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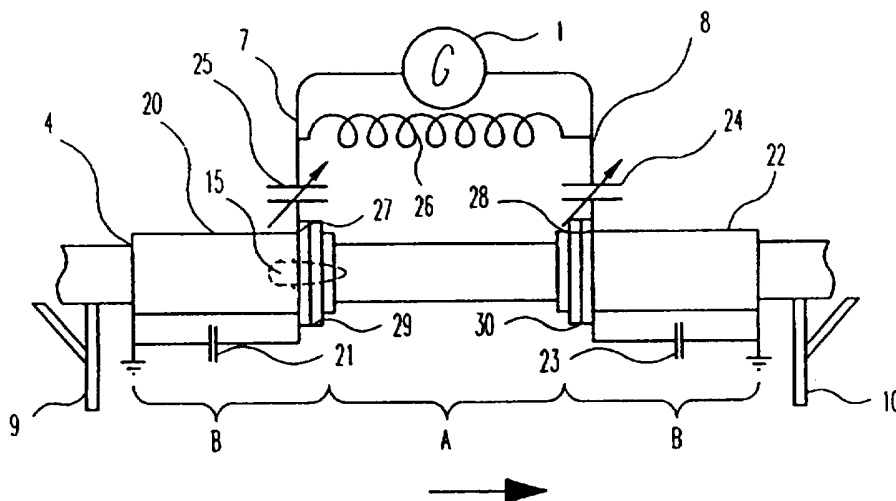
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(54) Title: METHOD AND APPARATUS FOR HEATING PRODUCTS BY MEANS OF HIGH-FREQUENCY ELECTROMAGNETIC WAVES

**(57) Abstract**

The invention relates to a method for the heat treatment of meat products in a feeding element (4) by means of high-frequency electromagnetic waves, and an apparatus for the execution of the method. The invention also relates to an advantageous application of an apparatus according to the invention. The object of the invention is to increase the depth of penetration of the electromagnetic waves in a product which is to be heated or boiled, where the electrodes (2, 3; 20, 22) are external and placed on the outside of the feeding element (4). The object is achieved by placing a product electrode (15) in the feeding element (4), in that said product electrode (15) serves as a short-circuiting element and is of a material having an electrical conductivity which is better than that of the product that is required to be heat treated.

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Method and apparatus for heating products by means of high-frequency electromagnetic waves

5 Background of the invention

The invention relates to a method for the heating of products as described in the preamble to claim 1, and an apparatus as disclosed in the preamble to claim 5.

10 It is known in several different connections to heat products by means of microwaves. The different techniques are used for different purposes, ranging as widely as from the drying of wood to the heat treatment of meat products and dairy products. Probably the best-known technique is in  
15 connection with microwave ovens, which have become a consumer commodity.

However, the hitherto-known techniques suffer serious disadvantages, and these are amplified and particularly  
20 pronounced in connection with large-scale operations.

From DK patent application no. 4718/86 it is known to continuously lead meat products through feeding elements, for example a tube, on which electrodes are mounted on  
25 diametrically-opposite sides. Before the meat products are fed to the active zone, the air contents are removed using a vacuum pump.

From DK patent application no. 1014/91 it is known to lead  
30 the products through a feeding element on which annular electrodes are mounted in two places around the tube.

Both of the above-mentioned methods are encumbered with certain disadvantages which become particularly pronounced  
35 during large-scale operations. The depth of penetration and herewith the tube diameter for the systems are thus

limited. Moreover, a problem arises in connection with the non-uniformity of the electric field. This gives problems in connection with the heating, boiling or drying of products or materials which require a uniform heating. This is similarly problematic in connection with the heating of products having temperature-dependent conductivity, since the depth of penetration is herewith strongly reduced. Moreover, it also gives rise to problems in relation to the dimensioning of the HF generator, the reason being that the efficiency of the generator is reduced in connection with the heating of products to higher temperatures, for example in connection with boiling or the like.

The object of the invention is thus partly to achieve a uniform and herewith a controllable heating or boiling of a wholly or partly fragmented medium, and partly to achieve a greater depth of penetration in the product.

#### Advantages of the invention

As disclosed in claim 1, by placing the product in the feeding element in which there is provided at least one product electrode, so that the product substantially surrounds the product electrode, said product electrode being placed in the centre of or in the vicinity of the centre of the cross-section of the feeding element, it is achieved that the applied field is short-circuited in the inside of the product, which means that the depth of penetration becomes optimal and can be adjusted in accordance with where the product electrode is placed. The product electrode thus serves as an antenna. According to the method, it is possible to achieve a hitherto-unknown depth of penetration for the field. This provides a special advantage in connection with products having dielectric characteristics which are temperature dependent, in that the heat from inside will spread outwards, whereby the product will be heated from inside. This must be seen in

relation to hitherto-known heating methods, where the field is applied from the outside, and where the heating is concentrated around the surface of the product and hereby results in a kind of negative feedback, in that the product on the surface, as a function of the heating, is a better electrical conductor, the result being that the current will hereby flow in the surface of the product.

As disclosed in claim 2, by letting at least two of the electrodes be annular or cylindrical and placing them at a distance axially from one another, said electrodes demarcating a primary heating or boiling zone in the feeding element, a particularly good heating is achieved in a demarcated area.

As disclosed in claim 3, by leading the product past only one product electrode, said product electrode being disposed in the supply end of the tube, it is achieved that the heating of the product begins from inside and spreads outwards towards the surface of the product gradually as the product reaches the discharge end. Moreover, it is advantageous with only one product electrode in connection with products with characteristics which change nature after heating or boiling. In connection with products which coagulate to form a "solid cross-section", it will not be possible, for example, to lead this past a further product electrode without ruining the characteristics of the product. Moreover, the field and herewith the heating is forced towards the surface of the product, gradually as the product approaches the discharge end, which contributes towards providing a hitherto-unachievable uniformity and quick heating, drying or boiling.

As disclosed in claim 4, by dimensioning the diameter and cross-section of the product electrode or product electrodes in accordance with the desired degree of heat-

ing, there is achieved a simple manner in which to adapt the different products to the method and vice-versa.

5 As disclosed in claim 5, by placing one or more product electrodes consisting of an electrically-conducting material in the feeding element, a simple and inexpensive embodiment according to the invention is achieved. The electrode or electrodes will thus function as a kind of antenna, and herewith centre the field around that area in  
10 which it/they are placed.

As disclosed in claim 6, by electrically connecting the product electrode or electrodes directly to the HF generator, a simple embodiment according to the invention  
15 is achieved, in that this embodiment is easy to dimension, the reason being that the field is led directly into the feeding element without external electrodes.

As disclosed in claim 7, by letting the feeding element be  
20 substantially tubular with a random cross-section, said feeding element having a supply end and a discharge end, the possibility is provided for quick heating, boiling or drying of a product, in that this can be supplied and discharged quickly.

25 As disclosed in claim 8, by letting the feeding element have at least one primary tube part that demarcates a primary boiling or heating zone, which in turn is demarcated by electrodes which wholly or partly extend  
30 around the feeding element, in that the heating of the product takes place in said primary zone, said apparatus also having at least two secondary tube parts which demarcate at least two secondary zones and which border up to the primary part or the primary parts and substantially  
35 connect the main part of the electromagnetic field which is radiated from the electrodes but which does not extend

directly or indirectly between two electrodes, to frame, an embodiment is achieved whereby the field which is applied is simple to control in connection with continuous operations.

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As disclosed in claim 9, by coupling the secondary tube parts wholly or partly with one or more reactive components, so that the secondary tube parts constitute one or more oscillatory circuits with at least one pole which is tuned substantially to resonance, it is achieved that the secondary fields can be minimized or eliminated by means of external reactive components. The flow-path across the secondary tube parts will thus be eliminated, which means that the field will exist primarily or exclusively in the primary tube part between the electrodes. This means that it becomes possible to carry out a uniform heating, boiling or drying of the product, which is uniform in both the longitudinal and the cross-sectional direction of the product.

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As disclosed in claim 10, by coupling the capacitive reactance in parallel across the inductive secondary tube parts from the interface between the primary tube part and the secondary tube part to frame, said capacitance being tuned in such a manner that the secondary tube parts are in resonance or in the area of resonance, a simple embodiment is achieved which is inexpensive and stable in operation and has all of the aforementioned advantages.

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As disclosed in claim 11, by carrying out an impedance adjustment with the HF generator by means of capacitances which are inserted in the supply leads between the HF generator and electrodes, an optimum emission of power by the HF generator is achieved in the feeding tube.

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As disclosed in claim 12, by providing an extended

electrically-conducting structure which extends from the secondary condenser's connection to the electrodes in over the primary tube part and surrounding a smaller part of the length of same, it is achieved that the field which flows in the primary tube part is symmetrical. The result is that no cold zones arise in the primary tube. A discreet capacitance across the secondary tube part will namely give rise to a non-uniform charge density at the tubular electrode, said charge density being greatest in the area around the terminals of the capacitance. However, the extended tube part in towards the primary tube part will result in the charge density distributing itself homogeneously across the extended tube part, and thereby give rise to a uniform and symmetrical field inside the primary tube part.

As disclosed in claim 13, by letting the capacitive reactance be a tubular condenser which surrounds the whole of the tube, a uniform and homogeneous charge density is achieved at the terminals of the condenser. This in turn will give rise to a uniform and symmetrical field inside the primary tube, which again means that no cold zones will arise in said tube, without the use of an extended conductive structure.

As disclosed in claim 14, by carrying out an impedance adjustment with the HF generator by means of capacitances which are inserted in the supply leads between the HF generator and the electrodes, an optimum transfer of power is achieved from the low-impedance generator to the high-impedance system.

As disclosed in claim 15, by coupling an inductive reactance across the generator which is adjusted in such a manner that it forms a parallel oscillatory circuit with the parasite capacitances that are between the generator's

leads and frame or earth, it is achieved that the paths of conductivity across the parasite capacitances are substantially compensated for, and thus do not load or distort the system.

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As disclosed in claim 16, by providing just one product electrode in the area of transition between the primary and the secondary zones in the supply end, so that the tip of the product electrode extends some distance into the primary zone, a practical embodiment is achieved which is particularly applicable in connection with products which change character from being a fragmented mass to a homogeneous mass as a result of the influence of heat, since an electrode at the discharge end will ruin or damage a desired structure. This embodiment provides the further advantage that the heat will automatically converge from the centre of the tube at the supply end out towards the inside surface of the tube at the discharge end where there is no product electrode. This further contributes towards providing a uniform heating of the product.

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As disclosed in claim 17, by letting the product electrode consist of a streamlined tubular electrode which is secured to the apparatus by means of an elbow outside the heating zone, from where it extends in through the secondary tube part, an advantageous embodiment is achieved with regard to the securing of the product electrode, in that this does not constitute an obstacle to the movement of the product inside the heating zone. Consequently, no possibility arises of parts of the fragmented product sticking to the securing elements for the product electrode, whereby the product would be exposed to a very long period of heating, and moreover could result in the blocking of the tube.

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The drawing

An example of known technique and two example embodiments according to the invention will now be described in more detail with reference to the drawing, where

fig. 1 shows a known heating apparatus,

fig. 2 shows an embodiment according to the invention,

fig. 3 shows a preferred embodiment according to the invention, and finally

fig. 4 shows a cross-section in the longitudinal direction of the feeding tube which illustrates the spreading of the heat in the tube.

Description of the example embodiments

In fig. 1 is seen a known heating tube, where a voltage generator 1 is connected to electrodes 2, 3 via leads 7, 8. The electrodes 2, 3 are placed as annular electrodes on the outside of a tube 4 which is not electrically conductive. Two frame electrodes 5, 6 are connected to earth or frame via frame connections 11, 12. The product to be heated is led through the tube 4 in the direction of the arrow. The tube is secured by holding elements 9, 10.

During operation, the way in which the apparatus works is that by means of the generator 1, an electromagnetic field is applied across the electrodes 2, 3. The electromagnetic field will in principle emanate in two ways, i.e. in a primary zone A between the two electrodes, and in two secondary zones B between the electrodes 2, 3 and the frame electrodes 5, 6. Since the fields are applied from outside, problems will arise especially in connection with tubes 4 of larger diameters with regard to the depth of penetration

of the electromagnetic field. These problems become particularly great when the product to be heated has dielectric characteristics which are temperature-dependent. In connection with products which have high conductivity as a function of the temperature, a kind of negative feedback will arise in the product in the vicinity of the inner surface of the tube. The electromagnetic field will give rise to a heating of the surface of the product, which in turn contributes towards giving the current which flows in the product a tendency to flow in the surface of the product.

In fig. 2 is seen an embodiment according to the invention, in that a product electrode 15 is placed in the supply end. The rest of the apparatus corresponds to that shown in fig. 1. As will be seen, the product electrode 15 extends slightly into the primary zone A in relation to the annular electrode 2. This means that when a field is applied between the electrodes 2 and 3, a current will flow in the product from the tip of the product electrode 15 in the direction of the electrode 3. The product electrode functions as a kind of antenna, and it short-circuits the system so that the electromagnetic field inside the tube 4 emanates from the tip of the product electrode 15. If the tip of the product electrode does not extend forwards in relation to the electrode 2, in principle this will result in the electromagnetic field emanating from the surface of the electrode 2 towards the electrode 3 in quite the same way as in fig. 1. However, the system can have a certain efficiency, even though the product electrode 15 does not extend forwards in relation to the electrode 2, in that the local heating in the middle of the tube will cause the current which flows to and from the electrode 2 to seek towards the middle of the tube.

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If the tip of the product electrode 15 extends forwards,

and thus offers a path of the lowest impedance for the electromagnetic field towards the electrode 3, the current will flow between the tip of the product electrode 15 and the electrode 3. The result is that the heat can be said to  
5 come from inside, and will spread out gradually as the product moves in the direction towards the electrode 3.

The dimensioning of the product electrode 15 will typically consist of an adaptation of two parameters: the length and  
10 the diameter of the product electrode. The parameters must be set in relation to the characteristics of the product, the power and efficiency of the generator in relation to the system and the speed at which the product is fed through the tube.

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In fig. 3 is seen the preferred embodiment according to the invention.

The shown embodiment is intended for the heating and boiling of meat products. The meat product is supplied in the  
20 direction of the arrow through an electrically-insulating tube 4. The tube is secured by retaining elements 9, 10. Via leads 7, 8, a generator 1 is connected to tubular electrodes 20, 22 on the outside of the tube via trimming capacitances 24, 25 and connection points 27, 28. Across  
25 the terminals of the generator there is connected a compensation coil 26 which compensates for parasite capacitances between the terminals and frame. The tubular electrodes are connected directly to frame via frame  
30 connections 11, 12.

A product electrode 15 is placed inside the tubular electrode 20. The product electrode 15 is adapted for the system on the basis of the same parameters as those  
35 mentioned above.

Two capacitances 21, 23 are connected in parallel across the electrodes 20 and 22. Each electrode functions as an inductance between the supply connections 27, 28 and frame 11, 12. The capacitances 21, 23 are therefore tuned so that the two oscillatory circuits, consisting respectively of the capacitance 21 and the tubular electrode 20 and the capacitance 23 and the tubular electrode 22, are both in resonance or in the area of resonance. Consequently, no current of any significance will flow between the connection point 28 and frame 12, nor between the connection point 27 and frame 11.

This means that the field inside the tube is no longer in several different zones, but is concentrated in the primary zone A. Moreover, this gives rise to the advantage that the product is not "preheated" in the secondary zone before it comes to the primary zone. This is of great significance in connection with the boiling or heating of products which have temperature-dependent dielectric characteristics, in that the preheating in the secondary zone according to fig. 1 is not particularly concentrated, and succeeds only in heating the border layer up against the tube. This means that when it reaches the primary zone, the product has a heated surface and hereby opposes the function of the product electrode 15, i.e. concentration of the applied electromagnetic field in the middle of the tube.

Extending at the front edges 20, 22 of the tubular electrodes, there are two extended electrically-conducting structures 29, 30. These are in direct electrical connection with the tubular electrodes 20, 22. The result is that the charge density, and herewith the field in the primary tube part, is homogeneous, in that the charges spread uniformly the whole way around the feeding tube 4 on these electrically-conducting structures 29, 30.

The current will hereby flow from the front edge of the electrically-conducting structure 29 in towards the tip of the product electrode 15, and from here towards the extended electrically-conducting structure 30, and from here to the front edge of the tubular electrode 22. Consequently, a very concentrated heating of the product occurs around the front edge, and the heating becomes more and more concentrated in towards the tip of the product electrode 15. Since that part of the product electrode 15 which lies inside the tubular electrode 20 does not conduct any current, a heating will take place exclusively in the area A as shown in the drawing. The areas B will thus not be heating zones, with the exception of the heat which is conveyed to the area B by the product electrode or by the product by means of simple thermal flow.

According to the preferred embodiment, both of the systems shown can be provided with a replaceable feeding tube (not shown) which is configured precisely to suit whatever task it is envisaged to carry out. Electrodes and external reactances can be mounted in a permanent manner on the feeding tube and be adjusted and dimensioned beforehand for precisely this tube, and the system's leads can be provided with plugs. This means that a production change can be effected very quickly.

In fig. 4 is seen a longitudinal cross-section of the feeding tube 4, where a meat product 40 is led in the direction of the arrow through the tube 4. At each end of the tube is seen the end of the extended electrically-conducting structures 29, 30. In the centre of the tube 4 is seen the product electrode 15, from which the electromagnetic field extends between the tip of the product electrode 15 and the extended conducting structure 30. It is seen how the field, and herewith the heat, spreads towards the surface of the tube 4.

## C L A I M S

1. Method for the heat treatment of products in a feeding  
element which electrically is substantially non-conductive  
5 by means of high-frequency electromagnetic waves, said  
waves being generated by at least two electrodes which are  
connected to an HF generator, said electrodes being placed  
on the outer sides of the feeding element and hereby having  
no contact with the product, c h a r a c t e r i z e d in  
10 that the product is placed in or fed through a feeding ele-  
ment (4) in which there is at least one product electrode  
(15), so that the product substantially surrounds the pro-  
duct electrode (15), in that said product electrode (15) is  
disposed in the centre of or in the vicinity of the centre  
15 of the cross-section of the feeding element.

2. Method according to claim 1, c h a r a c t e r -  
i z e d in that at least two of the electrodes (2, 3) are  
annular or cylindrical and are placed at a distance from  
20 each other, said electrodes demarcating a primary heating  
zone (A) in the feeding element.

3. Method according to claim 1 or 2, c h a r a c t e r -  
i z e d in that the product is led past just one product  
25 electrode (15), said product electrode being disposed in  
the inlet end of the tube.

4. Method according to any of the foregoing claims 1-3,  
c h a r a c t e r i z e d in that the product electrode  
30 (15) or the diameter and the cross-section of the product  
electrodes are dimensioned in accordance with the desired  
degree of heating.

5. Apparatus for the heat treatment of meat products by  
35 means of an electromagnetic field, said apparatus com-  
prising a feeding element which demarcates a heating zone,

said feeding element being substantially non-conductive electrically, said apparatus further comprising at least one HF generator which is connected electrically to at least two electrically conductive electrodes on the outside of the feeding element, characterized in that one or more product electrodes (15) are placed in the feeding element, said product electrodes (15) consisting of an electrically-conducting material with better conductivity than that of the product.

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6. Apparatus according to claim 6, characterized in that the product electrode (15) is electrically connected to the HF generator (1).

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7. Apparatus according to claim 6 or 7, characterized in that the feeding element (4) is substantially tubular with a cross-section which, for example, can be circular, elliptical or rectangular, said feeding element having an inlet end and a discharge end.

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8. Apparatus according to any of the foregoing claims 6-8, characterized in that the feeding element has at least one primary tube part which demarcates a primary zone (A), which in turn is demarcated by electrodes which extend wholly or partly around the feeding element, in that the heating of the product is effected in said primary zone, and in that said apparatus further comprises at least two secondary tube parts which demarcate at least two secondary zones (B), said secondary tube parts bordering up to the primary part or the primary parts and connecting substantially the main part of the electromagnetic field which is radiated from the electrodes, but which does not extend directly or indirectly between the two electrodes, to frame.

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9. Apparatus according to any of the foregoing claims 6-9,

5 c h a r a c t e r i z e d in that the secondary tube parts are coupled wholly or partly with one or more reactive components, so that the secondary tube parts constitute one or more oscillatory circuits with at least one pole which is tuned substantially to resonance.

10 10. Apparatus according to claim 9 or 10, c h a r a c t e r i z e d in that a capacitive reactance (21, 23), the secondary capacitance, is coupled in parallel across the inductive secondary tube parts (20, 22) from the interface between the primary tube part and the secondary tube part to frame, said capacitance being tuned so that the secondary tube parts are in resonance or in the area of resonance.

15 11. Apparatus according to any of the claims 9-11, c h a r a c t e r i z e d in that the individual secondary tube part (20, 22) consists of an electrically-conducting structure which wholly or substantially surrounds the secondary tube part and thus short-circuits the electrode to frame.

25 12. Apparatus according to claim 11 or 12, c h a r a c t e r i z e d in that from the connection points (27, 28) for the leads (7, 8) to the electrodes (20, 22) there extends an extended electrically-conducting structure (29, 30) in over the primary tube part and surrounds a smaller part of the length of said tube part.

30 13. Apparatus according to claims 11 and 13, c h a r a c t e r i z e d in that the capacitive reactance is a tubular condenser which surrounds the whole of the tube part.

35 14. Apparatus according to any of the foregoing claims 6-14, c h a r a c t e r i z e d in that an impedance adjust-

ment of the HF generator (1) is carried out by means of capacitances (24, 25) which are inserted in the supply leads (7, 8) between the HF generator (1) and electrodes (20, 22).

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15. Apparatus according to any of the foregoing claims 6-15, characterized in that across the generator (1) there is coupled an inductive reactance (26) which is adjusted so that it forms a parallel oscillatory circuit with the parasite capacitances which are between the generator leads and frame or earth.

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16. Apparatus according to any of the foregoing claims 9-16, characterized in that just one product electrode (15) is placed in the area of transition between the primary (A) and secondary (B) zone in the feeding end, so that the tip of the product electrode projects a distance into the primary zone (A).

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17. Apparatus according to any of the foregoing claims 6-17, characterized in that the product electrode consists of a streamlined tubular electrode (15) which is secured to the apparatus by means of an elbow outside the heating zone, from where it extends in through the secondary tube part.

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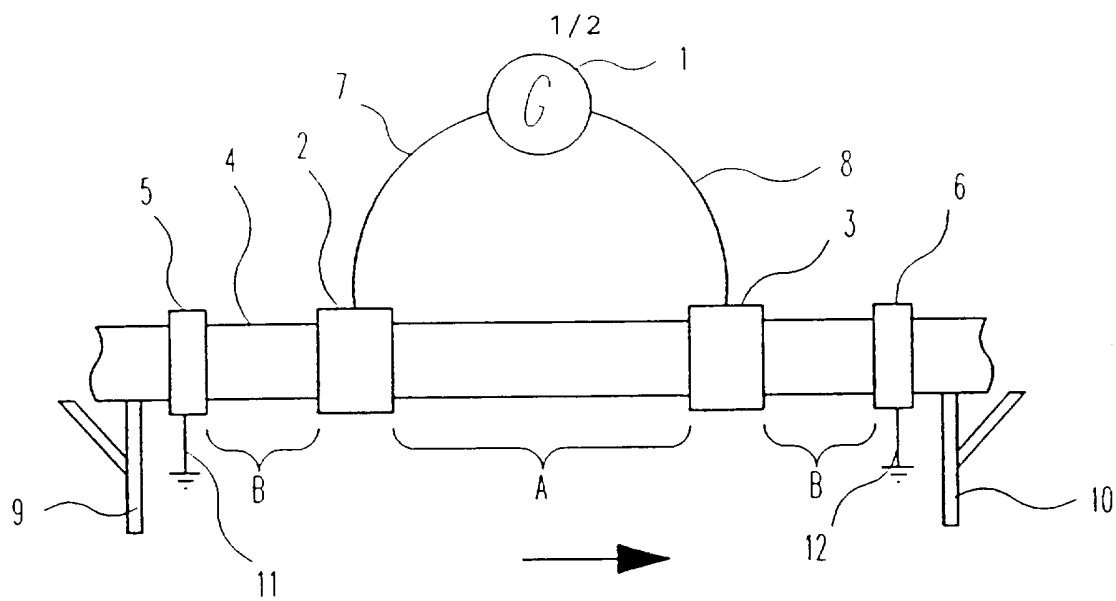


Fig. 1

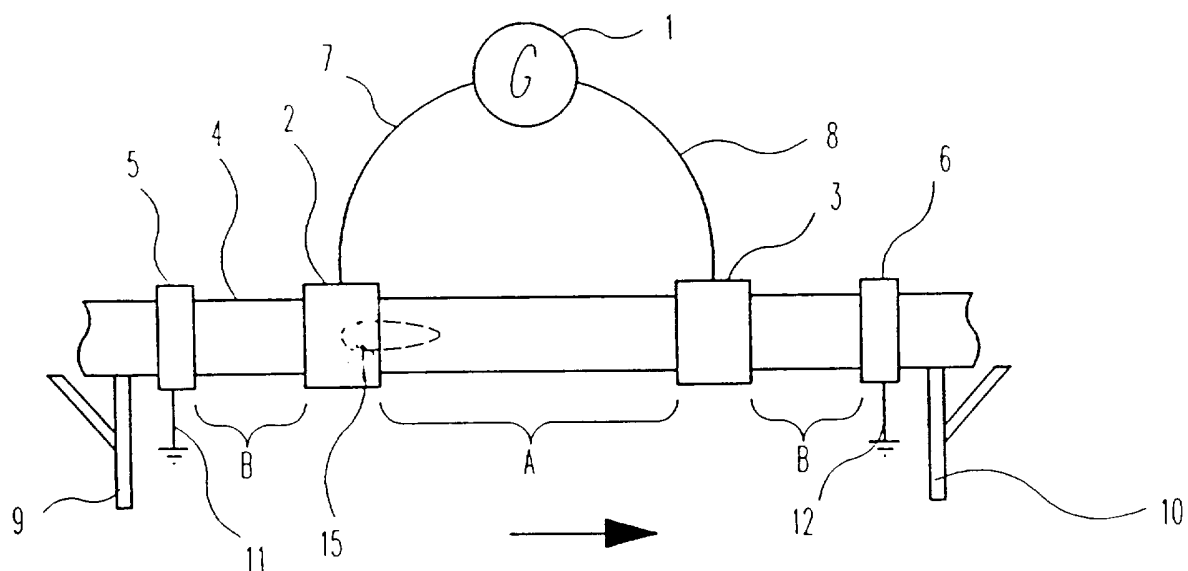
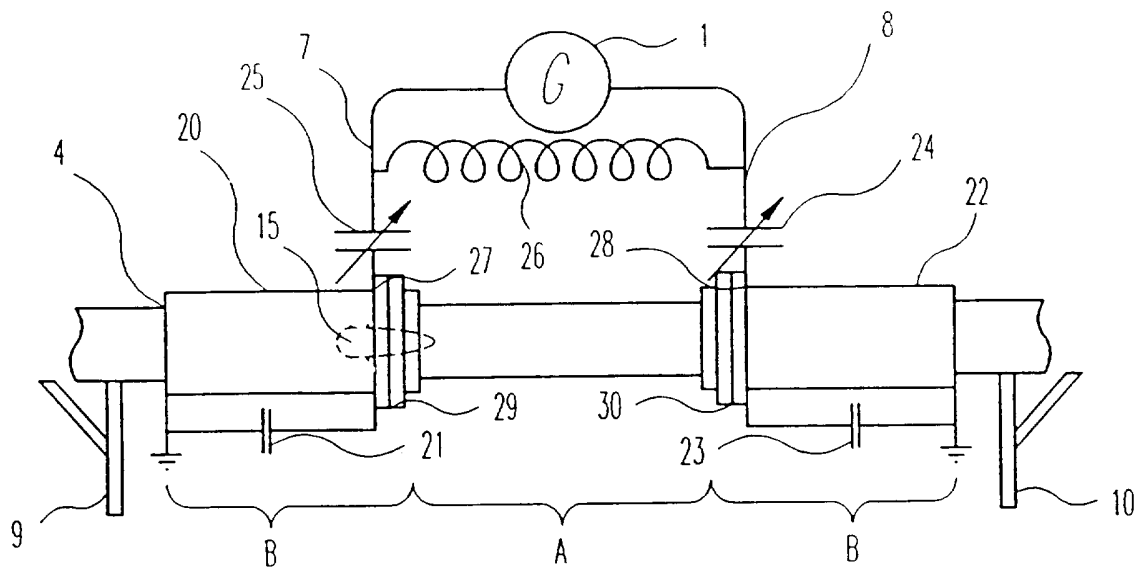
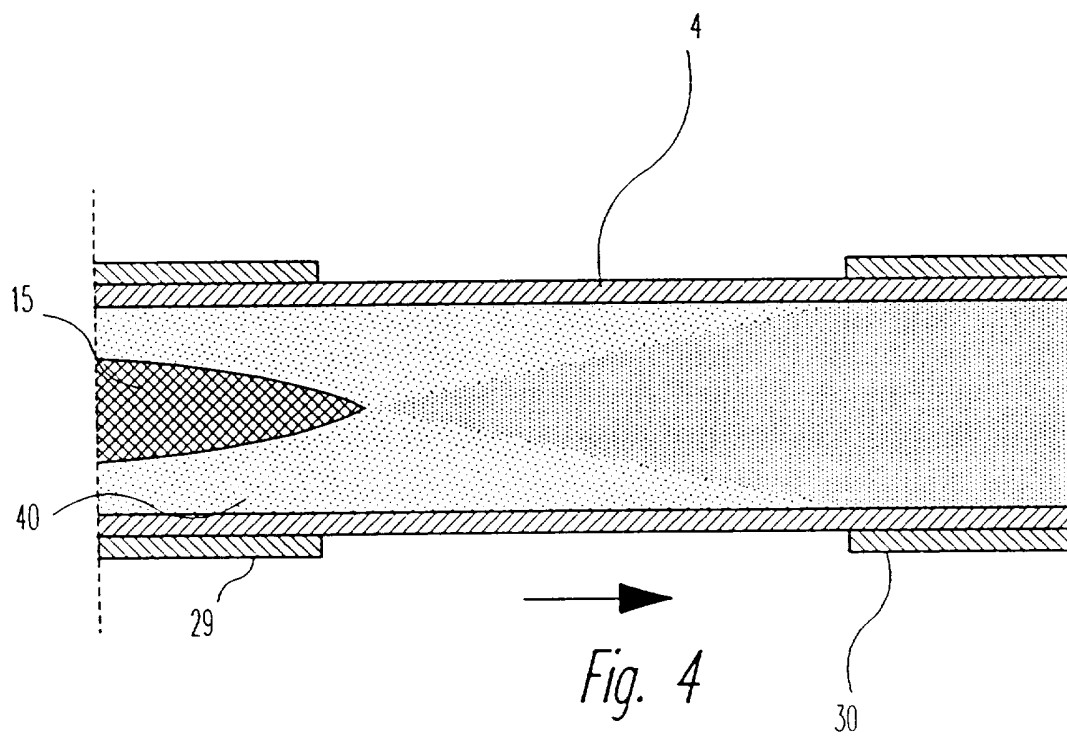


Fig. 2



→  
*Fig. 3*



→  
*Fig. 4*

## INTERNATIONAL SEARCH REPORT

International application No.

PCT/DK 95/00333

## A. CLASSIFICATION OF SUBJECT MATTER

IPC6: A23L 3/01, H05B 6/78

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC6: A23L, A23B, H05B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

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Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

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## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	WO 9222180 A1 (PEDERSEN, IB, OBEL), 10 December 1992 (10.12.92), page 6, line 33 - page 7, line 12; page 8, line 10 - line 21 --	1-9
Y	EP 0457179 A1 (GEA FINNAH GMBH), 21 November 1991 (21.11.91), column 3, line 44 - column 4, line 1, figure 1, claim 1 --	1-9
A	EP 0439696 A2 (HERMANN BERSTORFF), 7 August 1991 (07.08.91) --	1-17

 Further documents are listed in the continuation of Box C. See patent family annex.

## \* Special categories of cited documents:

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Date of the actual completion of the international search

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## INTERNATIONAL SEARCH REPORT

International application No.

PCT/DK 95/00333

## C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 0128397 A2 (SIEMENS AKTIENGESELLSCHAFT), 19 December 1984 (19.12.84)  -- -----	1-17

## INTERNATIONAL SEARCH REPORT

Information on patent family members

30/10/95

International application No.

PCT/DK 95/00333

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