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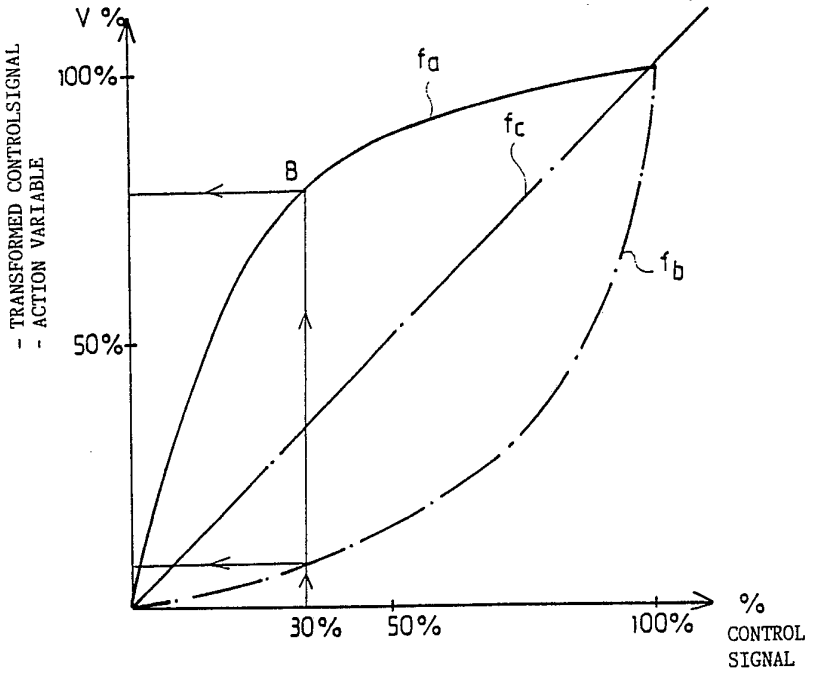
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(54) Title: PROCEDURE AND MEANS FOR CONTROLLING VOLUMETRIC FLOW RATE IN AIR-CONDITIONING INSTALLATIONS



(57) Abstract

The invention concerns a procedure for controlling volumetric flow rate in air-conditioning installations, wherein the volumetric flow passing through an air-conditioning duct is controlled with the aid of a control means (10) disposed in the air duct by opening or closing the control damper (11) or equivalent of the control means (10). In the procedure, the control signal of the control damper (11) or equivalent air flow-controlling member of the control means (10) is non-linearized on the basis of the effective characteristic curve of the control means and of the desired effective characteristic curve. The opening and closing of the control damper or equivalent of the control means is controlled with the aid of said non-linearized control signal function. The invention also concerns a means for controlling air flow.

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Procedure and means for controlling volumetric flow rate in air-conditioning installations

The present invention concerns a procedure for controlling volumetric flow rate in air-conditioning installations, in said procedure the volumetric flow in an air-conditioning duct being controlled with the aid of a control means disposed in the air duct by opening, respectively closing, the control damper of said control means.

A major drawback of control valves and control dampers installed in air-conditioning ducts is their poor controllability. When the damper is opened, the air quantity passing through the damper begins the increase steeply, and the increase of the air flow rate levels out when the control damper reaches its other extreme position. Often, however accurate air flow control is required, and precisely that kind of control in which exactly the desired volumetric flow rate is obtained with the control variable. Control damper designs of prior art enable no such operation: the operation of the valve is highly non-linear and therefore also frequently uncontrolled.

One of the most difficult present-day problems in air flow control is the control of great air flows. Most commonly a control damper provided with turnable slats is used to control air flows.

Air-conditioning systems have to be dimensioned and controlled so that no unnecessary loss of pressure occurs in the system. Major pressure drops cause noise problems in the duct system and require bigger and more powerful blowers, and stronger ducts. These facts directly increase the building and running costs of the installation and impair its comfort in use. The same facts also give rise to special requirements regarding the components of the duct system, e.g. the control dampers. The pressure drop problem is one of the reasons why the control dampers are constructed to be congruent

with the duct systems of their nominal dimensions so that they might not cause any pressure drop when fully open. For this reason the control dampers are over-dimensioned from the viewpoint of control technology. Therefore their effective operational characteristic curve is also strongly non-linear and, furthermore, their effective control range is narrow. As a result of the non-linear effective characteristic curve, the change of the control damper's control variable (from 0 to 100%) will not alter the volumetric flow in the direct proportion: in the worst case the controlled volumetric flow rate may be a multiple of that which is desired.

The object of the invention is primarily an apparatus design and procedure design by which it becomes possible to alter the effective characteristic curve of the control damper in such manner that to a given change of control signal corresponds a given change of volumetric flow rate. Also an aim of the invention is an apparatus and procedure design by which it becomes possible expressly to linearize the opening of the control damper in such manner that to 0 to 100% control value change linearly corresponds 0 to 100% volumetric flow rate change.

The aim of the invention is achieved with a procedure design which is mainly characterized in that in the procedure the control signal of the control damper or equivalent air flow-controlling member of the control means is non-linearized on the basis of the effective characteristic curve of the control means and the effective characteristic curve desired and with said non-linearized control signal function is controlled the opening and closing of the control damper or equivalent of the control means.

The apparatus of the invention is mainly characterized in that the means comprises a transformation unit connected to the action means moving the control damper or equivalent, with the aid of which the control signal meant for moving the control damper or equivalent is non-linearized on the basis of the effective characteristic curve of the control means and the desired effective characteristic curve, and in said means the opening or closing of

the control damper or equivalent of the control means is controlled with the aid of said non-linearized control signal function.

The invention is described in the following, referring to certain advantageous embodiments of the invention, presented in the figures of the attached drawings, yet to which the invention is not meant to be exclusively confined.

In Fig. 1, the procedure of the invention is graphically displayed.

In Fig. 2A, an electrical implementation of the procedure of the invention is presented in the form of a block diagram.

In Fig. 2B, a mechanical implementation of the procedure of the invention is presented in the form of a block diagram.

In Fig. 3A is presented an advantageous mechanical embodiment of the apparatus of the invention.

In Fig. 3B is presented another advantageous embodiment of the means of the invention.

In Fig. 3C is presented a third advantageous mechanical embodiment of the means of the invention.

The procedure and apparatus of the invention are applicable in air flow control. They are particularly suited to be used in controlling air flows in connection with control means that are used in air-conditioning installations, such as control dampers.

In Fig. 1A is graphically displayed the characteristic curve of a conventional non-linear control damper. On the horizontal axis is plotted the control signal, or control variable,, of the control damper, in per cent. On the vertical axis is plotted the controlled volumetric flow rate, or here the action variable.

It is seen in the figure when the control damper opens, the air

quantity passing through the control damper increases strongly, and said increase of air flow levels out when the control damper reaches its extreme open position. In Fig. 1B has been plotted the characteristic curve of the transformed control signal, which is the inverse function of the effective characteristic curve of the control damper.

In Fig. 1B is illustrated, on an enlarged scale, the procedure principle of the invention. The coordination on the horizontal axis represent the original control signal in per cent, or the control variable. The vertical coordinates represent the transformed control signal, or the action variable. In the procedure of the invention, the controlled air flow rate is the action variable. In the procedure of the invention, the control signal is non-linearized inversely relative to the non-linearity of the effective characteristic curve of the action means employed and to the desired effective characteristic curve.

In Fig. 1B is presented one instance of control according to the invention. Desired is the volumetric flow rate V'_1, which is e.g. 30% of the maximum air flow. With a 30% control signal value is obtained, as the figure reveals, a volumetric flow rate of over 70%. The aim in linearizing is that 30% volumetric flow is reached expressly with 30% control signal, i.e., that the magnitude of the control signal is 30% of the total control variable range.

As shown in Fig. 1B, linearizing is accomplished by first forming for the effective characteristic curve fa of the action means the inverse function relative to the desired effective characteristic curve fc. The graph f_b representing this inverse function is the mirror image of the effective characteristic curve graph f_a with reference to the curve f_c. The curve fb entered in the figure is thus obtained. The figure reveals that when 30% volumetric flow rate is to be obtained with 30% control signal, the control signal should have the magnitude indicated by the ordinate of the point B on the inverse function graph fb, or about 10%.

In Fig. 1B the vertical coordinate also represents the transformed control signal, in per cent. The desired linear effective characteristic curve of the control damper has been entered in Fig. 1B and indicated with the symbol fc.

In Fig. 2A is in the form of a block diagram shown the way in which the procedure of the invention is electrically implemented. In the figure, the first block has been denoted with N_o, the second block with L_o, and the last block with P_o. The original electric control signal is carried to the electromotor control unit M_o, which performs modulation of the original control signal S_1 in the electrical transformation unit L_o in such manner that the curve of the non-linearized control signal consistent with the shape of the effective characteristic curve of the control damper or equivalent means is formed. The transformation unit produces the transformed control signal S_2, by which the rotating axis 11a or equivalent of the control damper 11 is moved. In the linearized model said non-linearized control signal curve is the inverse function of the effective characteristic curve of the control means, and it yields that control signal value at which to a given per cent original control signal value corresponds the value of the action variable having the respective percentage, this being in the present embodiment expressly the volumetric air flow rate V' which is to be controlled. The non-linearization can be implemented in the electrical procedure, by analog or digital techniques or by a combination of these.

The electrical procedure is also characterized in that to it may be supplied the actual effective characteristic curve and the desired effective characteristic curve, in the procedure further on their basis being determined the non-linearizing function.

As taught by the invention, one may particularly in the electrical procedure apply different non-linearizing functions. In order to carry out a given, and desired, transformation, the user may select the non-linearizing function curve he desires from among various, pre-defined such curves stored in the computer memory. The user

may also exert an influence with the aid of the connection associated with the control damper, directly on the non-linearity of the control signal. The user may tune the non-linearity curve to conform to the system that is being controlled by means of such parameters which have been measured on the system that is being controlled and which have been supplied to the non-linearizing unit. Particularly in the electrical procedure, one may determine the effective characteristic curve (function) of the control means meant to be installed in the air-conditioning duct, which includes as variables the position of the control damper of the control means and the volumetric flow rate therewith obtained. Hereafter, the curve shape of the desired effective characteristic curve can be entered in the microprocessor, and the microprocessor or equivalent will on the basis hereof determine the non-linearity curve.

In Fig. 2B is presented, in block diagram illustration, a mechanically implemented modification of the action means controlling the opening of the control damper. This modification can implement linear opening of the control damper or any desired non-linear opening of the control damper.

The control signal S_1 is carried, in the mechanical design, e.g. in the form of a rotation on the shaft of a gear wheel. Said mechanical transmission has been indicated with M_1. Between the shaft 11a of the control damper and said mechanical transmission M_1 has been connected a mechanical modulator L_1, for instance a cam wheel, which transforms the control signal S_1 taken to the unit M_1 to a control signal S_2, by which the control damper 11 is opened and closed by moving its shaft 11a or equivalent.

In the mechanical procedure various non-linearizing curves prepared in advance may be provided, from which the appropriate curve is selected in each instance. It is thus possible with the procedure and apparatus of the invention to achieve any desired control of the control damper also when non-linear control is desired.

As shown in Fig. 3A, a given control variable is carried to the

electromotor 12. The quantity of the control variable may for instance be p% of the total control variable quantity. Linear opening of the control damper 11 is desired and it should be such that in correspondence to a control variable quantity of a given percentage an air flow rate amounting to the desired percentage will be obtained.

As shown in Fig. 3A, this is implemented in that on the shaft 12a of the electromotor 12 has been connected a cylindrical body 13 presenting a curved surface 13a and a belt transmission 14 is employed to transmit the rotation further to the shaft 11a of the control damper 11 in the control means 10, over its cooperating pulley 15. The belt 14a is shifted, in order to implement the desired linearization, with a shifter 14b along the surface 13a and 15a (arrow L_1) of the cylindrical body 13 and 15, said surface having been shaped so that the desired linearization or non-linearization will be implemented so that correspondence is obtained between any given control variable and the desired magnitude of air flow passing through the valve or control damper 11.

In Fig. 3B is presented another implementation of the mechanical linearizing according to the invention. The shaft 12a of the motor 12 has been fitted with a pinion 16, which further moves a rack 17. One end of said rack 17 has been disposed to move, with the aid of a follower member 17', in a slide groove 18 of which the shape corresponds to the non-linearization curve. It is thus achieved that the movement is transmitted from the rod 17 coupled with the pinion 12 further over an intermediate link 19 to the shaft 11a of the damper or slat 11 in the duct K. Any desired transformation is achieved by changing the shape of the curve 18, and for instance linearizing of a control damper may thus be implemented.

In Fig. 3C is presented a third apparatus design implementing the procedure, implemented mechanically according to the invention. The action variable is carried over the shaft 20a of the pinion 20 to the rack 21. The pinion 20 has been arranged to cooperate with

the teeth 21a on the tooth rack 21. The rack 21 further cooperates with a cam wheel 22 which has been disposed to rotate deriving its rotation from the pinion 20 over transmissions, advantageously intermediate gears 23. Therefore the point of contact D between the sliding surfaces of the cam 22a on the cam wheel 22 and the follower member 21' of the rack 21 will move along the cam and the movement of the pinion 20 is thus transmitted in a way dependent on the shape of the cam 22a on the cam wheel 22, further over the lever 24, to the shaft 11a of the control damper 11 or equivalent. Any desired control is achieved by changing the shape of the non-linearizing curve groove or equivalent.

The procedure of the invention may equally be applied in those control designs in which the force transmitted to the shaft of the control damper is controlled. When the control damper is closed, the force requirements when the control damper is now opened are higher than those in any other instance of control. Therefore a higher opening force can be directed on the control damper, by applying the transformation of the invention, in those instances when one starts to move the control damper from its closed position to its open position, or vice versa. The highest torque or force requirement is encountered precisely at the stage when the surfaces of the control damper meet the cooperating surfaces of the duct or of the cooperating member thereto connected.

Claims

1. A procedure for controlling volumetric flow rate in air-conditioning installations, wherein the volumetric flow passing through an air-conditioning duct is controlled with the aid of a control means (10) disposed in the air duct by opening or closing the control damper (11) or equivalent of the control means (10), characterized in that in said procedure the control signal of the control damper (11) or equivalent air flow-controlling member of the control means (10) is non-linearized on the basis of the effective characteristic curve of the control means and of the desired effective characteristic curve and the opening and closing of the control damper or equivalent of the control means is controlled with the aid of said non-linearized control signal function.

2. Procedure according to claim 1, characterized in that in the procedure the opening of the control damper (11) of the control means (10) is linearized by transforming the control function of the control signal into the inverse function of the effective characteristic curve of the control means relative to the desired effected characteristic curve.

3. Procedure according to any one of the preceding claims, characterized in that the user selects from among various non-linearizing function curves prepared in advance the desired curve.

4. Procedure according to any one of the preceding claims, characterized in that the user exerts an influence on the non-linearity of the control signal by the aid of the connection associated with the control damper (11).

5. Procedure according to any one of the preceding claims, characterized in that the user tunes the non-linearity curve to conform to the system to be controlled, with such parameters which have been measured on the system to be controlled and which have been supplied to the non-linearization unit.

6. Procedure according to any one of the preceding claims, characterized in that the procedure is used for transformation means a mechanical modulator, advantageously a slide curve, a cam wheel or equivalent.

7. Procedure according to any one of the preceding claims, characterized in that the non-linearization is carried out in the form of mechanical non-linear transmission, the original control signal being transformed into a transformed control signal mechanically by transmitting the control signal from a pinion (16;20) to a rack (17;21) and guiding the rack with the aid of a modulation means (18;22), e.g. a slide curve (18), which conforms to the shape of the graph representing the desired non-linearization function, and in said means the movement of the rack (17;21) being transmitted further to the shaft (11a) or equivalent moving the closing member of the control damper (11) or slat or equivalent in the air-conditioning means.

8. Procedure according to the preceding claims, characterized in that in the procedure is used for mechanical modulator unit a cam wheel (22) of which the cam shape corresponds to the desired non-linearization curve and on which has been disposed to move an action means (21) imparting motion to the shaft (11a) of the control damper (11), this action means being at the same time also to derive its motion from a pinion (20) or equivalent to which the original control signal is transmitted, and in said means a separate transmission mechanism (23) deriving its movement from said pinion (20) being disposed to move the cam wheel (22).

9. A means for controlling volumetric flow rate in air-conditioning installations, wherein the volumetric flow is controlled by opening or closing the control damper (11) or equivalent of a control means (10), characterized in that the means comprises a transformation unit (L_0;L_1;18,22) connected to the action means moving the control damper (11) or equivalent, by its aid the control signal meant for moving the control damper (11) or equivalent being non-linearized on the basis of the effective characteristic

curve (fa) of the control means and of the desired characteristic curve (fc), and in said means the opening and closing of the control damper (11) or equivalent of the control means (10) being controlled with the aid of said non-linearized control signal function (fb).

10. Means according to the preceding claim, **characterized** in that the means comprises an electrical transformation unit (L_o) for non-linearizing the control signal function.

11. Means according to claim 8 or 9, **characterized** in that the means comprises action members implementing non-linear transmission and by which the original control signal (S_1) is transformed into a transformed (S_2) control signal, and that the means comprises a pinion (16;20) and a rack (17;21) and a slide curve (18;22a), the control signal (S_1) being mechanically transmittable from said pinion (16;20) to said rack (17;21) and the rack (17;21) being further controlled with the aid of said slide curve (18;22a), which conforms to the shape of the graph representing the non-linearization function, and in said means the movement of the rack (17;21) being ultimately transmitted to the shaft (11a) moving the control damper (11) or equivalent of the action means.

12. Procedure according to any one of the preceding claims 8-10, **characterized** in that the means comprises as its mechanical transformation unit (L_1) a cam wheel (22;13) of which the shape corresponds to the desired non-linearization curve.

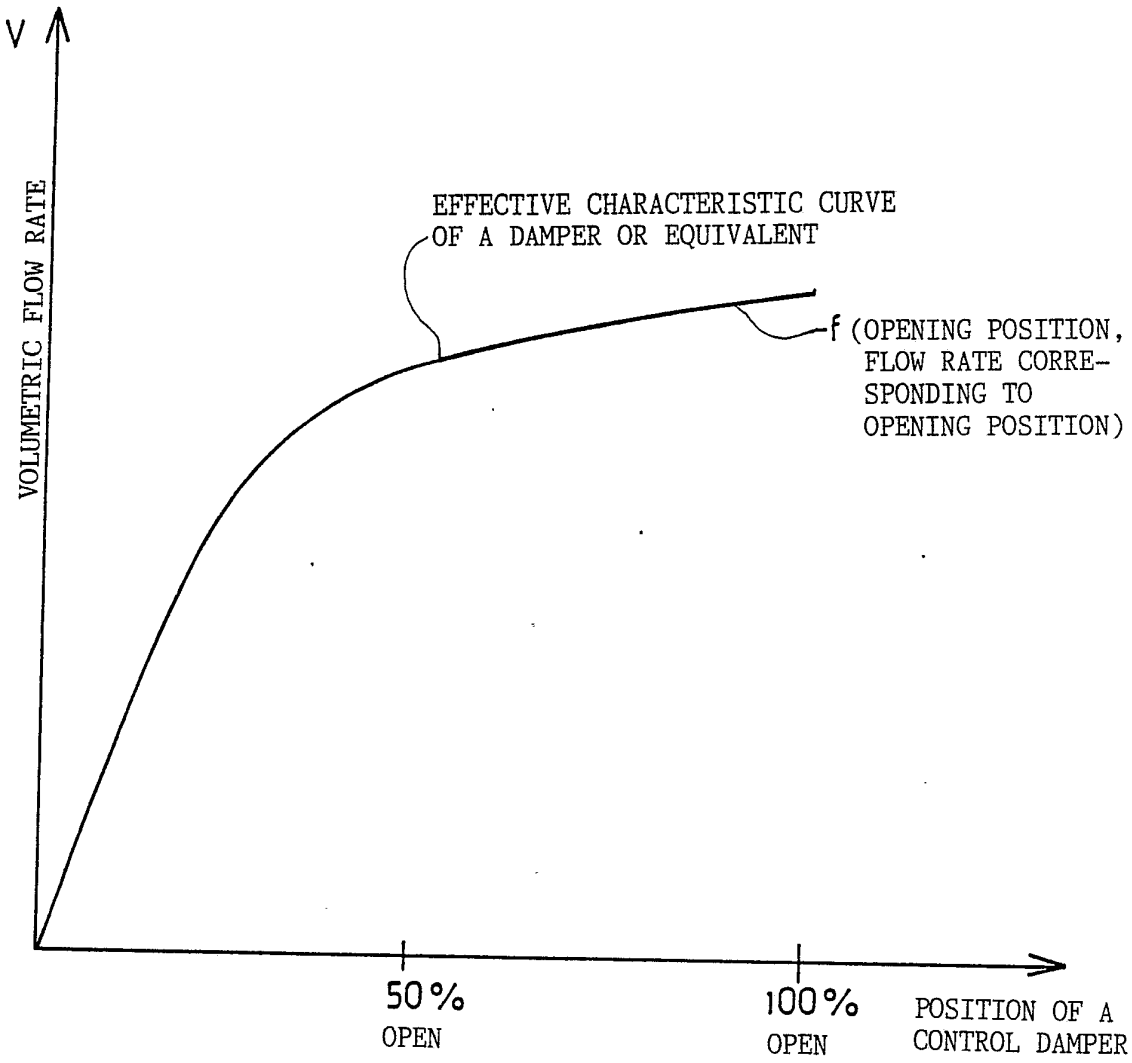

V
VOLUMETRIC FLOW RATE
EFFECTIVE CHARACTERISTIC CURVE
OF A DAMPER OR EQUIVALENT
f (OPENING POSITION,
FLOW RATE CORRE-
SPONDING TO
OPENING POSITION)
50 %
OPEN
100 %
OPEN
POSITION OF A
CONTROL DAMPER

FIG. 1A

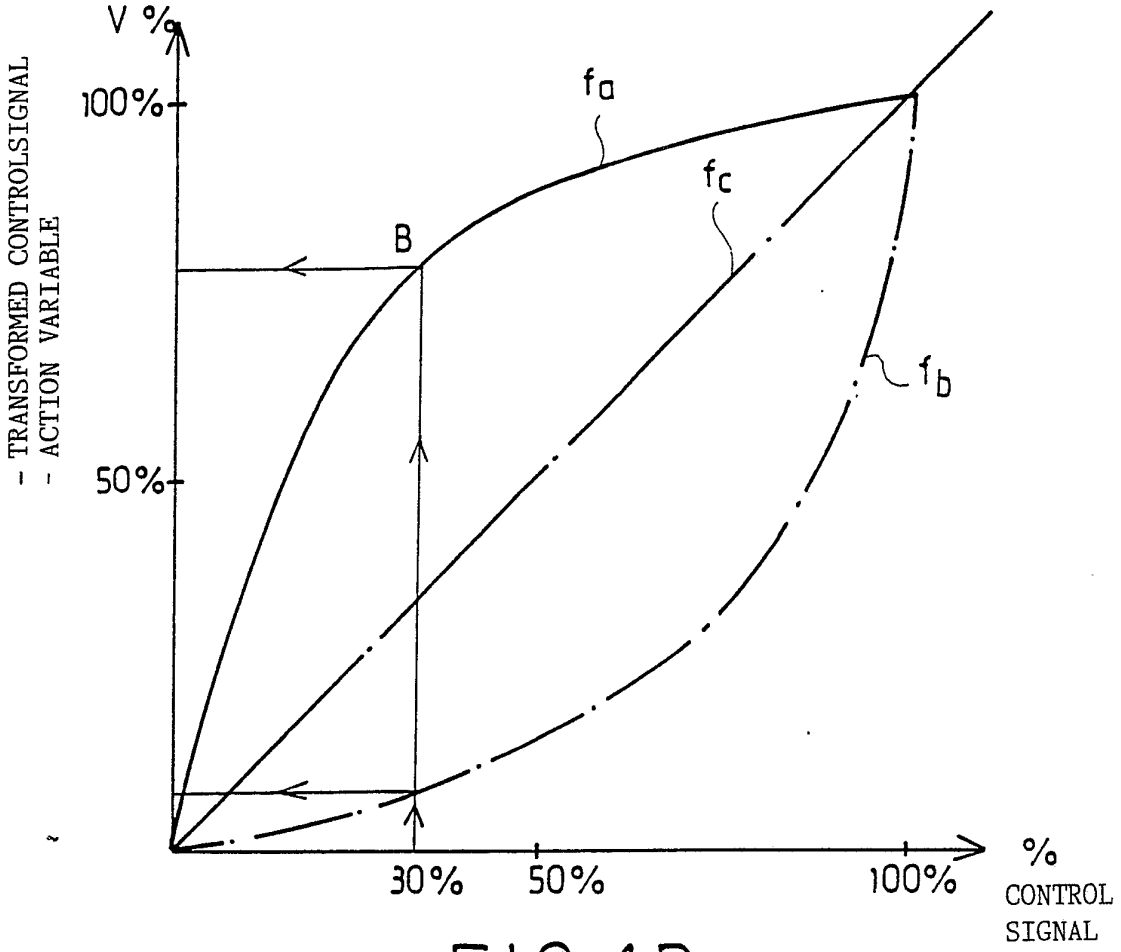


FIG. 1B

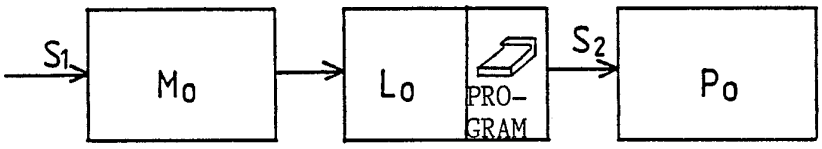


FIG. 2A

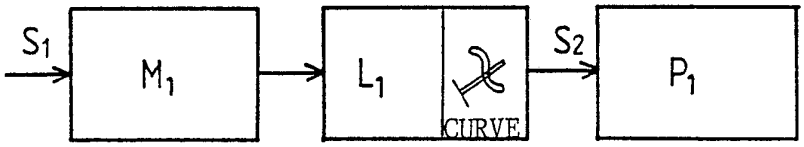


FIG. 2B

SUBSTITUTE SHEET

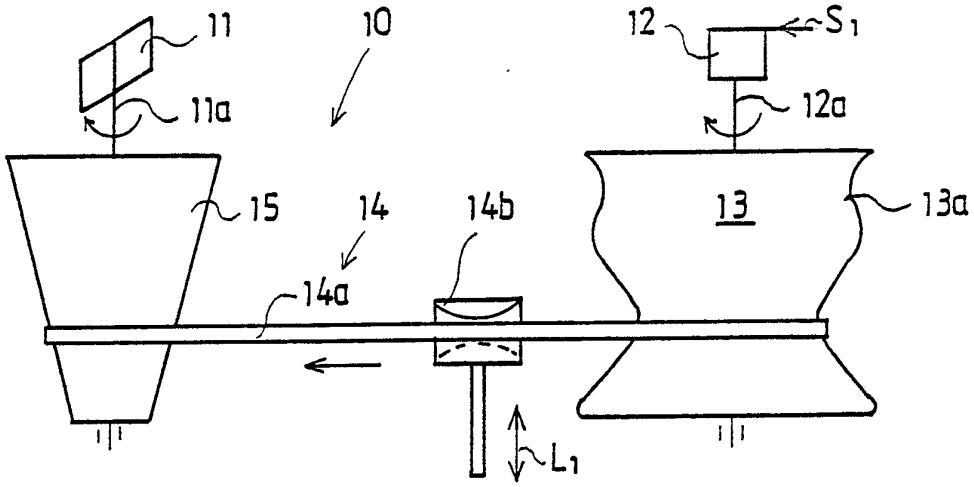

11
10
12
S1
11a
12a
15
14
14b
13
13a
14a
L1

FIG. 3A

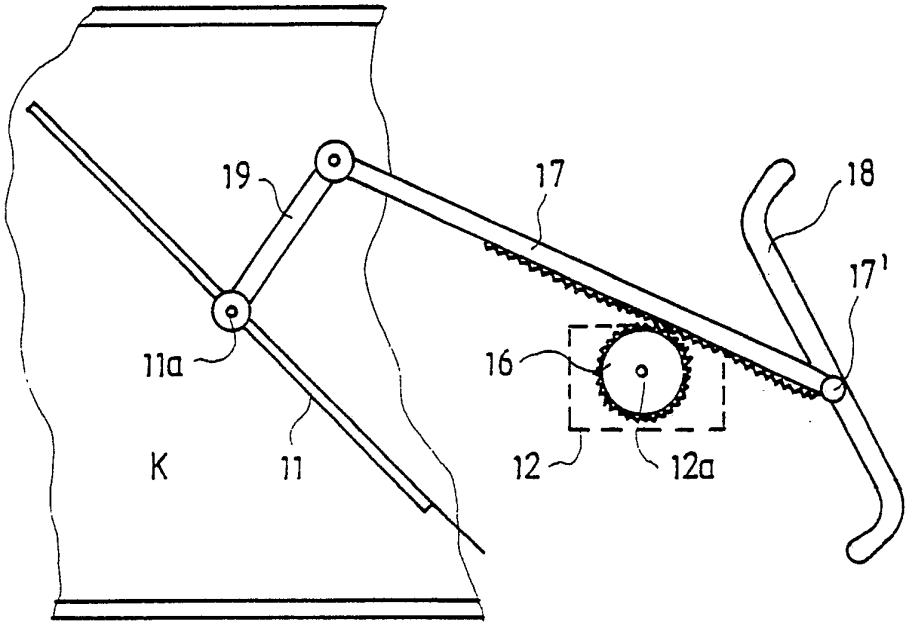

19
17
18
17'
11a
16
K
11
12
12a

FIG. 3B

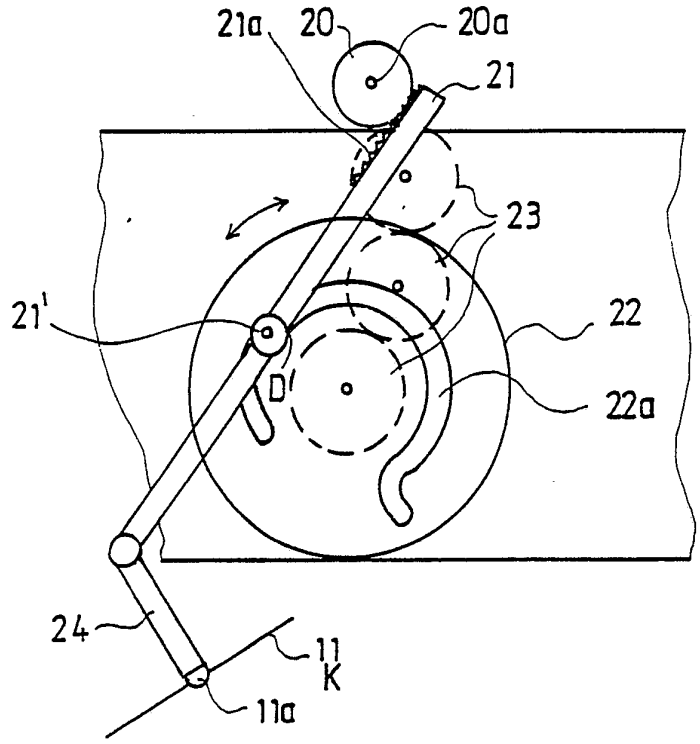


FIG. 3C

INTERNATIONAL SEARCH REPORT

International Application No PCT/FI88/00081

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [6]

According to International Patent Classification (IPC) or to both National Classification and IPC [4]

F 24 F 11/04

II. FIELDS SEARCHED

Minimum Documentation Searched [7]

Classification System	Classification Symbols
IPC 4	F 24 F 11/00, /02, /04, /047, 3/08, /10; F 16 K 31/44, /52, /524, /53, /54
Nat Cl	36d:3/01, /10

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [8]

SE, NO, DK, FI classes as above

III. DOCUMENTS CONSIDERED TO BE RELEVANT [9]

Category [10]	Citation of Document, [11] with indication, where appropriate, of the relevant passages [12]	Relevant to Claim No. [13]
X	SE, C, 224 315 (AB SVENSKA FLÄKTFABRIKEN) 14 January 1969 Fig 3, page 2 & FI C, 37 062	1,2,3
X	FI, C, 34 607 (AB BAHCO) 31 August 1964 Page 3, fig 2 and 3	1,3,4,5,6,8,9,12
X	CA, A, 1 196 710 (BELUSA MANFRED L) 12 November 1985	1,3,5,9,10
Y	Claims 1,5,9,10	2,4,11
X	US, A, 2 154 523 (JOHN T MIDYETTE JR) 18 April 1939 Fig 1,3 and related text)	1,4,6,8,9,12
X	US, A, 4 506 829 (GRANT) 26 March 1985 Fig 5,6 and 9, col 2-4	1,4,6,8,12

../..

* Special categories of cited documents: [10]

"A" document defining the general state of the art which is not considered to be of particular relevance

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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

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IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
1988-08-30	1988 -09- 09
International Searching Authority	**Signature of Authorized Officer**
Swedish Patent Office	Peter de Bellmond

FURTHER INFORMATION CONTINUED FROM THE SECOND SHEET

II Fields serched (cont)

US Cl 98:41; 236:38,49

V. ☐ OBSERVATIONS WHERE CERTAIN CLAIMS WERE FOUND UNSEARCHABLE [1]

This international search report has not been established in respect of certain claims under Article 17(2) (a) for the following reasons:

1. ☐ Claim numbers ..... because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claim numbers ..... because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claim numbers ....., because they are dependent claims and are not drafted in accordance with the second and third sentences of PCT Rule 6.4(a).

VI. ☐ OBSERVATIONS WHERE UNITY OF INVENTION IS LACKING [2]

This International Searching Authority found multiple inventions in this international application as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims of the international application.

2. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims of the international application for which fees were paid, specifically claims:

3. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claim numbers:

4. ☐ As all searchable claims could be searched without effort justifying an additional fee, the International Searching Authority did not invite payment of any additional fee.

Remark on Protest

☐ The additional search fees were accompanied by applicant's protest.

☐ No protest accompanied the payment of additional search fees.

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)

Category *	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No
X	DE, A, 2 519 408 (AERONA INC) 12 February 1976	2
Y		4
	Fig 4, page 12-14 & FR, 2 280 005 US, 3 967 642 US, 3 976 244 GB, 1 456 621 AUD, 80121/75 CA, 1 020 008	
Y	SE, B, 325 457 (COMMISSARIAT À L'ÉNERGIE ATOMIQUE) 29 June 1970 Fig 3	2,6,12
Y	US, A, 619 718 (L W CANADY) 21 February 1899 Fig 2	7,11
A	DE, A, 2 222 127 (DANFOSS A/S) 15 November 1973	