said plurality of microwave emitter means may comprise a plurality of antennas depending downwardly from said feeder waveguide, and a plurality of probes located in said waveguide, each said probe being directly connected to a respective one of the antennas.

The plurality of microwave emitter means may be arranged as a phased array, such that there is a uniform phase difference between adjacent pairs of emitter means of said plurality of emitter means, and that the feeder waveguide is located externally of the oven casing, and the plurality of microwave emitter means is connected with the feeder waveguide by a plurality of coaxial waveguide links, the links extending through the oven casing.

Various embodiments of the invention will now be described, by way of example only, with reference to the accompanying drawings in which:

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a schematic longitudinal vertical cross-section of one of the microwave zones of a first combined microwave-biscuit oven, in accordance with the invention, showing an applicator in transverse cross-section, the applicator comprising transverse waveguides incorporating slots, in combination with associated launch sections,

Figure 2 is a section in the line A-A of Figure 1 and looking in the direction of travel of the oven band, to show the broad, slotted side of one of the pair of slotted waveguides,

Figure 3 is a schematic longitudinal vertical cross-section of the microwave zone of a second combined microwave-biscuit oven in accordance with the invention, using transverse waveguides incorporating probe-fed monopole aeri-
als in combination with associated launch sections,

Figure 4 is a section on the line B-B of Figure 3 and looking in the direction of travel of the oven band, of a waveguide incorporating probe-fed monopole

aeri-
als,

Figure 5 shows a modification of the oven of Figures 3 and 4 in which the waveguide fitted with probes is external to the oven housing,

Figure 6 is a section similar to Figure 1 of a modified combined microwave biscuit oven, in accordance with the invention, and which utilises the TM_1 mode as well as the TEM mode,

Figure 7 is a section similar to Figure 3 but of a modification to the oven of Figure 6,

Figure 8 is a side elevation of a parallel plate transmission line supporting the TM_1 mode and showing the electric field lines in the volume between the parallel plates, and

Figure 9 is a schematic vertical cross-section, similar to Figures 2 or 4, of a modification in accordance with the invention.

With reference to Figure 1, an oven comprises side-walls S and a roof R. The side walls S are spaced-apart by a distance of typically 1 or 1.2 metres. Food products 1 are conveyed on a horizontal steel oven band 2 extending between side walls S through a vertically polarised E-field shown E_v and E_h , broadcast from an array of slots 8 formed on oppositely facing broad sides 3' of a pair of oblong-rectangular cross-section feeder waveguides 3 of a double applicator. Launch sections 5 of the applicator consist of first launch stage 6, adjacent to the respective waveguide 3, and a second launch stage remote from the respective feeder waveguide 3 in the form of a panel 7, curved at a radius R_1 to connect the end of the first launch stage smoothly with horizontal plates 11 of the applicator. A respective treatment space 7' is defined between the panel 7 and the band 2.

Thus the first stage 6 of each launch section 5 is defined by an upper first stage plate 6' and a respective lower first stage plate 6". The upper first stage plate 6' in proceeding from the associated waveguide 3 is directed upwardly and longitudinally of the oven, at an angle of 0 to the plane of band 2, whereas the respective lower first stage plate 6" lies beneath the upper first stage plate 6' and extends downwardly in proceeding longitudinally of the oven from the waveguide 3, from below the slots 8, at the same angle 0 relative to the plane of the band 2.

Thus the upper and lower first stage plate pairs define between them a respective cavity 15, in the near field of the slots 8, which expands in the direction proceeding away from the slots of the respective feeder waveguide 3.

The longer second stage panel 7 extends closer to the band 2 in proceeding longitudinally of the oven from the connection between the second stage panel 7 and the extremity of the respective upper first stage plate 6' to merge with the horizontal plates 11 of the applicator.

The applicator, as shown in Figure 2, extends for almost the full width of the oven, and the cross-sectional configuration shown in Figure 1 is uniform for that full length of the applicator. As shown in Figure 2 the feeder

waveguides extend through one wall S of the oven for connection to a remote microwave generator means.

With reference to Figure 2, food products 1 are conveyed on oven band 2 under the applicator 3. Slots 8 of length d_1 are formed in one broad side 3' of each waveguide 3 pitched evenly by dimension d_2 and arranged evenly and alternately about the centre-line 4 of the side 3' at a distance d_3 . This may require a flare to compensate for a bias of power transmitted from the first to the last slot. (Microwave theory would imply that the spacing about the centre-line of each slot should be different as the effect of neighbouring slots varies from slot to slot, depending upon their relative positions. (These variations are small in practice and can be ignored.) The positions of the edges 9 of the first stage plates 6', 6" of the launch section 5 are arranged so that the centre-line of the slots is equidistant between the edges 9 and the centre-line 4 of the broad face 3' of the respective waveguide.

A base plate 13 extends from the lower edges of lower panels 6", and also defines the lower short side of the feeder waveguides 3, the base plate 13 extending parallel to the band 2 to define between the plate 13 and band 2 a further treatment space 14. Standing waves created in space 14 by reflections from the launch sections 7 provide additional heating of the products 1 as they pass beneath plate 13.

Further treatment spaces 11' are defined between the horizontal plates 11 and band 2. Depending on the nature of the products being heated most of the microwave energy will have been absorbed by the products in the treatments space 7' and little radiation will reach space 11'. However, for some products heating will take place in space 11'.

In the embodiment of Figure 1 the upper and lower first stage plates 6' and 6" are set at equal angles θ relative to the plane of the band 2. In modifications, not illustrated, the plates 6' and 6" could be of different shape and orientation but best results are likely to be achieved when the plates 6' and 6" are arranged in mirror image configuration relative to that plane which includes the centre-line of the slots 8 and is parallel to the plane of the band 2.

In Figures 3, 4 and 5 parts corresponding to those of Figures 1 and 2 have been given corresponding reference numerals.

Referring now to Figures 3 and 4, food products 1 are conveyed on a steel oven band 2 beneath an applicator which creates a vertically polarised E-field, shown E_v and E_h , broadcast from an array of probe-fed monopole antennas 10 located on the bottom face of two rectangular cross-section spaced-apart feeder waveguides 3. Each antenna 10 is fed by a respective probe 10'. The launch sections 5 in this case each consist of a flared panel structure 7 set at a radius R_2 to extend between the waveguide 3 and portions 11 of the applicator parallel to the band 2. Dimension d_7 is determined by the power requirements.

In the embodiment of Figures 1 and 2, the applicator uses a pair of waveguides 3 extending substantially transverse to the direction of travel of the steel band conveyor 2, each of the waveguide feeds being of oblong-rectangular cross-section, as shown in Figure 1, with the longer dimension of this cross-section disposed vertically and with the slots 8 formed on one of the broad sides 3'. This arrangement is used in combination with the launch section 5 to direct the waveform 'through' the top plate of the equivalent parallel plate waveguide. The length of the slots 8 is substantially one half the free-space wavelength for the chosen frequency and the slots 8 are spaced apart by one half guide-wavelength. Adjacent slots 8 are arranged alternately on opposite sides of the centre-line 4 of the broad face 3' of the waveguide 3 to allow for phase reversal of the waveform in the guide. In this way a substantially uniform microwave illumination can be achieved.

Additionally, by arranging a second similar pattern of slots 8 to be repeated on the outwardly-facing broad face 3' of the second waveguide 3, but out-of-phase, in the transverse direction of the band, to the first set of slots by an amount equal to one quarter guide-wavelength, compensation for any non-uniformity of microwave illumination can be achieved, in that the accumulated exposure of a single product to the waveform will be evened out when the product has passed through the two fields generated by the respective waveguides 3.

The launch section 5 of the applicator of Figures 1 and 2 is arranged initially to ensure symmetry in the very near field of the slots 8 and then to provide a guide for the waves 'through' the top plate of the equivalent parallel plate waveguide. The exact dimensions are determined empirically to achieve a substantially uniform microwave illumination across the oven band and to maintain vertical polarisation of the E-field.

In the arrangement of Figures 3 and 4, the applicator uses an array of probe-fed monopole antennas distributed across the width of the oven but located on the underside of the transverse feeder waveguide.

This arrangement is used in combination with a launch section 5 arranged to direct the waveform 'through' the top plate of the equivalent parallel plate waveguide. The length of each of the monopoles 10 is preferably substantially one quarter the wavelength of the free-space waveform for the chosen frequency.

Folded monopoles, as shown in Figure 4, are preferred because they are self-supporting and do not require a ceramic holder.

The power broadcast from each antenna 10 is proportional to the protrusion of the associated probe 10' into the waveguide, this being arranged to suit the power transmission requirements.

The configuration of the launch sections 5 in Figure 3 is based on similar principles to those used for the slotted waveguide of Figures 1, 2 but in this case the provision of plates such as plates 6', 6" used in Figures

1, 2 to ensure symmetry in the near field is unnecessary. Thus, the curved plate 7 extends directly from the respective feeder waveguide 3. Additionally, and in a similar manner to the slotted configuration of Figures 1, 2, the arrangement of probes 10 is repeated on a second waveguide 3 but so as to be out-of-phase with respect to the antennas on the first waveguide 3, in the transverse direction of the band, by an amount equal to one quarter the guide wavelength; in a like manner this compensates overall for any non-uniformity of microwave illumination.

The exact dimensions of the launch sections 5 are determined empirically to achieve a substantially uniform microwave illumination across the oven band and to maintain vertical polarisation of the E-field, but approximate values can be related to the wavelengths used.

The wavelengths referred to are determined by the choice of frequency and can be expressed as follows:

$$\lambda = C/f$$

where

λ is the free-space wavelength of the waveform
 f is the chosen frequency in Hertz
 c is the speed of propagation of the waveform in free-space
 E_r is the relative dielectric constant

and

$$\lambda_g = \lambda [E_r - (\lambda/\lambda_c)^2]^{-1/2}$$

where

λ_g is the guide-wavelength
 λ_c is the factor related to the waveguide, and is typically twice the broad dimension of waveguide

With reference to Figures 1, 2, 3 and 4, the dimensions noted have typical values defined as follows:

$d_1 = \lambda/2$
 $d_2 = \lambda_g/2$
 d_3 is symmetrical about the centre-line of the broad face of the waveguide and is found experimentally by means of power reflection measurements to give equal power drop per slot pair.
 d_4 should be the minimum possible compatible with the construction of the waveguides.
 $d_5 = 6\lambda$ (minimum)
 $d_6 = \lambda/4$
 d_7 is proportional to the power transmission

requirement

$d_8 = 1.3\lambda$ (approx)
 $d_9 = 3.3\lambda$
 $d_{10} = 40\text{mm}$ (this is selected to be a minimum to clear the product)
 R_1 and R_2 are in the range of 4λ to 5λ
 0 is in the range of 10 to 20 degrees.

Figure 5 shows that the feeder waveguide 3 fitted with probes 10' may be positioned external to the oven, the probes 10' being connected to respective antennas 10 positioned within the oven by respective coaxial waveguide links 15.

Whereas the ovens of Figures 1 to 5 utilise the TEM mode, those of Figures 6 and 7 principally utilise the TM_1 mode, but with some TEM mode in the upstream and downstream portions of the applicator.

In Figures 6 and 7 corresponding reference numerals have been applied to parts which correspond to the ovens of Figures 1 to 5.

With reference to Figure 6, the central portion of the applicator, comprising the pair of waveguides 3 with slots in their broad sides 3', respective upper and lower plates 6' and 6", and base plate 13, is essentially the same as the central portion of the applicator of Figure 1, but the upper plates 6' connect with respective horizontal main applicator plates 20 which extend parallel to the metal band 2 at a spacing d_{11} which is greater than 60 mm, typically 70 mm, in order to establish the TM_1 mode in the respective treatment spaces 21 defined between the band 2 and the main applicator plates 20.

Figure 8 shows schematically the distribution of the electric field in the equivalent parallel plate transmission line supporting the TM_1 mode. Immediately above the band the electric field is, in fact, parallel to the band, but in proceeding away from the band the electric field rapidly becomes normal to the band, so that effectively the field in the product is perpendicular to the band. At the mid-height the electric field lines again become horizontal. Therefore the products would preferably be chosen to have a maximum height less than half d_{11} , and this represents the effective treatment space in this case.

As will be appreciated by the skilled addressee, the TM_1 mode may alternatively be designated the TM_{01} mode, since there are no loops of the electric field in the direction extending parallel to but transversely of the metal band 2.

As shown in Figure 6, the ends of the main plates 20 remote from the waveguides 3 are continuous with downwardly and outwardly sloping flat plates 7, extending at an angle of typically 45° to the band, the plates 7 connecting with horizontal plates 11 spaced at a distance d_{10} above the band 2. The distance d_{10} is typically 15 to 20 mm in order to support the TEM mode in the further treatment spaces 11'.

Since the products to be heated, biscuits 1 being shown in Figure 6, are supported on the band 2 and

therefore occupy the region immediately above the band, the E-field to which the products are exposed in the main treatment spaces 21 extends substantially normal to the plane of band 2.

The length of d_{12} of the main plates 20 in Figures 6

Figure 7 shows an equivalent arrangement to that of Figure 6 but employing antennas 10 in a similar manner to Figure 3. The dimensions d_{10} , d_{11} and d_{12} are typically as given for Figure 6. Again, the TM_1 mode is supported in the main treatment spaces 21, whereas the TEM mode is supported in the further treatment spaces 11'.

With reference to Figure 9, a modification is shown which can be applied to any of the embodiments of Figures 1 to 8. In order to prevent escape of the microwaves from the sides of the parallel plate transmission line and to contain all microwaves (within safety limits) inside the treatment space/s, a microwave circuit 22 is defined to enclose the emitter assembly, launch section and oven band. As shown, the oven band 2 is supported by electrically conductive skids 23, running lengthwise of the band 2, on the base 25 of the microwave containment circuit 22 of channel section, the band 2 and the applicator panel 11 forming a parallel plate transmission line as previously described. Chokes are arranged at the opposite ends of the applicator, where the products enter and leave. The microwave circuit 22 is continuous along the length of the treatment zone and the sides 26 of the circuit 22 are connected by means of a respective welded or slideable joint at J to the applicator in such a way as to ensure substantially no leakage of microwaves at the join.

Claims

1. A microwave tunnel oven for subjecting products conveyed through the oven to microwave radiation comprising a tunnel oven casing (R, S), the oven casing comprising spaced apart tunnel oven side-walls (S) and an oven roof (R) connecting the side-walls, an electrically conductive product-supporting conveyor band (2) positioned between the side-walls (S) and beneath the roof (R) to extend lengthwise of the tunnel, band drive means operative to drive the band, a microwave generator means, a microwave applicator (3, 5, 11) positioned between the side-walls and above the band, microwave supply means connecting the generator means to the microwave applicator, the microwave applicator comprising an elongate microwave emitter assembly (3) extending transversely of the oven band, the emitter assembly comprising a plurality of spaced-apart microwave emitter means characterised by the provision of microwave launch means (5) extending longitudinally of the oven and above the band (2) from adjacent to the emitter assembly (3),

the emitter assembly (3) being operable to emit radiation into the oven generally in a longitudinal direction of the oven with a plane of polarisation substantially perpendicular to the conveyor band (2), at least a portion of the launch means (5) and the band (2) defining therebetween a microwave treatment space (21) through which the products are conveyed in use for being subjected to microwave radiation, the launch means (5) being configured to maintain the polarisation of the radiation in the treatment space (21) substantially perpendicular to the conveyor band, and by a microwave containment assembly (22) extending for substantially the full length of the microwave applicator, in the longitudinal direction of the band (2), and comprising an electrically conductive floor (25) extending beneath the band (2), and spaced-apart electrically conductive containment side-walls (26) on either side of the band, and connecting the conductive floor (25) with the microwave applicator (3, 5, 11).

2. An oven as claimed in claim 1, characterised in that the emitter assembly comprises a feeder waveguide (3) extending transversely of the oven band (2), and a plurality of spaced-apart slots (8) in the feeder waveguide, the slots (8) facing longitudinally of the oven for emitting radiation into the oven generally in a longitudinal direction of the oven with a plane of polarisation substantially perpendicular to the oven band (2), at least a portion (7) of the launch means and the band (2) defining therebetween a microwave treatment space (7') through which the products (1) are conveyed in use for being subjected to microwave radiation, the launch means being configured to maintain the polarisation of the radiation in the treatment space (7') substantially perpendicular to the oven band, and the microwave launch means (5) comprises, as viewed in longitudinal vertical section of the oven, a first stage (6', 6'') positioned adjacent to the feeder waveguide (3), and a second stage (7) remote from the feeder waveguide, the first stage comprising upper (6') and lower (6'') first stage plates disposed above and below respectively the slots (8), and extending generally longitudinally of the oven from the feeder waveguide, the second stage comprising a panel (7) extending closer to the band (2) in proceeding away from the first stage, the upper first stage plate (6') meeting the second stage panel (7) at a junction therebetween, and the upper and lower first stage plates (6', 6''), as viewed in longitudinal vertical section of the oven, being essentially mirror images of each other about a longitudinal plane (4) that extends symmetrically through the plurality of slots (8) and parallel to the band (2).
3. An oven as claimed in claim 2, characterised in that the junction between the upper first stage plate (6')

and the second stage plate (7) is an angled junction.

4. An oven as claimed in claim 1, 2 or 3, characterised in that the launch means (5) is configured to maintain the polarisation of the radiation in the treatment space (21) substantially perpendicular to the oven band (2), whereby the mode of radiation in the treatment space (21) is at least predominantly the TM₁ mode. 5
5. An oven as claimed in claim 4, characterised in that the microwave applicator comprises a plate (11) extending substantially parallel to the band and positioned remote from the emitter assembly (3, 8) to define a further treatment space (11') between the plate (11) and the band (2), the arrangement being such that the mode of radiation in the further treatment space (11') is at least predominantly the TEM mode. 10 15
6. An oven as claimed in claim 1, characterised in that said plurality of microwave emitter means comprises a plurality of antennas (10) depending downwardly from said feeder waveguide (3), and a plurality of probes (10') located in said waveguide, each said probe (10') being directly connected to a respective one of the antennas (10). 20 25
7. An oven as claimed in any one of claims 1 to 5, characterised in that the plurality of microwave emitter means (10) are arranged as a phased array, such that there is a uniform phase difference between adjacent pairs of emitter means (10) of said plurality of emitter means, and that the feeder waveguide (3) is located externally of the oven casing (R,S), the plurality of microwave emitter means (10) being connected with the feeder waveguide (3) by a plurality of coaxial waveguide links (15), the links (15) extending through the oven casing. 30 35 40

Patentansprüche

1. Mikrowellen-Tunnelofen, in welchem durch den Ofen geführte Produkte einer Mikrowellenstrahlung ausgesetzt werden, welcher ein Tunnelofengehäuse (R, S) aufweist, das voneinander beabstandete seitliche Tunnelofenwandungen (S) und eine die Seitenwände miteinander verbindende obere Tunnelwandung (R) besitzt, sowie ein elektrisch leitfähiges Förderband (2) als Auflage für die Produkte, welches zwischen den Seitenwandungen (S) und unter der oberen Wandung (R) so angeordnet ist, daß es sich in Längsrichtung des Tunnels erstreckt, ferner Bandantriebs Einrichtungen, die zum Antreiben des Förderbandes betätigbar sind, eine Einrichtung zum Erzeugen der Mikrowellen, eine Einrichtung zum Abstrahlen der Mikrowellen (3, 5, 11), 45 50 55

der zwischen den Seitenwandungen und über dem Band angeordnet ist, eine Einrichtung zum Zuführen der Mikrowellen, welche die Einrichtung zum Erzeugen der Mikrowellen mit der Einrichtung zum Abstrahlen der Mikrowellen verbindet, wobei die Einrichtung zum Abstrahlen der Mikrowellen eine langgestreckte Mikrowellenstrahlereinrichtung aufweist, die sich quer zum Förderband im Ofen erstreckt, und wobei die Mikrowellenstrahlereinrichtung eine Vielzahl von beabstandeten Mikrowellenstrahlern umfaßt, **gekennzeichnet** durch die Anordnung von Mikrowelleneinkopplern (5), die sich in Längsrichtung des Ofens und über dem Band (2) von der Umgebung der Mikrowellenstrahlereinrichtung (3) aus erstrecken, wobei die Mikrowellenstrahlereinrichtung (3) so betätigbar ist, daß sie Strahlung in den Ofen im wesentlichen in Längsrichtung desselben mit einer Polarisierungsebene abstrahlt, die im wesentlichen senkrecht zum Förderband (2) verläuft, wobei zumindest ein Teil der Einkopplungseinrichtung (5) und des Bandes (2) dazwischen einen Raum (21) zur Mikrowelleneinwirkung definieren, durch welchen die Produkte bei Betrieb geführt werden, damit die Mikrowellen auf sie einwirken, wobei die Einkopplungseinrichtung (5) so ausgelegt ist, daß sie die Polarisierung der Strahlung im Einwirkungsraum (21) im wesentlichen senkrecht zum Förderband aufrechterhalten, sowie durch eine Sicherheitsumschließung (22) zur Abschirmung der Mikrowellenabschirmung, die sich im wesentlichen über die gesamte Länge der Mikrowellenstrahlereinrichtung in Längsrichtung des Bandes (2) erstreckt und eine elektrisch leitfähige Bodenwandung (25) aufweist, die unterhalb des Bandes (2) verläuft, sowie durch beabstandete, elektrisch leitfähige Seitenwandungen (26) der Sicherheitsumschließung zu beiden Seiten des Bandes, welche die leitfähige Bodenwandung (25) mit der Mikrowellenabstrahlereinrichtung (3, 5, 11) verbindet.

2. Ofen nach Anspruch 1, **dadurch gekennzeichnet**, daß die Mikrowellenstrahlereinrichtung einen Wellenleiter (3) als Zuleiter aufweist, der sich quer zum Förderband (2) erstreckt, und eine Vielzahl beabstandeter Schlitze (8) in dem Wellenzuleiter, wobei die Schlitze (8) sich in Längsrichtung des Ofens so gegenüberstehen, daß sie Strahlung in den Ofen im wesentlichen in Längsrichtung desselben mit einer zum Förderband (2) im wesentlichen senkrechten Polarisierungsebene abstrahlen, wobei zumindest ein Teil (7) der Einkopplungseinrichtung und des Bandes (2) dazwischen einen Raum (7') zur Mikrowelleneinwirkung definieren, durch welchen die Produkte (1) im Betrieb geführt werden, damit die Mikrowellenstrahlung auf sie einwirkt, wobei die Einkopplungseinrichtung so ausgelegt ist, daß sie die Polarisierung der Strahlung im Einwirkungs-

raum (7') im wesentlichen senkrecht zum Förderband aufrechterhält, und daß die Mikrowellen-Einkopplungseinrichtung (5), bei Blickrichtung im vertikalen Längsschnitt durch den Ofen, eine erste Stufe (6', 6'') aufweist, die in der Nähe des Wellenzuleiters (3) liegt, und eine zweite Stufe (7) im Abstand vom Wellenzuleiter, wobei die erste Stufe eine obere (6') und eine untere (6'') Stufenplatte aufweist, die jeweils über und unter den Schlitzen (8) angeordnet sind und sich im wesentlichen in Längsrichtung des Ofens vom Wellenzuleiter aus erstrecken, wobei die zweite Stufe eine Platte (7) aufweist, die sich von der ersten Stufe weg näher an das Band (2) heran erstreckt wobei die obere Platte (6') der ersten Stufe auf die Platte (7) der zweiten Stufe an einem dazwischen liegenden Kreuzungspunkt trifft, und wobei die obere und untere Platte (6', 6'') der ersten Stufe bei Blickrichtung im vertikalen Längsschnitt durch den Ofen im wesentlichen spiegelbildlich zu einer Längsebene (4) ausgebildet sind, die symmetrisch durch die Vielzahl der Schlitze (8) und parallel zum Band (2) verläuft.

3. Ofen nach Anspruch 2, **dadurch gekennzeichnet**, daß der Kreuzungspunkt zwischen der oberen Platte (6') der ersten Stufe und die Platte (7) der zweiten Stufe einen Winkelanschluß darstellen.

4. Ofen nach Anspruch 1, 2 oder 3, **dadurch gekennzeichnet**, daß die Einkopplungseinrichtung (5) so ausgelegt ist, daß sie die Polarisierung der Strahlung im Einwirkungsraum (21) im wesentlichen senkrecht zum Förderband (2) hält, wodurch der Strahlungsmodus im Einwirkungsraum (21) zumindest vorwiegend der TM_1 -Modus ist.

5. Ofen nach Anspruch 4, **dadurch gekennzeichnet**, daß die Mikrowellenabstrahleinrichtung eine Platte (11) aufweist, die sich im wesentlichen parallel zum Förderband erstreckt und im Abstand von der Mikrowellenstrahlereinrichtung (3, 8) so positioniert ist, daß zwischen der Platte (11) und dem Förderband (22) ein weiterer Einwirkraum (11') definiert wird, wobei die Anordnung so getroffen ist, daß der Strahlungsmodus im weiteren Einwirkraum (11') zumindest überwiegend der TEM-Modus ist.

6. Ofen nach Anspruch 1, **dadurch gekennzeichnet**, daß die Vielzahl der Mikrowellenstrahler eine Vielzahl von Antennen (10) umfaßt, die von dem Wellenzuleiter (3) aus nach unten hängen, sowie eine Vielzahl von Sonden (10'), die in dem Wellenleiter angeordnet sind, wobei jede Sonde (10') direkt mit einer jeweiligen Antenne (10) verbunden ist.

7. Ofen nach einem der Ansprüche 1 bis 5, **dadurch gekennzeichnet**, daß die Vielzahl von Mikrowellenstrahlern (10) als phasengesteuerte Anordnung

in der Weise angebracht ist, daß zwischen benachbarten Paaren der Strahlereinrichtungen (10) der Vielzahl von Mikrowellenstrahlern eine einheitliche Phasenverschiebung vorliegt, und daß der Wellenzuleiter (3) außerhalb des Ofengehäuses (R, 2) angeordnet ist, wobei die Vielzahl von Mikrowellenstrahlern (10) mit dem Wellenzuleiter (3) durch eine Vielzahl koaxialer Wellenleiterverbindungen (15) verbunden ist, die durch das Ofengehäuse geführt sind.

Revendications

1. Un four tunnel micro-ondes pour soumettre des produits transportés à travers le four à un rayonnement micro-ondes, comprenant une enveloppe du four tunnel (R,S), l'enveloppe de four comprenant des parois latérales (S) de four tunnel, espacées l'une de l'autre, et une voûte ou un toit de four (R) reliant les parois latérales, une bande de transport conductrice de l'électricité (2) supportant le produit, positionnée entre les parois latérales (S) en dessous de la voûte (R) et s'étendant selon la longueur du tunnel, des moyens d'entraînement de bande qui, fonctionnent pour entraîner la bande, des moyens générateurs de micro-ondes, applicateur des micro-ondes (3, 5, 11) positionné entre les parois latérales et au-dessus de la bande, des moyens de fourniture de micro-ondes, reliant les moyens de génération à l'applicateur de micro-ondes, l'applicateur de micro-ondes comprenant un assemblage allongé d'émission de micro-ondes (3) s'étendant transversalement par rapport à la bande du four, l'assemblage d'émission comprenant une pluralité de moyens d'émission de micro-ondes, espacés l'un de l'autre, caractérisé par la disposition de moyens de lancement (5) de micro-ondes qui s'étendent longitudinalement par rapport au four et au-dessus de la bande (2) à partir d'une position adjacente à l'assemblage d'émission (3), l'assemblage d'émission (3) émettant, lors de son fonctionnement, du rayonnement à l'intérieur du four selon une direction généralement longitudinale du four présentant un plan de polarisation sensiblement perpendiculairement à la bande de transport (2) au moins une partie des moyens de lancement (5) et de la bande (2) définissant entre eux un espace de traitement par micro-ondes (21) à travers lequel les produits sont transportés en service pour les être soumis à du rayonnement micro-ondes, les moyens de lancement (5) présentant une configuration propre à maintenir la polarisation du rayonnement dans l'espace de traitement (21) sensiblement perpendiculaire à la bande de transport, et caractérisé par un assemblage de confinement de micro-ondes (22) s'étendant sensiblement micro-ondes, dans la direction longitudinale de la bande (2), et com-

prenant une sole ou plancher conducteur de l'électricité (25) s'étendant en dessous de la bande (2) et des parois latérales de confinement (26), espacées l'une de l'autre et conductrices de l'électricité, de part et d'autre de la bande, et reliant la zone conductrice (25) à l'applicateur de micro-ondes (3, 5, 11).

2. Un four selon la revendication 1, caractérisée en ce que l'assemblage d'émission comprend un guide d'onde d'alimentation (3) qui s'étend transversalement par rapport à la bande (2) du four et une pluralité de fentes (8), espacées l'une de l'autre et prévues dans le guide d'onde d'alimentation, les fentes (8) étant dirigées de façon longitudinale par rapport au four pour émettre du rayonnement à l'intérieur du four généralement selon une direction longitudinale du four avec un plan de polarisation sensiblement perpendiculaire à la bande (2) du four, au moins une partie (7) des moyens de lancement et la bande (2) définissant entre eux un espace de traitement aux micro-ondes (7') à travers lequel les produits (1) sont transportés en service pour être soumis à du rayonnement micro-ondes, les moyens de lancement présentant une configuration propre à maintenir la polarisation du rayonnement à l'intérieur de l'espace de traitement (7') sensiblement perpendiculaire à la bande du four, et en ce que les moyens de lancement de micro-ondes (5) comprennent, tel qu'on le voit dans une coupe verticale longitudinale du four, un premier étage (6', 6'') positionné adjacente au guide d'onde d'alimentation (3), et un deuxième étage (7) à distance du guide d'onde d'alimentation, le premier étage comprenant des plaques de premier étage supérieure et inférieure (6'') disposées respectivement au-dessus et en dessous des fentes (8), et s'étendant généralement selon le sens longitudinal du four à partir du guide d'onde d'alimentation, le deuxième étage comprenant un panneau (7) s'étendant plus proche à la bande (2) lorsqu'il s'éloigne du premier étage, la plaque supérieure de premier étage (6') rejoignant le panneau de deuxième étage (7) à une jonction mutuelle, et les plaques de premier étage supérieure et inférieure (6', 6''). considérées selon une coupe verticale longitudinale du four, étant sensiblement des images-speculaires l'une de l'autre autour d'un plan longitudinal (4) qui s'étend symétriquement à travers la pluralité de fentes (8) et parallèlement à la bande (2).

3. Un four selon la revendication 2, caractérisé en ce que la jonction entre la plaque supérieure de premier étage (6') et le panneau de deuxième étage (7) est une jonction angulaire.

4. Un four selon la revendication 1, 2 ou 3, caractérisé en ce que les moyens de lancement (5) présentent

une configuration propre à maintenir la polarisation du rayonnement dans l'espace de traitement (21) sensiblement perpendiculaire à la bande (2) du four, de sorte que le mode de rayonnement à l'intérieur de l'espace de traitement (21) soit au moins de façon prédominante le mode TM_1 .

5. Un four selon la revendication 4, caractérisé en ce que l'applicateur de micro-ondes comprend une plaque (11) s'étendant de façon sensiblement parallèle à la bande et positionnée à distance de l'assemblage d'émission (3, 8) afin de définir un espace de traitement supplémentaire (11') entre la plaque (11) et la bande (2). l'agencement étant tel que le mode de rayonnement dans cet espace de traitement supplémentaire (11') soit au moins de façon prépondérante le mode (TEM) (à onde électromagnétique transverse).

6. Un four selon la revendication 1, caractérisé en ce que ladite pluralité de moyens d'émission de micro-ondes comprend une pluralité d'antennes (10) qui s'étendent vers le bas à partir dudit guide d'onde d'alimentation (3) et une pluralité de sondes (10') situées à l'intérieur dudit guide d'onde, chacune desdites sondes (10') étant reliée directement à l'une respective des antennes (10).

7. Un four selon l'une quelconque des revendications 1 à 5, caractérisé en ce que la pluralité des moyens d'émission des micro-ondes (10) sont agencés pour constituer un réseau à phase commandée, de sorte qu'il existe une différence de phase uniforme entre des paires adjacentes des moyens d'émission (10) de ladite pluralité de moyens d'émission (3), et en ce que le guide d'onde d'alimentation (3) est situé à l'extérieur de l'enveloppe du four (R, S), la pluralité des moyens d'émission de micro-ondes (10) étant reliés au guide d'onde d'alimentation (3) par une pluralité de liaisons coaxiales pour guide d'ondes (15), les liaisons (15) s'étendant à travers l'enveloppe du four.

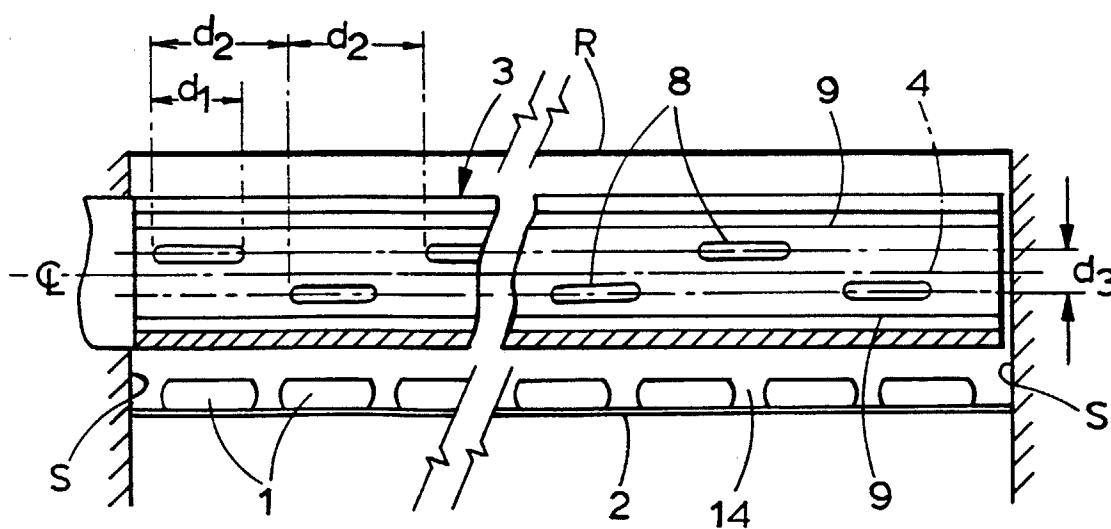
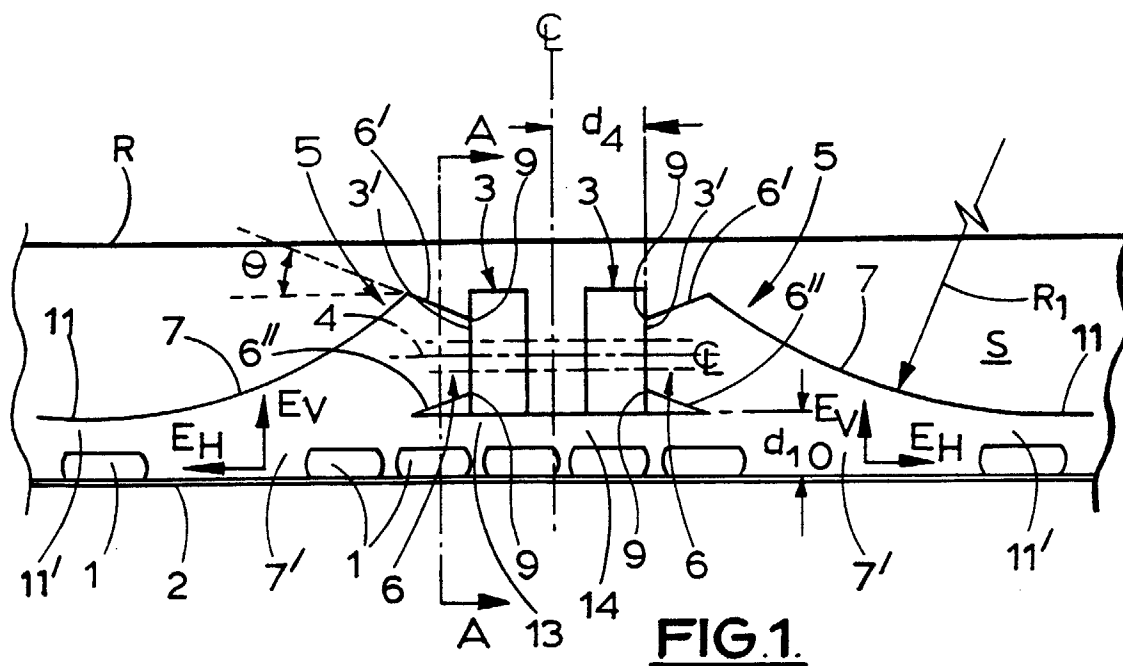
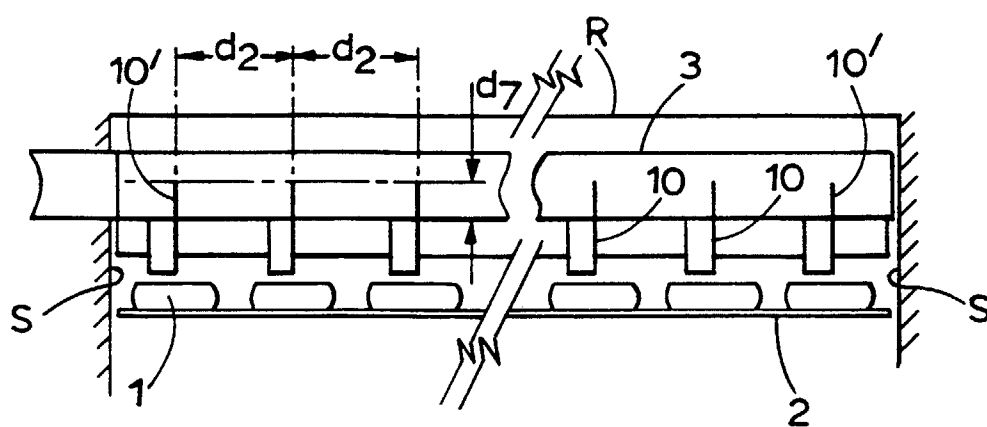
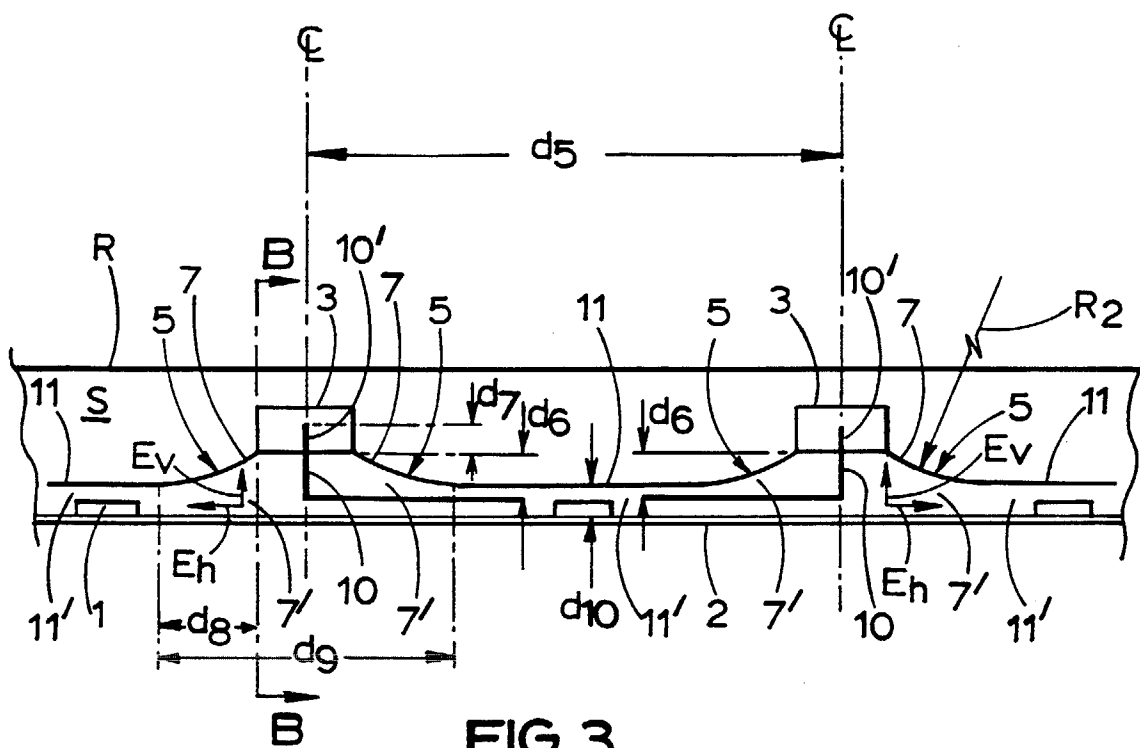


FIG. 2.



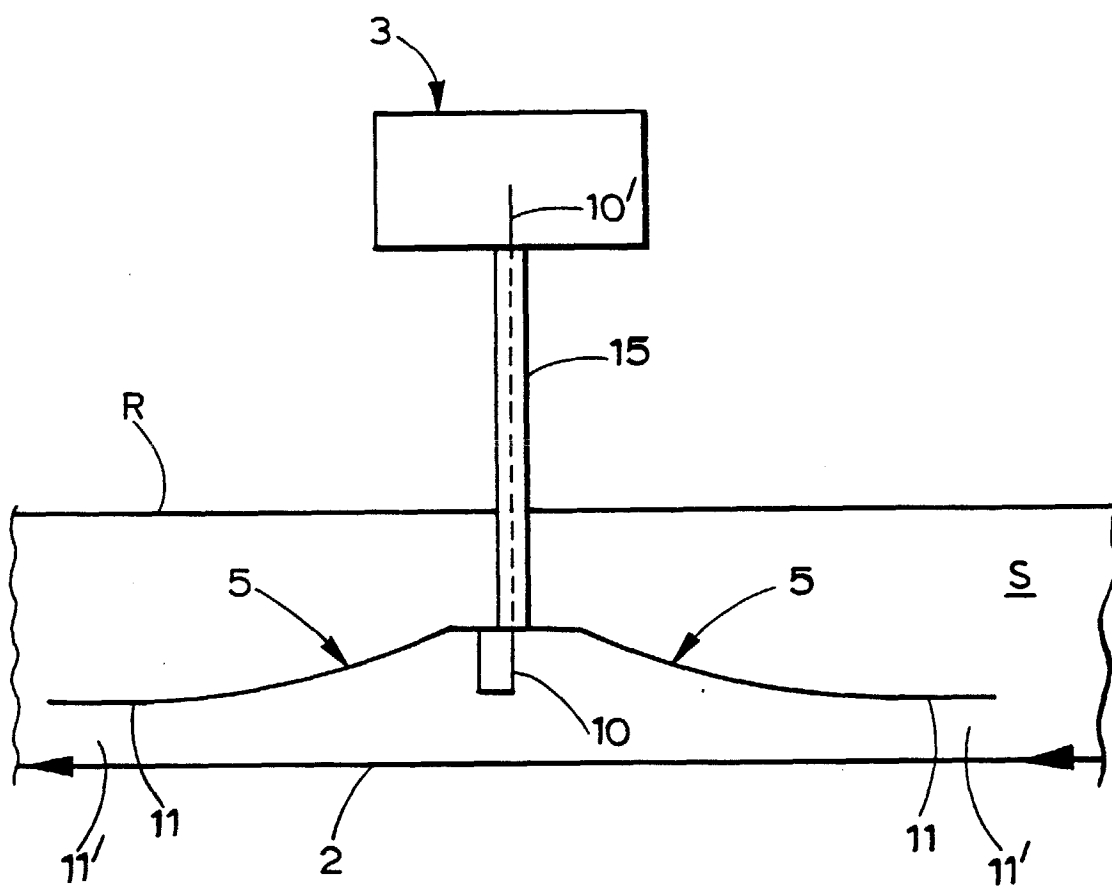
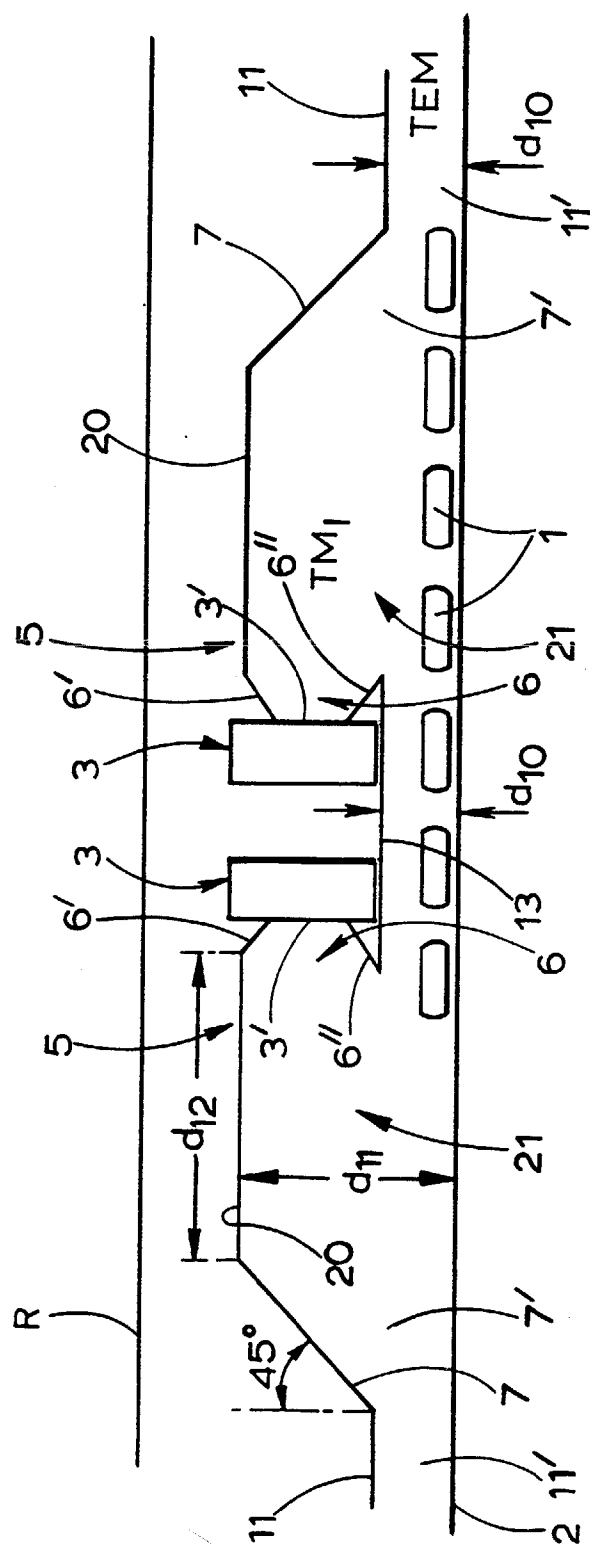


FIG. 5.



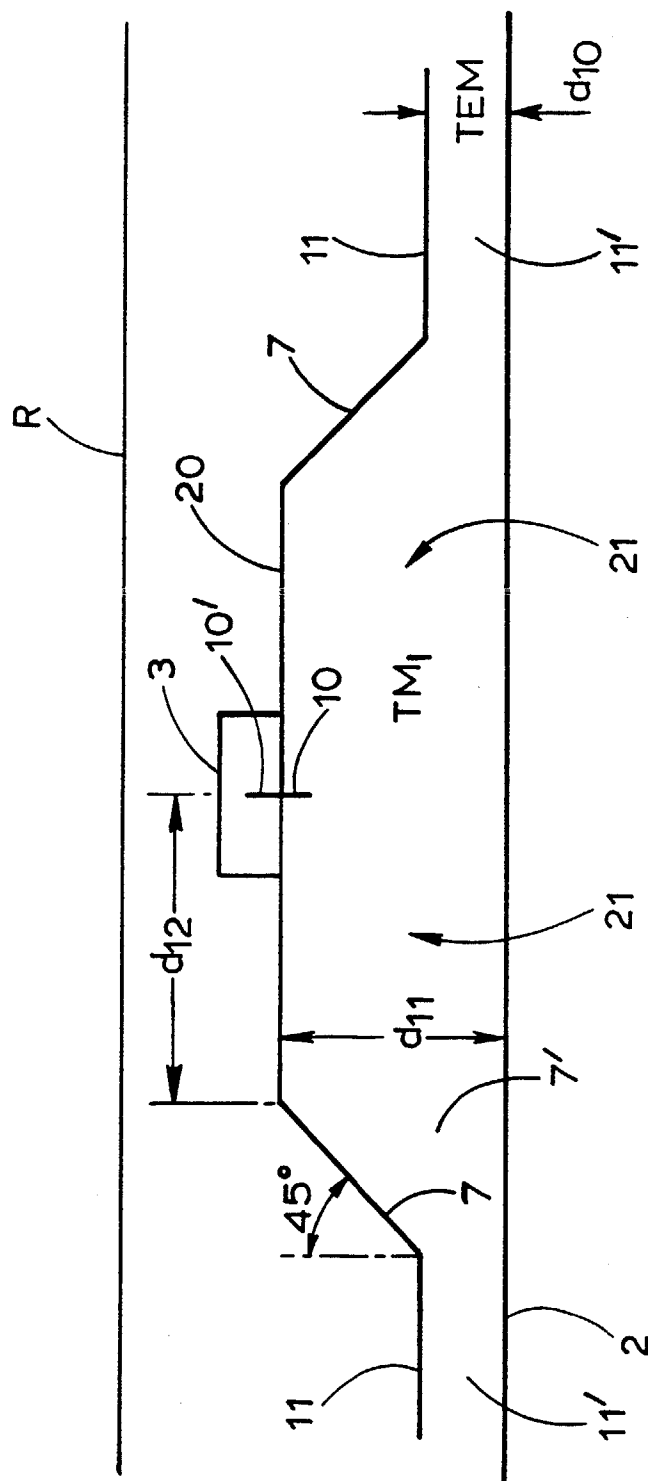


FIG. 7.

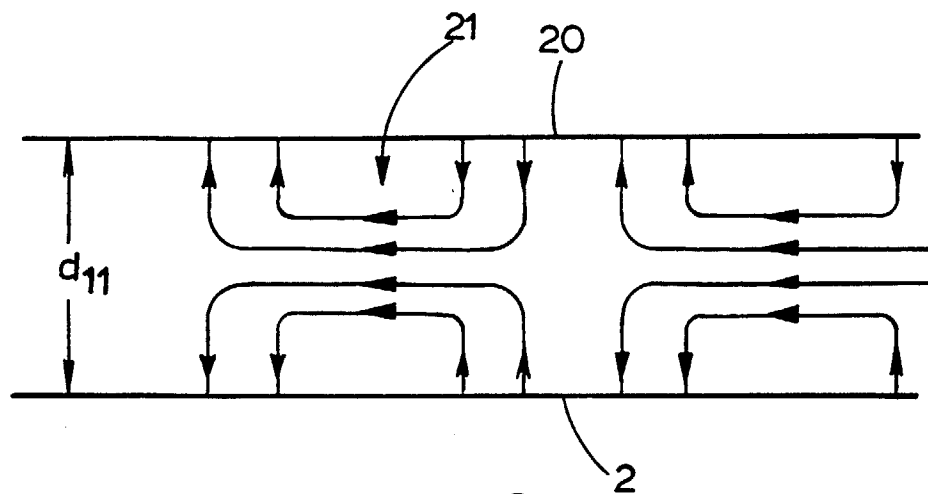


FIG. 8.

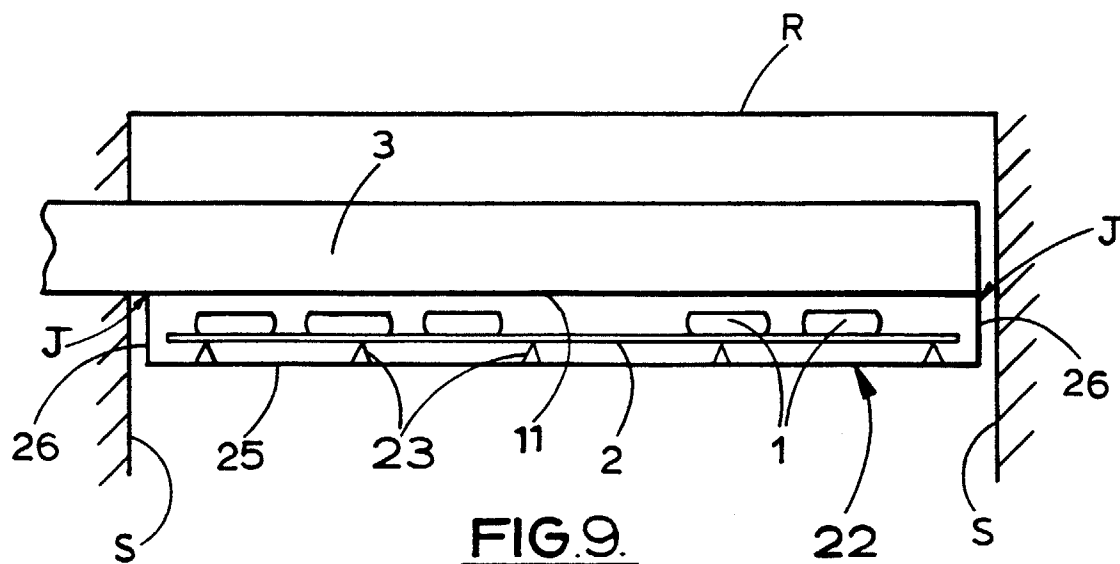


FIG. 9.