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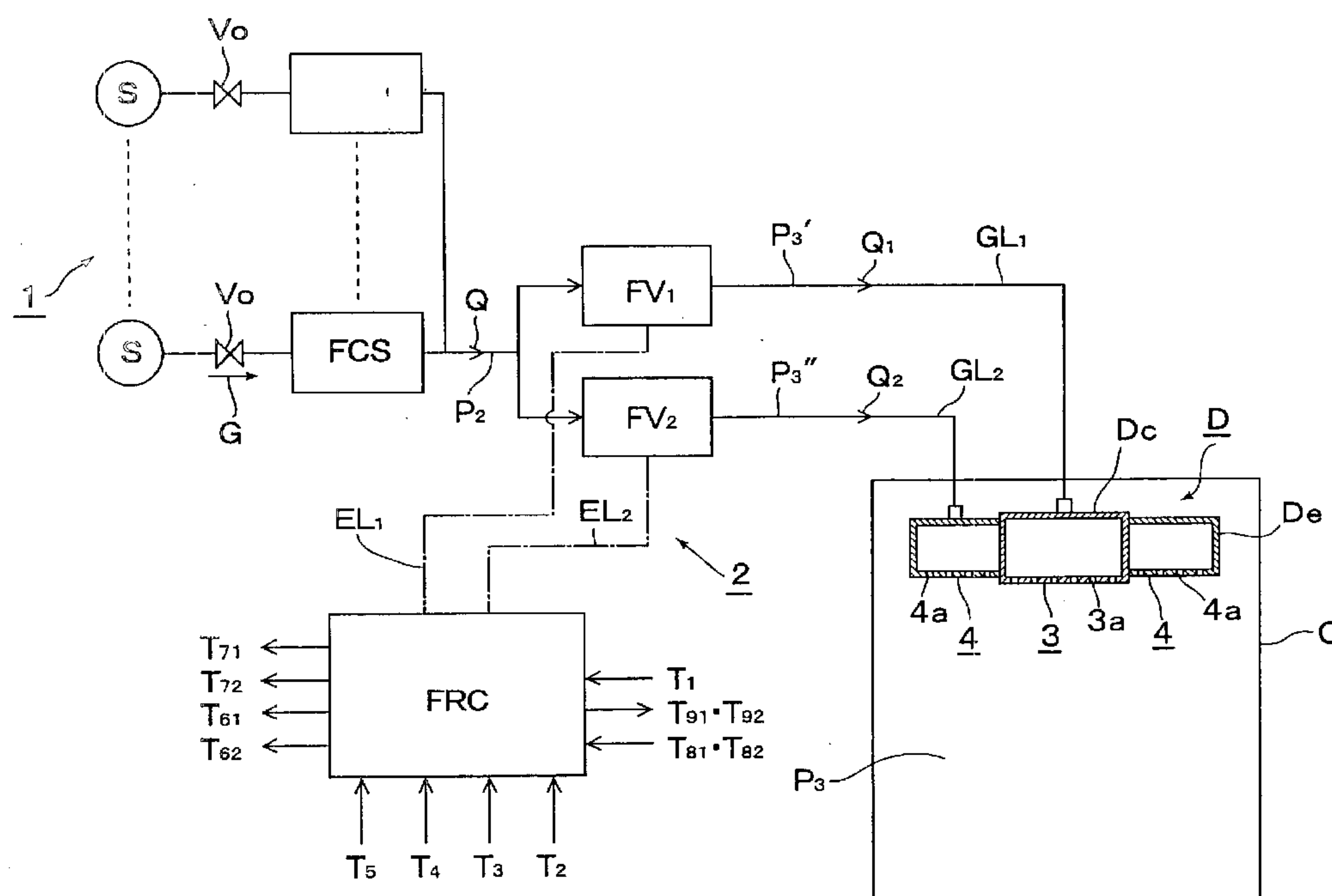
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(54) Titre : PROCEDE POUR ACHEMINER UN GAZ ENTRE UNE INSTALLATION D'ACHEMINEMENT DE GAZ
EQUIPEE D'UN REGULATEUR DE DEBIT ET UNE CHAMBRE, TOUT EN LE DIVISANT
(54) Title: METHOD FOR SUPPLYING DIVIDED GAS TO A CHAMBER FROM GAS SUPPLY APPARATUS EQUIPPED
WITH FLOW-RATE CONTROL SYSTEM



(57) Abrégé/Abstract:

A method for supplying a specified quantity Q of processing gas while dividing at a desired flow rate ratio Q_1/Q_2 accurately and quickly from a gas supply facility equipped with a flow controller into a chamber. When a specified quantity Q of gas is supplied while being divided at a desired flow rate ratio Q_1/Q_2 from a gas supply facility equipped with a flow controller into a pressure reduced chamber C through a plurality of branch supply lines and shower plates fixed to the ends thereof, pressure type division

(57) **Abrégé(suite)/Abstract(continued):**

quantity controllers FV_1 and FV_2 are provided in the plurality of branch supply lines GL_1 and GL_2 . Opening control of both division quantity controllers FV_1 and FV_2 is started by an initial flow rate set signal from a division quantity control board FRC for fully opening the control valve CV of the pressure type division quantity controller having a higher flow rate and pressures P_3' and P_3'' on the downstream side of the control valve CV are regulated thus supplying a total quantity $Q=Q_1+Q_2$ of gas while dividing into the chamber C through orifice holes (3a, 4a) made in shower plates (3, 4) at desired division quantities Q_1 and Q_2 represented by formulas $Q_1=C_1P_3'$ and $Q_2=C_2P_3''$ (where, C_1 and C_2 are constants dependent on the cross-sectional area of the orifice hole or the gas temperature on the upstream side thereof).

Abstract

A method for supplying a specified quantity Q of processing gas while dividing at a desired flow rate ratio Q_1/Q_2 accurately and quickly from a gas supply facility equipped with a flow controller into a chamber. When a specified quantity Q of gas is supplied while
5 being divided at a desired flow rate ratio Q_1/Q_2 from a gas supply facility equipped with a flow controller into a reduced pressure chamber C through a plurality of branch supply lines and shower plates fixed to the ends thereof, pressure type division quantity controllers FV_1 and FV_2 are provided in the plurality of branch supply lines GL_1 and GL_2 . Opening
10 control of both division quantity controllers FV_1 and FV_2 is started by an initial flow rate set signal from a division quantity control board FRC for fully opening the control valve CV of the pressure type division quantity controller having a higher flow rate and pressures P_3' and P_3'' on the downstream side of the control valve CV are regulated thus supplying a
total quantity $Q = Q_1 + Q_2$ of gas while dividing into the chamber C through orifice holes
15 (3a, 4a) made in shower plates (3, 4) at desired division quantities Q_1 and Q_2 represented by formulas $Q_1 = C_1 P_3'$ and $Q_2 = C_2 P_3''$ (where, C_1 and C_2 are constants dependent on the cross-sectional area of the orifice hole or the gas temperature on the upstream side thereof).

Method of supplying divided gas to a chamber from a gas supply apparatus equipped with a flow-rate control system

Field of the invention

5 The present invention relates to an improved method of gas supply for supplying automatically divided gas to a chamber from a gas supply apparatus equipped with a pressure-type flow-rate control system for use in semiconductor manufacturing at semiconductor manufacturing facilities and the like.

10 **Background of the invention**

 The so-called "pressure-type" flow-rate control system has been widely employed for the purpose of controlling the flow rate of gas to be supplied to semiconductor manufacturing facilities.

15 Figure 7 illustrates an example of a situation where a treatment gas G is supplied to a chamber C for forming silicone dioxide films by employing a pressure-type flow-rate control system FCS. The treatment gas G, which has a prescribed flow-rate Q, is supplied *via* the pressure-type flow-rate control system FCS into the chamber C at reduced pressure using a vacuum pump Vp, and is delivered at flow rate Q through a gas discharger D onto a wafer H placed on a supporting device I.

20 On the other hand, said pressure-type flow-rate control system FCS operates on the basis of the theory that when $P_1 > \text{approximately } 2 \times P_2$, a critical expansion pressure condition, is maintained, the flow rate Q of gas passing through an orifice L is determined only by the gas pressure P_1 on the upstream side of the orifice, and the relation is expressed by the equation: $Q = CP_1$ (where C is a constant determined by the calibre of the orifice L and the gas temperature). As a result, the flow rate Q on the downstream side of the orifice
25 can be maintained at a desired set value by adjusting said pressure P_1 with a control valve CV.

 Referring to Figure 7, P_0 indicates the supply pressure of the treatment gas G, P_M a pressure meter, F a filter, CPU a central processing unit, Q_s an input signal for setting the
30 flow rate, and Q_e an output signal for the control flow rate.

 The pressure-type flow-rate control system is disclosed in Toku-Kai-Hei 8-338546 and 11-63265. Accordingly, a detailed explanation is omitted here.

 With regard to said pressure-type flow-rate control system FCS, it is a prerequisite, as

stated above, that the gas pressure P_1 on the upstream side of the orifice, and the gas pressure P_2 on the downstream side of the orifice satisfy the aforementioned critical expansion pressure condition. Hence, it is a disadvantage of the pressure-type flow-rate control apparatus FCS that when the gas pressure P_2 on the downstream side of the orifice rises greatly and disproportionately compared with the gas pressure P_1 on the upstream side of the orifice, the critical expansion pressure condition is no longer satisfied, making it impossible to control the flow rate.

Furthermore, when the pressure P_2 on the downstream side of the orifice rises, and P_1/P_2 approaches the limit value of the above-mentioned critical expansion pressure condition, the accuracy of flow rate control actually decreases. As a result, there is a problem in that the practical range for flow rate control is limited when the pressure P_2 on the downstream side of the orifice increases.

As described above, it is noted that numerous problems arise in connection with gas flow rate control using a pressure-type flow-rate control system when the pressure P_2 on the downstream side of the orifice L increases. On the other hand, according to the pressure-type flow-rate control system, the use of a pressure-type flow-rate control system FCS makes it possible to control accurately with ease the gas flow rate of the gas supply to the chamber. In addition, it is unnecessary to install an additional high precision pressure adjustment device at the gas supply source, thereby permitting a great reduction in the cost of the gas supply device, which is an excellent practical advantage.

On the other hand, it is to be noted that recently there has been a trend for the outer diameter of a silicone wafer for use in manufacturing a semiconductor to become larger and larger. By way of example, if the outer diameter of the wafer H is 300 mm, then it is necessary for the volumes of the treatment gas supplied to the centre part of the wafer and the peripheral part (or edge part) of the wafer to be individually adjusted.

To meet this requirement, if the treatment gas supply to said centre part and the treatment gas supply to said peripheral part are effected by separate supply lines GL_1 and GL_2 as shown in Figure 8, then the treatment gas can be supplied without difficulty at the prescribed flow rates Q_1 and Q_2 from the gas supply source S by the gas supply lines GL_1 and GL_2 , both of which are provided with a pressure-type flow-rate control system FCS.

However, it is not recommended that gas be supplied to a single chamber C using gas supply lines GL_1 and GL_2 having independent pressure-type flow-rate control systems FCS_1 and FCS_2 respectively, because the semiconductor manufacturing equipment is then

forced to be enlarged, the facility cost increases, and maintenance becomes laborious.

To overcome these problems, it is found more desirable that the two gas supply lines GL₁ and GL₂ should be split from a single pressure-type flow-rate control system FCS, as shown in Figure 9, so that the flow rates Q_1 and Q_2 of the separate gas supply lines GL₁ and GL₂ can be controlled by adjusting flow rate control valves V_1 and V_2 installed in the gas supply lines GL₁ and GL₂ respectively.

On the other hand, the pressure-type flow-rate control system FCS commonly used today for gas supply equipment has flow rate control characteristics which can be used optimally when the pressure P_2 downstream of the orifice is in the range 0 – 100 Torr. Therefore, with the aforementioned pressure-type flow-rate control system FCS, when the pressure P_2 downstream of the orifice exceeds approximately 100 Torr, the range of flow rate control is greatly limited with respect to the precision of flow rate control.

For example, referring to Figure 9, assume that the treatment gas G is supplied at a flow rate of $Q = 300$ SCCM, so that the gas G is supplied to the chamber C at flow rates of $Q_1 = 130$ SCCM and $Q_2 = 170$ SCCM through the supply lines GL₁ and GL₂ respectively. Where the gas supply equipment is not one that employs a pressure-type flow-rate control system FCS, the following method can be employed: That is, both of the control valves V_1 and V_2 are first closed; next the treatment gas flow rate of the flow-rate control equipment is set at $Q = 300$ SCCM; then the control valves V_1 and V_2 are adjusted so that both the flow rates Q_1 and Q_2 can be adjusted to the set values automatically, or by checking with a flow-rate meter (not illustrated).

However, where the gas supply equipment employs a pressure-type flow-rate control system FCS as a flow-rate control system as shown in Figure 9, it is difficult first to set the flow rate Q (300 SCCM) of the pressure-type flow-rate control system FCS when both of the control valves V_1 and V_2 are completely closed, and then to adjust swiftly the flow rates Q_1 (130 SCCM) and Q_2 (170 SCCM) of the respective split supply lines GL₁ and GL₂ with great precision by adjusting the control valves V_1 and V_2 .

The reason is as follows: If the control valves V_1 and V_2 are only open to a small extent, then the pressure P_2 on the upstream side of the control valves V_1 and V_2 rises, with the result that the value of P_1/P_2 deviates from the limit value of said pressure-type flow-rate control system FCS. As a result, the flow rate Q established by the pressure-type flow-rate control system FCS differs greatly from the set flow rate ($Q = 300$ SCCM).

Object of the invention

It is an object of the present invention to provide a method of supplying divided gas to a chamber from a gas supply apparatus equipped with a pressure-type flow-rate control system which solves the above-mentioned problems that are encountered when a gas G at a given flow rate Q, adjusted by the pressure-type flow-rate control system FCS, is divided into split supply lines GL₁ and GL₂ with set flow-rates Q₁ and Q₂ according to a conventional method of dividing a gas supply from a gas supply apparatus equipped with a pressure-type flow-rate control system FCS to a chamber C, namely: the flow rate Q controlled by the pressure-type flow-rate control system FCS may deviate greatly from the set flow rate with the result that it is extremely difficult to adjust not only the flow rate Q, but also the flow rates Q₁ and Q₂, if the control method adopted is one in which flow rate control valves V₁ and V₂ installed in the split supply lines GL₁ and GL₂ are first closed completely (or almost closed) and then opened gradually; and the precision of the flow rate control is low and/or it takes too much time to control the flow rate, even if the flow rates Q₁ and Q₂ are somehow adjusted. It is, therefore, another object of the present invention to provide a method of supplying divided gas to a chamber from a gas supply apparatus equipped with a pressure-type flow-rate control system in which gas at a predetermined flow rate Q can be quickly divided and supplied at a desired ratio Q₁/Q₂ with great precision, even if the gas is divided and supplied from a gas supply apparatus equipped with a pressure-type flow-rate control system FCS.

Disclosure of the invention

To achieve the above stated object, the inventors of the present invention have rejected the conventional method used in divided gas supply control for this type of gas supply apparatus in which respective flow-rate control valves V₁ and V₂ installed in split lines are gradually opened from being completely closed (or almost completely closed), and have instead adopted a novel method in which the flow-rate control valves V₁ and V₂ are closed stepwise from being initially fully open (or almost fully open), so that the flow rates Q₁ and Q₂ of the split supply lines GL₁ and GL₂ can be adjusted to a desired flow rate ratio Q₁/Q₂ quickly and with precision, while the overall flow rate Q is controlled with precision by means of the pressure-type flow-rate control system FCS. The inventors have conducted many experiments on the supply of divided gas on the basis of the above-mentioned novel method.

The present invention has been devised on the basis of the aforementioned finding, and also on the results of the experiments on the dividing of gas. The present invention as claimed in claim 1 relates to a method of supplying divided gas, characterised in that gas G with a set flow rate Q is supplied to a chamber C at a prescribed flow rate ratio Q_1/Q_2 from a gas supply apparatus 1 equipped with a flow-rate supply system through a plurality of split supply lines GL_1 and GL_2 and shower plates fixed to the ends thereof, wherein with split pressure-type flow-rate controllers FV_1 and FV_2 installed in said split supply lines GL_1 and GL_2 , control of the patency of said split flow-rate controllers FV_1 and FV_2 is initiated by means of an initial flow-rate setting control signal from a divided flow-rate control board FRC, causing the control valve CV of the split pressure-type flow-rate controller with the greater flow rate to open to its full extent, and the desired split flow rates Q_1 and Q_2 are supplied through orifices 3a and 4a installed in said shower plates 3 and 4 by adjusting the pressures P_3' , P_3'' on the downstream sides of the control valves CV , the flow rates Q_1 and Q_2 being expressed by the formulae $Q_1 = C_1 P_3'$ and $Q_2 = C_2 P_3''$ (where C_1 and C_2 are constants determined by the sectional areas of the orifice holes 3a and 4a and the gas temperature on the upstream side of the orifices), thereby supplying the total amount $Q = Q_1 + Q_2$ into the chamber C .

The invention of claim 2 relates to a method of supplying divided gas to a chamber as claimed in claim 1, wherein said divided flow-rate control board FRC is equipped with a CPU, and is provided with a start and stop signal input terminal T_2 , an initial flow-rate ratio setting signal input terminal T_3 , a shower plate combination indicator signal input terminal T_4 , control flow rate signal output terminals T_{71} and T_{72} for the split pressure-type flow-rate controllers FV_1 and FV_2 , and input/output abnormality alarm output terminals T_{91} and T_{92} for transmitting signals on the basis of the deviation between the flow-rate setting input signals and the control flow rate output signals for the split pressure-type flow controllers FV_1 and FV_2 . With regard to different combinations of shower plates 3 and 4, the pressures P_3' , P_3'' of gas G flowing downstream of the control valves CV of the split pressure-type flow controllers FV_1 and FV_2 when the gas G totalling $Q = Q_1 + Q_2$ flows through the shower plates 3 and 4 respectively at the flow rate ratio Q_1/Q_2 are calculated from the aforementioned $Q_1 = C_1 P_3'$ and $Q_2 = C_2 P_3''$, with the flow rate ratio Q_1/Q_2 being a parameter for a plurality of total flow rates Q , and the initial flow-rate setting signal to the split pressure-type flow-rate controller FV_1 having the greater flow-rate is an input signal voltage V_0 for full opening of the control valve, while the initial flow-rate setting signal to

the other split pressure-type flow-rate controller FV₂ is the aforementioned $P_3''/P_3' \times V_0$. Next, after an indicator signal corresponding to the combination of said shower plates 3 and 4 and the ratio P_3'/P_3'' between the initial flow-rate setting signals for said split pressure-type flow-rate controllers FV₁ and FV₂ have been inputted respectively to said input terminal T₄ and the initial flow-rate ratio setting signal input terminal T₃, the flow rate Q of gas G supplied from the gas supply apparatus 1 is set at a desired flow rate with the control valves CV of said split pressure-type flow-rate controllers FV₁ and FV₂ being fully open. Then, an activation (START) signal is inputted to said start signal input terminal T₂ (STEP 5), and when the input of said start signal is confirmed (STEP 6), the existence or non-existence of said shower plate combination indicator signal and said initial flow-rate ratio setting signal is confirmed (STEP 7). Then, the initial flow-rate setting signals V_0 , $V_0 \times P_3''/P_3'$ for the split pressure-type flow-rate controllers FV₁ and FV₂ obtained from said flow-rate ratio setting signal are progressively increased stepwise at the same rate (STEP 8 and STEP 10). The deviation between the current flow-rate setting input signal and the control flow rate output signal is checked (STEP 9). If it is found that the input and output deviation is within a set range, then the flow-rate setting signals to the split flow-rate controllers FV₁ and FV₂ are reverted to the previous values of the flow-rate setting signals one step before the input-output deviation fell within the set range (STEP 11). The flow-rate setting signals to the split flow-rate controllers FV₁ and FV₂ are then subjected to a ramp-change at the same rate (STEP 13 and STEP 14), while the deviation between the input and output signals is checked continuously (STEP 15). When it is found that the deviation between the input and output signals registered at the time of the ramp-change is within a set range, the flow-rate setting signals registered at that time are fixed and maintained as the flow-rate setting signals for the split flow-rate controllers FV₁ and FV₂ (STEP 16), thereby making it possible to effect the divided supply of the gas G under the said flow-rate setting signals.

The invention of claim 3 according to the invention as claimed in claim 2 is carried out such that the stepwise change of the flow-rate setting signals increases both the flow-rate setting signals at the same stepwise rate, from the initial flow rate setting value (100%) by 50%, 30%, 20%, 10%, and then 5%, every 0.5 seconds.

The invention of claim 4 according to the invention as claimed in claim 2 is carried out such that said ramp-change increases both of said flow-rate setting signals at the same rate of 10% every 0.5 seconds.

The invention of claim 5 according to the invention as claimed in claim 2 is carried out such that when the deviation between the input and output remains continuously nil for more than a certain period of time, then the flow-rate setting signals for the time-being are fixed and maintained as the flow-rate signals for the flow-rate controllers FV₁ and FV₂.

5 The invention of claim 6 according to the invention as claimed in claim 2 is carried out such that the gas pressures on the downstream side of the split pressure-type flow-rate controllers FV₁ and FV₂ are kept at or below 100 Torr, the total flow-rate Q is set at 100 sccm ~ 1600 sccm, and the divided flow-rate ratio Q₁/Q₂ is 1/4, 1/2, 1/1, 2/1, 3/1, or 4/1.

10 The invention of claim 7 according to the invention as claimed in claim 1 or claim 2 is carried out such that the initial flow-rate setting signal for the pressure-type divided flow-rate controller FV₁ or FV₂ having the greater divided flow-rate Q₁ or Q₂ is a voltage input for full opening of the control valve CV, the control voltage input for full patency of the control valve having the greater divided flow-rate being 0v, and the range of the control voltage being 0 ~ 5V.

15 The invention of claim 8 according to the invention as claimed in claim 2 is carried out such that the input and output signals to the terminals of the divided flow-rate control board FRC are serial input and output.

Brief description of the drawings

20 Figure 1 is a complete diagrammatic view illustrating a method of supplying divided gas to a chamber by means of a gas supply apparatus equipped with a flow-rate control system according to the present invention.

Figure 2 is a constructional diagram showing a split pressure-type flow-rate controller FV₁.

25 Figure 3 is a characteristic curve showing the relationship between a flow-rate setting signal, and a flow rate control pressure and a flow-rate output signal for the split pressure-type flow-rate controller FV₁.

30 Figure 4 is a diagrammatic view (a calculated value) for the divided flow supply of Figure 1 showing the relationship between the flow rate control pressures (P₃' and P₃'') for the split pressure-type flow-rate controllers, the total flow-rate Q, and the divided flow ratio Q₁/Q₂ where the combination of shower plates 3 and 4 is as *per* PATTERN 1.

Figure 5 is a diagrammatic view (a calculated value) showing the same relationship as Figure 4, where the combination of shower plates 3 and 4 is as *per* PATTERN 2.

Figure 6 is a flow chart of divided gas flow control using a pressure-type flow-rate control system to illustrate a method of supplying divided gas to a chamber.

Figure 7 is an illustration showing a method of supplying a treatment gas to a chamber C using a conventional pressure-type flow-rate control system FCS.

5 Figure 8 is an illustration showing the division and supply of a treatment gas from a single gas supply source S to a chamber using a plurality of pressure-type flow-rate control systems.

10 Figure 9 is an illustration showing the division and supply of a treatment gas to a chamber from a gas supply source equipped with a pressure-type flow-rate control system using control valves.

List of reference letters and numerals

	1	Gas supply apparatus
	S	Treatment gas supply source
15	Vo	Gas main valve
	FCS	Pressure-type flow-rate control system
	G	Treatment gas
	2	Split flow-rate control system
	FV ₁	Split pressure-type flow-rate controller (split flow-rate controller no. 1)
20	FV ₂	Split pressure-type flow-rate controller (divided flow-rate controller no. 2)
	FRC	Divided flow-rate control board
	C	Chamber
	D	Gas discharger
	Dc	Centre part gas discharger
25	3	Centre part shower plate
	3a	Orifice
	De	Edge part gas discharger
	4	Edge part shower plate
	4a	Orifice
30	GL ₁	Centre part split supply line
	GL ₂	Edge part split supply line
	Q	Total gas flow rate
	Q ₁	Split flow rate

	Q ₂	Split flow rate
	EL ₁ , EL ₂	Signal connection lines
	T ₁	Power source input terminal (DC 15V)
	T ₂	Start stop signals input terminal
5	T ₃	Initial flow rate ratio setting signal input terminal (4 bits input)
	T ₄	Shower plate combination indicator signal input terminal (2 bits)
	T ₅	Automatic zero point adjustment signal input terminal
	T ₆₁ , T ₆₂	Automatic zero point setting error signal output terminals
	T ₇₁ , T ₇₂	Control flow rate signal output terminals
10	T ₈₁ , T ₈₂	Flow rate setting signal input terminals
	T ₉₁ , T ₉₂	Input and output abnormality alarm output terminals
5		Activation (START) STEP
6		Start signal confirmation STEP
7		STEP for confirming the pattern indicator signal and initial flow rate setting
15	signal	
8		STEP for the start of stepwise change of flow rate setting signal
9		STEP for the evaluation of deviation between input and output signals
10		STEP for stepwise decrease in flow rate setting signals
11		STEP for switching the flow rate setting signal back to previous stage
20	12	STEP for evaluation of the deviation between input and output signals
	13	STEP for the start of the ramp-change to the flow rate setting signals
	14	STEP for the ramp-change of the flow rate setting signals
	15	STEP for the evaluation of the deviation between input and output signals
	16	STEP for maintaining the flow rate setting signals
25	17	STEP for confirming maintenance of the flow rate setting signals

Mode of carrying out the invention

The following embodiment of the present invention is described with reference to the attached drawings hereunder.

30 Figure 1 is a complete diagrammatic view illustrating a method of supplying a divided gas to a chamber from a gas supply apparatus equipped with a flow-rate control system according to the present invention.

Referring to Figure 1, a gas supply apparatus 1 comprises *inter alia* a supply source

S of a treatment gas G, a gas main valve Vo, and a pressure-type flow-rate control system FCS.

A divided flow-rate control system 2 comprises *inter alia* split pressure-type flow-rate controllers FV₁ and FV₂, and a divided flow-rate control board FRC.

5 Furthermore, referring to Figure 1, C designates a chamber, D a gas discharger, Dc a centre part gas discharger, De an edge part gas discharger, GL₁ a centre part split supply line, GL₂ an edge part split supply line, Q the total gas flow rate, Q₁ and Q₂ the divided flow rates, P₂ the pressure on the downstream side of the orifice of the pressure-type flow-rate control system FCS, P₃' and P₃'' the pressures on the outlet side of the split pressure-type flow-rate controllers FV₁ and FV₂, P₃ the pressure inside the chamber C, 3 a shower plate of the centre part gas discharger Dc, 3a an orifice formed on the shower plate, 4 a shower plate of the edge part gas discharger De, and 4a an orifice formed on the shower plate.

15 In addition, referring to Figure 1, EL₁ and EL₂ designate signal connection lines connecting the divided flow-rate control board FRC to the split pressure-type flow-rate controllers FV₁ and FV₂, T₁ a power source input terminal, T₂ a start/stop signal input terminal, T₃ an initial flow rate ratio setting signal input terminal, T₄ an orifice plate combination indicator signal input terminal, T₅ an automatic zero point adjustment signal output terminal, T₆₁ and T₆₂ automatic zero point setting error signal output terminals, T₇₁ and T₇₂ control flow rate signal output terminals (output voltages corresponding to P₃' and P₃''), T₈₁, T₈₂ flow rate setting signal input terminals, and T₉₁, T₉₂ input and output abnormality alarm output terminals.

25 Said gas supply apparatus 1 comprises *inter alia* a treatment gas supply source S (supply pressure 250KpaG or more), and a plurality of pressure-type flow-rate control systems FCS (Figure 7). The pressure P₁ upstream of the orifice L is adjusted using the control valve CV by inputting a prescribed flow rate setting signal Q_s to the central processing unit (CPU) of the pressure-type flow-rate control system FCS, and thus the flow rate Q downstream of the orifice is adjusted automatically to the set flow rate Q_s.

30 Further, a control flow rate output signal Q_e corresponding to the adjusted flow rate is outputted from the central processing unit (CPU). If the deviation between the flow rate setting input signal Q_s and said control flow rate output signal Q_e exceeds a set value after a prescribed period of time, then an input and output deviation abnormality signal is dispatched from the CPU (not shown in FIG 7) as described below.

Said divided flow-rate control system 2 comprises *inter alia* a plurality of split pressure-type flow-rate controllers FV_1 and FV_2 , a divided flow-rate control board FRC which controls the controllers FV_1 and FV_2 , and orifice plates 3 and 4 connected to respective split pressure-type flow-rate controllers FV_1 and FV_2 .

5 With regard to the embodiment shown in Figure 1, two split pressure-type flow-rate controllers are employed. However, more than two split pressure-type flow-rate controllers could of course be employed instead. In such case, the number of the orifice plates would be correspondingly more than two, or the number of the supply outlets would also be more than two.

10 Said split pressure-type flow-rate controllers FV_1 and FV_2 are arranged such that the orifice plate L, which is a basic component of a pressure-type flow-rate control system FCS as illustrated in Figure 7, is removed and replaced by the centre part orifice plate 3 (or the edge part orifice plate 4) having orifices 3a (or 4a).

15 In particular, said split pressure-type flow-rate controllers FV_1 and FV_2 are constructed as shown in Figure 2. In the present embodiment, a metal diaphragm valve of the electromagnetic valve actuation type is used so that it can deal easily with high flow rates Q_1 and Q_2 .

The operation of said split pressure-type flow-rate controllers FV_1 and FV_2 is identical to that of the flow-rate control system FCS.

20 With reference to Figure 2, if the relation $P_3' > 2P_3$ is maintained between the pressure P_3 inside the chamber C and the pressure P_3' on the upstream side of the orifices 3a of the centre part orifice plate 3, then the divided flow rate Q_1 can be controlled on the basis of $Q_1 = CP_3'$ by adjusting the pressure P_3' using the control valve CV, where C is a constant determined *inter alia* by the cross-sectional area of the orifice 3a, its shape, and the gas temperature.

25 Referring to Figure 2, said divided flow-rate control board FRC is provided *inter alia* with said power source input terminal T_1 , the input terminal T_2 for the start stop signal [which opens one of the control valves CV of FV_1 and FV_2 fully (i.e. to its full extent) while opening the other one to a set patency], said initial flow-rate ratio setting signal input terminal T_3 , the shower plate combination indicator signal input terminal T_4 which is explained below, said automatic zero point adjustment signal input terminal T_5 , said automatic zero point adjustment error signal output terminals T_{61} and T_{62} , said control flow rate signal output terminals T_{71} and T_{72} , said set flow rate signals Q_1 and Q_2 input terminals

T₈₁, T₈₂, and said input and output abnormality alarm output terminals T₉₁, T₉₂, and is connected to the pressure-type flow-rate controllers FV₁ and FV₂ through said signal connection lines EL₁, EL₂.

Thus, when an actuation signal is inputted to said input terminal T₂, the respective
 5 split pressure-type flow-rate controllers FV₁ and FV₂ start operating at a predetermined initial set flow rate ratio. (In particular, as described below, the control valve CV of the split flow-rate controller for the greater flow rate of the two flow rates Q₁ and Q₂ is opened to its full extent, whilst the degree to which the control valve CV of the other flow-rate controller is opened is adjusted to a value obtained from "the full opening degree x a
 10 coefficient (<1) as calculated in advance".

When a stop signal is inputted to the input terminal T₂, the control valves CV of both the split pressure-type flow-rate controllers FV₁ and FV₂ are shut fully.

Furthermore, a zero point adjustment signal is normally inputted to the automatic zero point adjustment signal input terminal T₅ for automatic zero point adjustment of the
 15 split pressure-type flow-rate controllers FV₁ and FV₂ before the actuation signal is inputted to said input terminal T₂.

If automatic zero point adjustment is not performed as required, then an alarm is outputted to the automatic zero point adjustment error signal output terminals T₆₁, T₆₂.

An initial flow rate ratio setting signal calculated on the basis of the supply flow
 20 rate ratio Q₁/Q₂ between the flow rates Q₁ and Q₂ for the split supply lines GL₁ and GL₂ respectively, using the numerical values listed in Table 1 given below, is inputted to said initial flow rate ratio setting signal input terminal T₃.

Referring to the embodiment of the present invention, said flow rate ratio Q₁/Q₂ can be set to one of 1/1, 1/2, 1/3, 1/4, 2/1, 3/1, and 4/1. The initial flow rate ratio setting signal
 25 calculated based on this set flow rate ratio is inputted to the input terminal T₃ in the form of a 4-bit digital signal. The flow rate ratio Q₁/Q₂ and the initial flow rate setting ratio signal are of course not of the same values.

Further, each numerical value listed in Table 1, as explained below, designates the ratio P₃''/P₃' between the control pressures P₃' and P₃'' upstream of the orifices 3a and 4a,
 30 where the control pressures P₃' and P₃'' upstream of the orifices 3a, 4a required to discharge said gas G at said prescribed flow rates Q₁ and Q₂ are calculated on the basis of the calibres and numbers of the orifices 3a and 4a in the shower plates 3, 4 connected to the ends of the split gas supply lines.

A signal to indicate the combination of the shower plates (orifice plates) 3, 4 of the gas dischargers Dc, De is inputted to said terminal T4. In particular, in the present embodiment, two kinds of centre part shower plate 3 are provided, one equipped with 420 orifices 3a, and the other with 480 orifices 3a. Similarly, two kinds of edge part shower plate 4 are provided, one equipped with 360 orifices 4a, and the other with 476 orifices 4a.

Two different combinations of said shower plates 3, 4 are predetermined; namely, one combination of the shower plate 3 having 420 orifices 3a and the shower plate 4 having 360 orifices 4a (hereinafter called PATTERN 1); and the other combination of the shower plate 3 having 480 orifices 3a and the shower plate 4 having 476 orifices 4a (hereinafter called PATTERN 2). 2-bit digital signals indicating said PATTERN 1 or PATTERN 2 are inputted to said terminal 4.

Said control flow rate output signal output terminals T71 and T72 are output terminals for indicating the control flow rates (actual flow rates) Q1 and Q2 of the split pressure-type flow-rate controllers FV1 and FV2 in operation, and the control flow rates (actual flow rates) Q1 and Q2 are outputted in the form of a voltage output (0 ~ 5V).

Said flow rate setting signal input terminals T81, T82 are input terminals for voltage signals of 0 ~ 5V corresponding to the flow rates Q1 and Q2 supplied to the split supply lines GL1 and GL2.

Since the total flow-rate Q is set by the upstream side pressure-type flow-rate control system FCS, and the initial flow rate ratio setting signal calculated on the basis of the flow rate ratio Q1/Q2 is inputted to the terminal T3, the level of the flow rate setting signals of the divided flow rates Q1 and Q2 can be automatically calculated inside the CPU. Consequently, it is unnecessary in practice to input flow rate setting signals for the flow rates Q1 and Q2 to said input terminals T81, T82 in advance. However, it is desirable that the flow-rates Q1 and Q2 could be set independently at the split pressure-type flow-rate controllers FV1 and FV2 in order to deal with a situation where the total flow-rate Q cannot be set with great precision by the upstream pressure-type flow-rate control system FCS, or where the gas is supplied directly from the treatment gas supply source S to the split pressure-type flow-rate controllers FV1 and FV2. For this reason it would be desirable that said input terminals T81, T82 are installed.

Said input and output abnormality alarm output terminals T91, T92 compare the flow rate setting signals for the flow rates Q1 and Q2 with the control flow rate signals (actual flow rates Q1 and Q2) and sends an abnormality signal if the deviation between the flow

rate setting signal and the actual control flow rate signal is found to be greater than a prescribed value even after the lapse of a predetermined period of time.

The present embodiment is arranged such that the input and output signals at the prescribed levels are inputted and outputted directly to the terminals of the divided flow-rate control board FRC. However, input and output signals by serial communication could
5 of course be used for the input and output signals for the terminals.

Divided flow-rate control using said pressure-type divided flow-rate controllers FV₁ and FV₂ is conducted by controlling the pressure P₃' and P₃'' on the downstream side using the control valves CV as mentioned above. In the present embodiment, divided
10 pressure-type flow rate controllers FV₁ and FV₂ are used which have the characteristics shown in Figure 3 as between the setting signals (0 ~ 5V) for the flow rates Q₁ and Q₂, the control pressure P₃ (Torr), and the output signals (0 ~ 5V) for the actual flow rate (the control flow rate).

Figure 4 is a graphical presentation of numerical values calculated using the flow
15 rate ratio ($C/E=Q_1/Q_2$) as a parameter, representing the relationship between the total flow-rate Q, the control pressure P₃' for the centre part split pressure-type flow-rate controller FV₁, and the control pressure P₃'' for the edge part split pressure-type flow-rate controller FV₂, for the combination of the shower plate 3 having 420 orifices and an inside diameter of 0.2mm. for the centre part gas discharger D_c and the shower plate 4 having 360 orifices
20 and an inside diameter of 0.2mm. for the edge part gas discharger D_e (PATTERN 1). By way of example, where $Q_1/Q_2 = 1$ and $Q = 1600, 1200, 800, 400$ and 100 SCCM, the mean value of the ratio P₃''/P₃' between the centre part control pressure P₃' and the edge part control pressure P₃'' is 0.961.

Similarly, Figure 5 is a graphical presentation of numerical values calculated in the
25 same manner as those of Figure 4 for the combination of the shower plate 3 having 480 orifices 3a and an inside diameter of 0.2mm. for the centre part gas discharger D_c and the shower plate 4 having 476 orifices 4a and an inside diameter of 0.2mm. for the edge part (PATTERN 2). By way of example, where $Q_1/Q_2 = 1$ and $Q = 1600, 1200, 800,$ and 100 SCCM, the mean value of the ratio P₃''/P₃' between the centre part control pressure P₃' and
30 the edge part control pressure P₃'' is 0.999.

Table 1 is a list of calculated values showing the relationship between the flow rate ratio Q_1/Q_2 and the ratio P₃''/P₃' (i.e. edge part control pressure / centre part control pressure) for PATTERN 1 and PATTERN 2 as shown in Figures 4 and 5. Table 1 shows that

if, for example, PATTERN 1 is employed for the combination of the shower plates 3 and 4 in use and the flow rate ratio Q_1/Q_2 is set to 1, then the ratio P_3''/P_3' between the control pressure P_3' for the centre part split pressure-type flow-rate controller FV_1 and the control pressure P_3'' for the edge part split pressure-type flow-rate controller FV_2 is

5 computationally 0.961.

Said relationship between Q , Q_1/Q_2 and P_3''/P_3' is calculated using the following computation formulae for conductance:

The gas flow rate Q in a pipe is expressed as

$$Q = C \times (P_1 - P_2) \dots$$

10 whilst $C = 182 \times D^4 \times (P_1 + P_2)/2 \times 1/L \dots$,

wherein C designates conductance (L/sec), D the diameter of the pipe (cm), L the length of the pipe length (cm), P_1 the pressure (Torr) at the upstream end of the pipe, P_2 the pressure (Torr) at the downstream end of the pipe, and Q the flow rate (Torr.L/sec).

15 The pressure (P_3' and P_3'') inside the pipe on the upstream side of the shower plates is calculated using and . above, with the inside diameter of the orifice hole of the shower plate as D , the length of the orifice hole of the shower plate as L , the internal pressure ($P_3 = 0.015$ Torr) of the chamber as the downstream side pressure P_2 , and the flow rate in each orifice hole as the flow rate Q .

20 **Table 1**

Flow rate ratio Q_1/Q_2	PATTERN 1	PATTERN 2	Initial flow rate ratio setting
	Control pressure ratio P_3''/P_3'	Control pressure ratio P_3''/P_3'	
1/1	0.961	0.999	Full opening (initial setting input signal = 5V) of FCSV ₂ for flow rate Q_2
1/2	0.679	0.705	
1/3	0.557	0.578	
1/4	0.481	0.498	
2/1	0.736	0.707	Full opening (initial setting input signal = 0V) of FCSV ₁ for flow rate Q_1
3/1	0.601	0.579	
4/1	0.520	0.500	

The method of supplying a divided gas to a chamber according to the present

invention is explained below.

With reference to Figures 1 and 2, if the actuation signal is not inputted to input terminal T₂ of the divided flow-rate control board FRC, then the control valves CV of both of the pressure-type flow-rate controllers FV₁ and FV₂ are opened to their full extent. As a result, the treatment gas supplied from the gas supply source S and adjusted to the flow rate Q by means of the pressure-type flow-rate control system FCS is supplied through the split flow-rate controllers FV₁ and FV₂ at a ratio corresponding approximately to the ratio between the respective total areas of the nozzle holes 3a and 3b of the shower plates 3 and 4.

Now, for divided supply of the gas G having said total flow-rate Q at a prescribed ratio Q₁/Q₂ (for example Q₁/Q₂ = 2/1), an indicator signal (PATTERN 1) corresponding to the combination pattern of the shower plates 3 and 4 of the gas dischargers Dc and De that are connected to the ends of the split supply lines GL₁ and GL₂ is first inputted to input terminal T₄, and then an initial flow rate ratio setting signal is obtained from the desired flow rate ratio Q₁/Q₂ on the basis of Table 1, and the obtained signal is inputted to input terminal T₃.

In particular, where the combination pattern of the shower plates 3 and 4 is PATTERN 1, and the divided flow rate ratio Q₁/Q₂ is 2/1, the flow rate setting signal to the centre part split pressure-type flow-rate controller FV₁ is $5 - 1.000 \times 5 = 0V$, using Table 1. The initial flow rate setting signal to the edge part split pressure-type flow-rate controller FV₂ on the edge side is $5 - 0.736 \times 5 = 1.32V$, from Table 1. In this example, therefore, an initial flow rate setting signal of 0 / 1.32 is inputted to input terminal T₃.

In accordance with the embodiment, the initial flow-rate ratio setting to be inputted to both of the split pressure-type flow-rate controllers is calculated in advance using Table 1, and then what is obtained is inputted to the input terminal T₃. However, as an alternative, the following is also possible. That is, said flow rate setting signal input terminals T₈₁, T₈₂ could be provided, and the divided flow rates Q₁ and Q₂ could be inputted to the respective terminals. The data from Table 1 could be pre-stored in the internal CPU, and said initial flow-rate setting ratio 0 / 1.32 could be calculated within the CPU.

Of course, prior to the start of the divided flow supply, automatic zero point adjustment should be carried out on the split pressure-type flow-rate controllers FV₁ and FV₂ by applying an automatic zero point adjustment signal to input terminal T₅.

With reference to Figure 6, for the starting operation (STEP 5) the actuation (start)

signal is applied to terminal T₂, and then the presence of said start signal is verified (STEP 6). Once the input of the start signal has been acknowledged, the presence of a shower plate combination indicator signal (the pattern signal) which has been inputted to terminal T₄, and the presence of an initial flow rate ratio setting signal which has been inputted to terminal T₃ are verified (STEP 7).

When the input of the initial rate ratio setting signal has been acknowledged, the stepwise changing of said initial flow rate setting ratio signal commences (STEP 8).

Specifically, when the initial flow rate ratio setting signal is inputted to terminal T₃ (in this embodiment, the value of the initial flow rate setting ratio is 0.736, where the initial flow rate setting value for FV₁ is 0V and the initial flow rate setting value for FV₂ is 1.325V), the initial flow rate setting values are inputted to both of the split pressure-type flow-rate controllers FV₁ and FV₂ such that said controllers FV₁ and FV₂ pass the gas at flow rates corresponding to the initial flow rate setting values, while control flow rate output signals, corresponding to the current flow rates, are outputted to the terminals T₇₁ and T₇₂.

Said control flow rate output signals for said split pressure-type flow-rate controllers are compared with the flow rate setting input signals at STEP 9 to check if there is any deviation between the input and output signals.

If it is found that the deviation between the input and output signals exceeds a set value for a prescribed duration, then the flow rate setting signals to the split out flow-rate controllers FV₁ and FV₂ are increased stepwise at the same rate (or degree) (STEP 10).

Specifically, the input value of the flow rate setting signal to the split flow-rate controller FV₁ for the greater flow rate Q₁ is increased stepwise by 100% . 50% . 30% . 20% . 10% . 5% / 0.5 sec., and contemporaneously the input value of the flow rate setting signal to the split flow-rate controller FV₂ for the lesser flow rate Q₂ side is adjusted so as to maintain the same flow rate ratio.

In particular, in accordance with this embodiment, the initial flow rate ratio setting value is 0.736 (3.68/5) [said initial flow rate setting value for FV₁ is 0 (5 - 5 = 0) V, and the initial flow rate setting value for FV₂ is 1.32 (5 - 3.68 = 1.32) V], and said initial flow rate setting value of 0 (5 - 5 = 0) V and initial flow rate setting value of 1.32 (5 - 3.68 = 1.32) V are respectively increased stepwise at the same rate by 50% . 30% . 20% . 10% . 5% / 0.5 sec. With the 50% change in the first stage (stage 1), the initial flow rate ratio setting is increased to 2.5 (5 - 5 x 0.5 = 2.5) / 3.16 (5 - 2.5 x 0.736 = 3.16).

And with the elapse of every 0.5 seconds thereafter, said stepwise changes are repeated in the series:

- 3.5 (5 - 5 x 0.3) / 3.896 (5 - 1.5 x 0.736) (stage 2);
 4.0 (5 - 5 x 0.2) / 4.264 (5 - 1 x 0.736) (stage 3);
 5 4.5 (5 - 5 x 0.1) / 4.632 (5 - 0.5 x 0.736) (stage 4); and
 4.75 (5 - 5 x 0.05) / 4.816 (5 - 0.25 x 0.736) (stage 5).

When the deviation between the input and output signals at STEP 9 falls within a set range as a result of the stepwise changes of said flow rate setting signal inputs, the input values of the flow rate setting signals for the split flow-rate controllers FV₁ and FV₂ are
 10 caused to return to the input signal values for the immediately preceding stage (STEP 11), and then the presence of the deviation between the input and output signals is rechecked

If the deviation between the input and output signals at STEP 9 exceeds a value corresponding to 3% of the full scale (that is, 5V) for more than about 0.5 seconds, then it
 15 is determined that there is an abnormality in the deviation and the stepwise change moves on to the next stage.

When the existence of a deviation between the input and output signals is recognized at STEP 12, ramp control commences (STEP 13) to cause the flow rate setting signal inputs for the split flow-rate controllers FV₁ and FV₂ undergo a ramp change at the same
 20 rate or degree following on from the present flow rate setting signals.

By way of specific explanation, the ramp change in said flow rate setting signals is carried out in such a manner that the flow rate setting signal input to the split flow-rate controller FV₁ having the greater flow rate Q₁ is subjected to a ramp change of 10% / 0.5 seconds, whilst the flow rate setting signal input for the split flow-rate controller FV₂
 25 having the lesser flow rate Q₂ is increased contemporaneously at the same rate (STEP 14). The deviation between the flow rate setting signal input after application of the ramp change and the current control flow rate signal output observed at that time is then checked at STEP 15.

For example, in the embodiment described above, assuming that no deviation is found
 30 between the input and output at stage 4 of STEP 10 (i.e. a flow rate setting ratio of 4.5 / 4.632), the flow rate setting signals for the split flow-rate controllers FV₁ and FV₂ are reverted to their state at stage 3 of STEP 10 (i.e. a flow rate setting ratio of 4.0 / 4.264). Then, once the flow rate setting input to the split pressure-type flow-rate controller FV₁ has

been set to 4.0V and the flow rate setting input to the split pressure-type controller FV₂ has been set to 4.264V (STEP 11), the existence or non-existence of a deviation between the input and output signals is confirmed once again at STEP 12. The ramp change of the flow-rate setting signals then commences at STEP 13. The flow rate setting signal input of 4.0V to said split pressure-type flow-rate controller FV₁ is subjected to said ramp change at a rate of 0.5V / 0.5 second, while the flow rate setting signal input of 4.264V to the split pressure-type flow-rate controller FV₂ is increased at the rate of $0.5V \times 0.736 = 0.368V$ / 0.5 second.

Subsequently, the deviation between said flow rate setting signal input which has been subjected to the ramp change and the control flow rate signal output is checked at STEP 15. When a deviation is not seen (that is to say, when it falls below the prescribed value) continuously for a given time, e.g. for 0.1 seconds, the flow rate setting signal inputs to the split flow-rate controllers FV₁ and FV₂ are fixed and maintained at the flow rate setting signal values of STEP 14 respectively (STEP 16).

Lastly, in STEP 17, the existence or non-existence of the input of said fixed and maintained flow rate setting signal is verified, and thus automatic control of the divided flow rate by the split flow-rate controllers FV₁ and FV₂ for the divided supply of the material gas (flow rate Q) from the gas supply source S is accomplished.

That is, the material gas G having the prescribed flow rate Q from the gas supply source S is divided in the prescribed flow rate ratio Q_1/Q_2 such that it is supplied to the wafer H placed inside the chamber C *via* the gas dischargers Dc and De.

Effects of the invention

In accordance with the present invention, a treatment gas G having a flow rate Q is divided and supplied to a pressure chamber C from a gas supply apparatus equipped with a pressure-type flow-rate control system FCS through split pressure-type flow-rate controllers FV₁ and FV₂, wherein flow rate control of the split pressure-type flow-rate controllers FV₁ and FV₂ is initiated by means of an initial flow rate control setting signal from a divided flow-rate control board FRC which causes the control valve CV of the pressure-type flow-rate controller for the greater divided flow rate to open fully, and wherein the treatment gas G is divided and supplied to the controllers FV₁, FV₂ at divided flow rates Q₁ and Q₂ expressed as flow rates $Q_1 = C_1 P_3'$ and $Q_2 = C_2 P_3''$ (where C₁ and C₂ are constants) by adjusting the pressures P₃' and P₃'' on the downstream side of said

respective control valves CV, using the orifices 3a and 4a of the shower plates 3 and 4 provided in the chamber C.

Consequently, according to the present invention, even with treatment gas from a gas supply apparatus equipped with a pressure-type flow-rate control system FCS, the pressure P_2 on the downstream side of the orifice of the pressure-type flow-rate control system FCS is not permitted to rise sharply at the time of splitting the flow, with the result that the total flow rate Q can be controlled to the desired flow rate value with precision regardless of the divided control by means of the pressure-type flow-rate controllers FV_1 and FV_2 .

According to the present invention, operation of the present invention can be performed in an extremely easy and inexpensive manner because the orifices 3a and 4a of the shower plates 3 and 4 provided inside the chamber C are effectively utilized as component parts of the split pressure-type flow-rate controllers FV_1 and FV_2 , and, further, both of the split pressure-type flow-rate controllers FV_1 and FV_2 are practically identical to the pressure-type flow-rate control system FCS.

Furthermore, according to the present invention, the initial flow rate setting signal causes the control valve of the split pressure-type flow-rate controller having the greater flow rate to be fully opened (opened to its full extent) and the control valve of the other split pressure-type flow-rate controller to be opened to a degree equal to the full opening $\times$ (where $\cdot$ is a computed opening ratio P_3''/P_3' calculated in advance in accordance with the final flow rate ratio Q_2/Q_1) for commencing divided flow rate control, wherein rough adjustment of the divided flow rate ratio Q_1/Q_2 is performed first by stepwise changes of said flow rate setting signals, and then, when it is found that the deviation between the input and output signals is within a prescribed range, the flow rate setting signals are subjected to a ramp-change once the flow rate setting signals have been returned to the ones one step previously. The flow rate setting input signal and the control flow rate output signal are then compared with one another. When it is found that the deviation between the input and output signals has been brought below a set value for a prescribed time, then the flow rate signals are fixed and maintained as final flow rate setting signals to the split pressure-type controllers FV_1 and FV_2 .

As a result, the method according to the present invention makes it possible to conduct divided flow rate control by means of pressure-type flow-rate controllers FV_1 and FV_2 with extreme promptness and precision with respect to many flow rate ratios Q_1/Q_2 .

As explained above, the present invention achieves excellent, practical effects.

Claims

1 A method of supplying divided gas to a chamber from a gas supply apparatus equipped with a flow rate control system,

5 characterised in that a gas G with a set flow rate Q is supplied into a chamber C at a prescribed flow rate ratio Q_1/Q_2 from a gas supply apparatus 1 equipped with a flow rate supply system through a plurality of split supply lines GL_1 and GL_2 and shower plates 3 and 4 attached to the ends thereof,

10 wherein, with split pressure-type flow-rate controllers FV_1 and FV_2 installed in said plurality of split supply lines GL_1 and GL_2 , control of the degrees of opening of said split flow-rate controllers FV_1 and FV_2 is commenced by means of an initial flow rate setting control signal from a divided flow-rate control board FRC causing the control valve CV of the split pressure-type flow-rate controller having the greater flow rate to open to its full extent,

15 and the desired divided flow rates Q_1 and Q_2 are supplied through orifices 3a and 4a provided in said shower plates 3 and 4 by adjusting the pressures P_3' , P_3'' on the downstream side of the control valves CV,

with the flow rates Q_1 and Q_2 being expressed by the formulae $Q_1=C_1P_3'$ and $Q_2=C_2P_3''$ (where C_1 and C_2 are constants determined by the sectional areas of the orifice holes 3a and 4a and the gas temperature on the upstream side of the orifice),

20 thereby supplying the total amount $Q = Q_1 + Q_2$ into the chamber C.

2 A method of supplying divided gas into a chamber C from a gas supply apparatus equipped with a flow-rate control system to a chamber as claimed in claim 1,

25 wherein the divided flow-rate control board FRC is equipped with a CPU, and is provided with a start and stop signal input terminal T_2 , an initial flow rate ratio setting signal input terminal T_3 , a shower plate combination indicator signal input terminal T_4 , control flow rate signal output terminals T_{71} and T_{72} for the split pressure-type flow-rate controllers FV_1 and FV_2 , and input/output abnormality alarm output terminals T_{91} , T_{92} for transmitting signals on the basis of a deviation between the flow rate setting input signals and the control flow rate output signals for the split pressure-type flow-rate controllers FV_1 and FV_2 ,

30

wherein with regard to a plurality of combinations of said shower plates 3 and 4, when the gas G totalling $Q = Q_1 + Q_2$ flows through the shower plates 3 and 4 respectively at the flow rate ratio Q_1/Q_2 the pressures P_3' and P_3'' of gas flowing downstream of the

control valves CV of the split pressure-type flow controllers FV₁ and FV₂ are calculated from $Q_1=C_1P_3'$ and $Q_2=C_2P_3''$, with the flow rate ratio Q_1/Q_2 being a parameter for a plurality of total flow rates Q,

5 the initial flow rate setting signal to the split pressure-type flow-rate controller FV₁ having the greater flow rate is caused to be an input signal voltage V₀ for full opening of the control valve, while the initial flow rate setting signal to the other split pressure-type flow-rate controller FV₂ is caused to be said $P_3''/P_3' \times V_0$,

10 whereafter, once a signal indicating the combination of the shower plates 3 and 4 and the ratio P_3'/P_3'' between the initial flow rate setting signals for said split pressure-type flow-rate controllers FV₁ and FV₂ have been inputted respectively to said input terminal T₄ and said initial flow rate ratio setting signal input terminal T₃, the flow rate Q of the gas supplied from the gas supply apparatus 1 is set at a desired flow rate with the control valves CV of the split pressure-type flow-rate controllers FV₁ and FV₂ being fully opened,

15 whereafter an actuation (START) signal is inputted to said start signal input terminal T₂ (STEP 5), the existence or non-existence of said shower plate combination indicator signal and said initial flow rate ratio setting signal being verified (STEP 7) once the input of said start signal is confirmed (STEP 6),

20 then the initial flow rate setting signals $V_0 / V_0 \times P_3''/P_3'$ for the split pressure-type flow-rate controllers FV₁ and FV₂ obtained from said flow rate ratio setting signal are progressively increased stepwise at the same rate (STEP 8 and STEP 10),

the deviation between the flow rate setting input signal and the control flow rate output signal presently observed is checked (STEP 9),

25 if it being found that the input and output deviation is within a set range, then the flow rate setting signals to the divided flow-rate controllers FV₁ and FV₂ are reverted to their values as at one stage or step before the input-output deviation fell within said set range (STEP 11), and thereafter the flow rate setting signals for the split flow-rate controllers FV₁ and FV₂ are subjected to a ramp change at the same rate (STEP 13 and STEP 14) while the deviation between the input and output signals is continuously checked (STEP 15), and when it is found that the deviation between the input and output signals
30 registered at the time of the ramp change is within a set range, the flow rate setting signals registered at that time are fixed and maintained as the flow rate setting signals for the split flow-rate controllers FV₁ and FV₂ (STEP 16),

thereby making it possible to effect divided supply of said gas G under said flow

rate setting signals.

3 A method of supplying divided gas to a chamber from a gas supply apparatus
equipped with a flow-rate control system as claimed in claim 2, wherein the stepwise
change of the flow rate setting signals is caused to increase both of the flow rate setting
5 signals at the same stepwise rate from the initial flow rate setting value (100%) by 50% to
30% to 20% to 10% and 5% every 0.5 seconds.

4 A method of supplying divided gas to a chamber from a gas supply apparatus
equipped with a flow-rate control system as claimed in claim 2, wherein said ramp change
is effected such that both of the flow rate setting signals are increased by 10% at the same
10 rate every 0.5 seconds.

5 A method of supplying divided gas to a chamber from a gas supply apparatus
equipped with a flow-rate control system as claimed in claim 2, wherein if the deviation
between the input and output stays continuously nil for more than a given period of time,
then the flow rate setting signals at that moment are fixed and maintained as the flow rate
15 signals for the flow-rate controllers FV₁ and FV₂.

6 A method of supplying divided gas to a chamber from a gas supply apparatus
equipped with a flow-rate control system as claimed in claim 1 or claim 2, wherein the
internal pressure of the chamber C is maintained at 5 ~ 30Torr, the gas pressures on the
downstream side of the split pressure-type flow-rate controllers FV₁ and FV₂ are kept at or
20 below 100Torr, the total flow rate Q is set at 100 sccm ~ 1600 sccm, and the divided flow
rate ratio Q₁/Q₂ is 1/4, 1/2, 1/1, 2/1, 3/1, or 4/1.

7 A method of supplying divided gas to a chamber from a gas supply apparatus
equipped with a flow-rate control system as claimed in claim 1 or Claim 2, wherein the
initial flow rate setting signal for the one of the split pressure-type flow-rate controllers
25 FV₁ or FV₂ having the greater divided flow rate Q₁ or Q₂ is a voltage input for full opening
of the control valve CV, the control voltage input for full opening of the control valve CV
having the greater divided flow rate being 0v, and the range of the control voltage being 0
~ 5V.

8 A method of supplying divided gas to a chamber from a gas supply apparatus
30 equipped with a flow-rate control system as claimed in claim 2, wherein the input and
output signals to the terminals of the divided flow-rate control board FRC are serial
communication input and output signals.

FIG. 1

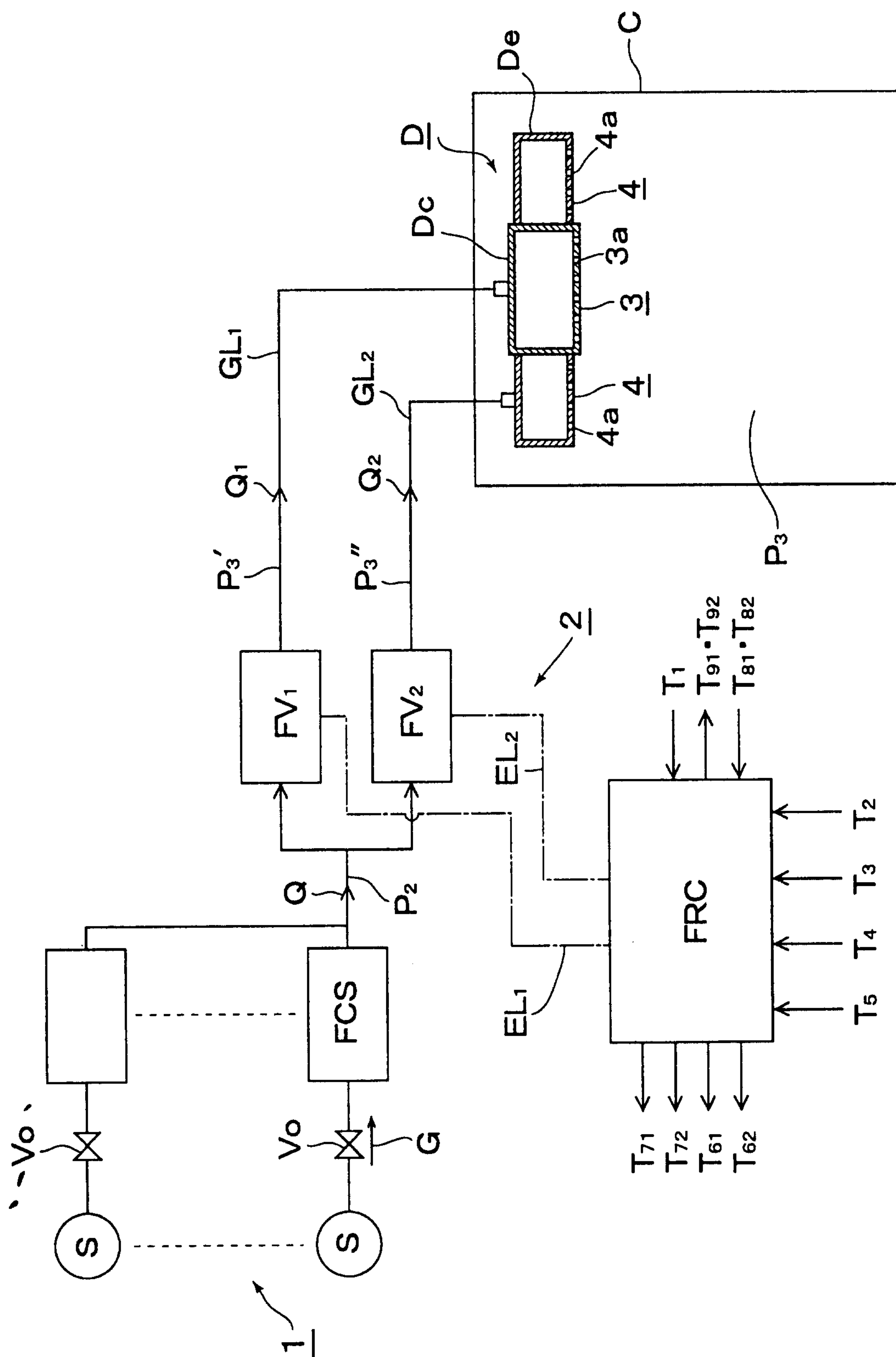


FIG. 2

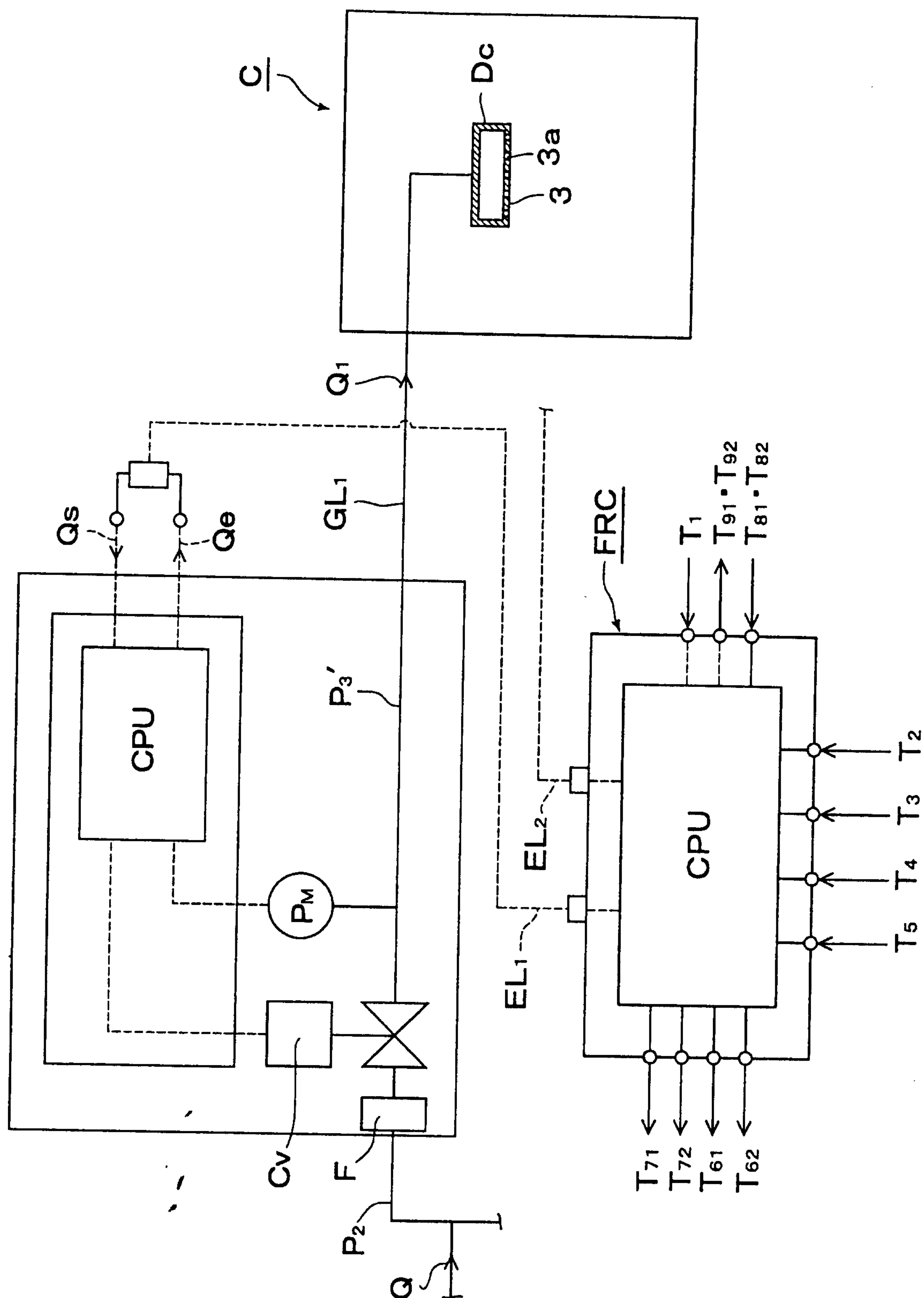
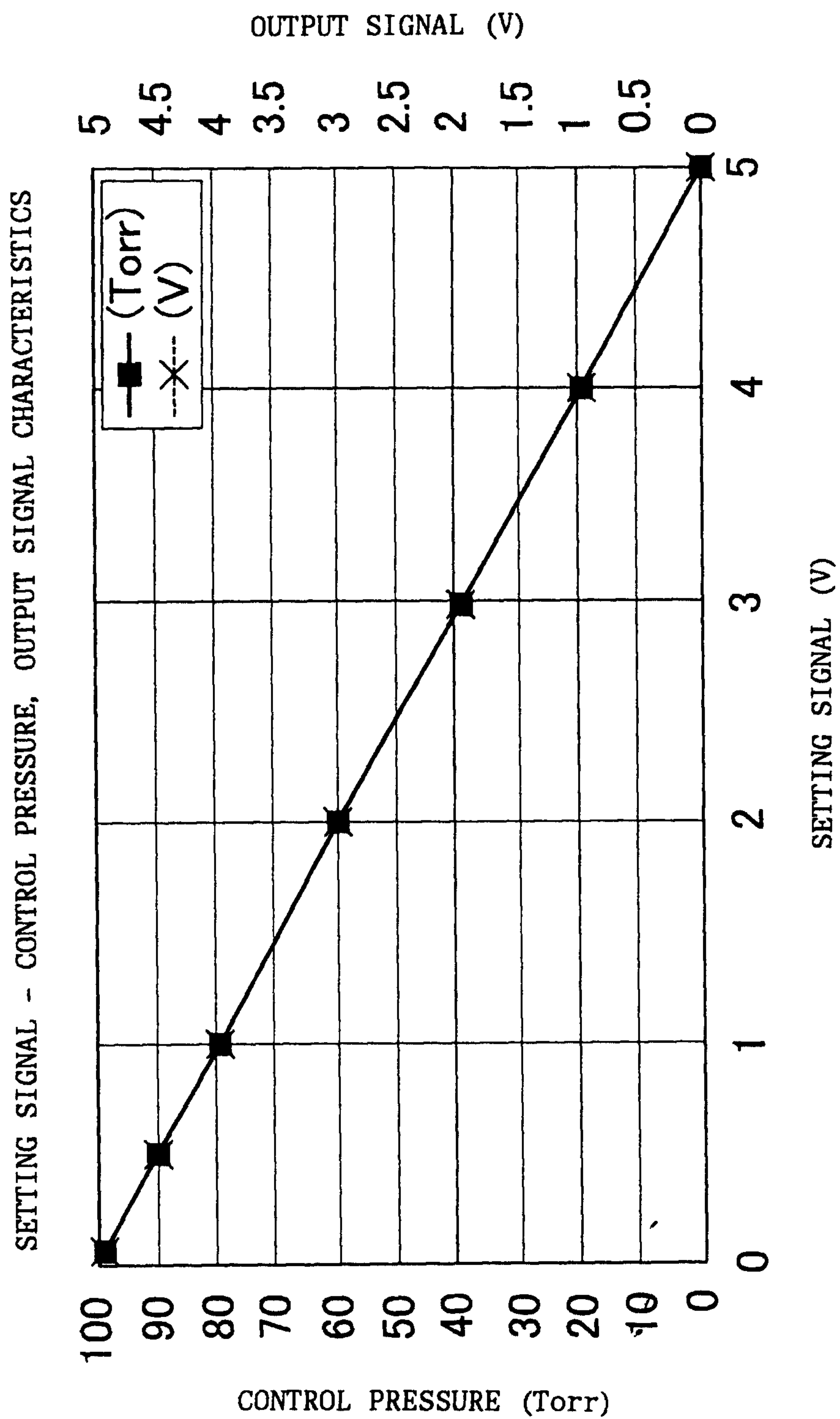


FIG. 3



FCS - FV CONTROL PRESSURE CHARACTERISTICS (CALCULATED VALUES)
AT THE TIME OF DIVIDED FLOW

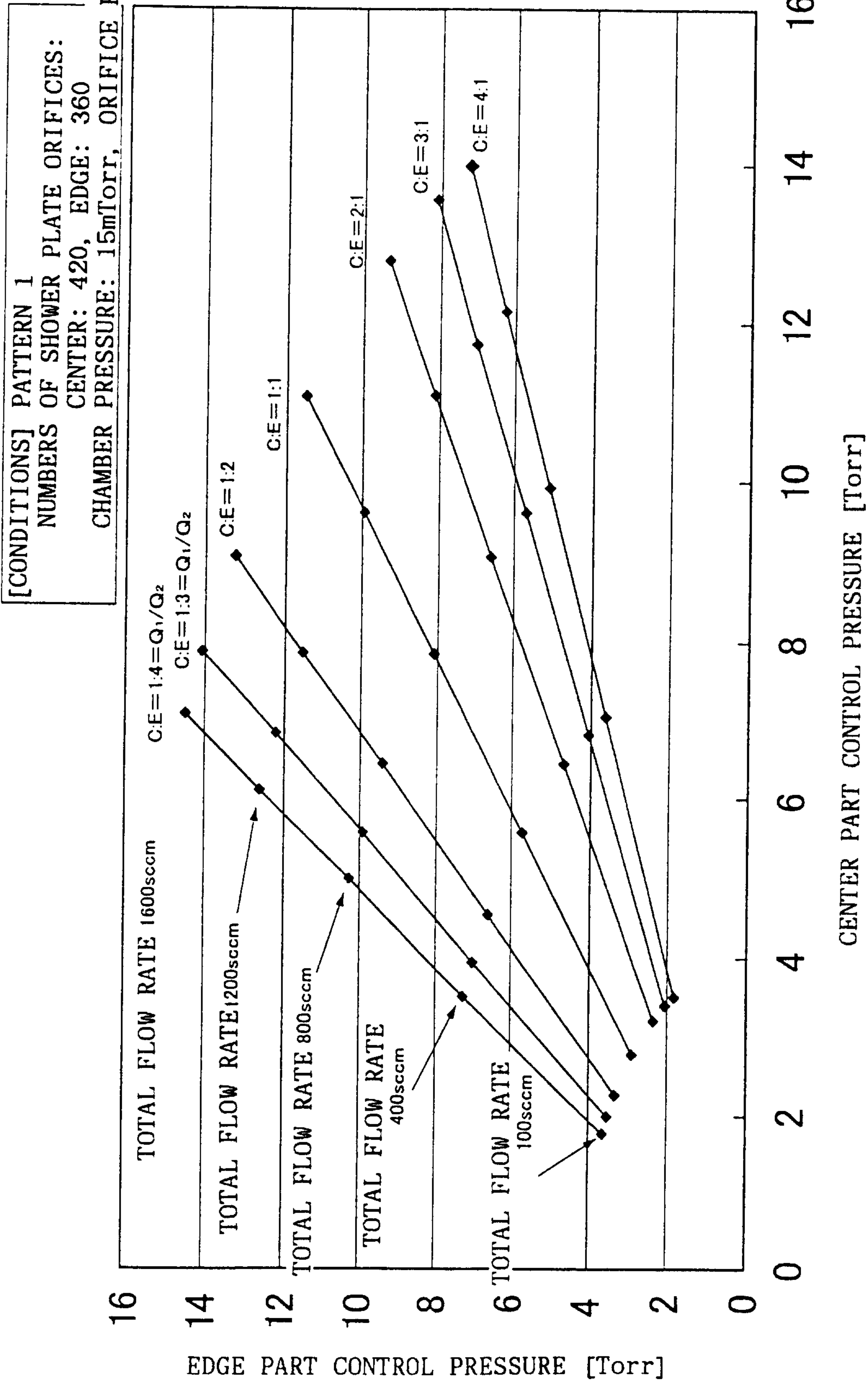


FIG. 4

FCS - FV CONTROL PRESSURE CHARACTERISTICS (CALCULATED VALUES)
AT THE TIME OF DIVIDED FLOW

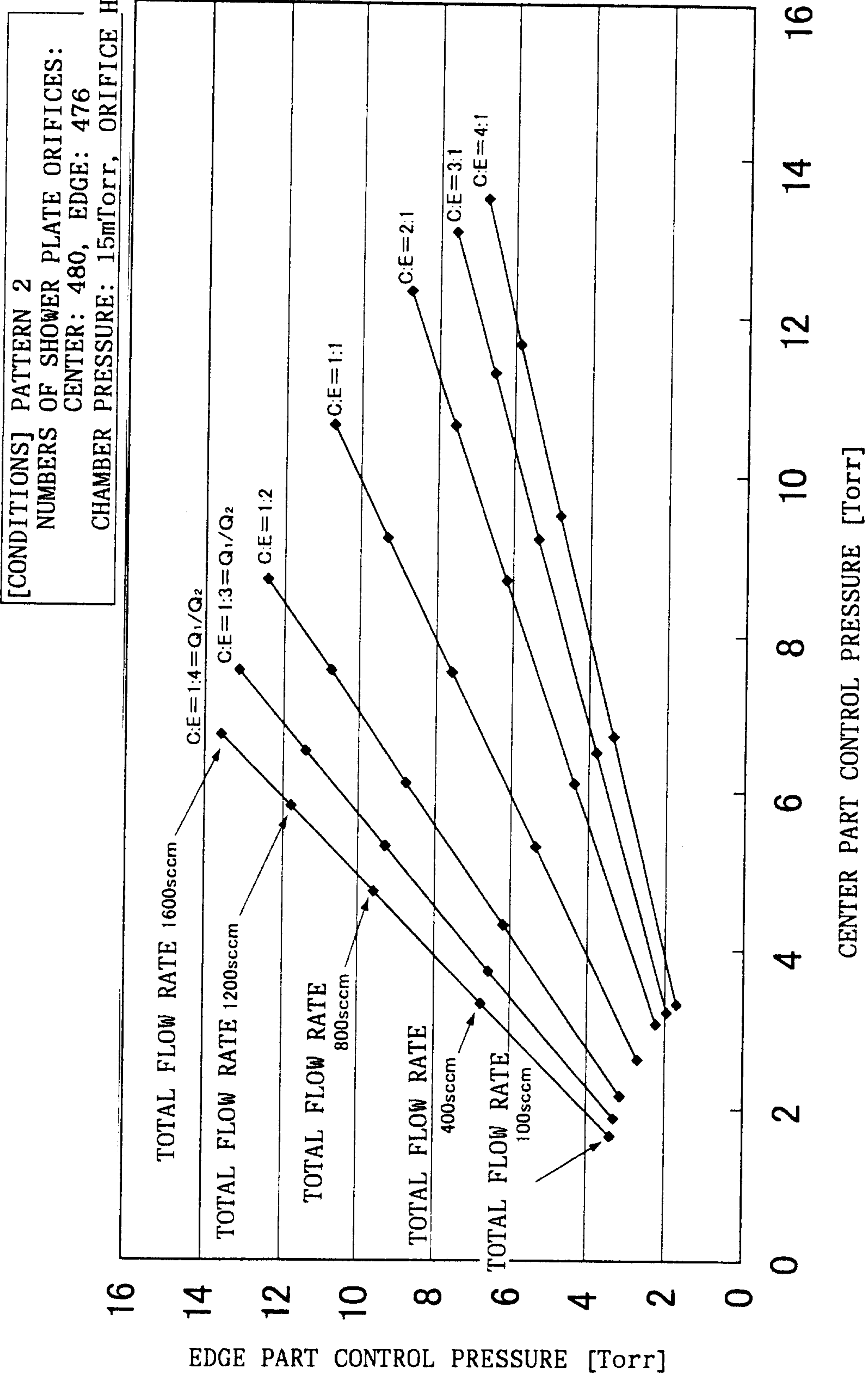


FIG. 5

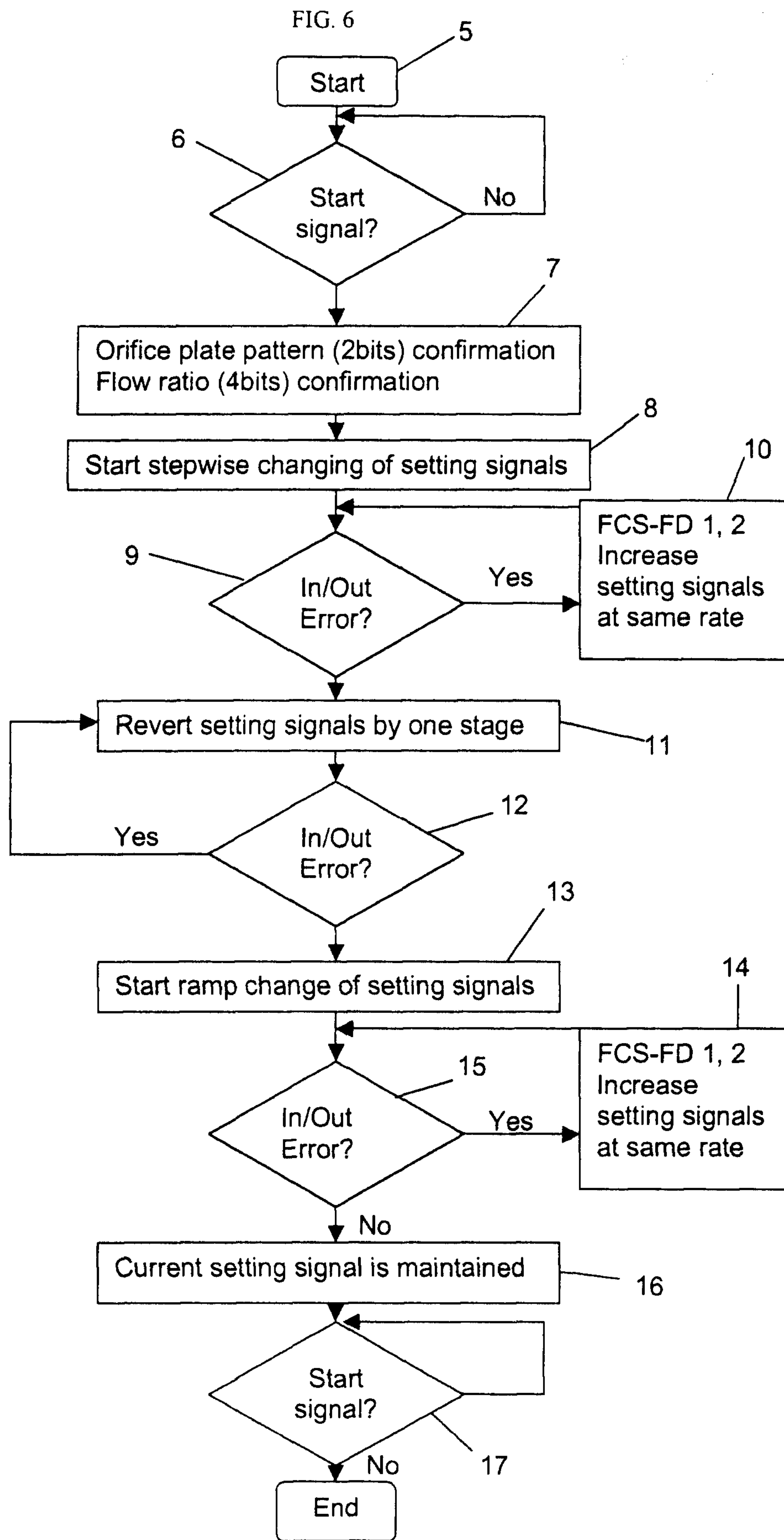


FIG. 7

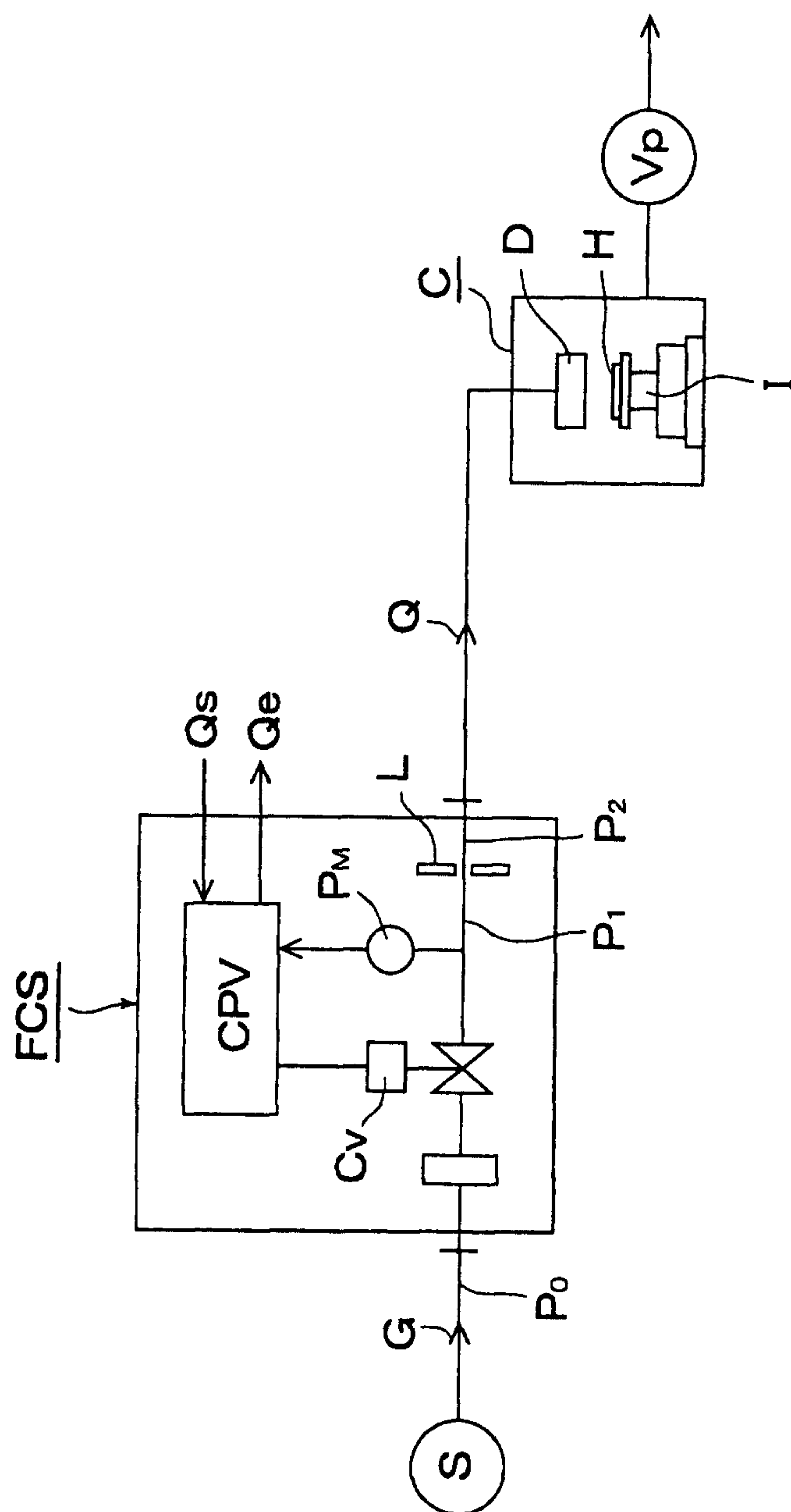


FIG. 8

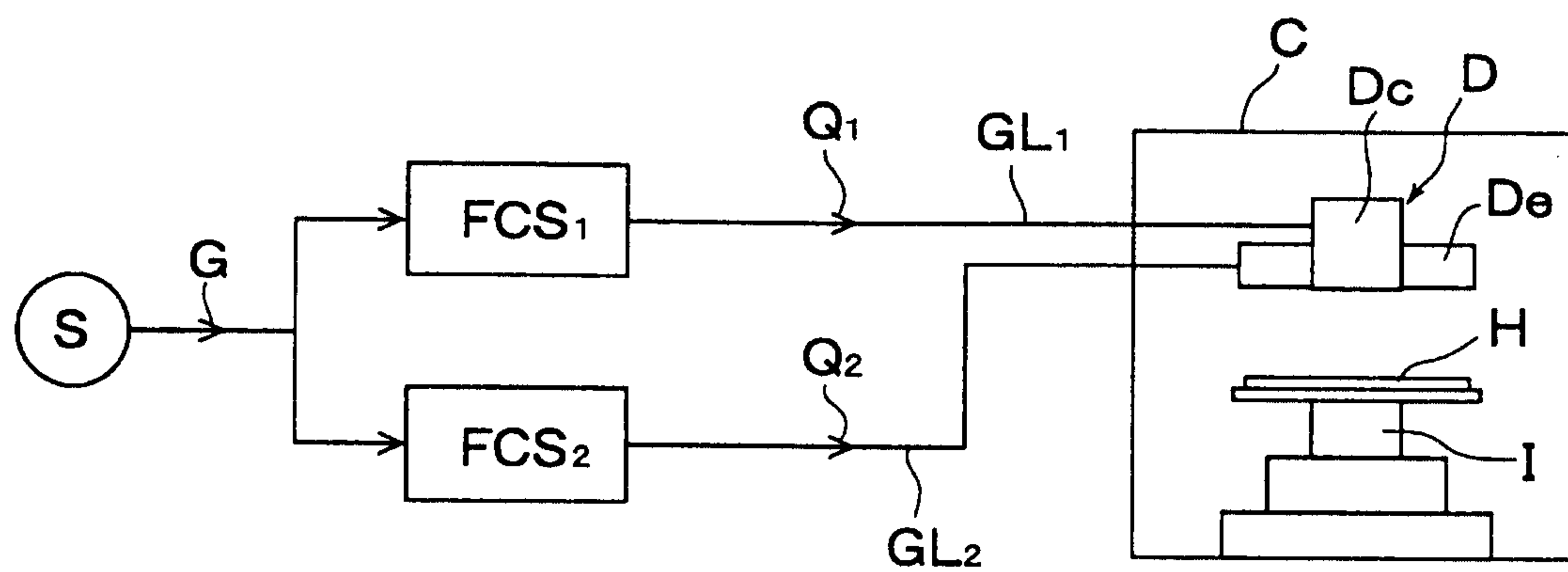


FIG. 9

