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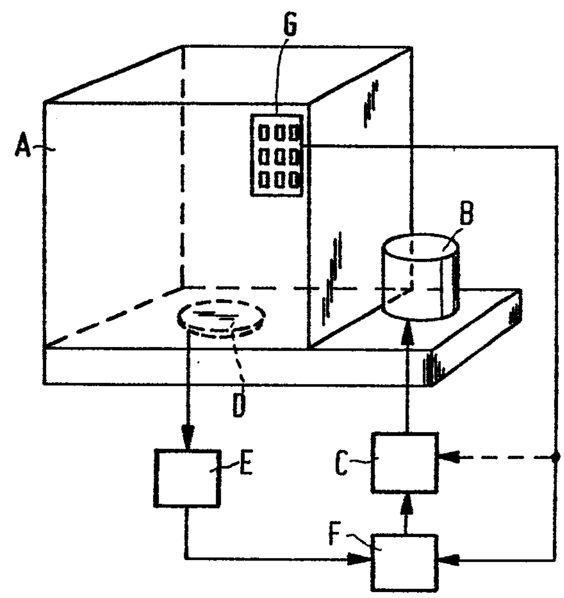
(54) **A method for heating in oven and microwave oven utilizing the method.**

(57) The invention relates to a method for automatic heating of food in an oven (A) by feeding back at least one control parameter, representing the condition of the food during the heating to a control device (F, C) for the energy source (B), and a microwave oven which utilizes the method. According to the invention a scale (D) is used to measure the weight of the food continuously or intermittently during the heating. By means of the weight indicating signal from the scale (D) the weight decrease and/or the weight decrease rate is determined, which parameters are then used as control parameters together with the initial weight in the automatic heating process.



EP 0 209 201 A1

0 209 201

A method for heating in oven and microwave oven utilizing the method.

The invention relates to a method for heating of food in oven, in which energy is fed into an oven space, where the food is placed, and at least one signal representing at least one parameter at the heating being fed back to a control device for the energy source for influencing the heating procedure, for example as regards power level and remaining processing time in an automatic heating process.

Recently several different methods for automatic control of the heating or cooking procedure in for example microwave ovens have come into use. In the first described methods the temperature or the temperature increase of the air surrounding the food was used to interrupt the heating; thereafter measurement of the air humidity or the increase of the same was introduced to obtain control parameter. The further development took place on the one hand as regards the transducers in order to achieve increased reliability and intensity of disturbances and on the other hand with the aim to utilize the transducer signal in combination with presetting of the kind and/or weight of the heating object and time from start until the appearance of transducer signal in order to obtain a controlled final heating. A limitation for hitherto described transducer systems is given by the physical properties of water, resulting in that humidity and temperature will reach a high value relatively early, which value then does not vary much at continued heating in spite of the fact that this is still not sufficient, for example due to required time for inner temperature equalization.

A common direct method is temperature measurement by means of insert transducers. However, these transducers do only function reliably in liquid-shaped or relatively thich heating objects. Furthermore overheating can arise in the surface at the place of insertion. Further drawbacks are due to difficulties in the handling and problems in case of rotating bottom place in the oven. An essential and principle weakness is that the temperature is only measured in one point, which is not always representative.

The same drawback is inherent in another method; pyrometric surface temperature measurement, in particular by means of infrared sensors: only a part of the surface is measured. Furthermore the method is expensive and sensitive for dirt.

Weight sensors of different types have come to increased use. Normally the heating pan is tared empty, whereafter the food is introduced and the whole is put into the oven. Usually it is also necessary to push a button for initial temperature (e.g. frozen, refrigirator temperature, room temperature) and another for desired process (e.g. defrosting, re-heating, cooking). In a newer type of automatic control humidity sensing and weight sensing have also been combined. In these knwon systems the weighing scale however only serves as an auxilliary device in order to decrease the requirement for judgement from the users side.

Summerizing it can be said that evident limitations are still inherent in systems using known technic. These are in first hand dirt sensitivity of humidity and infrared transducers and that the transducers will bottom early.

The invention relates to an automatic heating procedure in oven, which is controlled thereby that a signal representing the instantaneous condition of the food during the heating procedure is fed back to the energy source and the object of the invention is to enable an improved and more optimal control of the automatic process than that obtained with use of previously known sensors, in particular humidity sensors.

According to the invention this is achieved thereby that the weight decrease of the food during the heating is measured and used as control parameters in the automatic heating process.

The invention is based upon the idea that the weight decrease and the course of the same will give a better indication on the evaporation and its course, which in turn is a good indication on the instantaneous condition of the food, than that which can be obtained with use of humidity sensor. The weight decrease will for example not be constant until a moment, when the food has been heated down to an appreciable depth below the surface, so that its cooling due to heat convention inwardly is small. The surface temperature then does not need to be 100^{o}C because the power balance due to convective and evaporative surface cooling can occur earlier. The weight decrease and its course can be used for sensing the condition of the food far beyond the moment, when for example a humidity transducer according to know technic has ceased to produce signal variation. Furthermore supplied power can easily be sensed by the electronic means which are included in the system: then a further possibility is obtained for comparison with the weight decrease rate for controlling the termination of the heating or cooking process.

The weight decrease as such, however, does not always provide the best indication on how far the heating has advanced. However, if the initial weight and the variation rate of the weight are known an appreciably improved automatic control can be realized.

According to another feature of the invention therefore the initial weight of the food is measured and used in combination with the weight decrease for controlling the automatic process.

According to a further feature the instantaneous weight decrease rate, i.e. the weight decrease per time unit, is determined and used in order to control the process.

A usable control parameter representing the weight decrease is the elapsed time until a given absolute or relative weight decrease has occured.

Another usable control parameter representing the weight decrease rate is the elapsed time until a given weight decrease rate has been reached.

Suitably the absolute or relative weight decrease can be used in combination with the instantaneous weight decrease rate for controlling the automatic heating process.

In a preferred method according to the invention the intended process type (defrosing, re-heating, cooking) can be selected by the user, this selection being used in combination with measured weight decrease or weight decrease rate in a pre-programmed final processing algorithm with the initial weight as variable.

The method according to the invention can suitably be used in automatic control of the heating process in a microwave oven. A microwave oven, in which the method is used, comprising an oven cavity for accomodating the food to be heated and a microwave source for feeding microwave energy into the cavity, is according to the invention characterized thereby that it comprises a weighing device which consecutively (continously or intermittently) determines the weight of the food introduced into the oven cavity and delivers a signal representing this weight, an analogue-to-digital converter for converting the weight indicating signal to a digital magnitude and a control device for the microwave source, which is supplied with the signal from the analogue-to-digital converter and is adapted to influence the heating process as regards power level and/or remaining process time in dependence on parameters which are derived from the said weight indicating signal and which represent weight decrease or weight decrease rate and elapsed time and initial weight.

The microwave oven can furthermore comprise a keyboard for setting desired process type (defrosting, re-heating, cooking), the setting of the keyboard influencing the control device to produce desired final heating in combination with measured weight decrease or weight decrease rate and initial weight.

The invention is illustrated by means of the accompanying drawings, in which

Figure 1 shows the power balance during heating in a microwave oven,

Figure 2 shows the corresponding power balance in case of cooking, i.e. when the temperature no longer increases,

Figure 3 shows some curves over the weight decrease for different food products as function of the time in case of heating in microwave oven,

Figure 4 shows a coarse block diagram for a microwave oven according to the invention and

Figure 5 shows a flow diagram for the process in case of automatic control of a microwave oven according to the principles of the invention.

In Fig. 1, showing the power balance during heating at a temperatur of ca. 40^{o}C, P0 represents supplied power, P1 represents the evaporative losses, P2 represents the convective losses, P3 represents losses due to heating of vessel, while P4 represents the utilized power, i.e. the power which is dissipated in the food and which causes temperature increase therein. It is evident that the main part of the supplied is utilized in the food, while the evaporative loss power as well as remaining loss powers are relatively small as compared with the utilized power.

In Fig. 2 showing the power balance in case of cooking (ca. 100^{o}C), P0 again represents supplied power, while P1' represents the evaporative losses and P2' the convective losses. The utilized power in the food is zero as well as losses due to heating of the vessel. In this case all supplied power also must be removed, which usually takes place by evaporation. This will result in a constant weight decrease rate. An evaporative loss power of 300 W for example corresponds to a weight decrease rate of ca. 8g/minute at a surface temperature of +80^{o}C.

In state of transition from the heating condition according to Fig. 1 to the cooking condition according to Fig. 2 the evaporative losses will vary with time, resulting in a weight decrease rate which varies with time. By measuring the weight decrease or weight decrease rate it is thus possible to obtain a reliable indication on how far the heating has advanced.

Fig. 3 shows some curves over the weight decrease S as function of the time t in some different heating cases: the curve 1a relates to ca. 400 g water or soup in an open pan, the curve 1b the same quantity in a covered pan, the curve 2 relates the same quantity of compact food, for example pudding, in a covered pan and the curve 3 relates to a larger quantity (1000 g) of compact food. The initial temperature is in all cases normal room temperature and the oven is a microwave oven with ca. 600 W output power.

It is evident that the weight decrease as such not always gives the best indication on how far the heating has advanced. It is furthermore evident that a humidity sensor supplying a signal at a given -relatively low- derivata (see Fig. 3) should produce values which must be corrected due to inner convection, covering, if any, and quantity in order to be fully usuable. However, if the initial weight and the variation rate of the weight are known an appreciably improved system can be constructed. According to the invention this may be done in the following manner, reference being made to Fig. 3:

A. The initial weight M is stored in the electronic memory of the system (taring is presumed). The initial temperature T1 (frozen, refrigirator temperature, room temperature) is set by the user as well as intended process (heating, cooking).

B. The time t_1 until a weight decrease of for example 2 g has occured is stored. - In Fig. 3 a weight decrease of 2 g is indicated by the dashed horizontal line and two values of t_1 marked with an arrow; more closely t_1 (1a) in the case 1a and t_1 (2) in the case 2. - The program now can decide what type of food it is question of: if t_1/M (with correction for T1) is small then the food is bulky and difficult to heat and should in the following be heated at a low power; if the said magnitude is large the further heating can be effected at a high power; if M is small, t_1/M is large and heating (not cooking) is desired then the process can be interrupted directly.

C. The weight is determined at even intervals and the decrease rate <u>v</u> is calculated. - The program now compares <u>v</u> with the (power dependent) maximal value V in case of temperature equilibrium. When v/V has reached a certain value the final heating is initiated; its duration depends upon the total time reached until then, possibly also t_1, and the set process type. - If M is large the remaining time in case of reheating can be 0; the same is valid if M is small and cooking is concerned.

In the marked case t_1 (1a):

- t_1/M is rather large and
- M is rather small.

If heating is concerned the heating process can be interrupted immediately (the temperature is ca. 65°C).

If desired, the heating time can be elongated with ca. 30% which results in a final temperature of 75°C.

In the case t_1 (2):

- t_1/M is relatively small.

The heating continues with a relatively low power (this has not been done in the curve). After a while v/V will be > a given pre-programmed value (perhaps after 3 minutes). Then the heating continues further 30% of the total heating time until then, whereafter the food is ready.

Fig. 4 shows schematically a microwave oven with magnetron and a coarse diagram for a control circuit, by means of which the principles of the invention can be realized. In the drawing A designates an oven cavity, B is a magnetron which via a waveguide connection (not shown) feeds microwave energy into the cavity and C is a start-stop circuit for the magnetron. In C is included a timer and an intermittently operating switch arrangement, as a cam follower device, whereby the average power delivered by the magnetron can be set.

A weighing scale D is according to the invention placed in the bottom of the cavity and measures continously the weight of the introduced food. The scale, which may of strain gaugetype, delivers an electrical signal which represents the instantaneous value of the measured weight. This signal is fed to an analogue-to-digital converter E, in which it is converted to a digital signal, and is thereafter applied to a control device F. At a second input the control device F receives signals from a keyboard G and delivers its output signal to the start-stop circuit for the magnetron. The keyboard G can also be directly connected to the start-stop circuit for pure manual setting.

At operation with automatic control the heating or cooking process is according to the invention controlled with signals derived from the weight indicating signal delivered by the scale D. The control device F comprises for this purpose memory means, in which the initial weight of the introduced food with reduction for the weight of the vessel is stored. Furthermore the control device F has calculating means which from the weight indicating signal derives magnitudes representing the weight decrease and/or the weight decrease rate. By means of these magnitudes: initial weight, weight decrease and/or weight decrease rate then the heating or cooking process is controlled such that optimal result is obtained in each individual heating case.

The control device F can suitably comprise a microprocessor or the like, which is pre-programmed to perform desired function. An example of a flow diagram for a program which is executed by a microprocessor included in the control device is given in Fig. 5.

The process is started by pushing an "on"-button, represented by the block 10 in Fig. 5, whereby the oven is made clear for use. Thereafter taring is effected by putting the empty vessel into the oven and pushing a button marked "taring" represented by the block 11 in Fig. 5, whereby the vessel is weighed and the weight of the vessel M_T is stored. Then the vessel is filled with food to be heated and weighing of the food plus the vessel is initiated by pushing a corresponding button on the keyboard. This operation is represented by the block 12 in Fig. 5. The initial weight M of the food is then calculated by subtracting the weight M_T of the vessel from the total weight determined in the block 12 and the value of M is stored in order to serve as a control parameter during the whole heating process. The calculation and storing of the initial weight M is represented by the block 13 in Fig. 5. In the block 14 it is checked if M is smaller than 50 g. If the answer is "yes" then the process is interrupted, the block 15, and the oven assumes ready state for manuel heating. This is because so small quantities are not heated automatically. If the answer is "no" then the process continues thereby that a parameter T1 representing the initial temperature of the food is set, the block 16. T1 which is set by means of buttons on the keyboard can for example assume one of three values representing "freezing temperature", "refrigirator temperature" and "room temperature", respectively. Then desired process is selected, the block 17, also by means of buttons on the keyboard. For the selection in the block 17 there are for example two alternatives: "heating" and "cooking". The heating process is then started by pushing a start button, the block 18, whereby the magnetron is connected to its operation voltage. Simultanously the timer is started for indicating the running time $\underline{t}$ from the start of the magnetron, the block 19. In the block 20 the absolute decrease of weight $M-M_p$ is determined and the following question "is $M-M_p$ larger than 2 g ?" is made, M_p being the weight of the food during the heating. If the answer to the question in the block 20 is "no" then repeatedly new calculation of the absolute decrease of weight $M-M_p$ and comparison with the absolute value 2 g is effected. If the answer in the block 20 is "yes" then the timer is read and the time t_1 required to reach the weight decrease 2 g is stored, block 21. Now the program continues by forming a parameter A, the block 22, which is defined by the formula:

$$A = f\ (t_1/M + k\ T1)$$

where $\underline{f}$ is an empirically obtained function, t_1, M and T1 have the previously mentioned meanings and $\underline{k}$ is a scale factor. The value of the parameter A is an indication on how difficult it is to heat the food; the smaller A is the more difficult it is to heat the object.

In the block 23 the following question "is M small, A large and heating concerned?" is made. If the answer to this question is "yes" then the heating process can be interrupted, the block 24, and

0 209 201

oven returns to the ready position for new heating. If the answer in the block 23 is "no" then the process will continue, which in first hand is effected by selection of power.

The power selection is made in dependence of the parameter A and in the block 25 the question "is A larger than x?" is made, x being a stored constant. If the answer is "yes" then the oven is set to a high power $P = P_h$, the block 26. If the answer in the block 25 is "no" then the program continues to the block 27. Here the question "is A larger than y?" is made, y also being a stored constant ($y < x$). If the answer in the block 27 is "yes" then the oven is set to a mean power $P = P_m$, the block 28. If the answer in the block 27 is "no" then the program continues to the block 29. Here the question "is A larger than z?" is made, z ($z < y$) being a stored constant. If the answer in the block 29 is "yes" then the oven is set to a low power $P = P_1$, the block 30.

The constants x, y and z are empirically determined in such manner that the power P is adapted to the load in each individual operation case.

Immediatley after the selection of power level for the continued heating a parameter V is determined, which parameter is defined as the maximal weight decrease per time unit, i.e. the weight decrease rate at temperature equilibration and for the selected power. This is effected in the block 31 in Fig. 5. During the continued heating with the selected power now a measuring procedure takes place, which leads to final heating and switching-off of the oven. This is in first hand effected by means of the weight decrease rate, which is determined intermittently with a time interval of t_v, e.g. 20 seconds, the blocks 32 and 33. In the block 32 the running time t' from foregoing weight measurement is determined and the question "is t' equal to t?" is made. Is the answer "no" then the time measurement continues. Is the answer "yes" then the instantaneously prevailing weight M_{pi} is measured, the block 33. In the block 34 the weight decrease rate V_i is calculated according to the formula:

$$v_1 = \Delta M_1/t_v$$

where $\Delta M_i = M_{pi} - M_p\ (i-1)$ is the weight decrease and i is the running order number of the weight measurement.

In the block 35 the question "is V_i smaller than

V_{i-1}?" is made. If the answer is "yes" this can indicate a starting "dry-boiling" or a similar abnormal happening and the heating is immediately interrupted, the block 36. Is the answer in the block 35 "no" then the program proceeds to block 37, in which the ratio between actual measured weight decrease rate V_i and the previously defined weight decrease rate V is calculated.

This ratio v_i/V is in most cases a good indication on how far the heating has advanced and is used for initiating final heating. Before this is made, however, a check is made of the total heating time t, the block 38. Here the question "is t larger than f' (t, P, M)?" is made, where f' is a function of the time t, the power P and the initial weight M. If the answer in the block 38 is "yes" then the remaining heating time t_r in this case is set equal to f' (t, P, M), the block 39, whereafter the heating is interrupted, the block 40. the function f' (t, P, M) is then such that very large quantities of food, which could result in that a value for v/V, which normally is used to initiate final heating, never will be reached, instead are finally heated according to the rule given in the block 39.

If the answer in the block 38 is "no" then in block 41 the question "is vv/V larger than α?" is made, α being a stored constant. If the answer is "no" the program returns to the beginning of the block 32 and new determination of the weight decrease rate vv nad thereby of vv/V is effected. When the weight decrease rate has reached such a high value that the answer in the block 41 is "yes" then the program proceeds to the block 42. Here the question "is M smaller than m?" is made, m representing a relatively small quantity of food. If the answer in the block 42 is "yes" then the heating is interrupted immediately, the block 43, and the oven returns to the ready state. If the answer in the block 42 is "no", which is valid for medium-sized quantities of food, then the program proceeds to the block 44 where the final time tØ is determined according to the formula:

$$t_s = f''(s \cdot t + r \cdot t_1)$$

where f'' is an empirically determined function of t and t_1 and s, r are scale factors.

At the same time the final power PØ is determined, the block 45, according to the formula;

$$P = f'''(s \cdot M)$$

where $\underline{f}'''$ is an empirically determined function of M and $\underline{s}$ is a scale factor.

After setting of the final power PØ the question "is t equal to tØ?" is made in the block 46. As long as the answer in the block 46 is "no" the final heating continues with the determined power. When the answer in the block 46 is "yes" then the heating is interrupted, the block 47, and the oven returns to the ready state.

1. A method for heating food in oven, in which energy is fed into an oven space, where the food is placed, and at least one signal representing at least one parameter at the heating being is fed back to a control device for the energy source for influencing the heating procedure, for example as regards power level and remaining processing time, in an automatic heating process, characterized in that the weight decrease of the food during the heating is determined and used as control parameter in the automatic heating process.

2. A metod as claimed in the Claim 1, characterized in that the initial weight of the food is measured and used in combination with the weight decrease for controlling the automatic process.

3. A method as claimed in the Claim 1 or 2, characterized in that the time until a given absolute or relative weight decrease has occured is determined and used as control parameter.

4. A method as claimed in the Claim 1 or 2, characterized in that the instantaneous weight decrease rate, i.e. weight decrease per time unit, is determined and used as control parameter.

5. A method as claimed in the Claim 4, characterized in that the time until a given instantaneous weight decrease rate has been reached is determined and used as a measure of the weight decrease rate

6. A method as claimed in any of the Claims 1-5, characterized in that the absolute or relative weight decrease is used in combination with the weight decrease rate for controlling the automatic heating process.

7. A method as claimed in any of the Claims 1-6, characterized in that the intended process type (defrosting, re-heating, cooking) can be selected by the user and that this selection is used in combination with measured weight decrease or weight decrease rate in a pre-programmed final processing algorithm with the initial weight as variable.

8. A microwave oven for effecting the method as claimed in any of the Claims 1-7 comprising an oven cavity for accomodating the

food to be heated and a microwave source for feeding microwave energy into the cavity, characterized by a weighing device which consecutively (continously or intermittently) measures the weight of the food introduced into the oven cavity and delivers a signal representing this weight, an analogue-to-digital converter for converting the weight indicating signal to a digital magnitude and a control device for the microwave source, to which the signal from the analogue-to-digital converter is fed and which is adapted to influence the heating processing as regards power level and/or the remaining process time in dependence on parameters derived from the said weight indicating signal and representing weight decrease or weight decrease rate and initial weight.

9. A microwave oven as claimed in the Claim 8, characterized in that it is furthermore has a keyboard for setting of desired process type (defrosting, re-heating, cooking), the setting of the keyboard influencing the control device to produce desired final heating in combination with measured weight decrease or weight decrease rate and initial weight.

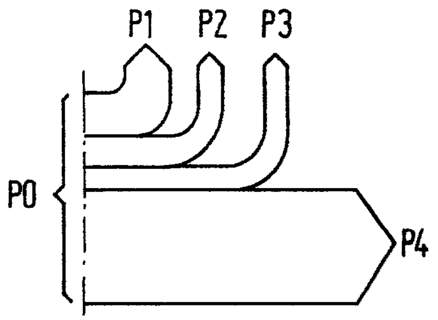


FIG. 1

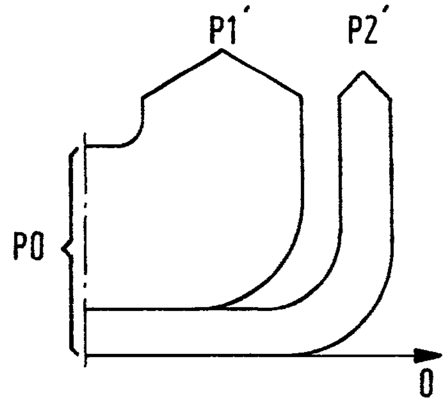


FIG. 2

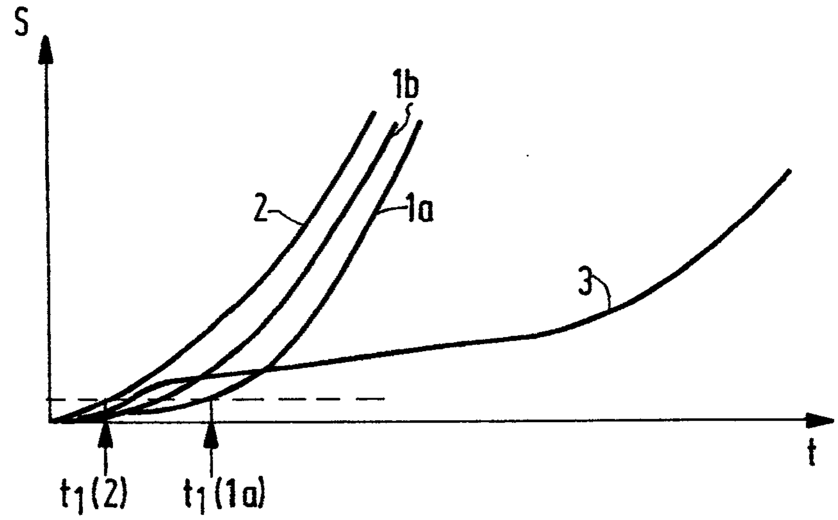


FIG. 3

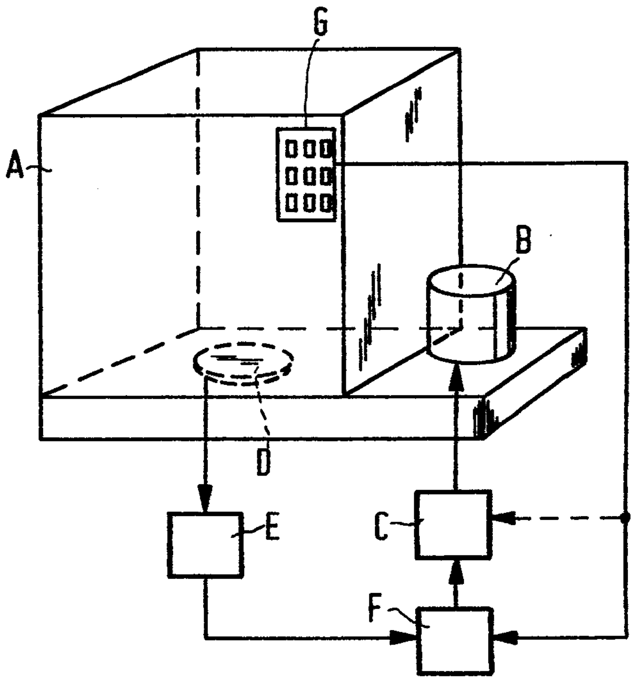


FIG. 4

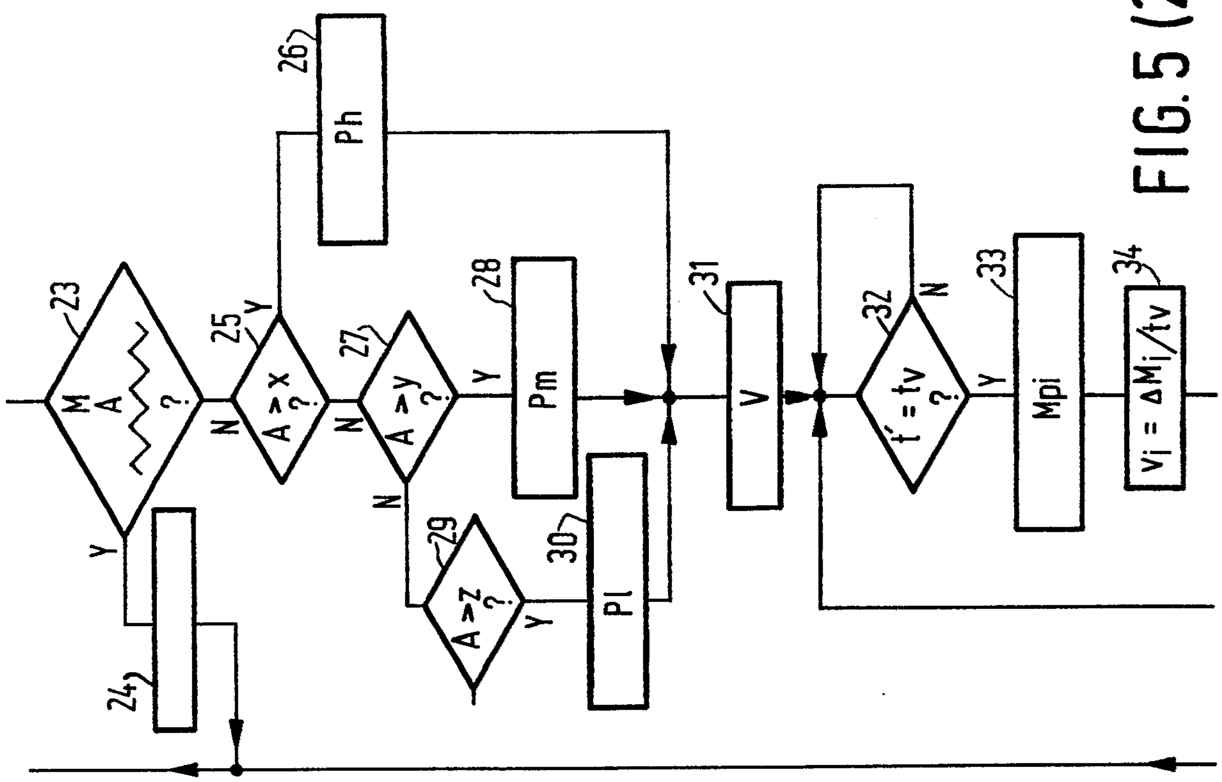

23
M
A
?
25
A > x
?
27
A > y
?
29
A > z
?
Ph
26
Pm
28
Pl
30
V
31
t' = tv
?
32
Mpi
33
$v_i = \Delta M_i / t_v$
34
24
Y
N

FIG. 5 (2)

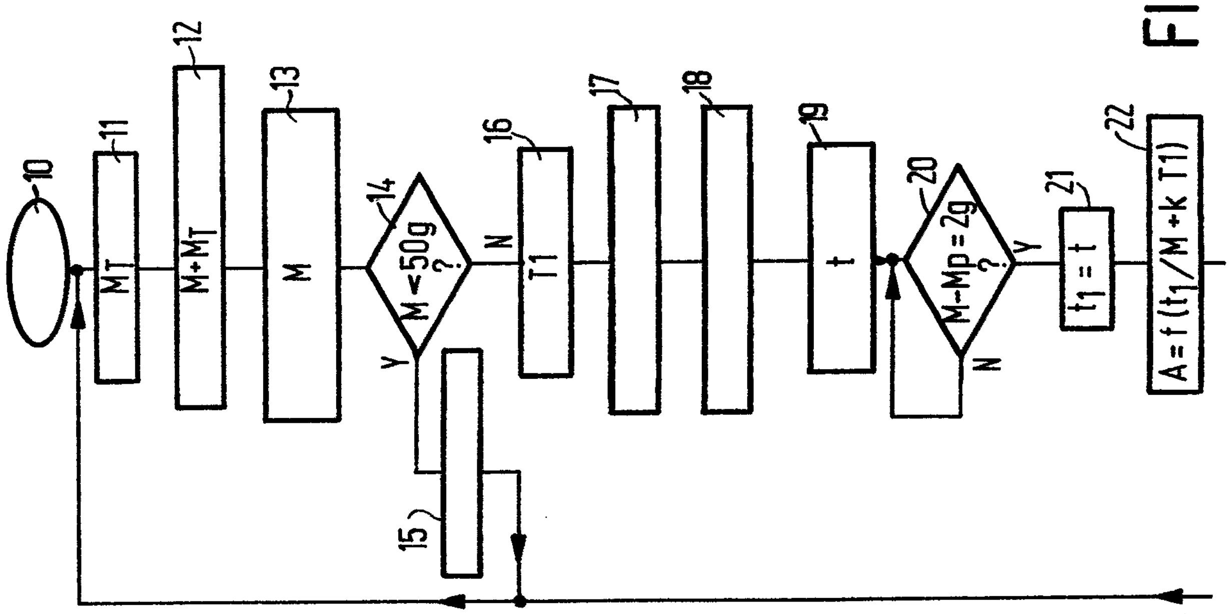

10
M_T
11
$M+M_T$
12
M
13
M < 50g
?
14
15
T1
16
17
18
t
19
$M-M_p = 2g$
?
20
$t_1 = t$
21
$A = f(t_1/M + k\,T1)$
22
Y
N

FIG. 5 (1)

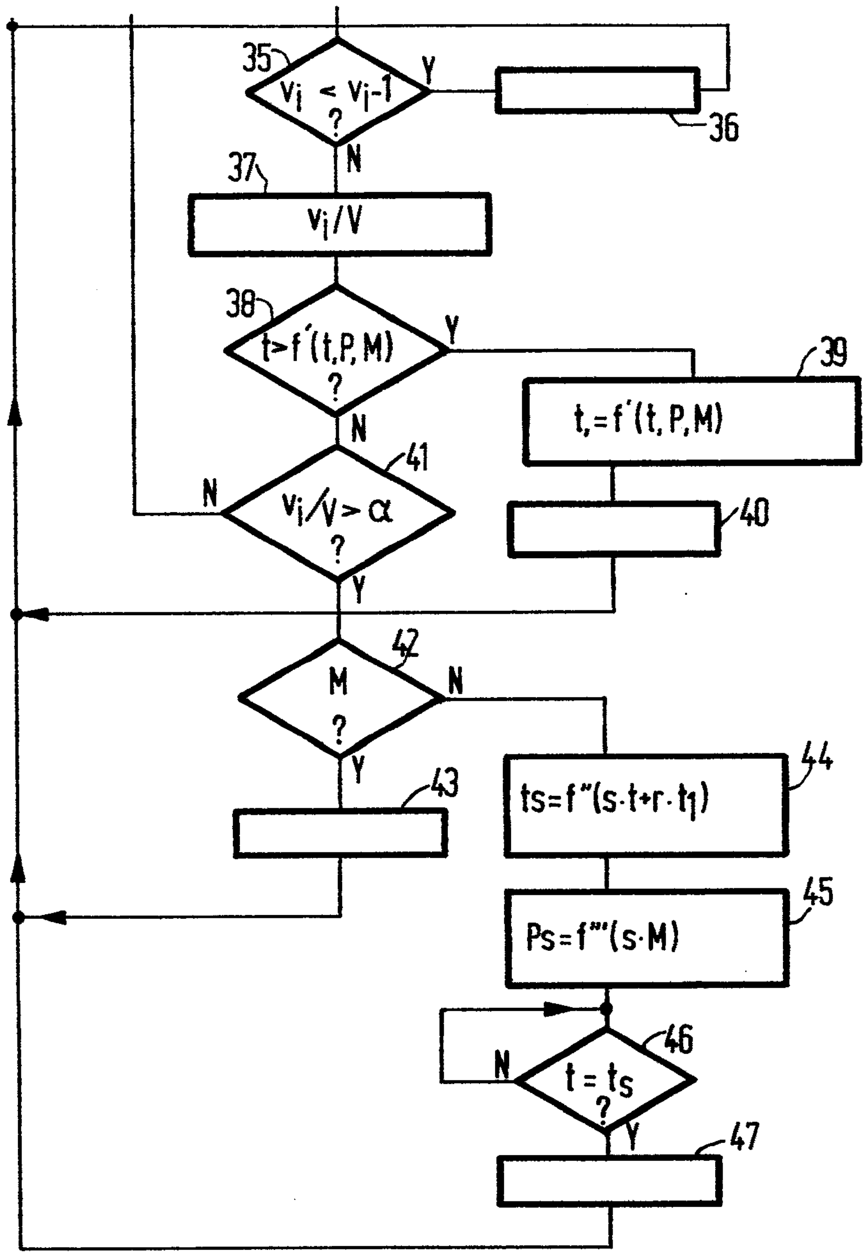

35
$v_i < v_i-1$?
Y
36
N
37
v_i/V
38
t>f´(t,P,M) ?
Y
39
t_1=f´(t,P,M)
N
41
N
$v_i/V > \alpha$?
40
Y
42
M ?
N
Y
43
44
ts=f"($s \cdot t + r \cdot t_1$)
45
Ps=f'''(s·M)
46
N
$t = t_s$?
Y
47

FIG. 5 (3)

European Patent Office

EUROPEAN SEARCH REPORT

0 209 201

EP 86201243.2

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.4)
A	DE - A1 - 3 138 026 (RAYTHEON) * Abstract; claims; fig. 1,2, 6,7 * --	1,2,8, 9	H 05 B 6/68 F 24 C 7/02 H 05 B 1/02
A	US - A - 4 508 948 (CARLSON) * Abstract; claims; fig. 1,2, 11-12b,16 * --	1,2,8, 9	
A	US - A - 4 447 693 (BUCK) * Abstract; claims; fig. 1,7, 9 * --	1,2,8, 9	
A	EP - A1 - 0 070 728 (MATSUSHITA) * Abstract; claims; fig. 1,2, 8 * ----	1,2,8, 9	**TECHNICAL FIELDS SEARCHED (Int. Cl.4)** F 24 C 7/00 G 05 D 23/00 H 05 B 6/00

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
VIENNA	29-09-1986	TSILIDIS

CATEGORY OF CITED DOCUMENTS

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