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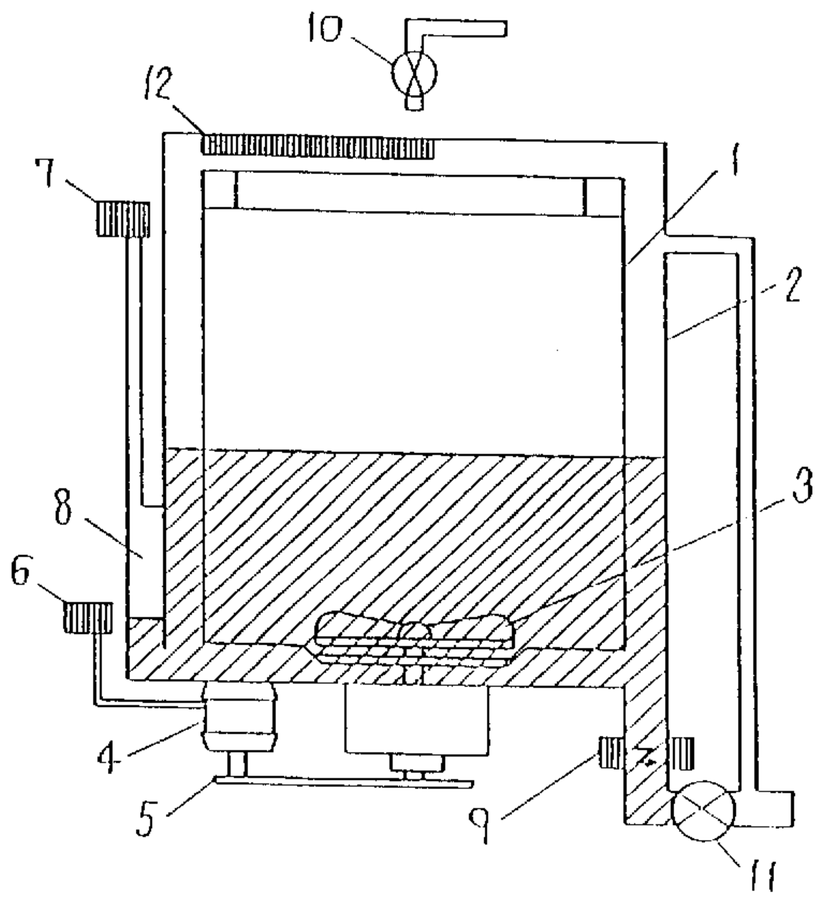
(54) **MACHINE A LAVER**
(54) **WASHING MACHINE**



(57) Because of being provided with a cleaning sensor (9) detecting the soiling of the laundry and a washing time inference unit (14) determining the washing time by means of the fuzzy inference with having a time through which the detected value of this cleaning sensor reaches its saturation and the detected value at that time as the input thereof, and in this washing time inference unit (14), the extent of soiling and the type of soiling which an operator judges as the degree of the soiling are input in a form of a detected value at the time when the cleaning sensor (9) indicated a saturation and a time up to reaching this saturation, and at the same time, the rule by which the user determines the washing time from the degree of soiling (extent of soiling and type of soiling) is realized by the fuzzy inference, then the washing time determined by the washing time inference unit (14) can be made to be the same as the user determines from his or her experience and know-how, enabling attaining a fine and most suitable washing which can be done by the user.

ABSTRACT

Because of being provided with a cleaning sensor (9) detecting the soiling of the laundry and a washing time inference unit (14) determining the washing time by means of the fuzzy inference with having a time through which the detected value of this cleaning sensor reaches its saturation and the detected value at that time as the input thereof, and in this washing time inference unit (14), the extent of soiling and the type of soiling which an operator judges as the degree of the soiling are input in a form of a detected value at the time when the cleaning sensor (9) indicated a saturation and a time up to reaching this saturation, and at the same time, the rule by which the user determines the washing time from the degree of soiling (extent of soiling and type of soiling) is realized by the fuzzy inference, then the washing time determined by the washing time inference unit (14) can be made to be the same as the user determines from his or her experience and know-how, enabling attaining a fine and most suitable washing which can be done by the user.

SPECIFICATION

TITLE OF THE INVENTION

Washing machine

FIELD OF THE INVENTION

The present invention relates to a washing machine performing washing control utilizing fuzzy inference.

BACKGROUND OF THE INVENTION

Heretofore, a washing machine that automatically determines various washing conditions by being provided with various kinds of sensor has been proposed.

For example, there exists a washing machine which is equipped with a cleaning sensor for detecting the degree of deterioration of washing water and determines the cleaning time according to the information from this cleaning sensor. There exists also a washing machine which is equipped with a cloth amount sensor which detects the laundry volume and determines the water level and the water flow at the time of cleaning as well as rinsing according to the information from this sensor. Furthermore, also there exists a washing machine which is equipped with, in addition to the above-mentioned cleaning sensor and cloth amount sensor, a manual-setting input part for setting manually various washing conditions of such as

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laundry volume, water flow, washing time. In the washing machines equipped with these various kinds of sensors as well as the manual-setting input part, although various washing conditions such as washing time or the water level were determined automatically according to the information from various sensors such as the cleaning sensor and others, the determination of the washing conditions in accordance with the information from various sensors and the determination of the washing conditions in accordance with the manual-setting input part were done independently.

However, in such washing machines of the prior art in which the washing time is determined by the information from the cleaning sensor, the relationship between the degree of deterioration of washing water and the washing time is expressed with a simple mathematical formula such that the setting is done in a manner that when the degree of deterioration of washing water is great, the cleaning time is made long, and then based on this mathematical formula the washing time is determined automatically. As a result, the washing time could not be determined based on a relationship between the washing time and the degree of deterioration of washing water gained from the experience of a user, bringing about a great difference from the washing time which was intended to be

determined by the user. This gave a problem that the most suitable washing time based on the user's experience could not be set for the washing machine.

Furthermore, neither washing water flow nor rinse water flow can be determined uniquely by the cloth amount, they should be determined also with considering the degree of soiling of the laundry (amount and type of soiling of the laundry). In washing machines of the prior art, however, since the water flow is determined only by the information from the cloth amount sensor and the degree of soiling of the laundry is not taken into account for the determination of the water flow, there has been a problem that careful washing and rinsing taking every factor into account could not be done.

Also, although the most suitable water level should be determined by mass, type, volume, etc. of the laundry, in the washing machines of the prior art, the water level was determined only by the information from the cloth amount sensor, there has been a problem that the water level was not sufficiently established.

Furthermore, in the washing machines of the prior art, since the determination of the washing condition and the determination of the washing condition through the manual-setting input part are independent of each other, the washing condition cannot be determined by a

combination of the information through the manual-setting input part which is the information on the sort of laundry that is difficult to be detected by the sensor and the detected values from the various sensors, hence there has been a problem that it was very difficult to determine the various washing conditions corresponding to laundry comprising a mixture of multiple sorts of items.

Furthermore, there has been a problem that, by adding the information through the manual-setting input part given manually by a user to the determination of the washing condition by the detected values from various sensors, "the most suitable washing" according to the various sensors and "washing according to the user's taste" could not be realized at the same time.

DISCLOSURE OF THE INVENTION

The object of the present invention is firstly to offer a washing machine which can determine the most suitable washing time based on the user's experience.

A further object of the present invention is to provide a washing machine which can determine the washing water flow as well as the rinse water flow by also taking the degree of soiling of the laundry into account.

Yet a further object of the present invention is to provide a washing machine which can determine the most

suitable water level by also referring to the detected value from a water level sensor provided in addition to a cloth amount sensor

Yet a further object of the present invention is to provide a washing machine which can determine various washing conditions corresponding to laundry comprising a mixture of multiple sorts of items.

Yet a further object of the present invention is to provide a washing machine wherein determination of "the most suitable washing" according to the various sensors and "washing according to the user's taste" by the manual input can be realized at the same time, and it can determine firstly the water level reflecting the user's taste, secondly the water flow reflecting the user's taste, thirdly the washing time as well as the rinse time reflecting the user's taste, and fourthly various washing conditions also reflecting user's taste.

A washing machine controller according to the present invention comprises:

a cleaning sensor for detecting the turbidity of water and the degree of soiling of laundry in a washing tub during a washing operation of the washing machine;

time measurement means for measuring a saturation time period from a start of a washing operation to a time point of saturation, the time point of saturation being determined when the detected turbidity saturates;

said washing time inference means for determining a washing time of a cleaning operation based on said saturation time period and the detected turbidity;

control means for controlling a motor for said washing operation; and

said control means stopping said motor when said washing time expires.

By affording the washing time inference unit the user's know-how at the time of determination of the washing time depending on the soiling of laundry, from the detected value of the cleaning sensor, the most suitable washing time can be determined by the fuzzy inference.

In a preferred embodiment of the invention, the machine is provided with a cleaning sensor for detecting the degree of deterioration of the washing water, a cloth amount sensor for detecting the quantity of laundry, a timer for measuring the washing time and the rinse time, and a water flow inference unit which receives the detected values of the cleaning sensor and the cloth amount sensor and the timer value from the timer as its input and thereby makes the fuzzy inference on the washing water flow and the rinse water flow.

In this arrangement, from the degree of removal of the soiling of the laundry detected by the cleaning sensor, the cloth amount detected by the cloth amount sensor, and the washing time and the rinse time detected by the timer,

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the washing water flow and rinse water flow are determined by the water flow inference unit. At this time, by affording the water flow inference unit the know-how of the water flow control, which users generally know from their experience, an appropriate determination of the water flow allowing human input can be attained.

In a further preferred embodiment, the machine is provided with the cloth amount sensor for detecting the quantity of laundry, a water level inference unit for making the inference on the predetermined water level, a water level sensor for detecting the water level, and a water-supply valve control means for controlling a water-supply valve according to the comparison between the detected value of the above-mentioned water level sensor and the predetermined water supply level determined by the inference of the above-mentioned water level inference unit.

In this arrangement, by determining the predetermined water-supply water level by the water level inference unit from the detected value of the cloth amount sensor immediately before the washing and rinse processes, then starting the water supply and detecting the water level rising

rate from the detected value of the water level sensor, and providing that the water-supply valve control means controls the water-supply valve by comparing the above-mentioned predetermined water-supply water level and the water level rising rate, the most suitable water level determination becomes possible.

In yet a further preferred embodiment, the machine is provided with a manual-setting input part for accepting the manual input by an operator on the type and the quantity of laundry, the cloth amount sensor for detecting the cloth amount, the cleaning sensor for detecting the degree of soiling, the washing condition inference unit which receives information from the above-mentioned manual-setting input part and the detected values of the cloth amount sensor and the cleaning sensor as its input and thereby determines various washing conditions, and a control part for controlling a motor, the water supply valve, and a drain valve responding to various washing conditions determined by the above-mentioned washing condition inference unit.

In this arrangement, since the fuzzy inference is made by determination of various washing conditions with considering simultaneously multifold sets of information such

as information concerning the type and the quantity of the laundry from the manual-setting input part as well as the detected values of the cloth amount sensor and the cleaning sensor, and the control part controls the motor, water supply valve, and the drain valve responding to the washing condition, an appropriate washing can be attained.

In yet a further preferred embodiment, the machine has a first means which is provided with the manual-setting input part for accepting the manual input by the operator on the water volume and the extent of soiling, the cloth amount sensor for detecting the cloth amount, and a water volume determination means which receives the detected value of the above-mentioned cloth amount sensor as well as the information from the above-mentioned manual-setting input part as its input and thereby determines the washing water level and the rinse water level by the fuzzy inference.

The machine has a second means that is provided with the manual-setting input art for accepting the manual input by the operator on the wash mode, the cloth amount sensor for detecting the cloth amount, and the water flow determination means which receives the detected value of the above-

mentioned cloth amount sensor as well as information obtained from the above-mentioned manual-setting input part as its input and thereby determines the washing water flow and the rinse water flow by the fuzzy inference.

The machine has a third means that is provided with the manual-setting input part for accepting the manual input by the operator on the degree of soiling, the cloth amount sensor for detecting the cloth amount, and the cleaning sensor for detecting the deterioration, and the washing time determination means which receives the detected value of the above-mentioned various sensors as well as information obtained from the above-mentioned manual-setting input part as its input and thereby determines the washing time and the rinse time by the fuzzy inference.

The machine has a fourth means that is provided with the manual-setting input part for accepting the manual input by the operator on the water volume, the extent of soiling, and the mode of washing, the cloth amount sensor for detecting the cloth amount, the cleaning sensor for detecting the deterioration, and a fuzzy inference unit which receives the detected values of various sensors and the information obtained from the above-mentioned manual-setting input part as

its input and thereby determines various washing conditions of water level, washing time, rinse time, washing water flow, rinse water flow, and others.

In accordance with the above first means, although normally the adequate water level is determined by making the fuzzy inference by the water level determination means using the detected value of the cloth amount sensor, the water level determination is made reflecting the user's taste in the adequate water level range according to the information obtained by the manual-setting input part which accepts the manual input by the user on the water volume and the extent of soiling.

In accordance with the above second means, although normally the adequate water flow is determined by making the fuzzy inference by the water level determination means using the detected value of the cloth amount sensor, the water flow determination is made reflecting the user's taste in the adequate water flow range according to the information obtained by the manual-setting input part which accepts the manual input by the user on the mode of washing.

In accordance with the above third means, although normally the adequate washing time as well as the rinse time are determined by making the fuzzy inference by the water level determination means using the detected

value of the cloth amount sensor and the cleaning sensor, the washing time as well as the rinse time determination are made reflecting the user's taste in the adequate time range according to the information obtained by the manual-setting input part which accepts the manual input by the user on the extent of soiling.

In accordance with the above fourth means, an adequate water level is determined from the detected value of the cloth amount sensor, and the washing water flow and the rinse water flow are determined from this detected value and the above-mentioned adequate water level. And the washing time is determined from the detected value of the cleaning sensor and the above-mentioned adequate water level and water flow. Although the above-mentioned various washing conditions are determined using a multiple-stage inference by the fuzzy inference unit, determination of those various washing conditions is made reflecting the user's taste in the adequate range of various washing condition according to the information obtained by the manual-setting input part which accepts the manual input by the user on water volume, extent of soiling, and mode of washing.

BRIEF EXPLANATION OF THE DRAWINGS

FIG. 1 is a constitutional drawing of a washing machine according to an embodiment of the present

invention;

FIG. 2 is a block diagram of a washing machine in a first embodiment of the present invention;

FIG. 3 is a block diagram of a washing time inference unit;

FIG. 4 is a block diagram showing a washing time inference rule of the same;

FIG. 5(a), (b), and (c) are graphs showing membership functions of saturation time, light-transmittance, and washing time, respectively;

FIG. 6 is a graph showing a result of inference of the washing time inference unit;

FIG. 7 is a graph showing a function between washing time and light-transmittance;

FIG. 8(a) is a graph of a weighted monotonous type membership function;

FIG. 8(b) is a drawing showing a fuzzy inference rule;

FIG. 9 is an input-output characteristic curve in the fuzzy inference shown in FIG. 8;

FIG. 10 is a block diagram of a washing machine according to a second embodiment of the present invention;

FIG. 11 is an explanatory drawing of inference for water flow of the same;

FIG. 12 is a drawing showing an inference rule of an inference 1 comprising a part of a water flow inference unit of the second embodiment;

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FIG. 13(a) and (b) are graphs showing membership functions of light-transmittance and lapse time, respectively;

FIG. 14 is a block diagram of the inference 1 of the second embodiment;

FIG. 15 is a block diagram of an inference 2 comprising a part of the water flow inference unit of the second embodiment;

FIG. 16 is a block diagram of an input-output characteristic curve of the inference 1;

FIG. 17 is a graph showing a fuzzy inference rule of the inference 2;

FIG. 18 is a graph showing a membership function of the cloth amount;

FIG. 19 is a graph showing functions f1(x) to f4(x) of a conclusion part of the inference 2;

FIG. 20 is an input-output characteristic curve of the inference 2;

FIG. 21 is a constitutional drawing of a washing machine according to a third embodiment of the present invention;

FIG. 22 is a block diagram of the washing machine of the third embodiment;

FIG. 23 is an inference rule of a water level inference unit of the third embodiment;

FIG. 24 is a graph showing membership function of the

laundry volume;

FIG. 25 is a graph showing membership function of water level;

FIG. 26 is a block diagram of a water level inference unit;

FIG. 27(a), (b), and (c) are graphs showing membership functions of water supply predetermined water level, integrated water supply predetermined water level, and judgment for completion of water supply, respectively;

FIG. 28 is a graph showing a relation between water level and water level rising rate;

FIG. 29 is a block diagram of a washing machine according to a fourth embodiment of the present invention;

FIG. 30 is a drawing showing a manual-setting input part;

FIG. 31 is an inference rule of a washing condition inference unit of the fourth embodiment;

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FIG. 32(a) and (b) are graphs showing membership functions of the cloth amount and water volume, respectively;

FIG. 33 is a block diagram of a washing condition inference unit;

FIG. 34 is a block diagram of a first means in a washing machine according to a fifth embodiment of the present invention;

FIG. 35(a) and (b) are drawings showing an inference rule for determining an amount of water volume correction and the water level;

FIG. 36(a), (b), and (c) are respectively graphs showing membership functions of water volume, extent of soiling, and amount of correction;

FIG. 37 is a block diagram of a fuzzy inference unit for determining the amount of correction;

FIG. 38 is a block diagram of a fuzzy inference unit for determining the water level;

FIG. 39 is a block diagram of a second means in a washing machine according to the fifth embodiment of the present invention;

FIG. 40 is a drawing showing a fuzzy inference rule for determining the water flow;

FIG. 41(a) and (b) are graphs showing membership functions of the cloth amount and the mode of washing;

FIG. 42 is a block diagram of a fuzzy inference unit for determining the water flow;

FIG. 43 is a block diagram of a third means in a washing machine according to the fifth embodiment of the present invention;

FIG. 44 is a drawing showing an inference rule for determining the washing time;

FIG. 45(a), (b), and (c) are graphs showing respectively membership functions of the laundry volume, light-transmittance, saturation time, and extent of soiling;

FIG. 46 is a block diagram of a fuzzy inference unit for determining the washing time;

FIG. 47 is a block diagram of a fourth means in a washing machine according to the fifth embodiment of the

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present invention;

FIG. 48 is a block diagram showing an actual constitution of a fuzzy inference;

FIG. 49 is a drawing showing an inference rule for determining the water flow;

FIG. 50 is a block diagram of a fuzzy inference unit for determining the water flow; and

FIG. 51 is a fuzzy inference unit for determining the washing time.

THE BEST MODE FOR EMBODYING THE INVENTION

In the following, explanation is given of the first embodiment of the present invention referring to FIG.1 through FIG.9.

FIG.1 is a constitutional drawing of a washing machine in an embodiment of the present invention. In this figure, numeral 1 is a washing tub into which the laundry and washing water are put, numeral 2 is an outer tub in which washing water is reserved. Numeral 3 is a pulsator stirring the laundry and the washing water which is rotated by a motor 4 via

a belt 5. Numeral 6 is a cloth amount sensor detecting the load upon the pulsator 3 during rotation thereof, numeral 7 is a water level sensor detecting the water volume in the washing tub 1 by detecting the air pressure in an air trap 8, numeral 9 is a cleaning sensor detecting the degree of deterioration of the washing water in the washing tub 1 by light-transmittance through a drain hose. Putting in and out of water into and from the washing tub 1 are controlled by a water supply valve 10 and a drain valve 11 which are driven by a solenoid valve.

Next, principle of action of the above-mentioned cleaning sensor 9 is explained. A light-emitting part and a light-receiving part are disposed at the drain outlet in such a manner that they are facing each other. Thus, the light from the light-emitting part is received by the light-receiving part, whereby the light-transmittance of the washing water can be detected by the amount of the received light. Hereupon the detected value of the cleaning sensor corresponds to the light-transmittance in the present embodiment and this light-transmittance varies depends on the turbidity of the washing water. That is, the degree of removal of soiling of laundry can be detected by the cleaning sensor 9 in this arrangement. The variation of the

light-transmittance starts, as shown in FIG.7, from a light-transmittance level VI at the beginning of the washing and decreases because the turbidity increases as the washing proceeds, and reaches a steady state at a light-transmittance level V2 after a time length T (hereinafter called the "saturation time"). That is, the turbidity of the washing water reaches a saturated state. At this time, V2 represents the extent of soiling and T represents the degree of difficulty of removal of soiling of the laundry (hereinafter called the "type of soiling").

Hereupon, considering an efficient removal of soiling of the laundry, in the case of keeping the washing water flow constant, the washing effectiveness is determined by the washing time. Then, consideration is given to how the washing time is determined from the above-mentioned light-transmittance and the saturation time.

Although the light-transmittance and the saturation time represent the extent of soiling and the type of soiling, respectively, determination of the washing time from these variables depends largely on intuition and experience of the user and hence it is difficult to express it by a mathematical formula.

By expressing the user's general know-how by the

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fuzzy rule, an appropriate washing time is determined by fuzzy inference.

Next, an explanation is given on the control action, referring to FIG.2. In the washing process, the pulsator 3 starts to rotate in response to a control part 15 which controls the motor 4, thereby a predetermined water flow is produced to start washing. A washing time inference unit 14 determines the washing time by the light-transmittance and the saturation time obtained from the cleaning sensor 9. The control part 15 stops the motor 4 when the above-mentioned washing time has passed. The washing process is completed by the action described above. Hereupon, the washing time inference unit 14 and the control part 15 can be realized easily by a micro-computer 16.

Next, one embodiment of the washing time determination is explained referring to FIG.3 to FIG.6. The washing time is determined by making the fuzzy inference from the information of saturation time and light-transmittance at the time of reaching the saturation point obtained by the cleaning sensor 9. The fuzzy inference is made based on six rules such as is shown in FIG.4, "when the saturation time is short and the light-transmittance is high, the washing time is made very short". Such a qualitative concept, that the saturation time is "short" or the light-

transmittance is "high", or making the washing time "very short", is expressed quantitatively by membership functions shown in FIG.5(a), (b), and (c).

An actual arrangement of the washing time inference unit 14 is shown in FIG.3. In the following, the action of the washing time determination is explained using this figure.

First, the saturation time membership value arithmetic processing means 17 receives the time elapsed until the light-transmittance reaches saturation after the washing started and calculates the grade (goodness of fit) of the saturation time based on a function stored in a saturation time membership function memory means 19 which memorizes a saturation time membership function shown in FIG.5(a). That is, the above-mentioned saturation time membership value arithmetic processing means 17 issues two different respective classes of grade (goodness of fit) of saturation times of "short" and "long" based on the saturation time membership function. And the light-transmittance (turbidity) membership value arithmetic processing means 18 receives the detected value (light-transmittance) of the cleaning sensor 9 at the saturation point and calculates the grade (goodness of fit) of the light-transmittance based on a function stored in a light-transmittance (detected value) membership function memory means 20 which memorizes a

light-transmittance membership function shown in FIG.5(b). That is, the above-mentioned light-transmittance membership value arithmetic processing means 18 issues three different respective classes of grade (goodness of fit) of light-transmittance of "low", "normal", and "high" based on the light-transmittance membership function. Next, an assumption part minimum arithmetic processing means 21 receives the output of the saturation time membership value arithmetic processing means 17 as well as the output of the light-transmittance arithmetic processing means 18 and at the same time accepts data of a washing time reasoning (inference) rule memory means 22 which memorizes a washing time inference rule. The above-mentioned assumption part minimum arithmetic processing means 21, based on the washing time inference rule memory means 22, compares the membership value of "high" of the light-transmittance membership value arithmetic processing means 18 with the membership value of "short" of the saturation time membership value arithmetic processing means 17, and takes the smaller one (MIN) of these two membership values as the assumption part membership value in the case of "high" light-transmittance, "short" saturation time, and "very short" washing time. Similarly, an assumption part membership value in case of "normal" light-

transmittance, "short" saturation time, and "short" washing time is obtained by comparing the membership value of "normal" from the light-transmittance membership value arithmetic processing means 18 with the membership value of "short" from the saturation time membership value arithmetic processing means 17, and takes the MIN of them. Furthermore, an assumption part membership value corresponding to those six cases shown in FIG.4 such as "low" light-transmittance, "short" saturation time, and "long" washing time is sought and the result is issued.

Next, a conclusion part minimum arithmetic processing means 23 receives the output of the above-mentioned six assumption part membership value of the assumption part minimum arithmetic processing means 21 as well as reads data of the washing time inference rule memory means 22, and at the same time, reads functions of a washing time membership function memory means 24 which memorizes membership functions shown in FIG.5(c). The assumption part minimum arithmetic processing means 23 calculates four different MIN's between six different assumption part membership value calculated according to the washing mode inference rule and four different grades of "very short", "short", "long", and "very long" in the membership functions. That is, the membership function of "very short"

washing time is cut at its top part with the assumption part membership value (grade) in the case of "high" light-transmittance , "short" saturation time, and "very short" washing time. Similarly, the membership function of "short" washing time is cut at its top part with two different assumption part membership values (grades) in the case of "normal" light-transmittance and "short" saturation time, or in the case of "high" light-transmittance and "long" saturation time, and then the larger one is taken as (MAX) out of these two assumption part matching (grade). Then, also on the membership functions of "long" and "very long" washing time, they are cut by respective assumption part matching (grade) at their top parts, and thereby the washing time membership function of FIG.5(c) is corrected to be a combination of trapezoids.

Finally, a center-of-gravity arithmetic processing means 25 takes the center of gravity of an area surrounded by the membership function obtained by the conclusion part minimum arithmetic processing means 23, and a washing time at this center of gravity is issued as the final washing time.

Hereupon, the light-transmittance membership function is composed of weighted monotonous type membership functions which are shown in FIG.5(b). Its function is explained using FIG.8 and FIG.9. As shown

in FIG.8(a), taking labels of respective membership functions of a weighted monotonous type membership function are taken to be A, B, and C, rule of the fuzzy inference is taken to be such as shown in FIG.8(b). In this example, the conclusion parts are taken to be real numbers. For the inference processing, an ordinary MIN-MAX method is used. In the fuzzy inference of this arrangement, the input-output characteristic when the slope of the membership function C is changed becomes as shown in FIG. 9. As shown in this figure, it is understood that, by changing the slope of the membership function C, various sorts of second-order curves can be easily expressed.

Using the effect of the weighted monotonous-type membership function as has been described above, in the present embodiment, by adjusting the slope of the membership function expressing that the light-transmittance is high as shown in FIG.5(b), a fuzzy inference unit suitable to the object can be easily constituted.

The result of inference obtained by the washing time inference unit 14 explained above expresses suitably a complex and difficult-to-express relationship of the washing time to the saturation time and the light-transmittance obtained from the cleaning sensor 9. That is, the washing

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time can be determined finely and most suitably responding to the degree of soiling of the laundry. And although it is considered that the degree of soiling and the washing time are in a linear relationship from the point of view of removal of soiling, if we add factors such as damage to the cloth caused by the washing or economy to the above viewpoints, the above-mentioned relationship becomes nonlinear. This is easily understood from consideration that a longer washing time can remove soiling well but imposes more damage on the cloth or a longer washing time is uneconomical from the viewpoint of efficiency. Since the **washing time determination by the washing time inference unit 14 is done by adding these factors mentioned above, the most suitable washing time is obtainable.**

Hereupon, in the present embodiment, although a triangular shape has been used for the washing time membership function, a method in which it is realized by a linear formula or real number can also be considered. And the number of rule is not always limited to six. Moreover, it is unnecessary to mention that the determination of the rinse time can be determined by a similar method to the determination of the washing time.

In the present embodiment, although the

cleaning sensor is constituted by a light sensor detecting the light-transmittance, a method such as using change of electric conductivity or using image processing can also be considered.

In the following, explanation is given of a second embodiment of the present invention using FIG.1, and FIG.10 to FIG.20. In FIG.10, numeral 9 is a cleaning sensor for detecting the turbidity of the water in the washing tub 1 of FIG. 1 by the light-transmittance in a drain hose. Numerals 26 and 27 are a timer provided inside a micro-computer and a water flow inference unit, respectively.

In the following, the action of the present embodiment is explained mainly in terms of the action of the water flow inference unit 27. Control of the water flow strength is made by receiving, as the input, the detected value of the cleaning sensor 9 as well as the cloth amount sensor 6 and the washing time after starting the washing and the lapse time after starting the rinse by the micro-computer 26 and driving a motor 4 with ON-OFF time of the motor which is determined by the inference made by the water flow inference unit 27 which is realized with a micro-computer. The determination of the ON-OFF time of the motor 4 by the flow inference unit 27 is made based on the general knowledge we usually have on the washing from our

experience, such that when the amount of cloth is large, the standard water flow must be made strong, or when the lapse time is short and the variation ratio of the light-transmittance is small, the water flow must be made stronger than the standard water flow.

An actual process of determination of the washing water flow by the fuzzy inference is described below.

The fuzzy inference in the present embodiment comprises a fuzzy inference 1 and a fuzzy inference 2 as shown in FIG.11. The fuzzy inference 1 (hereinafter called inference 1) determines by making inference the amount of correction which expresses magnitude of strengthening or weakening of the water flow from its standard value, using the variation ratio of the light-transmission representing the degree of removal of soiling and the lapse time after starting the washing as its input. The inference rule is such that, for example, "when the variation ratio of the light-transmission is large and the lapse time is short, the water flow is made weaker", and it is composed of four rules shown in FIG.12.

The qualitative concept that the variation ratio of the light-transmittance is "large" or the lapse time is "long" is expressed quantitatively by membership functions shown in FIG.13(a) and (b).

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The conclusion part of the inference 1 uses real number values represented by Q11 to Q34, and R11 to R34 shown in FIG.12, six correction values Q1 to Q3 and R1 to R3 are issued as the inference result.

Subsequently, the method of the fuzzy inference is explained. In FIG.14, an arrangement for realizing the inference 1 included in the water flow inference unit 27 is shown. Based on a rule memorized in a correction value inference rule memory means 32, in a variation ratio membership value arithmetic processing means 28, a membership value between the variation ratio of the light-transmittance, that is, the variation ratio of the output of the cleaning sensor 9 and the membership function memorized in the variation ratio membership function memory means 30 is obtained by taking MAX between them. Similarly, in a lapse time membership value arithmetic processing means 29, a membership value between the lapse time after starting the washing and the membership function memorized in the lapse time membership function memory means 31 is obtained. In the assumption part minimum arithmetic means 33, taking MIN between the above-mentioned two membership values, it is taken to be a membership value of the assumption part. In the conclusion part minimum arithmetic processing unit 34, by taking MIN between this assumption part membership value and a membership

function which is memorized in the conclusion part correction value membership function memory means 35, it is taken to be a conclusion for this rule.

After obtaining respective conclusions on all respective rules memorized in the correction value inference rule memory means 32, in a center-of-gravity arithmetic processing means 36, by taking MAX of all conclusions and calculating their center of gravity, the correction value is obtained finally. An example of the input-output characteristic of the inference 1 is as shown in FIG.16.

The fuzzy inference 2 (hereinafter called inference 2) receives the amount of cloth as its input and determines the ON-OFF time of the motor 4 by making inference thereon. The inference rule is such that, for example, "when the amount of cloth is much, the ON time is made longer and OFF time shorter", and it is composed of four rules shown in FIG.17.

The qualitative concept that the amount of cloth is "much" is expressed quantitatively by membership functions shown in FIG.18. The conclusion part is expressed by f1(x) to f4(x) shown in FIG.17, which are respectively linear functions such as;

$$f1(x) = a1*x + b1$$

$$f2(x) = a2*x + b2$$

$$f3(x) = a3*x + b3$$

$$f4(x) = a4*x + b4$$

Graphic representation of these f1(x) to f4(x) is as shown in FIG.19, wherein, f1(x0), f3(x0), f1(x1) (f2(x1)), f3(x1) (f4(x1)), f2(x2), f4(x2), which characterize respective functions, are equal to Q1 to Q3 and R1 to R3 which are the conclusions of the inference 1. That is, parameters a1 to a4 and b1 to b4 of the conclusion part functions f1(x) to f4(x) are determined by the result of the inference 1. Actual method of the inference 2 is described below. In FIG.15, an arrangement for realizing the inference 2 included in the water flow inference unit 27 is shown. Based on a rule memorized in a ON-OFF time inference rule memory means 41, in a cloth amount membership value arithmetic processing means 37, a membership value of the assumption part is obtained by taking MAX of the membership function memorized in the input cloth amount membership function memory means 38. Subsequently, in a conclusion part minimum arithmetic processing means 40, by taking MIN between this assumption part membership value and a membership function memorized in the ON-OFF time membership function in the conclusion part which is memorized in the memory means 39, it is taken to be a conclusion for this rule. After obtaining respective conclusions on all respective rules memorized in the

ON-OFF time inference rule memory means 41, in a center-of-gravity arithmetic processing means 42, by taking MAX of all conclusions and calculating their center of gravity, the ON-OFF time is obtained finally. An example of the input-output characteristic of the inference 2 is as shown in FIG.20. As is understood from FIG.20, the characteristic is such that when the amount of cloth is much, the ON time is made longer and the OFF time is made shorter, that is, the water flow is made stronger. This is because a pulsator 3 is disposed on the bottom of the washing tub 1 as is seen in FIG.1, then as the amount of cloth increases, propagation of the water flow up to the upper layer becomes harder and hence the water flow strength must be made stronger.

And the reason for the determination of parameters of the inference 2 by six outputs of the inference 1 is because, when the water flow is made stronger, the degree of strengthening is different depending on the amount of cloth.

By setting those parameters constituting the inference 1 and the inference 2 based on the knowledge we usually have from our experience, the ON-OFF control (water flow control) of the motor 4 by the water flow inference unit 27 becomes most the suitable one which takes the amount of cloth, the degree of soiling and the washing

time into account.

The water flow control action by the water flow inference unit 27 becomes such as described below. That is, the washing is done with an adequate strength responding to the amount of cloth at the starting time of washing, and when the soiling seems difficult to be removed, the water flow is made stronger. Then when the soiling starts being removed, the water flow is weakened so as to avoid damage to the cloth. Also in case that the soiling is not removed for a long time, the water flow is weakened for the same purpose. And, in spite of maintaining the washing for a considerably longer time, the soiling is removed sufficiently, the water flow is made stronger so as not to lengthen the washing time by removing the soiling quicker.

Since the water flow control by the water flow inference unit 27 as described above makes an action which is similar to that which we make from our experience, an adequate washing taking the amount of cloth and the damage to the cloth into account and responding to the soiling of the cloth can be made.

Hereupon, in the present embodiment, although the description has been done on the washing water flow control by the water flow inference unit 27, it is needless to mention that the same can be applied also

to the rinse water flow control. And although it has been described that "in spite of maintaining the washing for a considerably longer time, the soiling is removed sufficiently, the water flow is made stronger so as not to lengthen the washing time by removing the soiling quicker", in this case, another method wherein the removal of the soiling is made easier by supplying the water through a water supply valve 10 can also be considered. And also still another method in which the removal of the soiling is made easier by a control of the washing water temperature can be considered.

And for the agitation type washing machine and the drum type washing machine, by taking the output of the fuzzy inference to be respectively the driving speed of an agitator and the revolving speed of a drum, the same effect can be obtained.

At this time, sensing of the amount of cloth can be detected with the load current of the agitator or the drum, and the degree of the soiling can be detected in a similar manner to the present embodiment.

Next, explanation is given of a third embodiment of the present invention using FIG.21 to FIG.28. In FIG.21, in the water-extraction process, the washing tub 1 is driven by the motor 4, and numeral 13 is a second cloth amount sensor detecting the

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revolving speed of the washing tub 1 during the revolution thereof by an encoder. Hereupon this second cloth amount sensor 13 is for detecting the weight of cloth. The reason for this is that the revolving speed of the washing tub 1 is determined by the weight of the cloth without depending on such as the volume of the cloth.

Next, explanation is given ot the determination of the washing water level at the time of washing, referring to FIG. 22. The determination of the washing water level comprises two stages of a determination of water-supply predetermined water level at the starting time and a judgement of water-supply completion. The first determination of the water-supply predetermined water level is made by a water level inference unit 43 which is realized by a micro-computer 45. An inference at this time is done based on the judgment that a user of the washing machine usually makes that "when the amount of cloth is much, the water level must be high", or "when the amount of cloth is few, the water level must be low". Rule of the inference is composed of four rules shown in FIG. 23. The qualitative concept that the amount of cloth is "much" or "few" is expressed quantitatively by membership functions such as shown in FIG.24. The qualitative concept that making

the water level "high" or "low" is expressed quantitatively by membership functions such as those shown in FIG. 25.

Next, a method of arithmetic procedure of the inference process is described based on FIG.26. First, in a cloth amount membership value arithmetic processing means 46, a membership value of the assumption part for the input, that is, for the detected value of the second cloth amount detector 13 is obtained by taking MAX between the input and membership functions memorized in a cloth amount membership function memory means 47. Then, in a conclusion part minimum arithmetic processing means 49, based on a rule memorized in a water level inference rule memory means 48, taking MIN between membership functions memorized in the water level membership function memory means 50 and the assumption part membership value, it is taken to be a conclusion for this rule. After getting respective conclusions for all rules, by taking MAX out of all these conclusions by a conclusion part maximum arithmetic processing means 51, a predetermined washing water level is obtained as the final conclusion. This predetermined washing water level is expressed in a shape of a membership function as shown in FIG.27(a), which shows respective possibilities of determination of water

level at respective water levels. Next, explanation is given of the judgment of the water supply completion during the second water supply referring to FIG.27. First, integrating the membership function of the water supply predetermined water level shown in FIG.27(a) obtained from the first stage, it is normalized so that maximum value of the grade becomes 1. This takes a shape as shown by FIG.27(b), which shows respective possibilities of completion of water supply depending upon the water levels. The water level rising rate obtained from the detected value of the water level sensor during the water supply becomes small as the water level rises and finally converges to a predetermined value as shown in FIG.28. This decrease of the water level rising rate accompanying the water level rising is due to a cloth density distribution caused by a stacking of the laundry inside the washing tub 1. Namely, the cloth density is highest at the bottom of the washing tub 1 and it decreases as the height from the bottom of the washing tub increases. And, the final convergence of the water level rising rate to a predetermined value occurs because the water level rising rate is determined by the size of the outer tub 2 after the laundry is submerged completely in water. Judgement of the water supply completion is made by a comparison of this water level

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rising rate with the above-mentioned water supply predetermined water level. As shown in FIG.27(c), when the water level rising rate becomes lower than the water supply predetermined water level, it is taken as the water supply completion and the water supply valve 10 is closed. These comparisons and the control of the water-supply valve are made by a water-supply valve control means 44 realized by a micro-computer 45. As is easily understood from FIG.27(c), even if the water supply predetermined water level is constant, when the volume of cloth is low, the water level becomes low, while when the cloth volume is high, the water level becomes high.

Hereupon, although it is explained that the water-supply predetermined water level is expressed by a fuzzy set, and the final water level is determined by a comparison with the water level rising rate, the water level can also be determined through obtaining directly by determining the water level with respect to the center of gravity of the membership function of the water-supply predetermined water level which is obtained at the initial stage.

In the foregoing, although the explanation has been given of the determination process of the water level at the time of washing, the water level determination at the time of rinse can also be made by

a similar process. By determining the water level by such process as described above, the most suitable water level which takes both weight and volume of the cloth into account can be obtained. And, as for the second cloth amount sensor, a method in which the amount of cloth is measured directly using a weight sensor can also be considered.

In the following, explanation is given of a fourth embodiment of the present invention using FIG.1 and FIG.29 to FIG.33. In FIG.1, numeral 12 is a manual-setting input part accepting manual inputs by an operator and it has a panel configuration shown in FIG.30 which accepts the sort and number of the laundry.

Next, explanation is given of the control action referring to FIG. 29. Respective basic processes are performed by means of a control part 53 which controls washing conditions are determined by means of the washing condition inference unit 52 which makes the fuzzy inference using detected values of the cloth amount sensor 6 and of the cleaning sensor 9 and information from the manual-setting input part 12 as the input thereof. Hereupon, the above-mentioned washing condition inference unit 52 and the control

part 53 can be easily realized by a micro-computer 54.

Next, explanation is given of one embodiment of the washing water volume determination. The water volume at the initial stage of the washing is determined by the information of the manual-setting input part 12 on which the user operated and the water level information detected by the water level sensor 7. Thereafter, the determination of the washing water volume is made by making the fuzzy inference using the detected value of the cloth amount sensor 6 and the information from the manual-setting input part, and the control part 53 controls the water supply valve 10 depending on the determined water volume. The fuzzy inference is made by a rule based on a know-how that the user generally knows such that "when the type of laundry is lingerie and the cloth amount is fairly much, the water volume is made very much", and it comprises nine rules shown in FIG. 31. Such a qualitative concept that the amount of cloth is "fairly much" or the water volume is "very much" is expressed quantitatively by membership functions such as shown in FIG.32(a) and (b). The membership value of the assumption part on the sort of the laundry, in case of lingerie for example, is determined by the ratio of number of lingerie items present in the number of all of the items of laundry.

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Next, a method of arithmetic procedure of the inference process is described. In FIG.33 an actual arrangement of a washing condition inference unit 52 is shown. The following explanation is given using this figure. First, in accordance with a rule memorized in a water volume inference rule memory means 58, in a cloth amount (water volume) membership value arithmetic processing means 55, for the input, that is, for the detected value of the cloth amount sensor 6, MAX is taken with the membership functions memorized in a cloth amount membership function memory means 56. Then, in an assumption part minimum arithmetic processing means 57, membership value of the assumption part is determined by taking MIN of the MAX value and a ratio (grade) of the number of input cloth sort occupying in the number of all the laundry. Next, in the conclusion part minimum arithmetic processing means 59, by taking MIN between membership functions memorized in the water volume membership function memory means 60 and the assumption part membership value, it is taken to be a conclusion for this rule. Moreover, after getting respective conclusions for all rules memorized in the water volume inference rule memory means 58, the center of gravity is determined by taking MAX of all the conclusions in a center-of-gravity arithmetic processing means 61, whereby the

washing water volume is obtained as a final conclusion.

In the water volume determination by the fuzzy inference explained above, careful washing taking the sort of the laundry into account is performed in a manner that, for susceptible laundry such as lingerie, the water volume is increased to avoid damage to the cloth, whereas for tough washes such as jeans, the water volume is decreased to wash out soiling positively.

Hereupon, in the present embodiment, although the types of laundry to be specified by the manual-setting input has been limited to be three, it is not necessary to limit particularly, and it is needless to mention that the more the number of types to be specified is, the more carefully the washing can be done. And in the present embodiment, description has been made on the determination of the water level for the washing water, but the same can be applied also on the determination of the water level for the rinse. Moreover, by the same procedure as the determination of the washing water level, it is also possible to perform, for example, control of the washing water flow and rinse water flow, control of washing time, rinse time, and water-extraction time, water-extraction revolution control, and temperature control of washing water. At this time, by applying the detected value of the

cleaning sensor 9 to the input of a washing condition inference unit 52, it becomes possible to obtain the most suitable water flow control as well as time control responding more finely to the state of soiling of the laundry. And, although the conclusion part variable of the fuzzy conditioning has been taken to be a triangular shape, such a method that the realization thereof by using values or a real number function can also be considered.

In the following, on a fifth embodiment of the present invention, explanation is given using FIG.1 and FIG.34 to FIG.51.

In FIG.1, numeral 12 is a manual-setting input part accepting manual inputs by an operator and it is comprised of a slide resistor and has a constitution through which such quantities as the amount of the water volume, degree of the extent of soiling, and degree of the strength of the washing can be input as analogue values.

Next, explanation is given of the determination of the water level of the washing water by a first means. FIG. 34 is one embodiment of the first means, wherein the determination of the water level of the washing water comprises two steps, that is a determination of the correction value of the water level according to the input information such as the amount

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of the water volume, degree of the amount of soiling either from the manual-setting input part 12 and a determination of a suitable water level by the above-mentioned correction value and the detected value from the cloth amount sensor 6. These determinations of the correction value and the suitable water level are both done by the fuzzy inference in the water level determination means 64. A fuzzy inference in the first step is made based on a general judgment such that "when the water volume is fairly much and the soiling is much, the correction value is made very much". Rule of the inference comprises nine individual rules shown in FIG.35(a). Those qualitative concepts such that the water volume is "fairly much", the soiling is "much", or the correction value is "very much" are expressed quantitatively by membership functions as shown in FIG.36(a), (b), and (c). The fuzzy inference has a constitution as shown in FIG.37, wherein in a water volume membership value arithmetic processing means 65, a membership value of the external input and the membership functions on the water volume is obtained by taking MAX of them. In an extent of soiling membership value arithmetic processing means 66 a membership value on the amount of the soiling is obtained similarly. In an assumption part minimum arithmetic processing means 70, taking MIN between those above-mentioned two

membership values, it is taken as a membership value for the assumption part. In a conclusion part minimum arithmetic processing means 71, taking MIN between the assumption part membership value and the correction value membership function of the conclusion part, it is taken to be a conclusion of this rule.

After obtaining each conclusion on all of the rules, taking MAX of all conclusions in a center-of-gravity arithmetic processing means 73, thus by calculating the center of gravity, the correction value is determined finally.

Those membership functions concerning the water volume, amount of soiling, and correction value are obtained by referring respectively to a water volume membership function memory means 67, an extent of soiling membership function memory means 68, and a correction value membership function memory means 70. And the inference rule is obtained by referring to a correction value inference rule memory means 69.

The fuzzy inference of the second step is made based on the general judgment such that "when the cloth amount is much and the correction value is fairly much, the water level is made very high". Rule of the inference comprises four individual rules shown in FIG.35(b). Those qualitative concepts such that the cloth amount is "much", the correction value is "fairly

much", or make the water level "high" are expressed quantitatively by membership functions likewise as in the first step. The fuzzy inference has a constitution as shown in FIG.38, wherein a water level is obtained by a similar procedure as in the first step. The water level is adjusted in such a manner that it becomes a water level determined by those two steps as described above using a control section 62 which controls a water supply valve 10 according to the detected value of the water level sensor 7.

Functions of the above-mentioned water level determination means 64 and the control part 62 can be easily realized by a micro-computer 63.

Next, explanation is given of the determination of the water flow by a second means. FIG. 39 is one embodiment of the second means. The determination of the water flow is made by making a fuzzy inference in a water flow determination means 83 according to the input information of detected value from the cloth amount sensor 6 and the strength of the washing from the manual-setting input part 12. The fuzzy inference is made based on a general judgment such that "when the cloth amount is fairly much and the strength of the washing is fairly strong, the water flow is made very much". Rule of the inference comprises nine individual rules shown in FIG.40. Those

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qualitative concepts such that the cloth amount is "much" or the strength of the washing is "fairly strong" are expressed quantitatively by membership functions as shown in FIG.41(a) and (b). Such concept as "making the water flow strong" corresponds to an expression as "making ON-time long, and OFF-time short" on the motor 4, and these qualitative concepts such as making ON-time "long" or making OFF-time "short" are expressed quantitatively by membership functions likewise. The fuzzy inference has a constitution as shown in FIG.42, wherein in a cloth amount membership value arithmetic processing means 84, a membership value of the detected value of the cloth amount sensor and the membership functions on the cloth amount is obtained by taking MAX of them. In a washing mode membership value arithmetic processing means 86, a membership value of the manual-setting input and membership function on the the washing mode is obtained similarly. In an assumption part minimum arithmetic processing means 89, taking MIN between those above-mentioned two membership values, it is taken as a membership value for the assumption part. In a conclusion part minimum arithmetic processing means 90, taking MIN between the assumption part membership value and the ON-OFF time membership function of the conclusion part, it is taken to be a conclusion of this

rule.

After obtaining each conclusion on all of the rules, taking MAX of all conclusions in a center-of-gravity arithmetic processing means 92, thus by calculating the center of gravity, the ON-OFF time is determined finally.

Those membership functions concerning the cloth amount, washing mode, and ON-OFF time are obtained by referring respectively to a cloth amount membership function memory means 85, a washing mode membership function memory means 87, and an ON-OFF time memory means 91. And the inference rule is obtained by referring to an ON-OFF time inference rule memory means 88.

Water flow having an adequate strength can be obtained using the control part 62 which switches ON and OFF the motor 4 based on the ON-OFF time of the motor determined by the inference explained above. The above-mentioned water flow determination means 83 and control part 62 can be easily realized by a micro-computer 63.

Next, explanation is given of the determination of the washing time by a third means. Fig. 43 is one embodiment of the third means. The determination of the washing time is made by making a fuzzy inference in a washing time determination means

93 according to the input information of detected value from the cloth amount sensor 6 and the cleaning (water level) sensor 7 and the degree of the extent of soiling from the manual-setting input part 12. Hereupon, the detected value of the cleaning sensor 7 gives two different sets of information, that is, the time the light-transmission reaches its saturation and the light-transmittance at this time, and they become input to the washing time determination means.

The fuzzy inference is made based on a general judgement such that "when the cloth amount is much and the light-transmission is low, and the saturation time is long and the extent of soiling is much, the washing time is made very long". Rule of the inference comprises 24 individual rules shown in FIG.44. Those qualitative concepts such that the cloth amount is "fairly much" or the extent of soiling is "much" are expressed quantitatively by membership functions as shown in FIG.45(a) to (d). The fuzzy inference has a constitution as shown in FIG.46, wherein in a cloth amount membership value arithmetic processing means 94, a membership value of the detected value of the cloth amount sensor and the membership functions on the cloth amount is obtained by taking MAX of them. In a washing mode membership value arithmetic processing means 97, a membership value of

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the manual-setting input and the membership function on the the washing mode is obtained similarly. Also similarly, in a light-transmission membership value arithmetic processing means 95 or in the saturation time membership value arithmetic processing means 96, the required membership value is obtained. In the assumption part minimum arithmetic processing means 103, taking MIN among the above-mentioned four membership values, it is taken as a membership value for the assumption part. In a conclusion part minimum arithmetic processing means 104, taking MIN between the assumption part membership value and the washing time membership function of the conclusion part, it is taken to be a conclusion of this rule.

After obtaining each conclusion on all of the rules, taking MAX of all conclusions in a center-of-gravity arithmetic processing means 106, thus by calculating the center of gravity, the washing time is determined finally.

Those membership functions concerning the cloth amount, washing mode, light-transmission/saturation time, and washing time are obtained by referring respectively to a cloth amount membership function memory means 99, a washing mode membership function memory means 101, a light-transmission membership function memory means 98, a

saturation time membership function memory means 100, and the washing time membership function memory means 105. And the inference rule is obtained by referring to an washing time inference rule memory means 102.

The control of the motor 4 is carried out in the control part 62 based on the washing time determined by the fuzzy inference explained above, thereby the motor is turned OFF after a determined time. The above-mentioned washing time determination means 93 and control part 62 can be easily realized by a micro-computer 63.

Next, explanation is given of the determination of various washing conditions by a fourth means. FIG.47 is one embodiment of the fourth means. The determination of various washing conditions is made by making a fuzzy inference in a washing time determination means 107 according to the input information of detected value from the cloth amount sensor 6 and the cleaning sensor 9 and the degree of the water volume, the degree of the extent of soiling, and the strength of the washing from the manual-setting input part 12. The fuzzy inference comprises multiple-stage inference of three stages as shown in FIG.48.

A first stage is to determine an adequate water level similarly as in the embodiment of the above-mentioned first means. A second stage is to

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determine the water flow by means of fuzzy inference using information of the strength of the washing from the manual-setting input part, the detected value of the cloth amount sensor, and the water level determined by the first stage. The fuzzy inference is such that "when the cloth amount is fairly much and the water level is fairly high, and the washing mode is fairly strong, the water flow is made strong", which comprises 12 rules shown in FIG.49. The fuzzy inference has a constitution shown in FIG.50, wherein in a cloth amount membership value arithmetic processing means 108 a membership value of the detected value of the cloth amount sensor and the membership functions on the cloth amount is obtained by taking MAX of them. In a washing mode membership value arithmetic processing means 110, a membership value of the manual-setting input and the membership function on the the washing mode is obtained similarly. Also similarly, in a water level membership value arithmetic processing means 109, a desired membership value is obtained. In an assumption part minimum arithmetic processing means 115, taking MIN of the above-mentioned three membership values, it is taken as a membership value for the assumption part. In a conclusion part minimum arithmetic processing means 116, taking MIN between the assumption part membership value and the ON-OFF time membership

function of the conclusion part, it is taken to be a conclusion of this rule.

After obtaining each conclusion on all of the rules, taking MAX of all conclusions in a center-of-gravity arithmetic processing means 118, thus by calculating the center of gravity, the ON-OFF time is determined finally.

Those membership functions concerning the cloth amount, washing mode, water level, and ON-OFF time are obtained by referring respectively to a cloth amount membership function memory means 112, a washing mode membership function memory means 113, a water level membership function memory means 111, and an ON-OFF time membership function memory means 117. And the inference rule is obtained by referring to an ON-OFF time inference rule memory means 114.

A third stage is to determine the washing time by means of fuzzy inference using the detected value of the cloth amount sensor 6 and the cleaning sensor 9, the water level determined by the first stage, and the water flow determined by the second stage. Hereupon, the detected value of the cleaning sensor 9 gives two different sets of information, that is, the time the light-transmission reaches its saturation and the light-transmittance at this time, and they become input to the fuzzy inference unit 107. The fuzzy

inference is such that "when the cloth amount is much and the water level is fairly high, and the water flow is fairly strong, the saturation time is long, and the light-transmission is small, the washing time is made very long", which comprises 32 rules. The fuzzy inference has a constitution shown in FIG.51, and the washing time is obtained by a similar procedure as the above-mentioned second stage.

Responding to the result of three stages explained above, water supply control, water flow control, and washing time control are carried out using the control part 62 which controls the water supply valve 9 and the motor 4. The above-mentioned fuzzy inference unit 107 and control part 62 can be easily realized by a micro-computer 63.

Hereupon, by providing a manual-setting input part concerning the sort of cleaning material and the hardness of water, a further finer determination of the washing condition including temperature control, cleaning material control and others can be attained.

INDUSTRIAL APPLICABILITY

As has been described above, in accordance with the present invention, by letting a washing time inference unit have know-how by which the washing time is determined from the degree of the soiling on the basis of a user's knowledge, the washing time is determined after adding

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various factors as usually the user does, whereby a most suitable washing time can be obtained, enabling a more careful washing to be realized.

And, a most suitable washing water flow and rinse water flow corresponding to the soiling and taking the cloth amount and the damage to the cloth into account by a water flow inference unit which has cloth amount, degree of soiling, washing time, and rinse time as its input, can be obtained. The reason why this is possible is that it is not difficult to give the water flow inference unit the know-how of the water flow control that we usually know from our experience.

And, since the amount of the laundry is detected not only from the water level sensor but also from the water level increasing rate, the water level at the time of washing as well as at the time of rinse can be determined by a multi-dimensional information upon weight and volume of the laundry, whereby a careful washing and rinse responding to the quantity and the quality of the laundry can be attained.

And, by providing, beside the detected value from various sensors, the washing condition inference unit to which information from the manual-setting input part can be input, the determination of various washing conditions that account for simultaneously the multi-dimensional information such as the information

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concerning the sort and the quantity of the laundry and the detected value from the cloth amount sensor and the soiling sensor is carried out by the fuzzy inference, and responding to this determined washing condition, the control part controls the motor, water supply valve, and drain valve, whereby a careful and adequate washing can be realized. And the fuzzy inference unit can easily be designed by letting it have the know-how that we know from our experience.

And, since the manual-setting input part accepts the manual input by the operator concerning the water volume and the extent of soiling and the water level determination means determines the water level by both the information obtained from the manual-setting input part and the detected value of the cloth amount sensor, it becomes possible to determine the water level reflecting the operator's taste within a range of the adequate water level determined by the detected value of the cloth amount sensor. That is, the determination of the water level taking the operator's subjective point of view into account becomes possible.

And, since the manual-setting input part accepts the manual input by the operator concerning the washing mode and the water flow determination means determines the water flow by

both the information obtained from the manual-setting input part and the detected value of the cloth amount sensor, it becomes possible to determine the water flow reflecting the operator's taste within a range of the adequate water flow determined by the detected value of the cloth amount sensor. That is, the determination of the water flow taking the operator's subjective point of view into account becomes possible.

And, since the manual-setting input part accepts the manual input by the operator concerning the water volume and the extent of soiling and the washing time determination means determines the washing time and the rinse time by both the information obtained from the manual-setting input part and the detected value of the cleaning sensor, it becomes possible to determine the water flow reflecting the operator's taste within a range of the adequate washing time determined by the detected value of the cleaning sensor. That is, the determination of the washing time taking the operator's subjective point of view into account becomes possible.

Furthermore, since a fuzzy inference unit making the multiple stage on various washing conditions concerning the adequate water level, the washing water flow and rinse water flow, and washing time, and a manual-

setting input part which accepts the manual input by the operator concerning the water volume, the extent of soiling and the washing mode, it becomes possible to determine various washing conditions reflecting the operator's taste within a range of the adequate various conditions. That is, the determination of various washing conditions taking the operator's subjective point of view into account becomes possible. And, by making a multiple stage inference, it becomes possible to determine more precisely various washing conditions.

CLAIMS

1. A washing machine controller comprising:

a cleaning sensor for detecting the turbidity of water in a washing tub during a washing operation of the washing machine;

time measurement means for measuring a saturation time period from a start of a washing operation to a time point of saturation, the time point of saturation being determined when the detected turbidity saturates;

washing time inference means for determining a washing time of a washing operation based on said saturation time period and the detected turbidity;

control means for controlling a motor for said washing operation; and

said control means stopping said motor when said washing time expires.

2. A washing machine controller according to claim 1, wherein said washing time inference means uses a fuzzy inference operation.

3. A washing machine controller according to claim 1 or 2, wherein said cleaning sensor comprises a light-emitting part and a light-receiving part.

4. A washing machine controller according to claim 1 or 2, wherein said washing time inference means comprises:

a saturation time membership value determining means for obtaining a saturation time membership value of the measured saturation time period based on the saturation time period and a saturation time membership function;

a turbidity membership value determining means for obtaining a turbidity membership value of the detected turbidity based on the detected turbidity and a detected turbidity membership function;

an assumption part determining means for obtaining assumption part membership values based on said saturation

time membership value, said turbidity membership value, and a set of washing time inference rules;

a conclusion part determining means for obtaining conclusions from said washing time inference rules, said assumption part membership values, and a washing time membership function; and

a center-of-gravity determining means for obtaining the washing time as a center of gravity of the conclusions of all said rules, a saturation time membership function memory means, detected value membership function memory means, and a washing time membership function memory means, which are all for memorizing said respective membership functions, and a washing time inference rule memory means for storing said set of washing time inference rules.

5. A washing machine controller according to claim 4, wherein said assumption part determining means compares, based on said set of washing time inference rules, the saturation time membership value and the turbidity membership value, and takes a minimum of the saturation time membership value and the turbidity membership value as the assumption part membership value.

6. A washing machine controller according to claim 4, wherein said washing time at the center of gravity of the conclusions determined by said center-of-gravity determining means is determined as a final amount of washing time.

7. A washing machine controller according to claim 4, wherein said turbidity membership function comprises a weighted monotonous type membership function.

8. A washing machine controller according to any one of claims 1 to 7, further comprising:

a cloth amount sensor for detecting the quantity of the laundry in the tub;

a timer measuring the washing time and a rinse time; and

a water flow inference unit for making a fuzzy inference on the washing water flow and the rinse water flow using detected values of said cleaning sensor and cloth amount sensor and a timer value as its input.

9. A washing machine controller according to any one of claims 1 to 7, further comprising:

a cloth amount sensor detecting the quantity of the laundry;

a water level inference unit for making the fuzzy inference on a water-supply predetermined water level from the detected value of said cloth amount sensor;

a water level sensor detecting the water level;

a water supply valve control means controlling a water supply valve by means of comparison between the detected value of said water level sensor and the water-supply predetermined water level that is a result of the inference made by said water level inference unit.

10. A washing machine controller according to any one of claims 1 to 7, further comprising:

a manual-setting input part accepting manual inputs by an operator on the sort and quantity of said laundry;

a cloth amount sensor detecting the amount of said laundry;

a washing condition inference unit determining various washing conditions using manual inputs from said manual-setting input part and detected values from said cloth amount sensor as its input;

a water supply valve; and

a drain valve responding to various washing conditions determined by said washing condition inference unit.

11. A washing machine controller in accordance with claim 10, wherein

said manual-setting input part accepts manual inputs by an operator on the water volume and the extent of soiling; and

a water level determination means determines the washing water volume and rinse water volume by the fuzzy inference using, as its input, the detected value of said cloth amount sensor and the information obtained from said manual-setting input part.

12. A washing machine controller in accordance with claim 10, wherein

a manual-setting input part accepts manual inputs by an operator on a desired washing mode;

a cloth amount sensor detects the amount of the laundry; and

a water flow determination means determines the washing water flow by the fuzzy inference using, as its input, the detected value of said cloth amount sensor and the information obtained from said manual-setting input part.

13. A washing machine controller in accordance with claim 10, wherein

a manual-setting input part accepts manual inputs by an operator on the extent of soiling; and

a washing time determination means determines the washing time and the rinse time by fuzzy inference using, as its input, the detected values of the various said sensors and the information obtained from said manual-setting input part.

14. A washing machine controller in accordance with claim 10, wherein

a manual-setting input part accepts manual inputs by an operator on the water volume and the extent of soiling;

a cloth amount sensor detects the amount of the laundry;

a cleaning sensor detects the extent of soiling; and

a fuzzy inference unit makes multiple-stage inference and determines various washing conditions including water level, washing time and rinse time, using, as its input, the detected values of the various said sensors and the information obtained from said manual-setting input part.

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Fig. 1

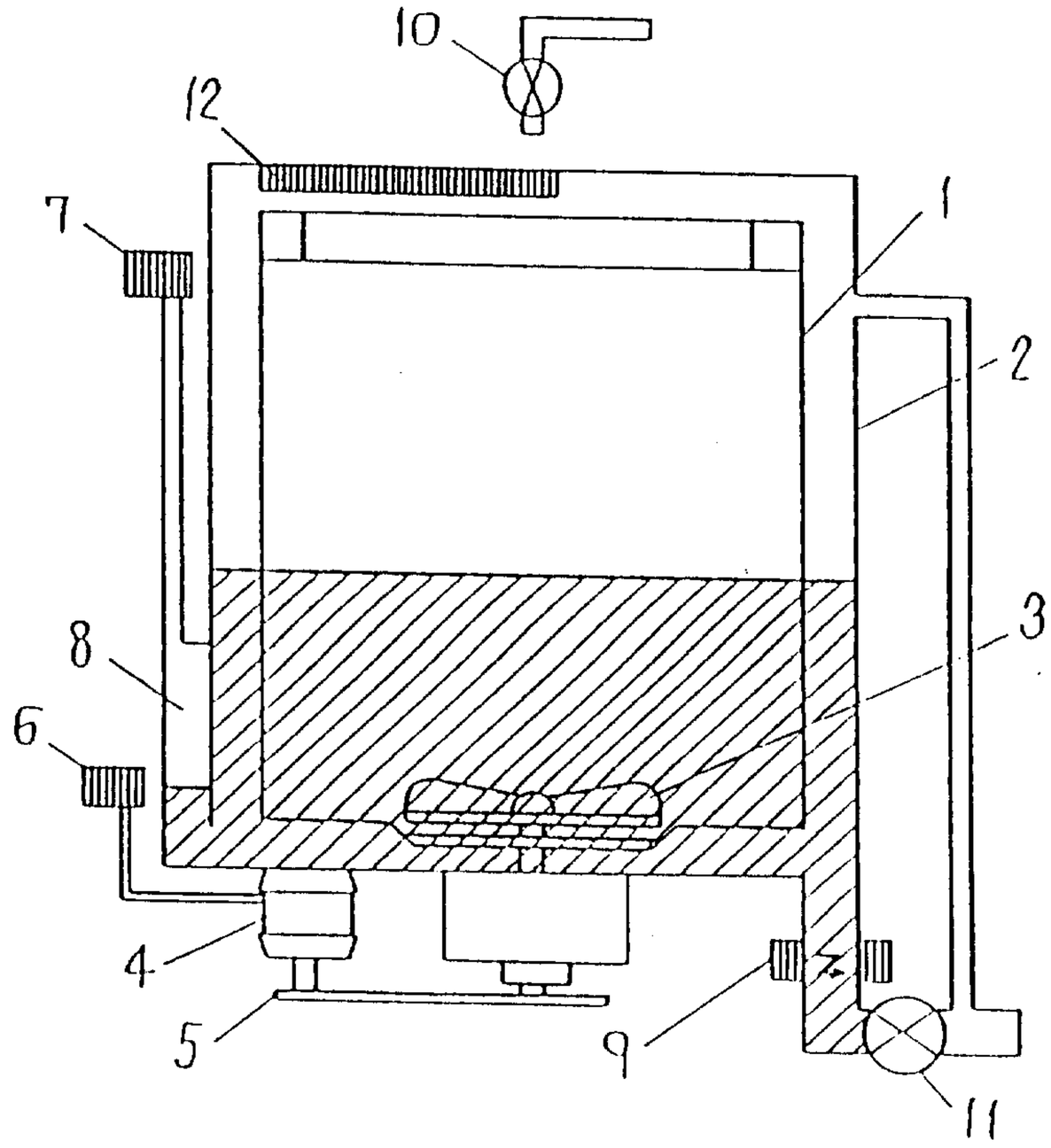


Fig. 2

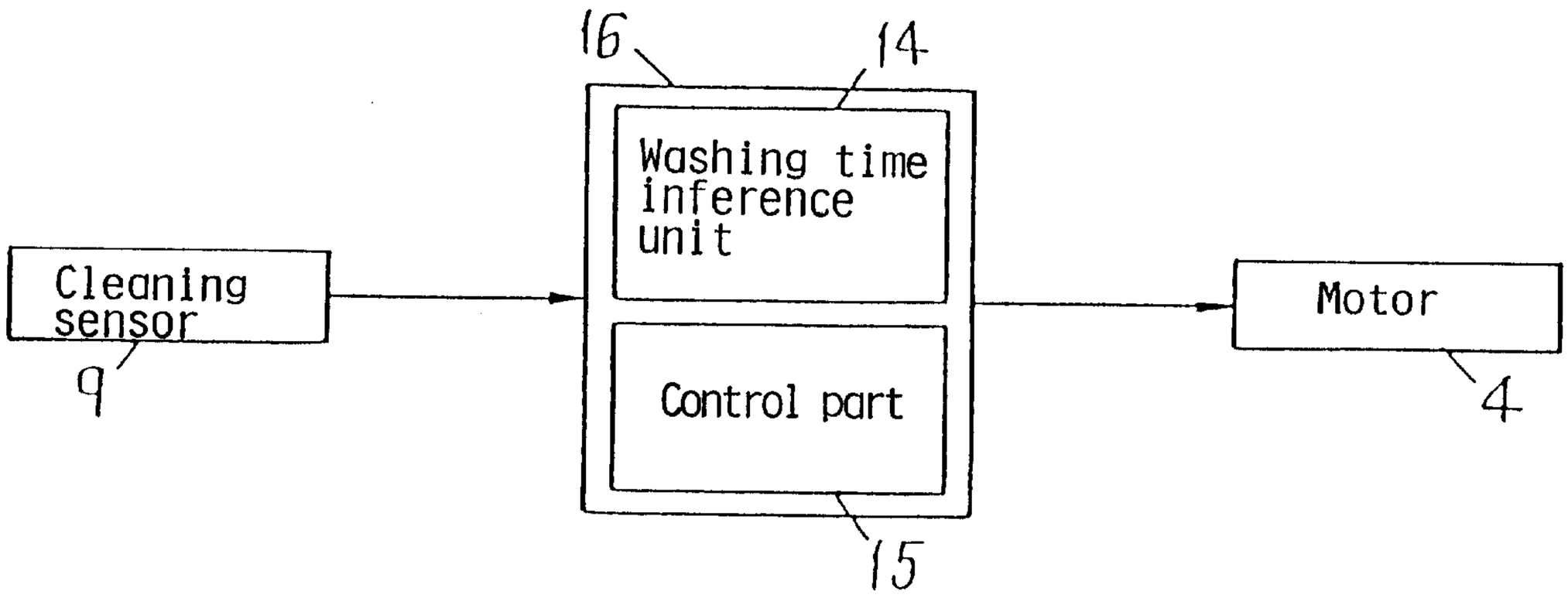


Fig.3

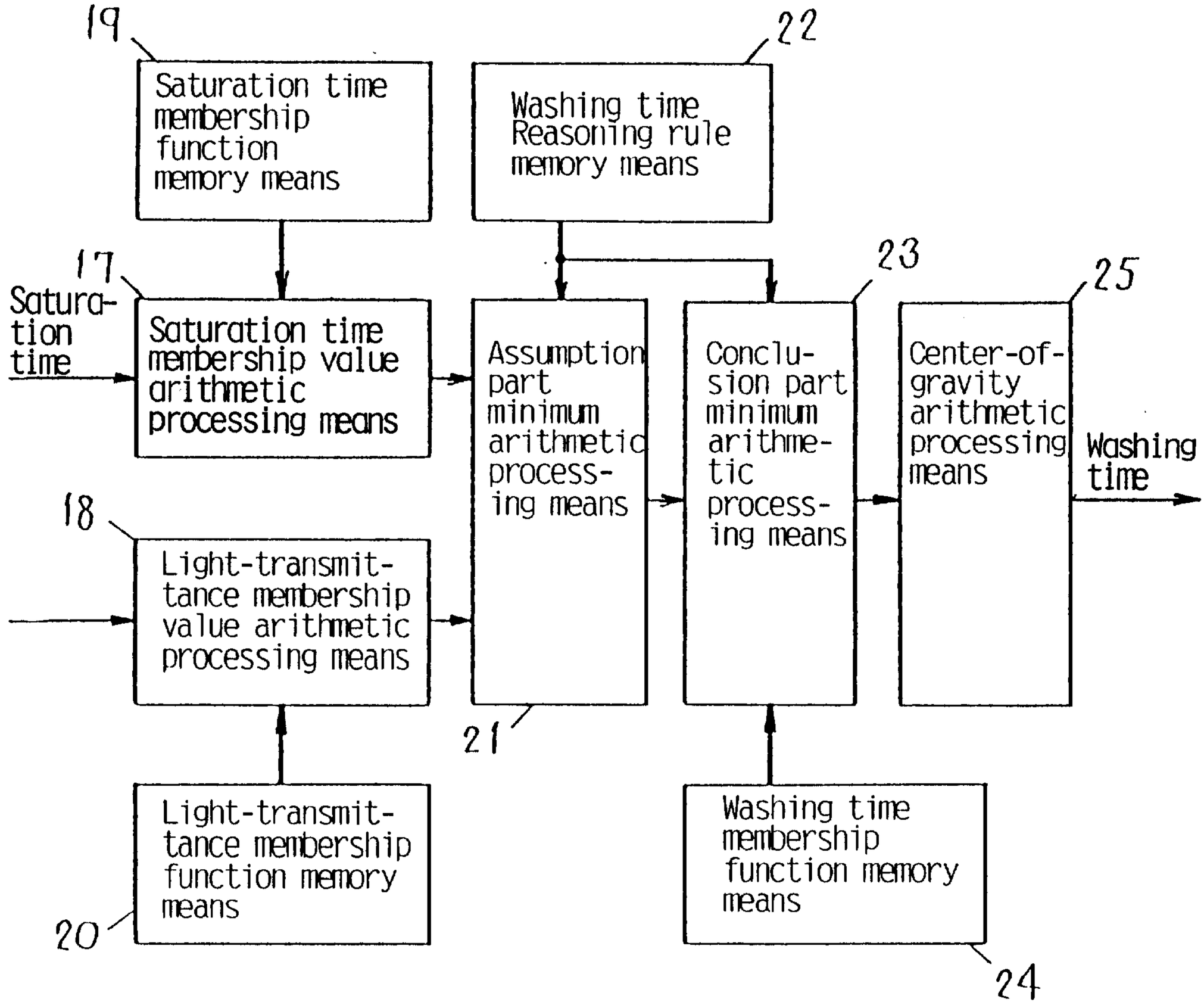


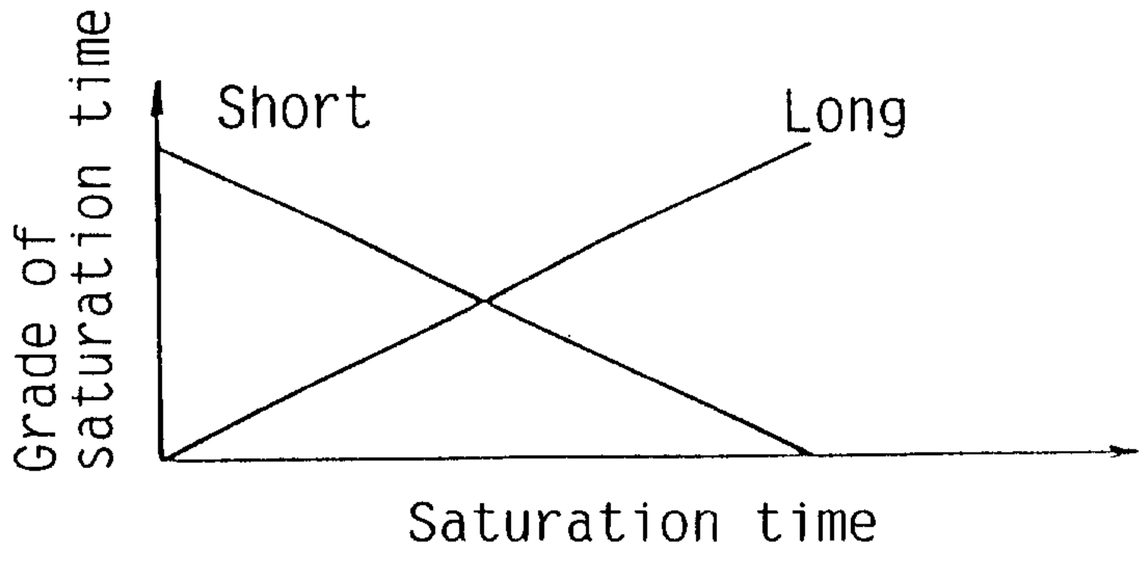
Fig.4

Light-transmittance / Saturation time	High	Normal	Low
Short	Very short	Short	Long
Long	Short	Long	Very long

Washing time

Fig.5

(a) Saturation timemembership function



(b) Light-transmittance membership function

(c) Washing time membership function

Very short

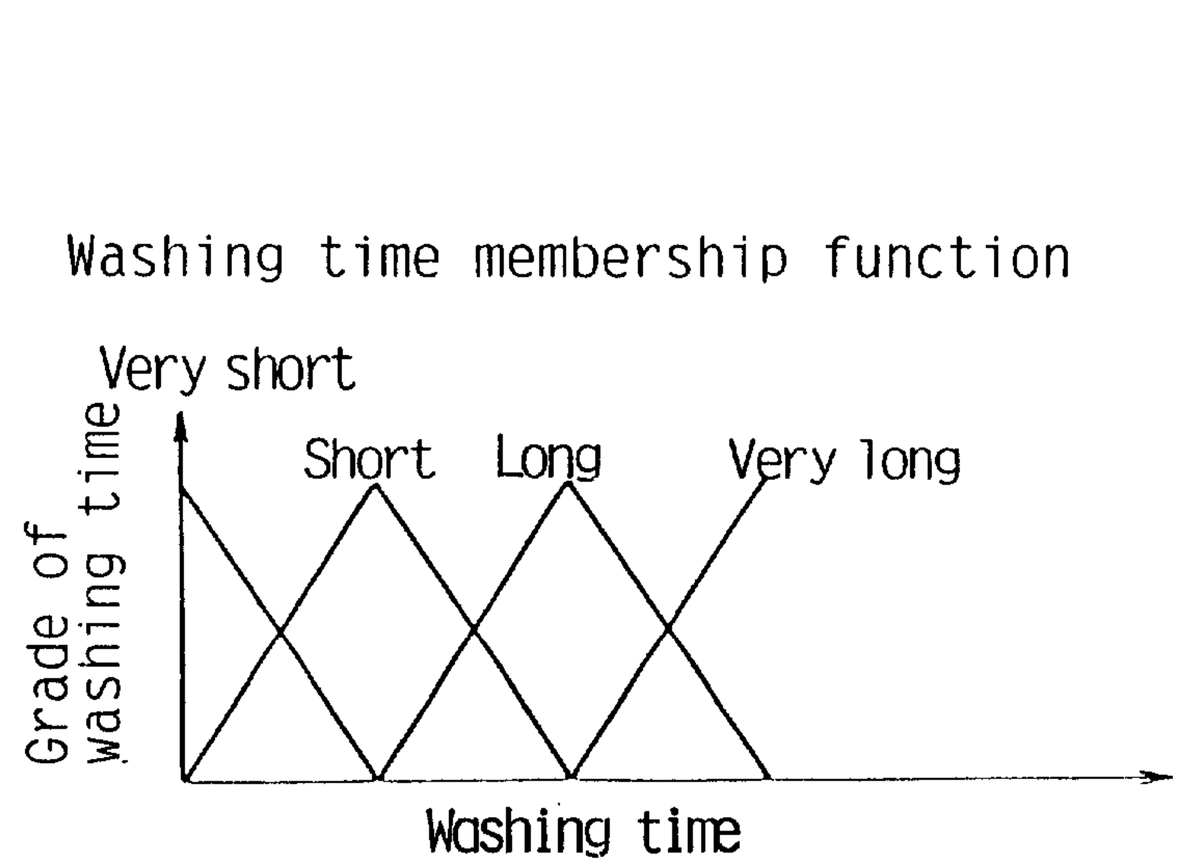


Fig.6

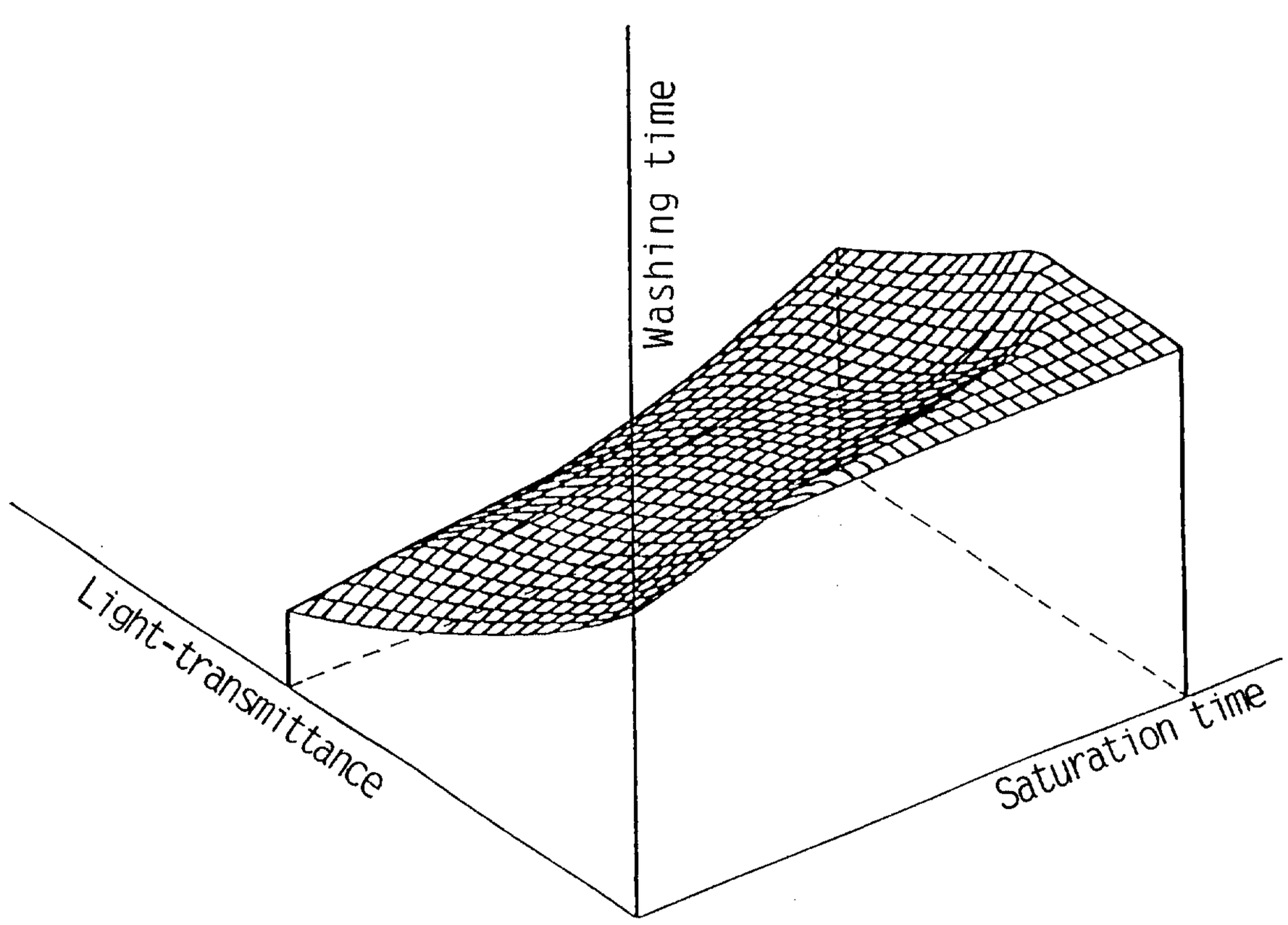

Washing time
Light-transmittance
Saturation time

Fig.7

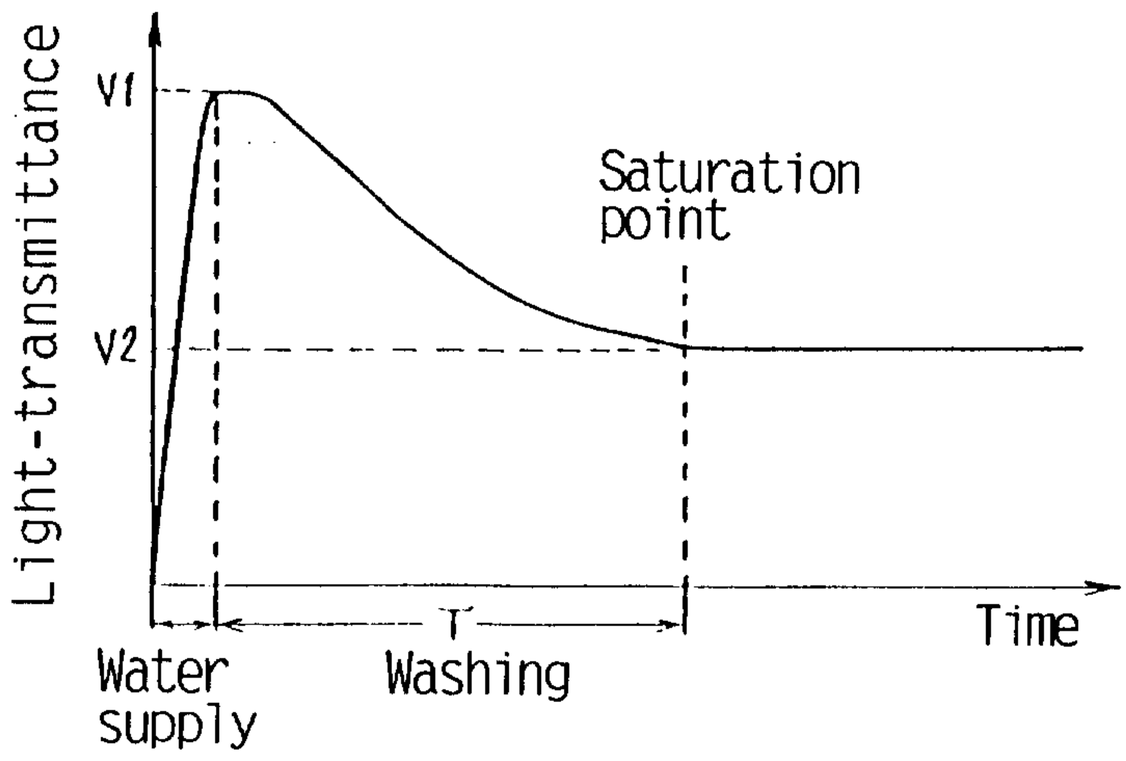
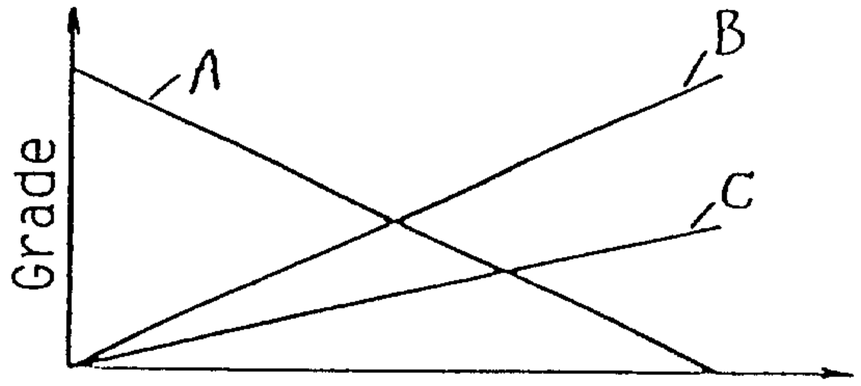

Light-transmittance
V1
V2
Saturation point
Time
Water supply
Washing
T

Fig.8

(a)



(b)

Assumption part	A	B	C
Conclusion part	10	0	0

Fig. 9

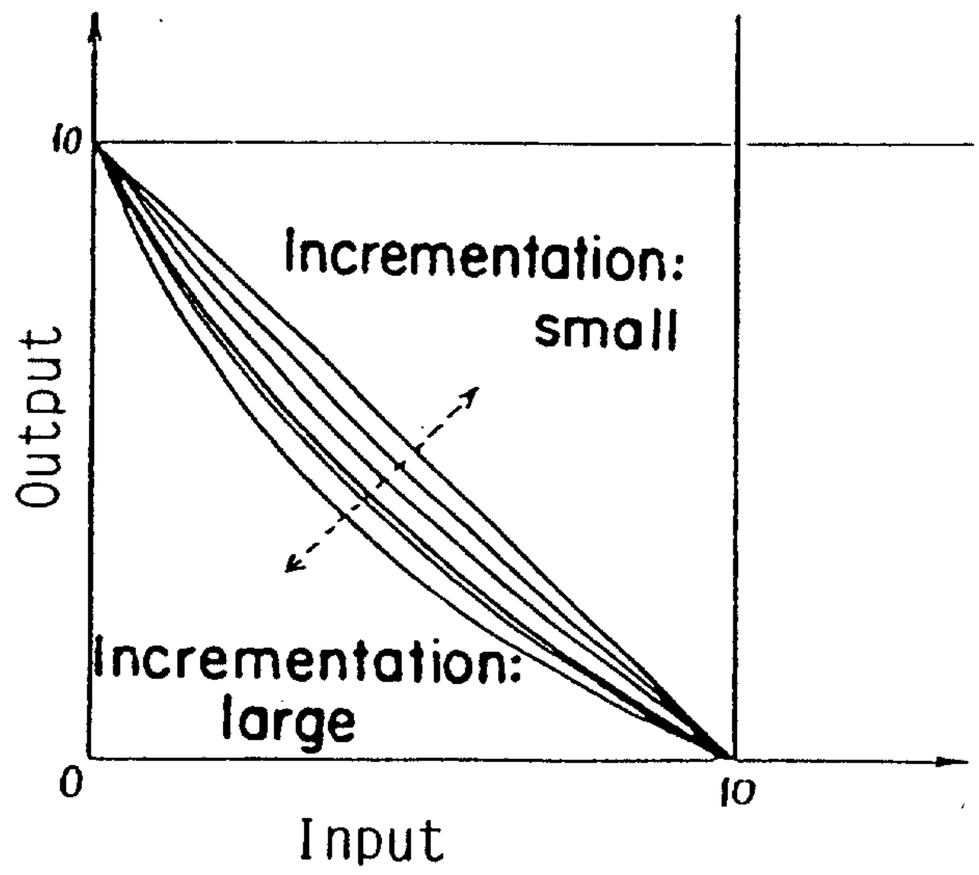


Fig. 10

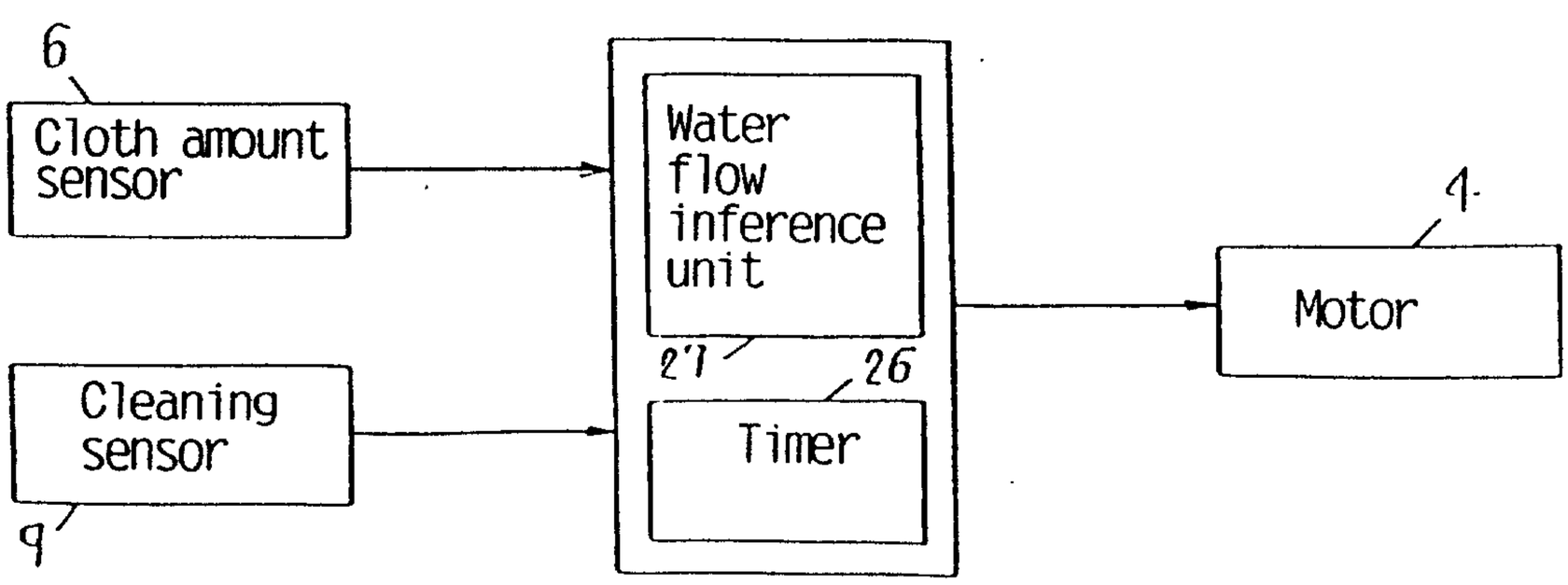


Fig. 11

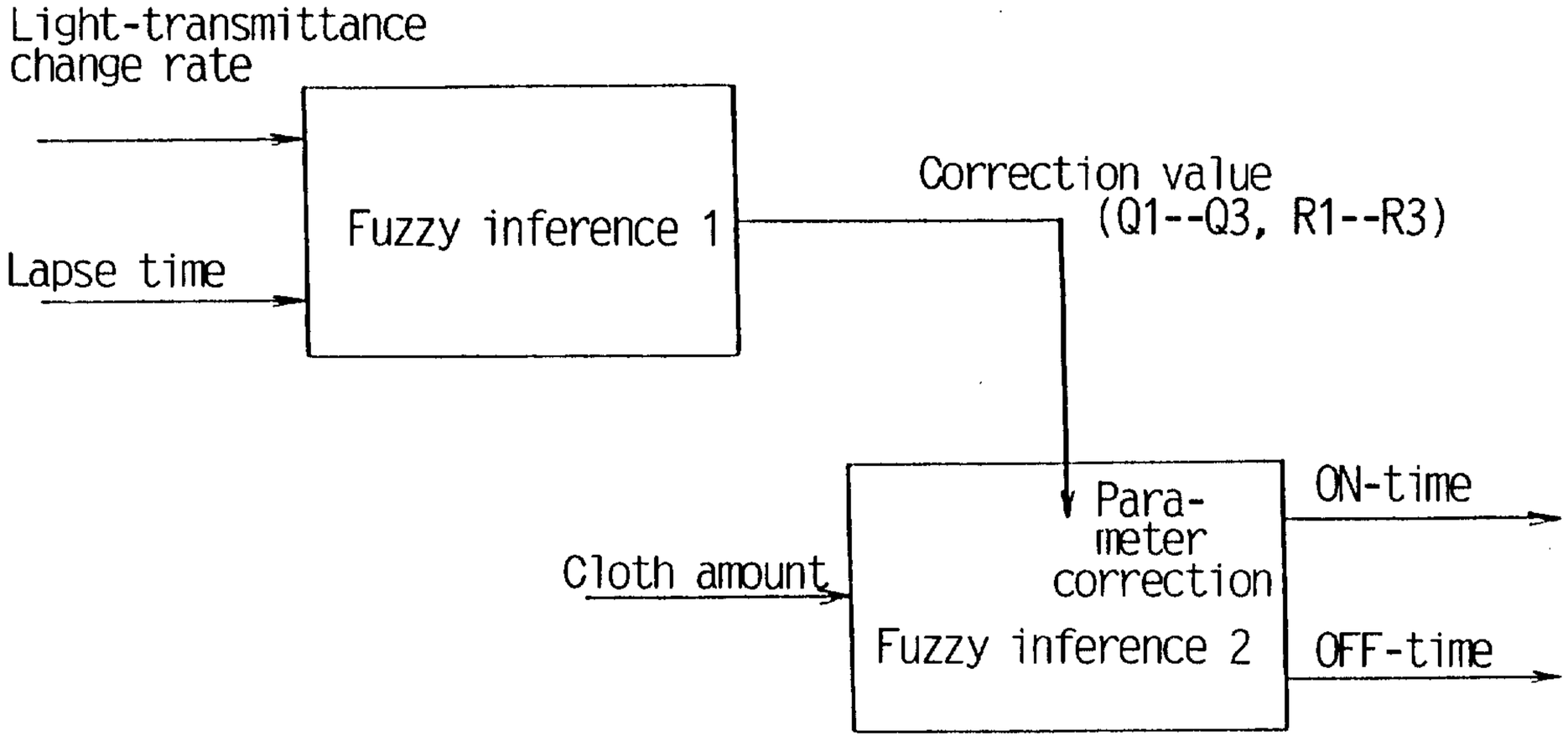


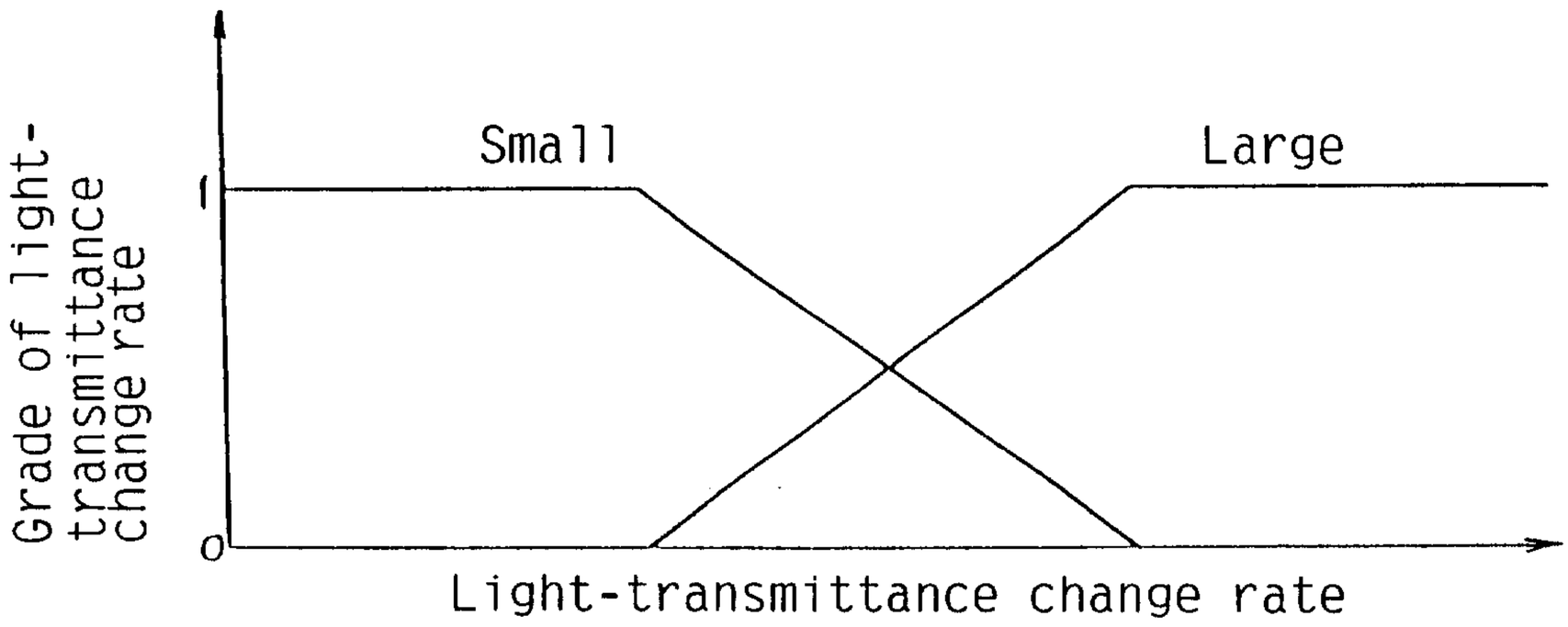
Fig. 12

Fuzzy reasoning 1 (Correction value)

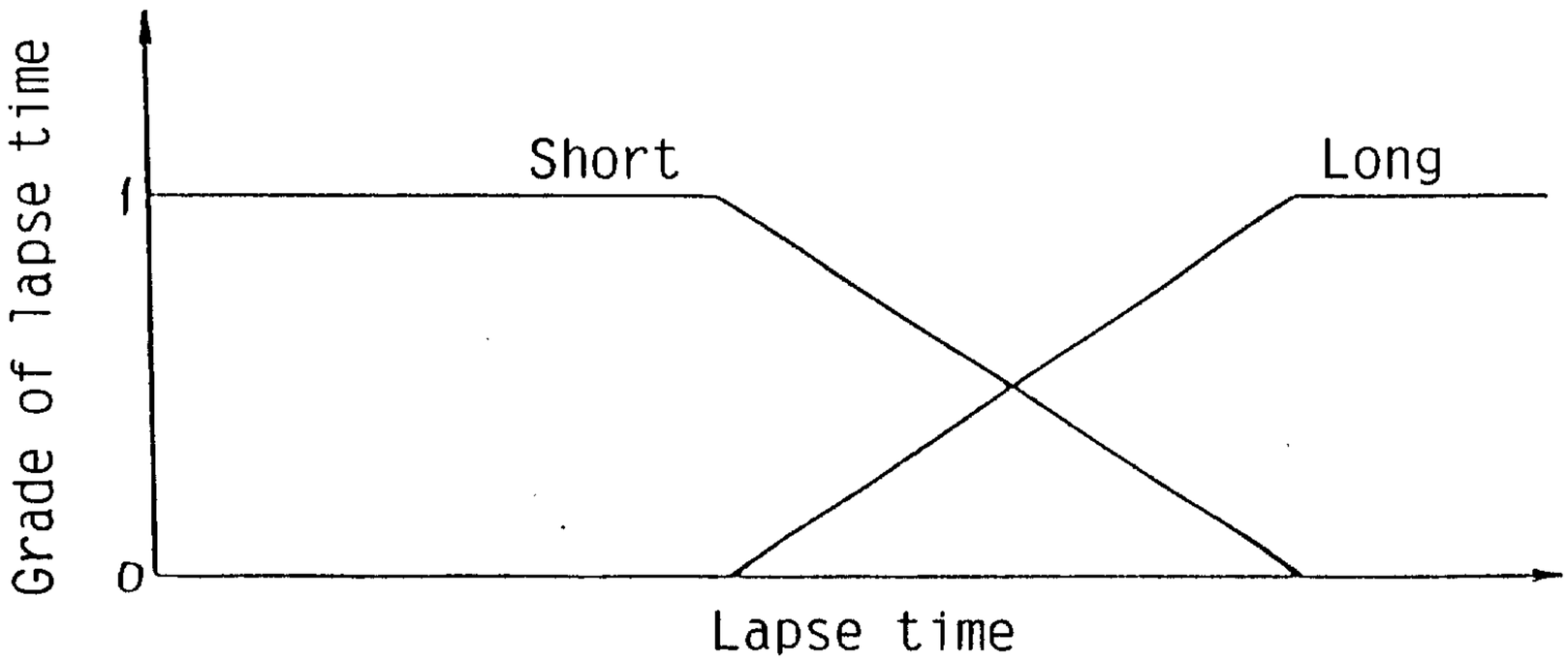
Light-transmittance change rate / Lapse time	Small	Large
Short	(Fairly strong) Q11 R11 Q21 R12 Q31 R13	(Fairly weak) Q12 R12 Q22 R22 Q32 R32
Long	(Fairly weak) Q13 R13 Q23 R23 Q33 R33	(Fairly strong) Q14 R14 Q24 R24 Q34 R34

Fig. 13

(a)


Grade of light-transmittance change rate
1
0
Small
Large
Light-transmittance change rate

(b)


Grade of lapse time
1
0
Short
Long
Lapse time

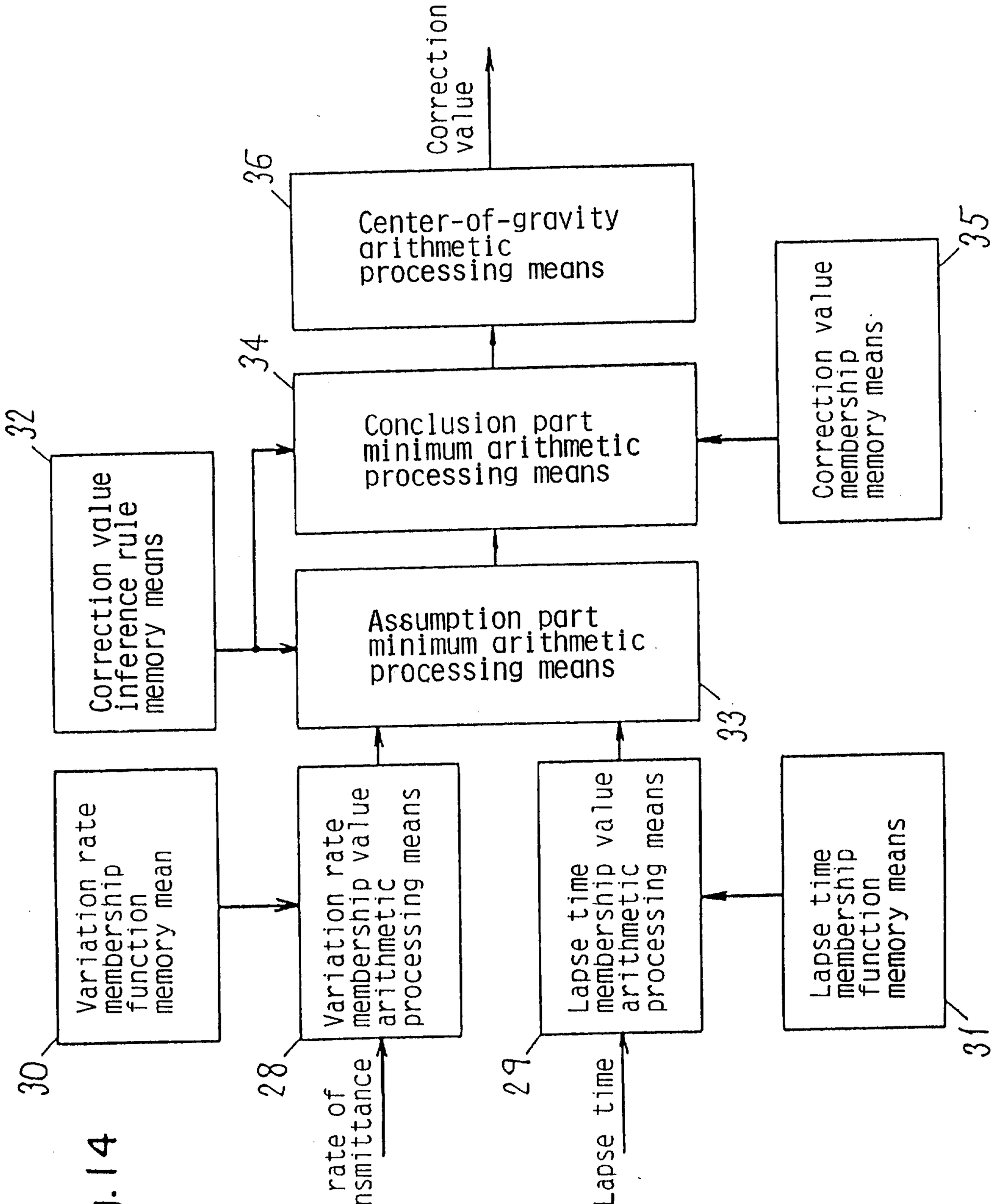

Correction value
36
Center-of-gravity arithmetic processing means
35
Correction value membership memory means
34
Conclusion part minimum arithmetic processing means
32
Correction value inference rule memory means
Assumption part minimum arithmetic processing means
33
Variation rate membership function memory mean
Variation rate membership value arithmetic processing means
Lapse time membership value arithmetic processing means
Lapse time membership function memory means
30
28
29
31
Variation rate of light-transmittance
Lapse time

Fig. 4

Fig. 15

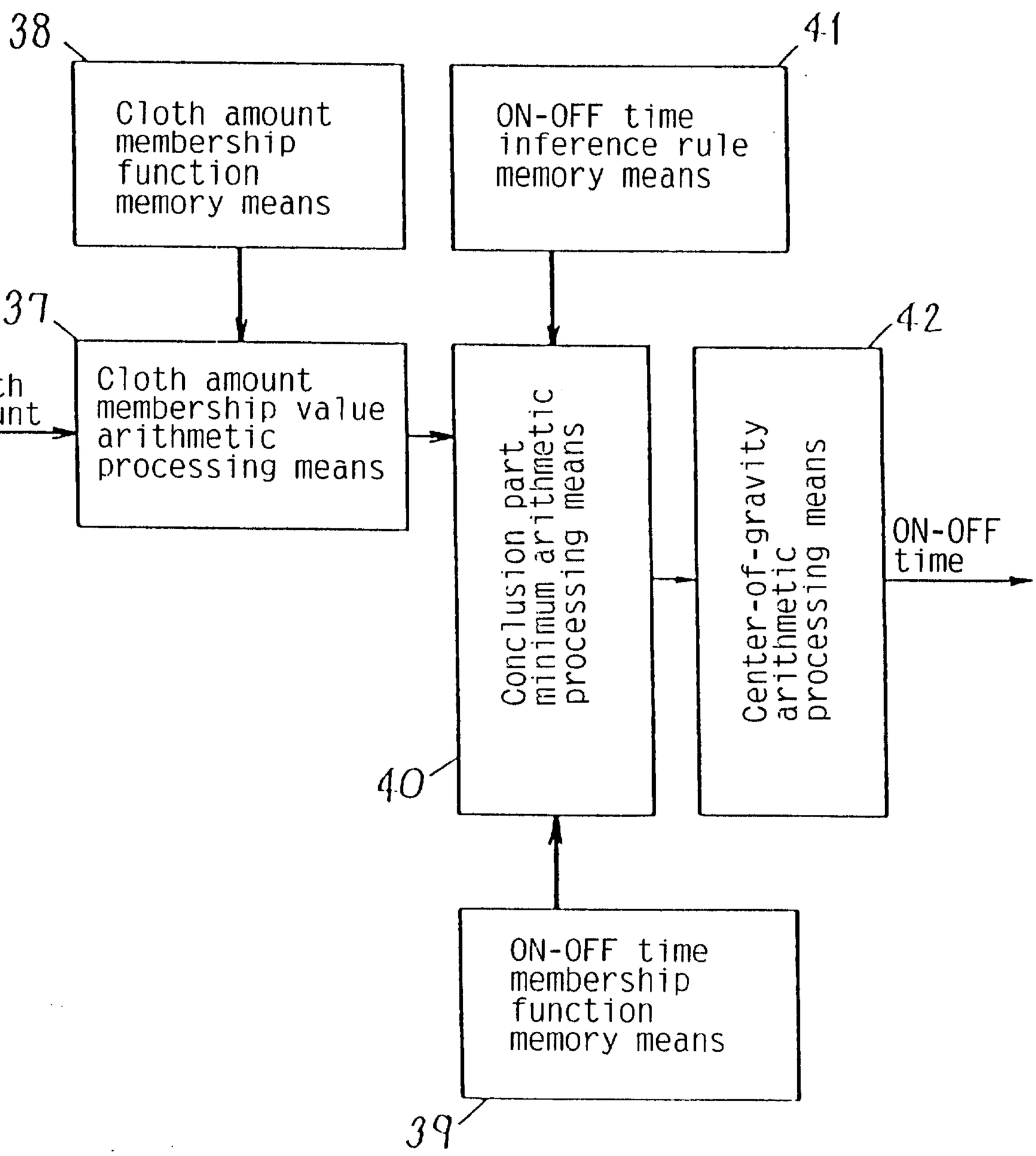

38
Cloth amount membership function memory means
41
ON-OFF time inference rule memory means
37
Cloth amount
Cloth amount membership value arithmetic processing means
42
Conclusion part minimum arithmetic processing means
Center-of-gravity arithmetic processing means
ON-OFF time
40
ON-OFF time membership function memory means
39

Fig. 16

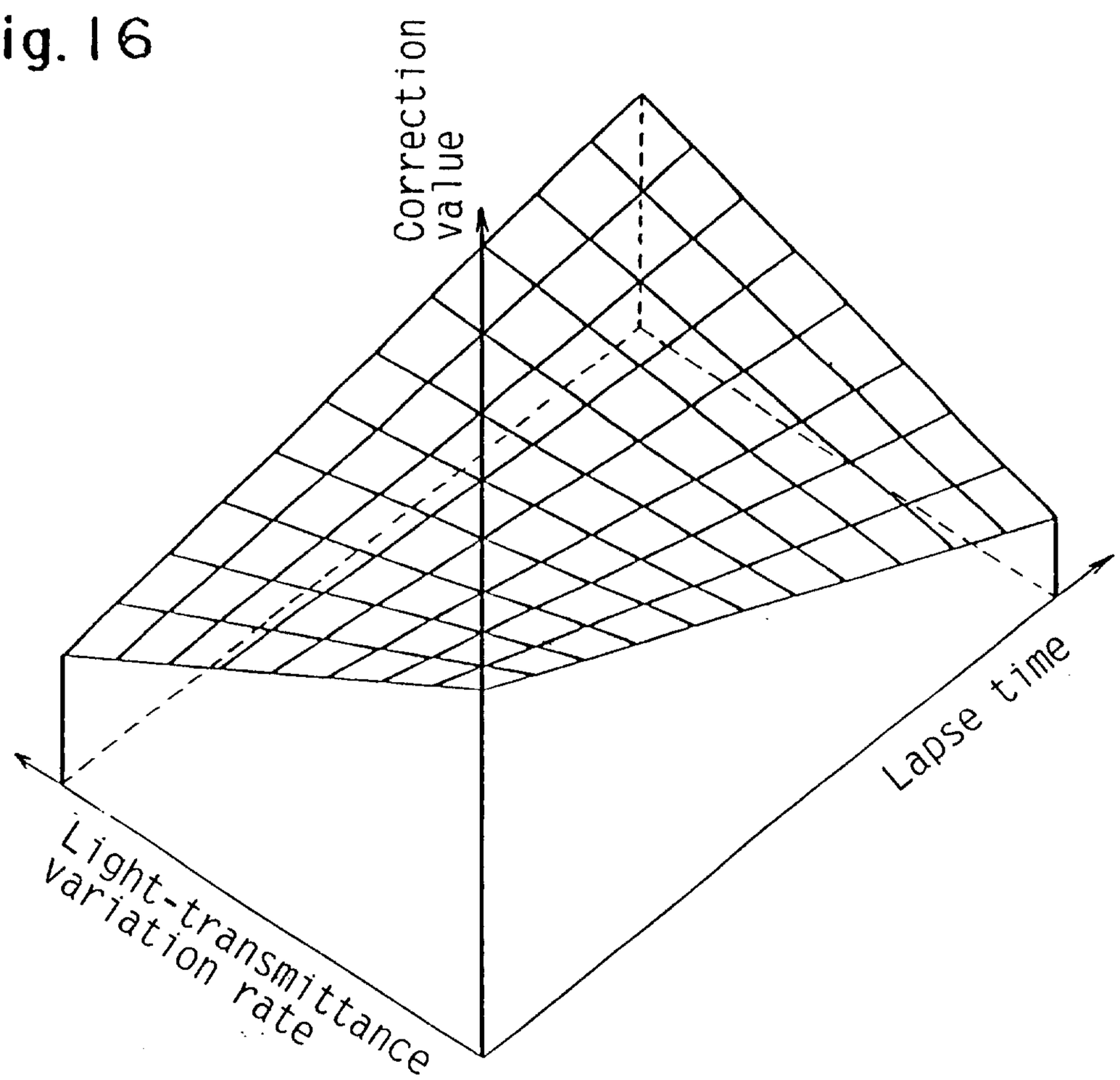


Fig. 17

Fuzzy inference 2

(Strength of water flow)

Cloth amount	Few	Much
	(Weak) f1(x) f3(x)	(Strong) f2(x) f4(x)

Fig. 18

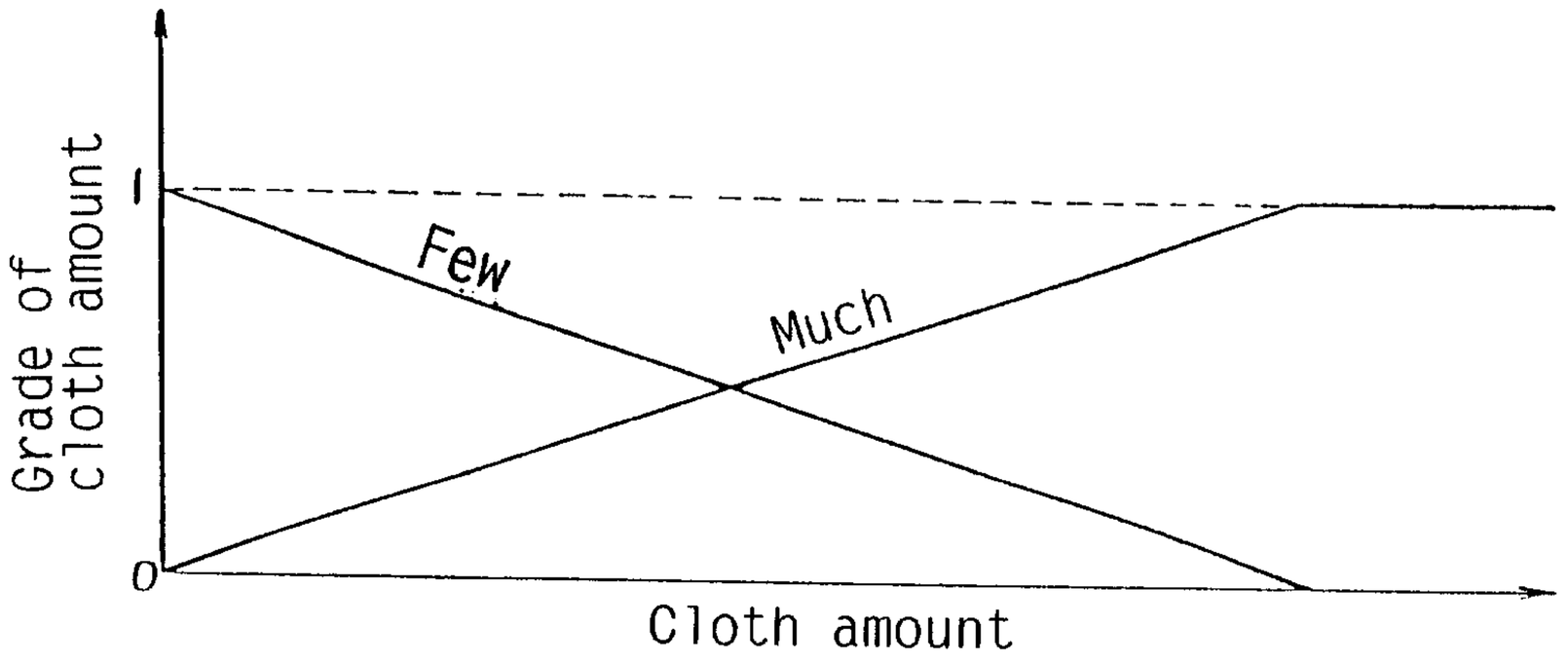

Grade of cloth amount
1
0
Few
Much
Cloth amount

Fig. 19

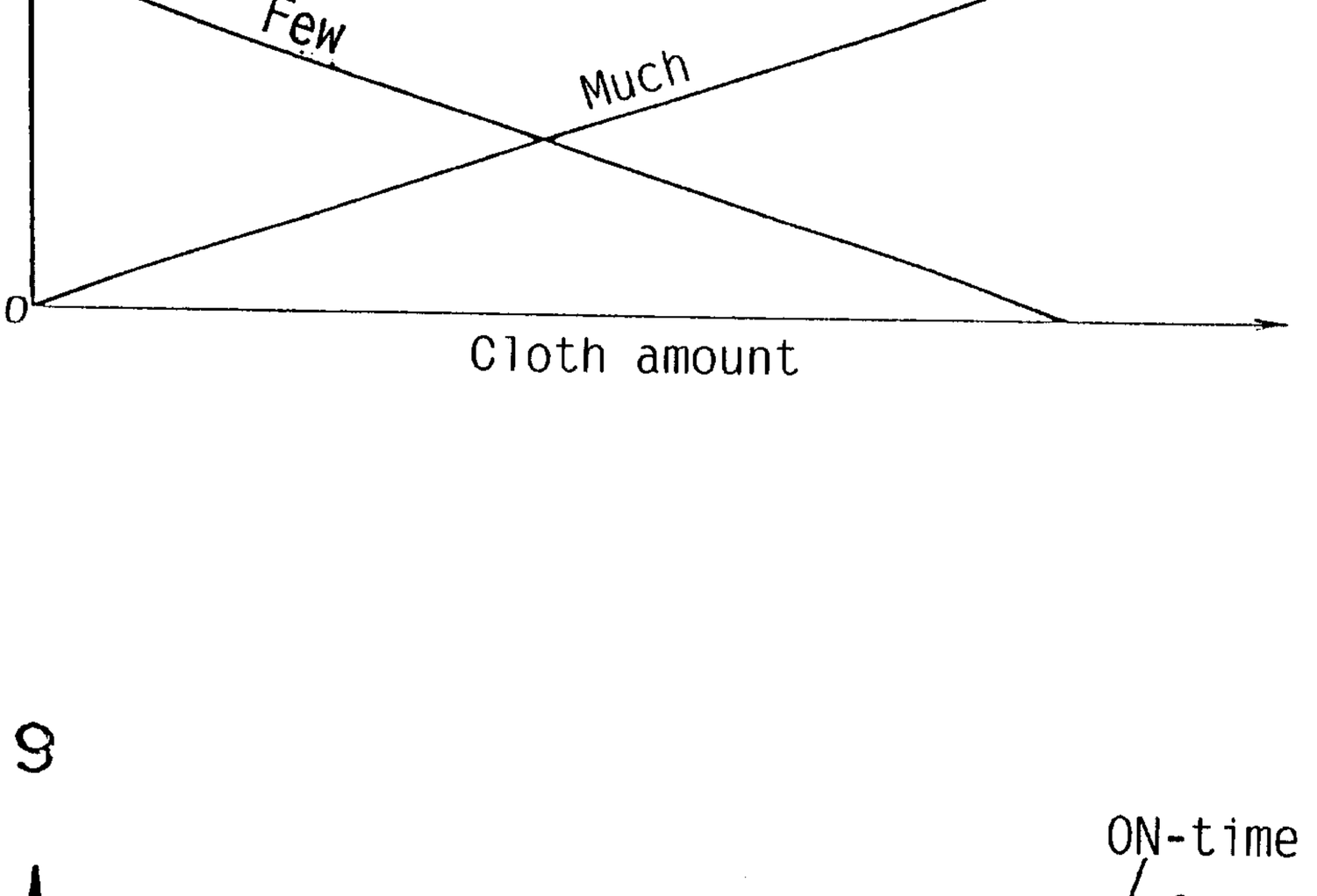

ON-time
Q3
R1
f1(x)
f2(x)
R2
Time
f3(x)
Q2
f4(x)
OFF-time
R3
Q1
x0
x1
x2
Cloth amount

Fig.20

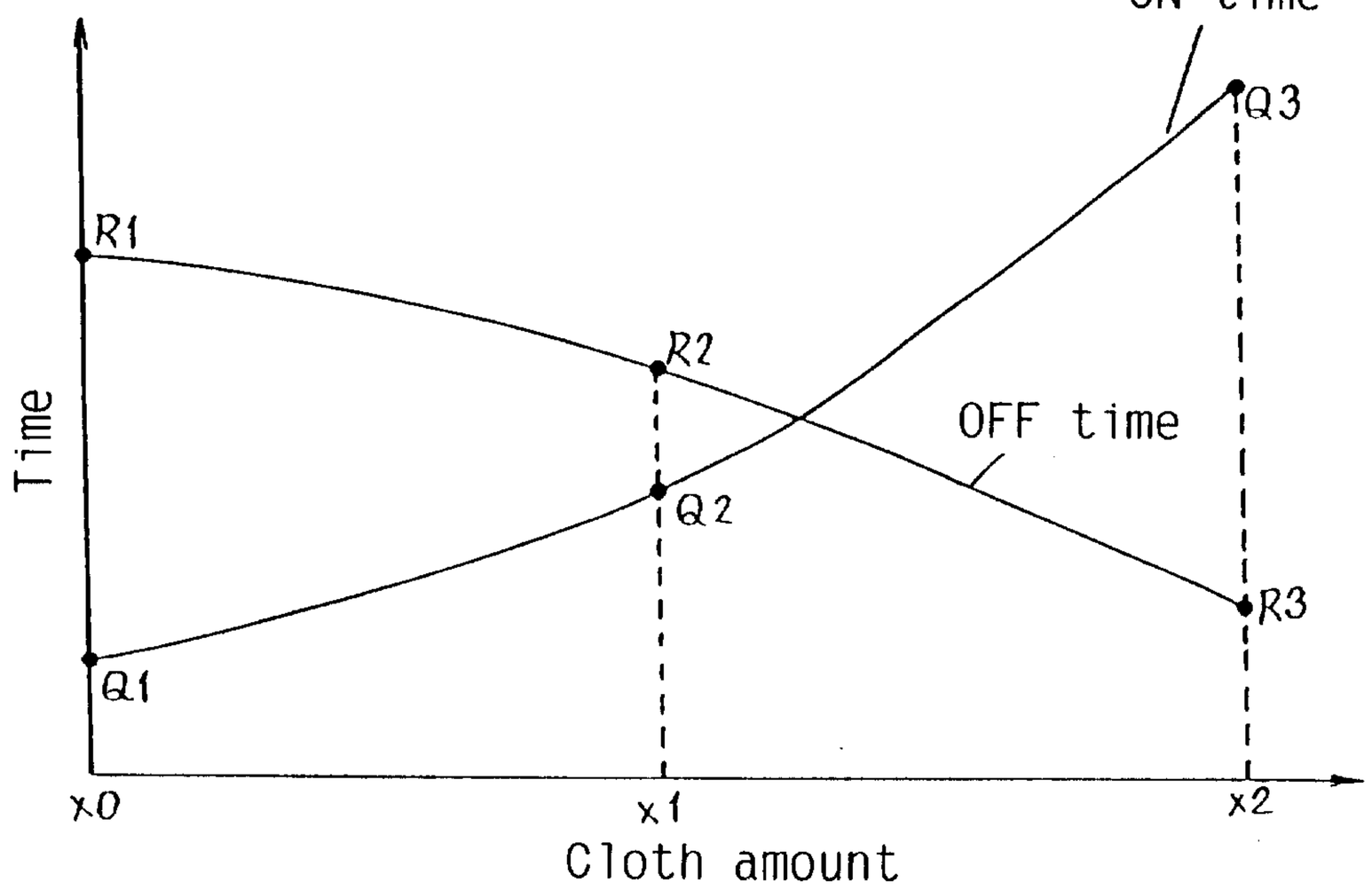

ON-time
OFF time
Time
R1
R2
R3
Q1
Q2
Q3
x0
x1
x2
Cloth amount

Fig.21

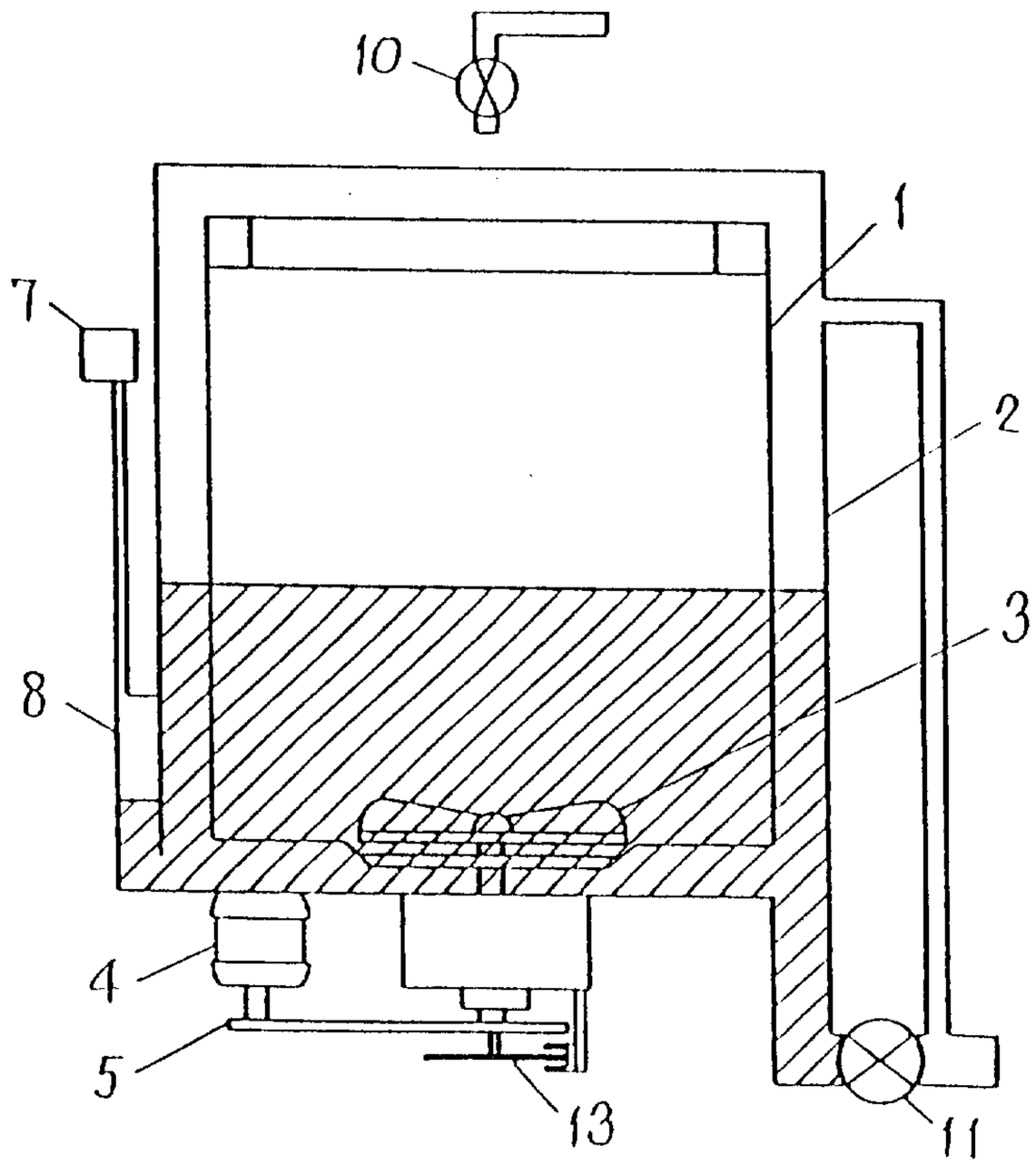

10
1
2
3
4
5
7
8
11
13

Fig. 22

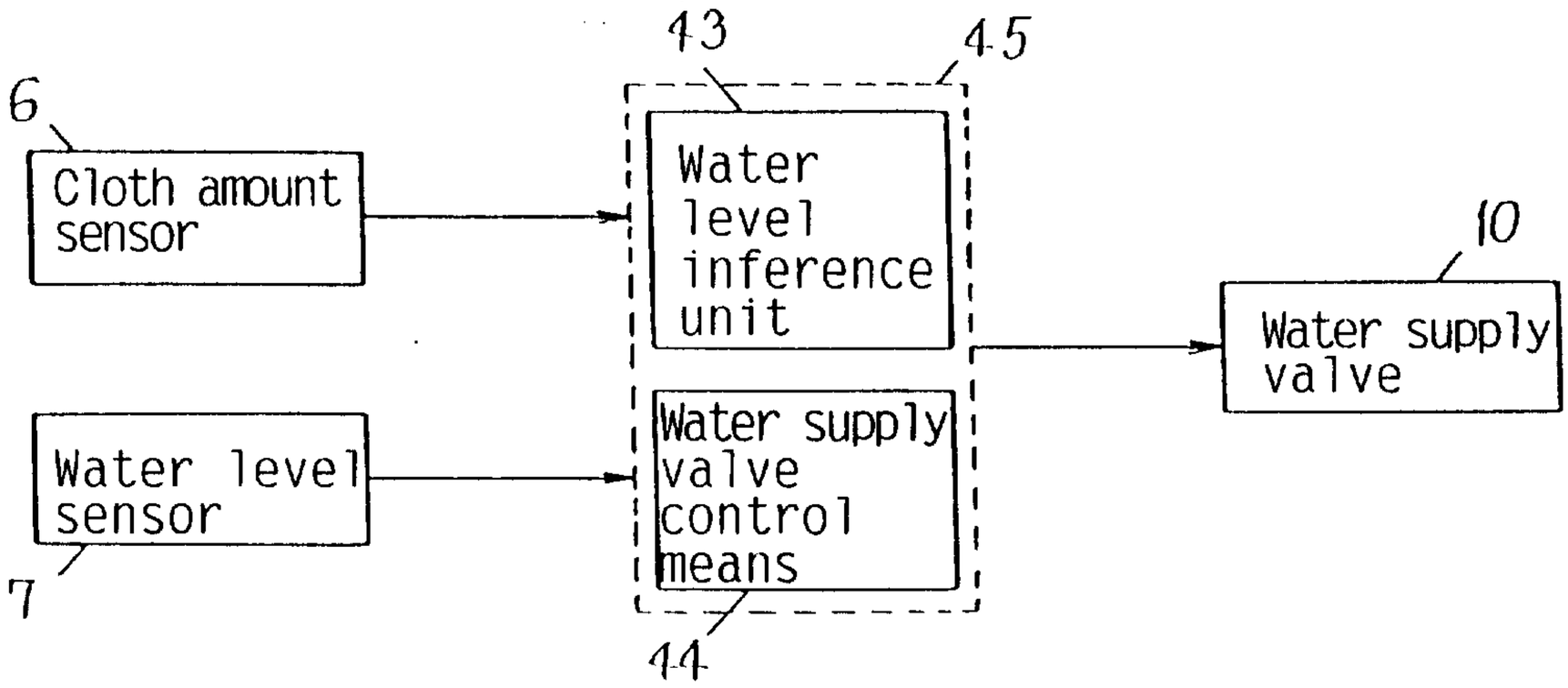


Fig. 23

Cloth amount	Very few	Few	Much	Very much
Water level	Very low	Low	High	Very high

Fig.24

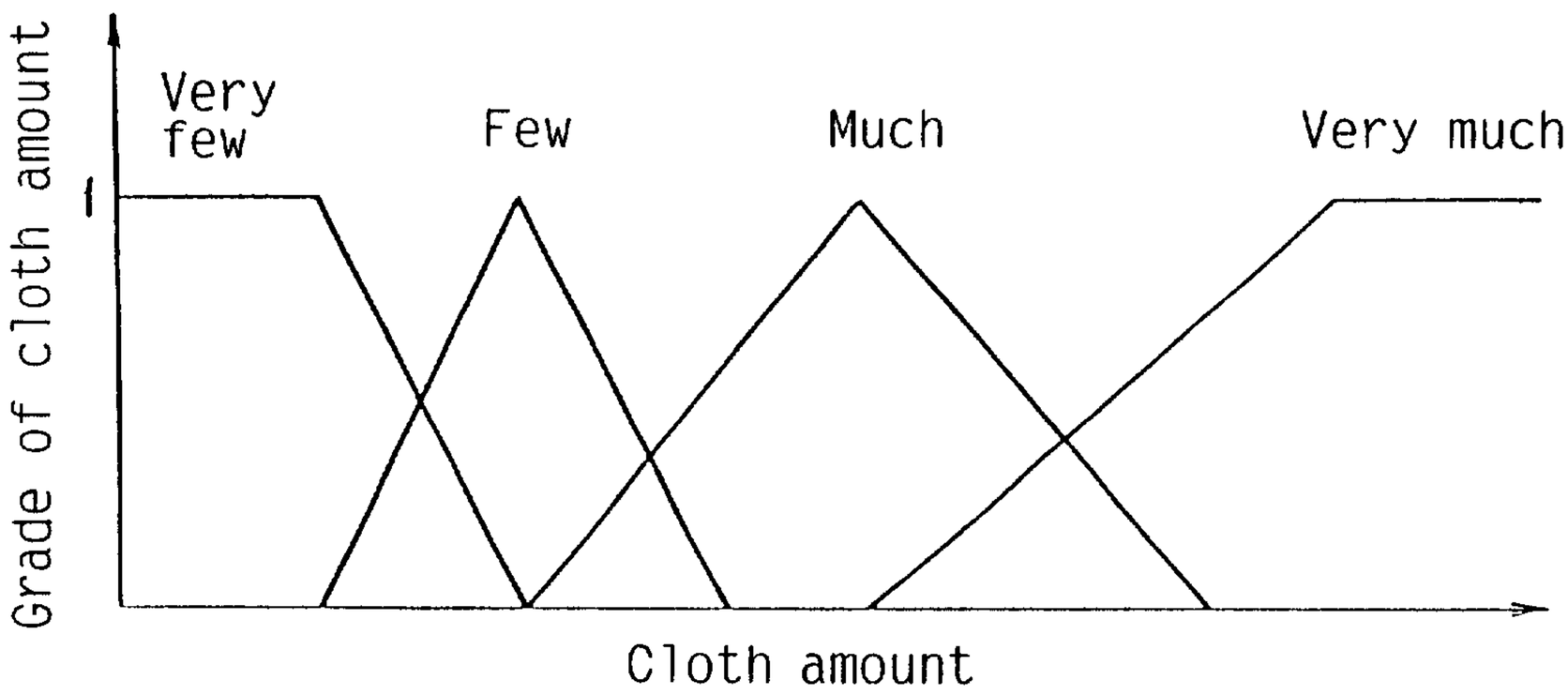

Grade of cloth amount
1
Very few
Few
Much
Very much
Cloth amount

Fig.25

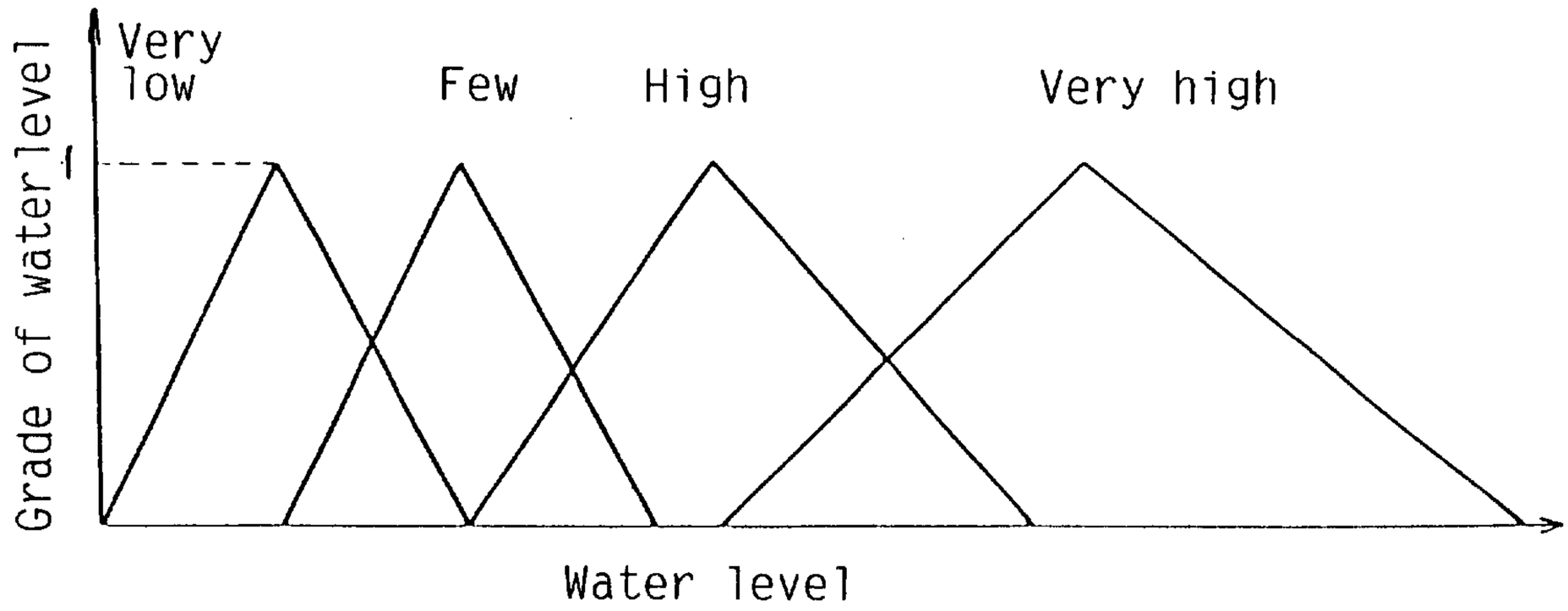

Grade of water level
1
Very low
Few
High
Very high
Water level

Fig. 26

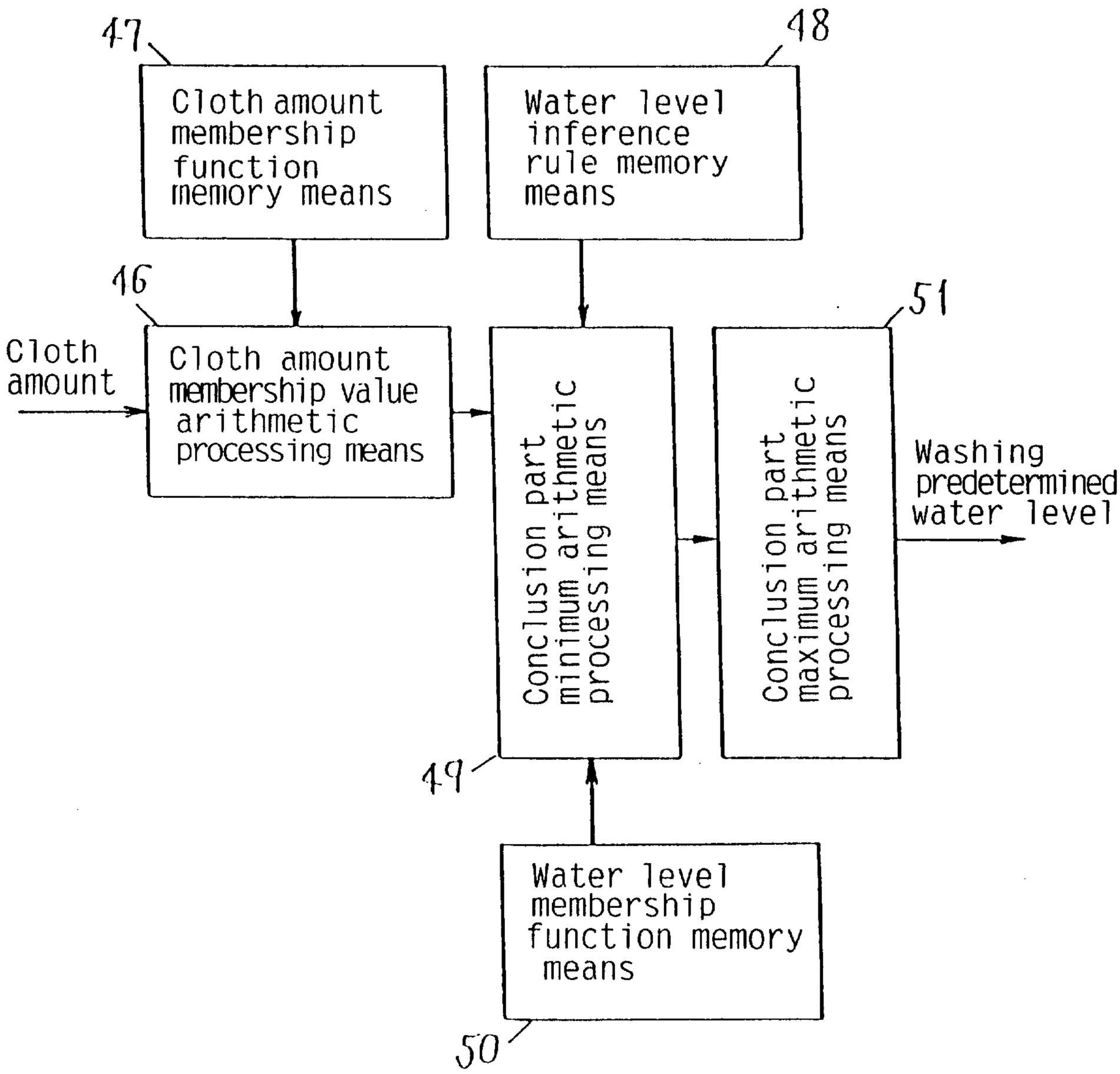
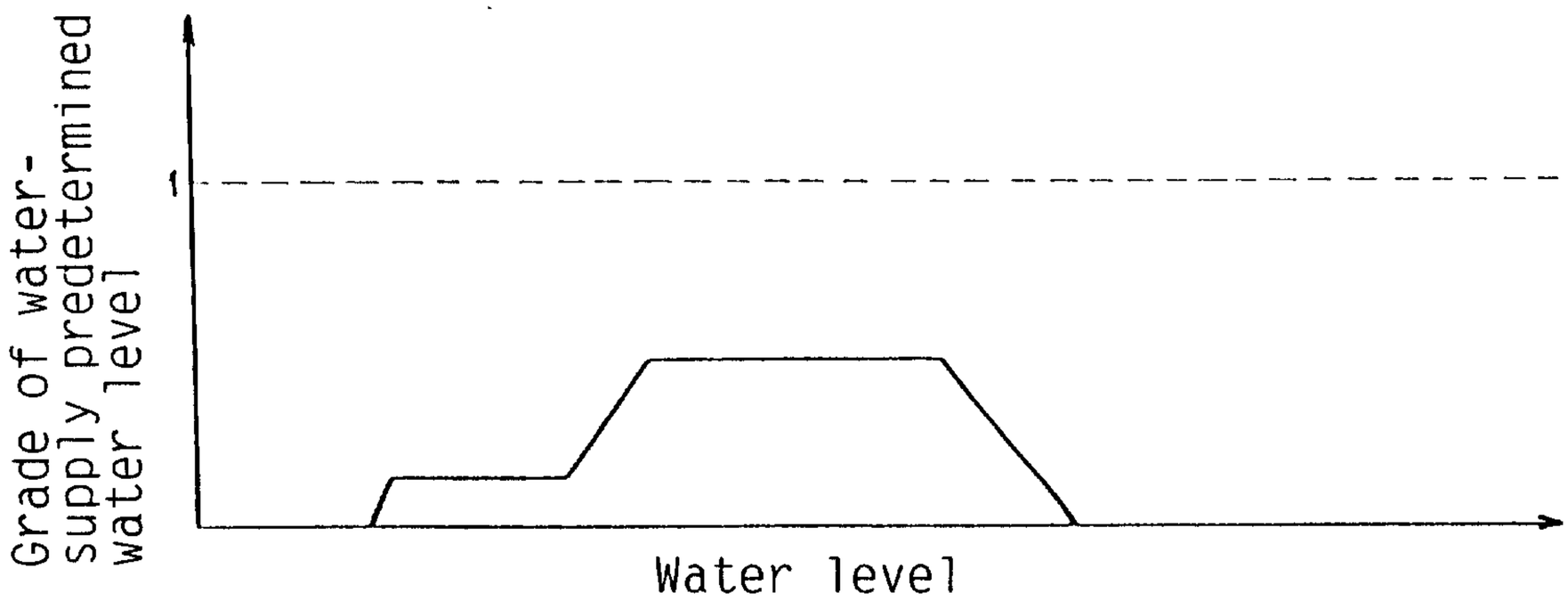
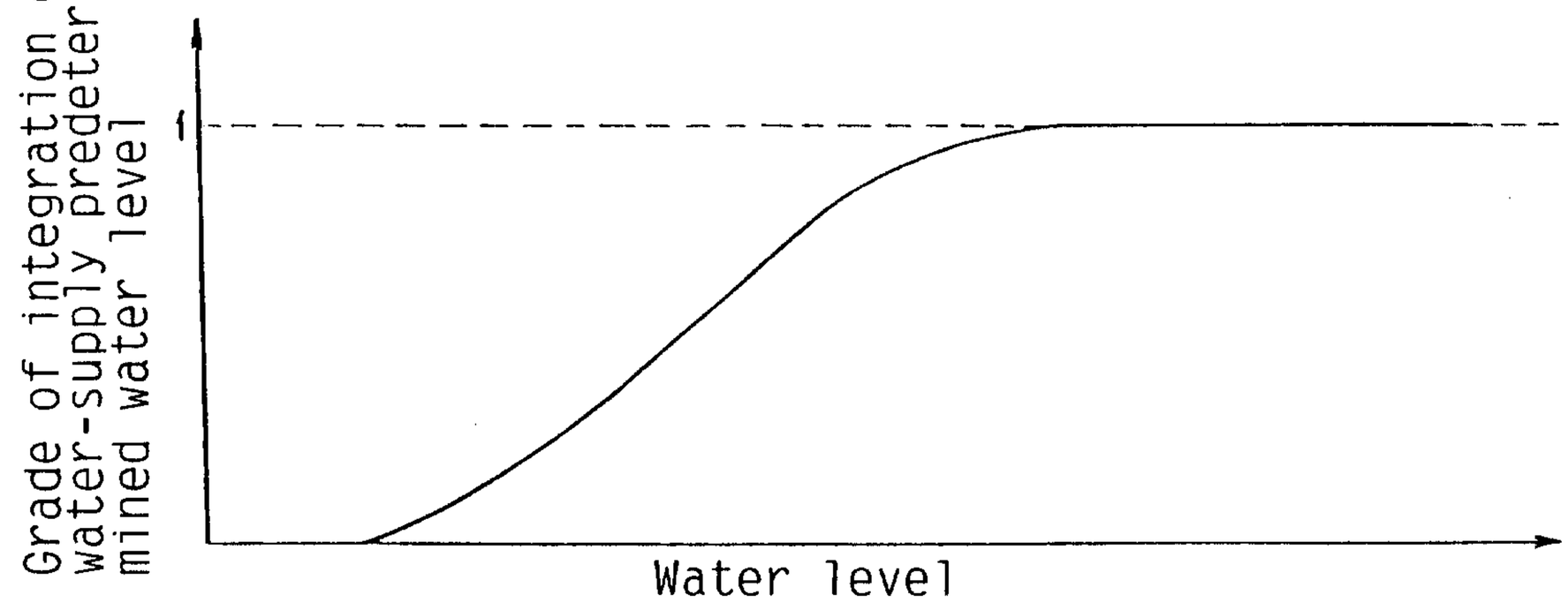

47
Cloth amount membership function memory means
48
Water level inference rule memory means
16
Cloth amount
Cloth amount membership value arithmetic processing means
Conclusion part minimum arithmetic processing means
51
Conclusion part maximum arithmetic processing means
Washing predetermined water level
49
Water level membership function memory means
50

Fig.27

(a)


Grade of water-supply predetermined water level
1
Water level

(b)


Grade of integration of water-supply predetermined water level
1
Water level

(C)

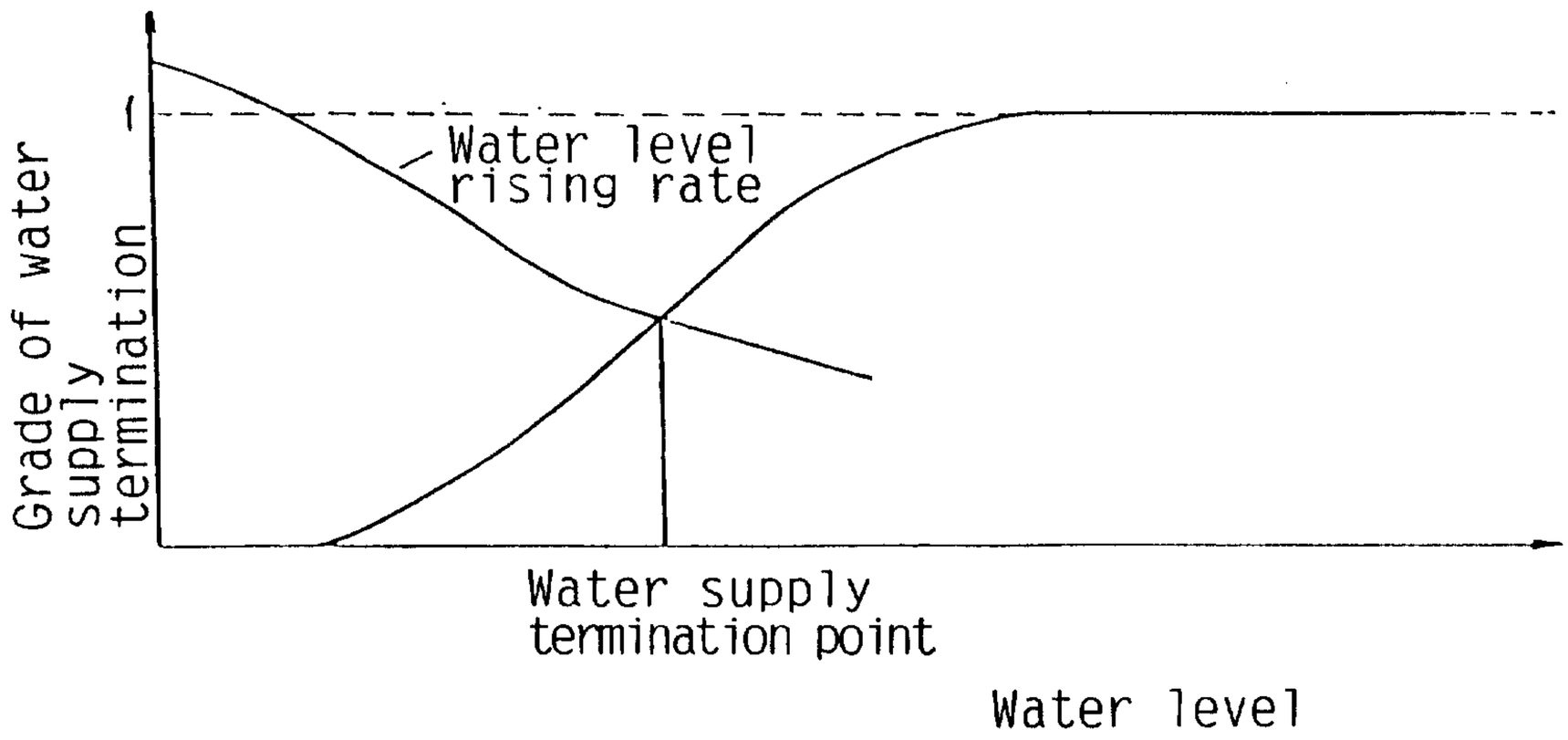

Grade of water supply termination
1
Water level rising rate
Water supply termination point
Water level

Fig.28

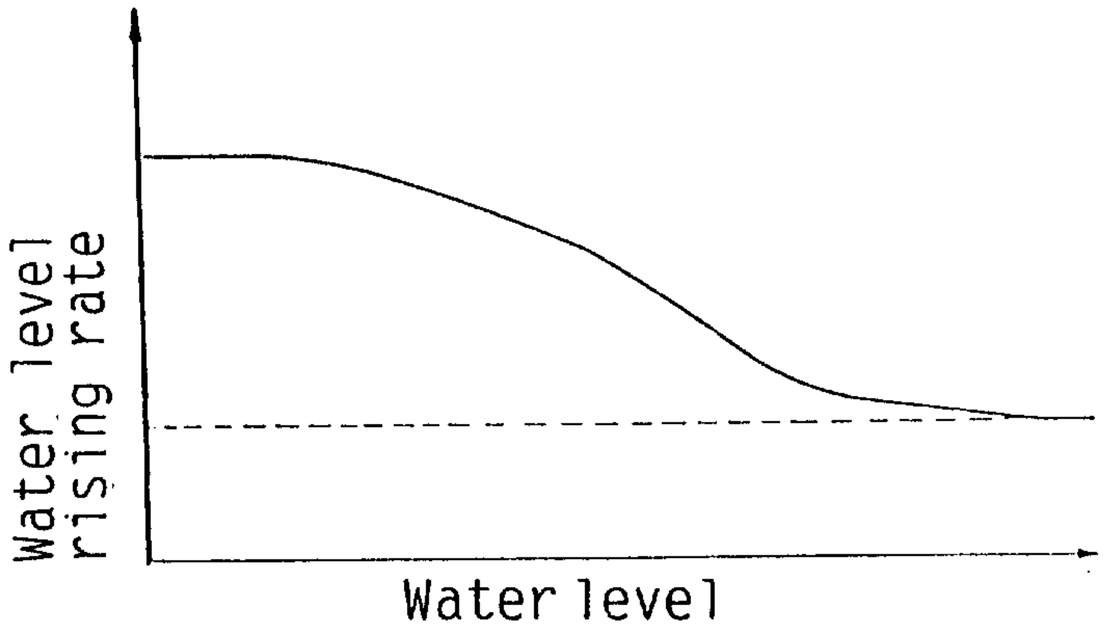


Fig.29

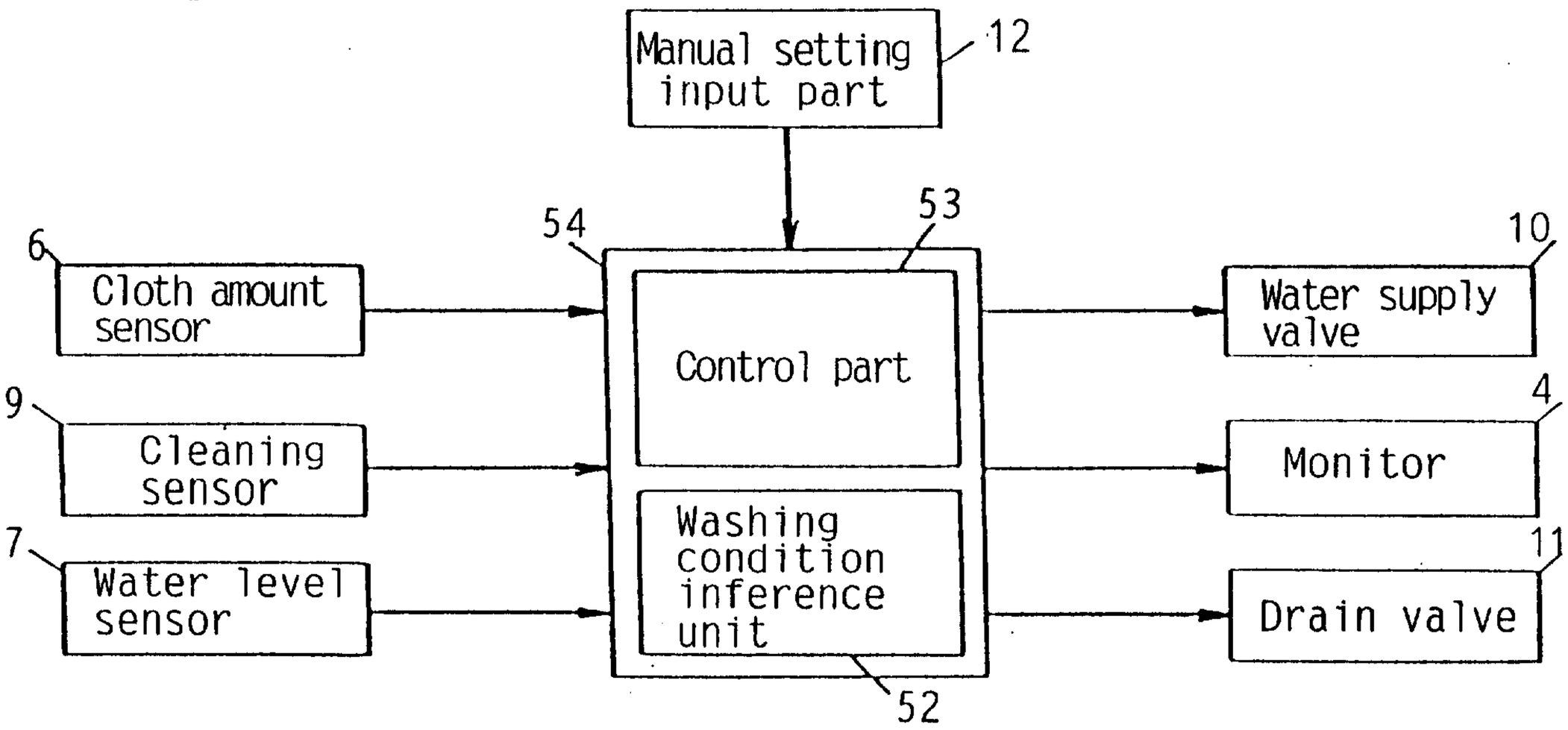


Fig.30

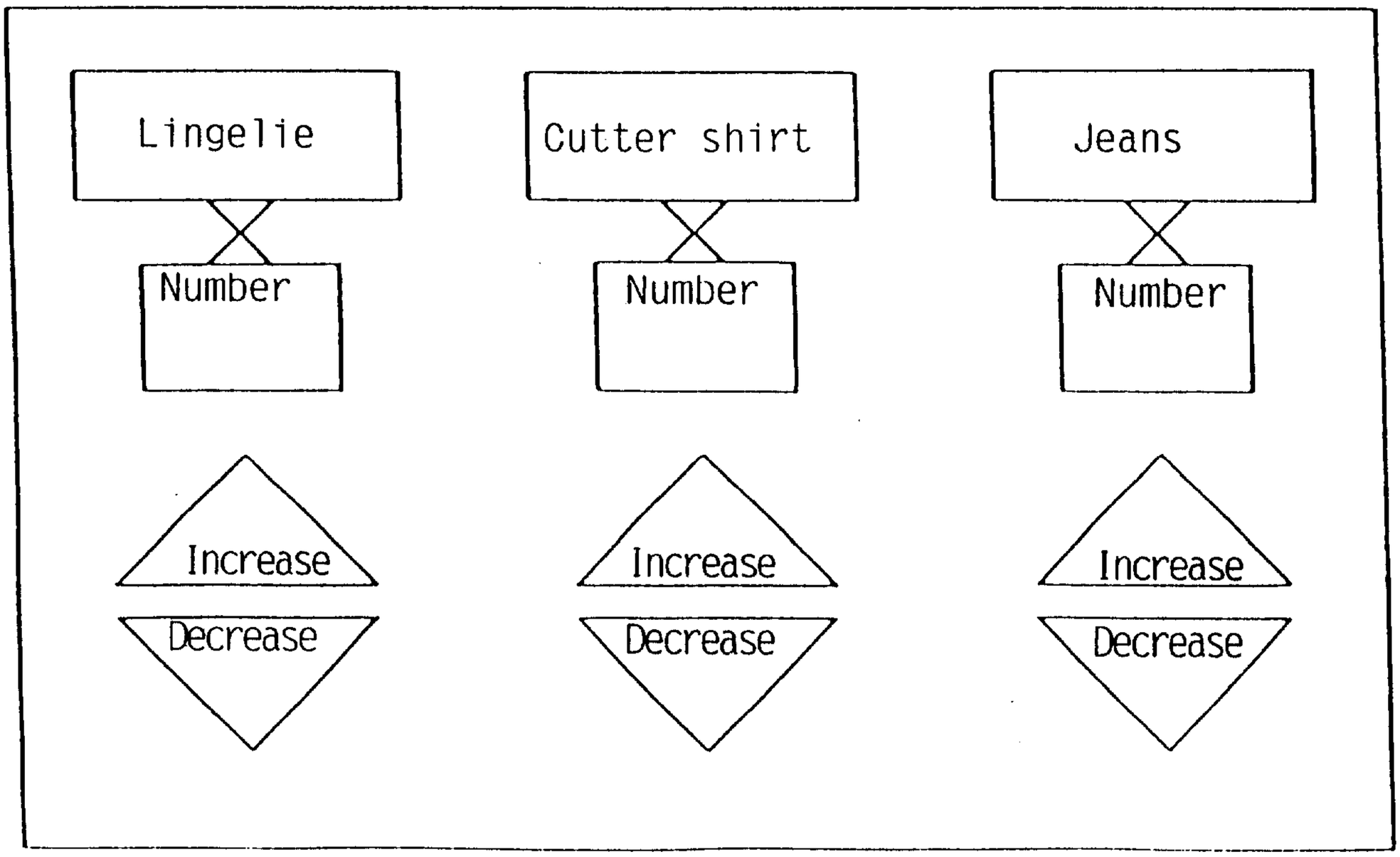
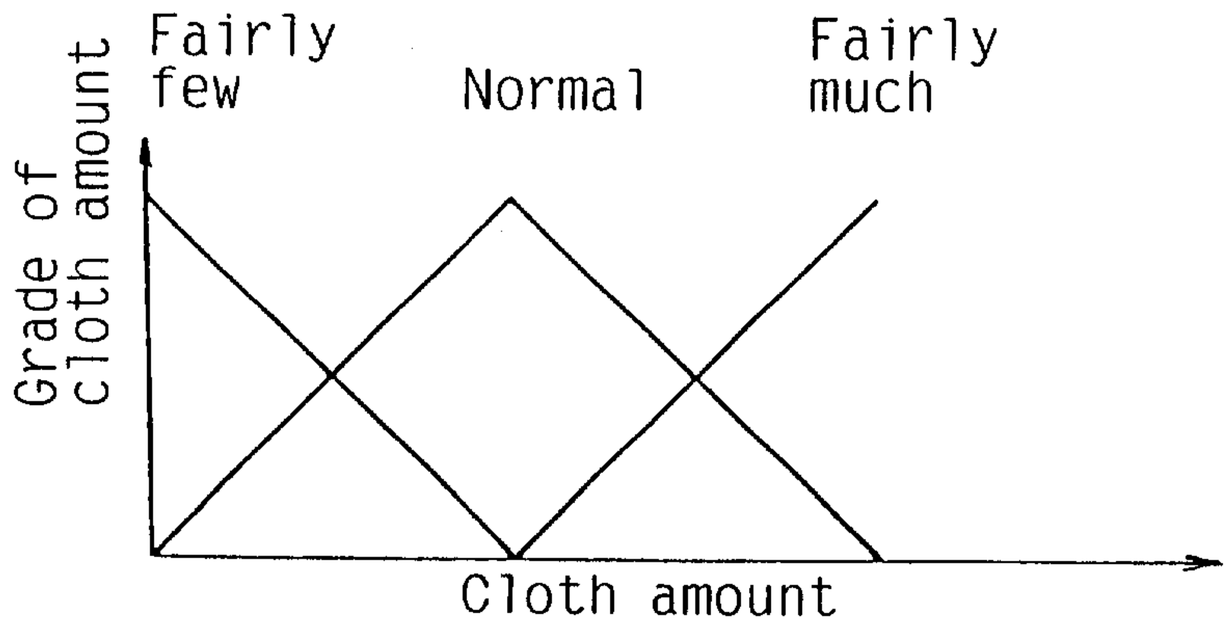


Fig. 31

Wash \ Cloth amount	Fairly few	Normal	Fairly much
Lingerie	Normal	Fairly much	Very much
Cutter shirt	Fairly few	Normal	Rather much
Jeans	Very few	Fairly few	Normal

Fig. 32

(a)



(b)

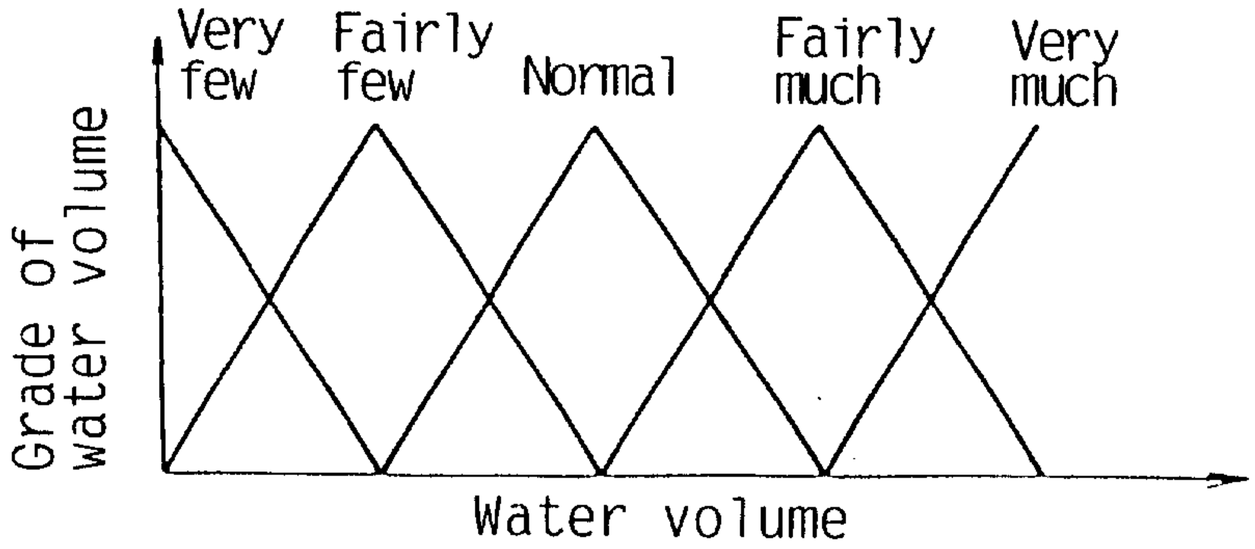


Fig. 33

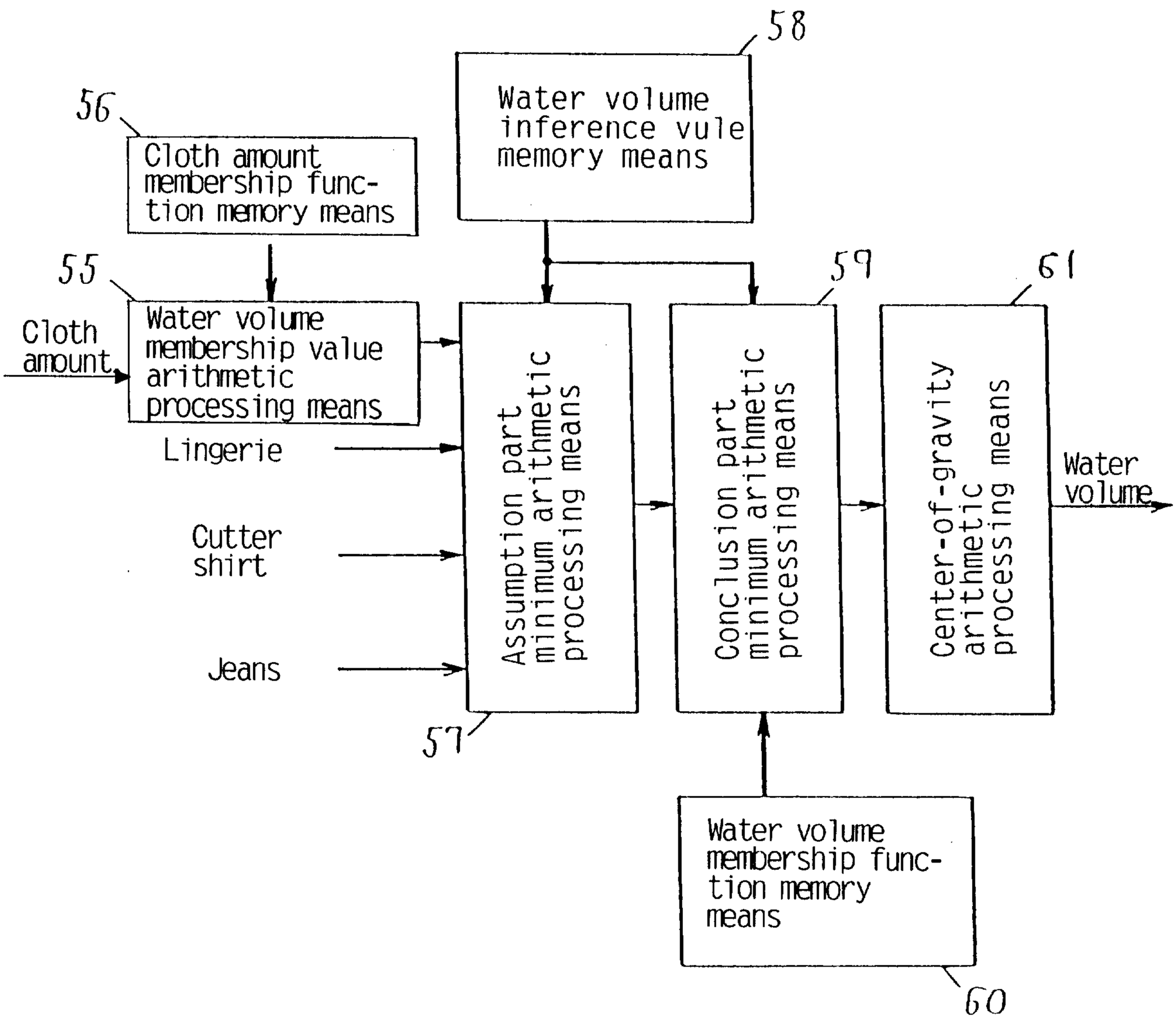

56
Cloth amount membership function memory means
58
Water volume inference vule memory means
55
Water volume membership value arithmetic processing means
Cloth amount
Lingerie
Cutter shirt
Jeans
57
Assumption part minimum arithmetic processing means
59
Conclusion part minimum arithmetic processing means
61
Center-of-gravity arithmetic processing means
Water volume
Water volume membership function memory means
60

Fig.34

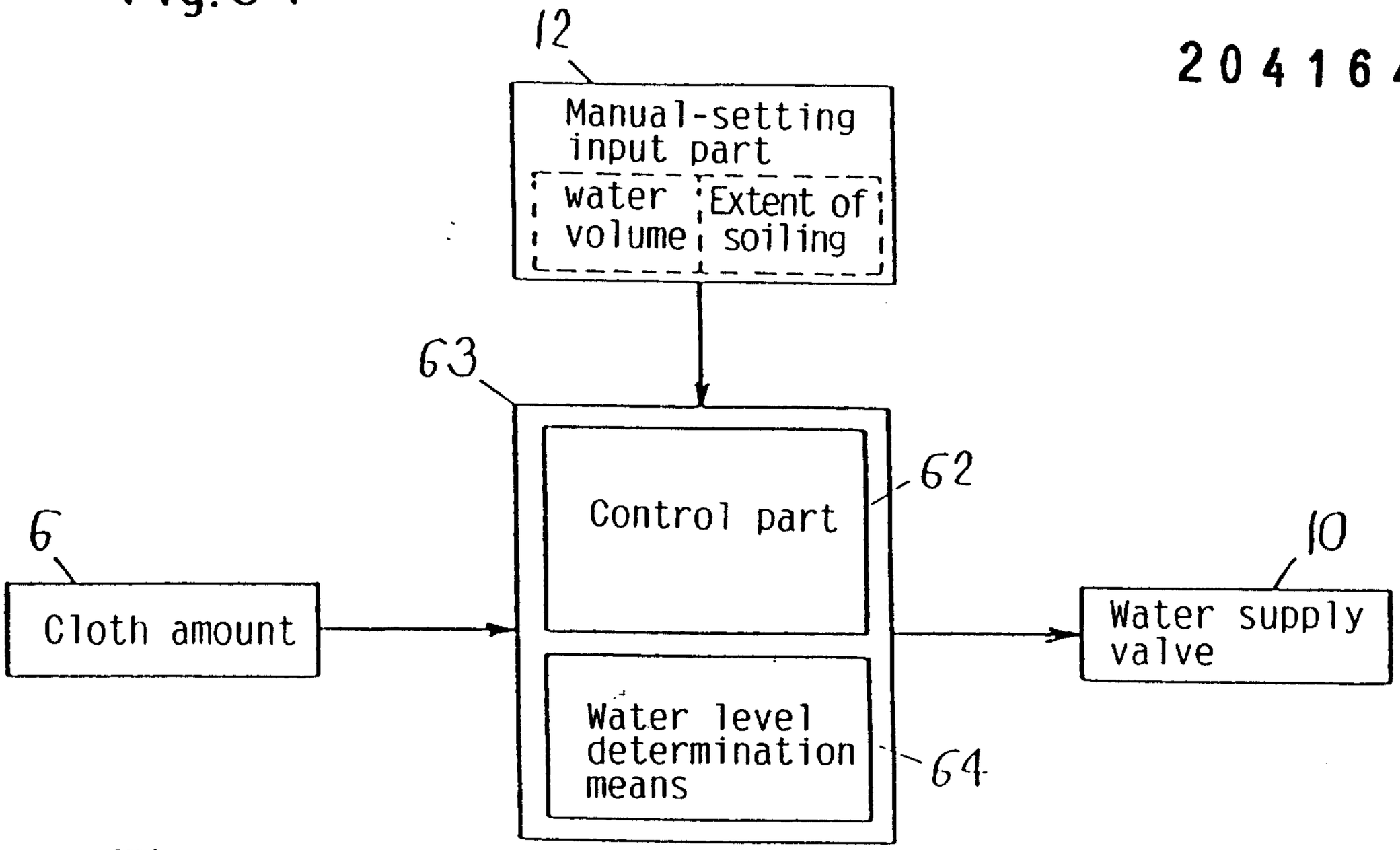


Fig.35

(a) Correction value

Water volume / Extent of soiling	Fairly few	Normal	Fairly much
Fairly few	Very few	Slightly few	Slightly much
Normal	Fairly few	Normal	Fairly much
Fairly much	Slightly few	Slightly much	Very much

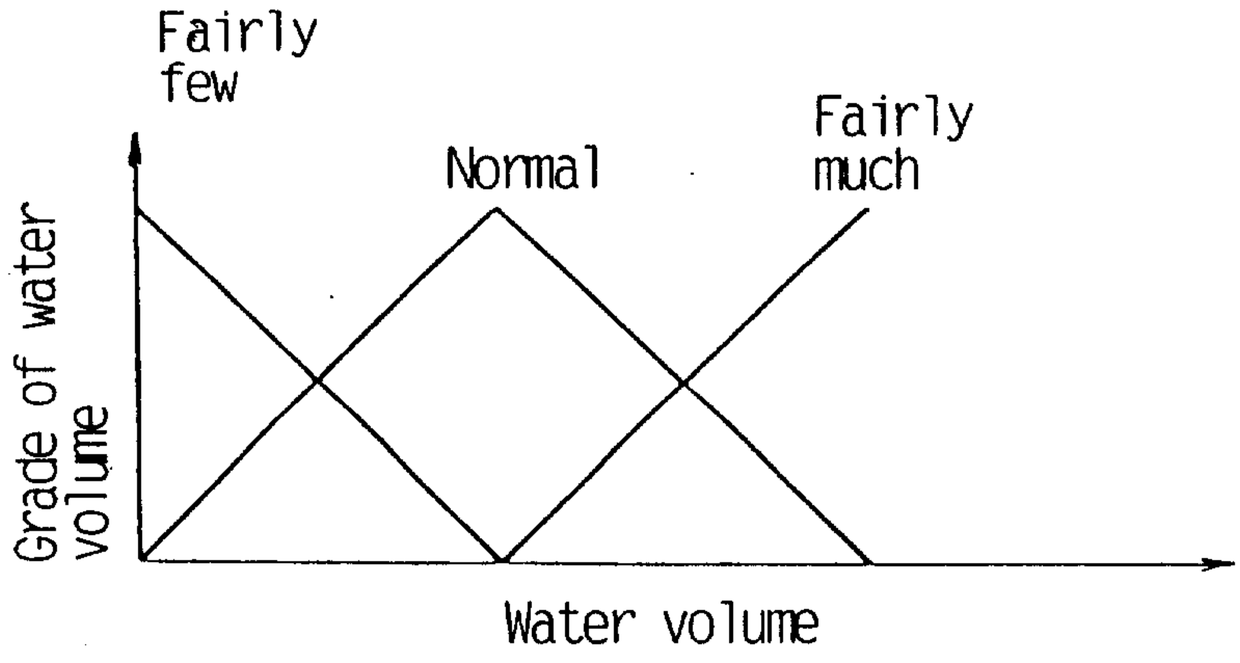
(b) Water level

Cloth amount / Correction value	Few	Much
Few	Low	High
Much	Normal	Very high

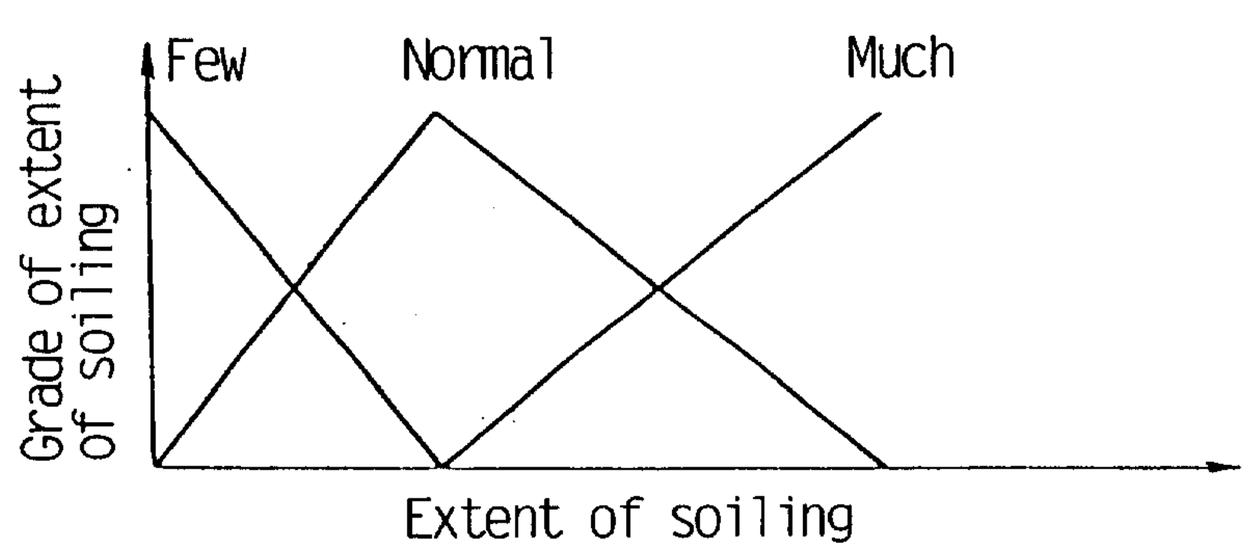
Scott & Aylen

Fig.36

(a)


Fairly few
Normal
Fairly much
Grade of water volume
Water volume

(b)


Few
Normal
Much
Grade of extent of soiling
Extent of soiling

(C)

Very few
Few
Normal
Much
Very much
Grade of correction value
Correction value

Fig. 37

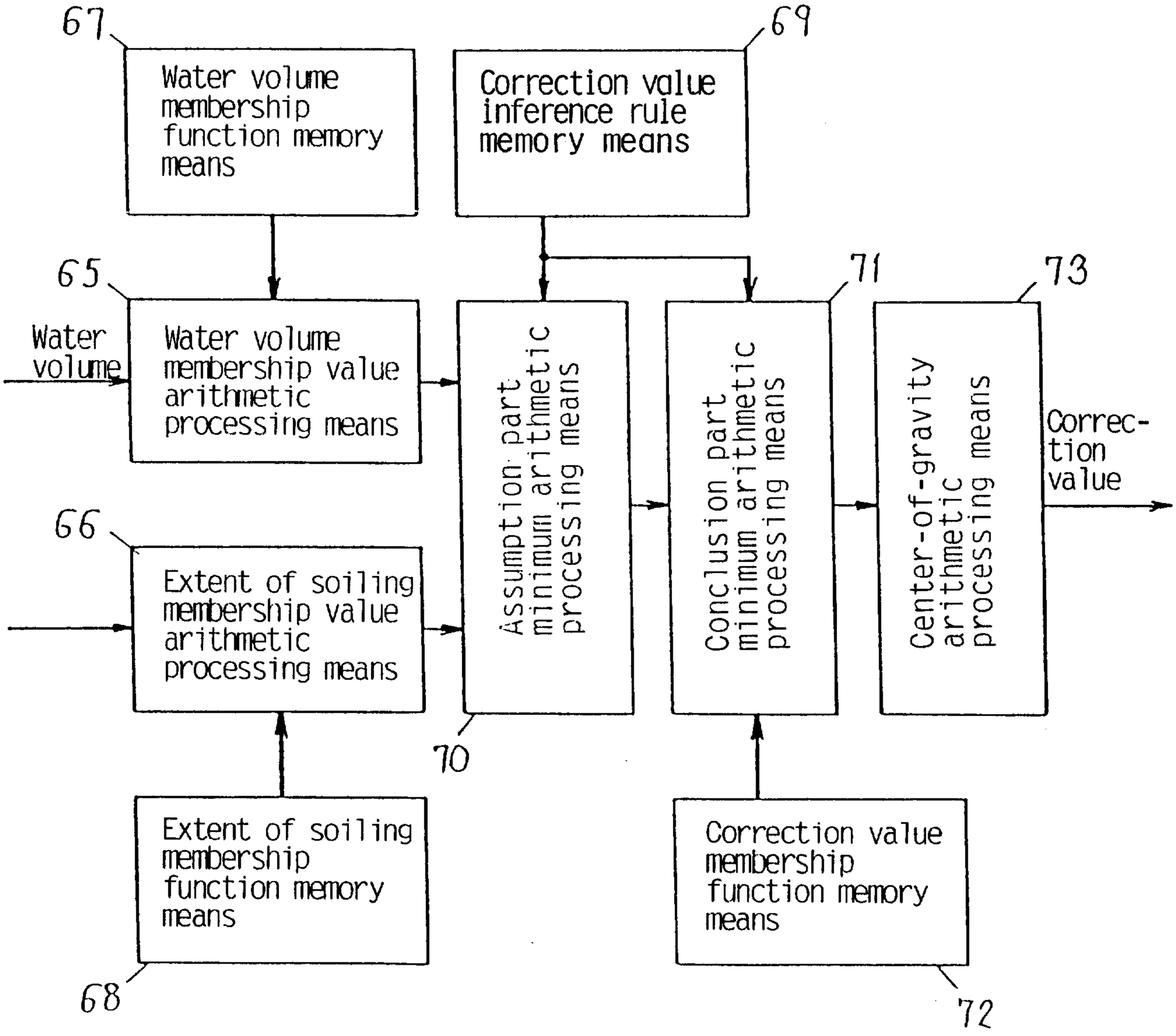

67
Water volume membership function memory means
69
Correction value inference rule memory means
65
Water volume
Water volume membership value arithmetic processing means
71
73
Correc-tion value
66
Extent of soiling membership value arithmetic processing means
Assumption part minimum arithmetic processing means
Conclusion part minimum arithmetic processing means
Center-of-gravity arithmetic processing means
70
Extent of soiling membership function memory means
Correction value membership function memory means
68
72

Fig. 38

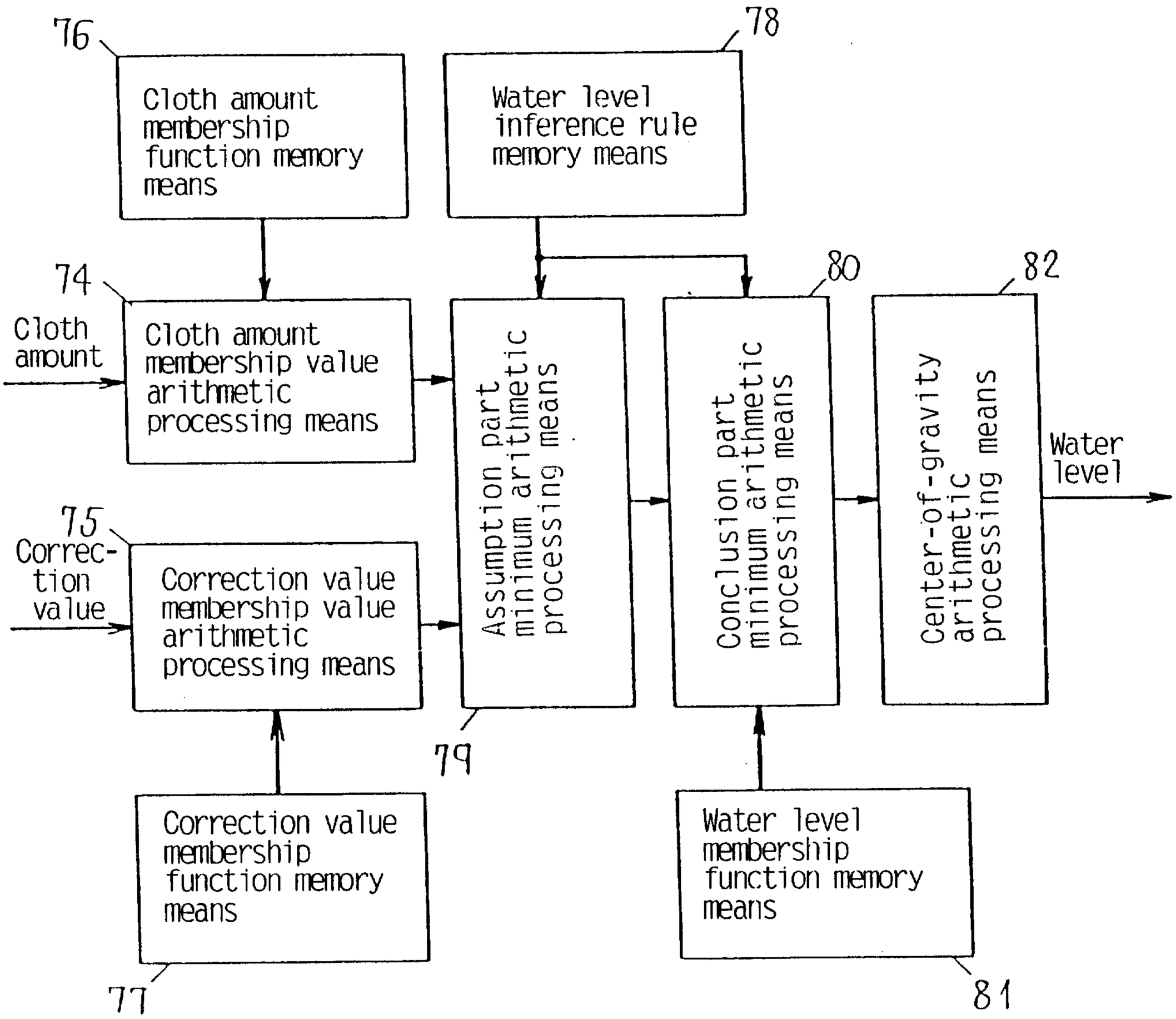

76
Cloth amount membership function memory means
78
Water level inference rule memory means
74
Cloth amount
Cloth amount membership value arithmetic processing means
75
Correc-tion value
Correction value membership value arithmetic processing means
Assumption part minimum arithmetic processing means
79
80
Conclusion part minimum arithmetic processing means
82
Center-of-gravity arithmetic processing means
Water level
Correction value membership function memory means
77
Water level membership function memory means
81

Fig. 39

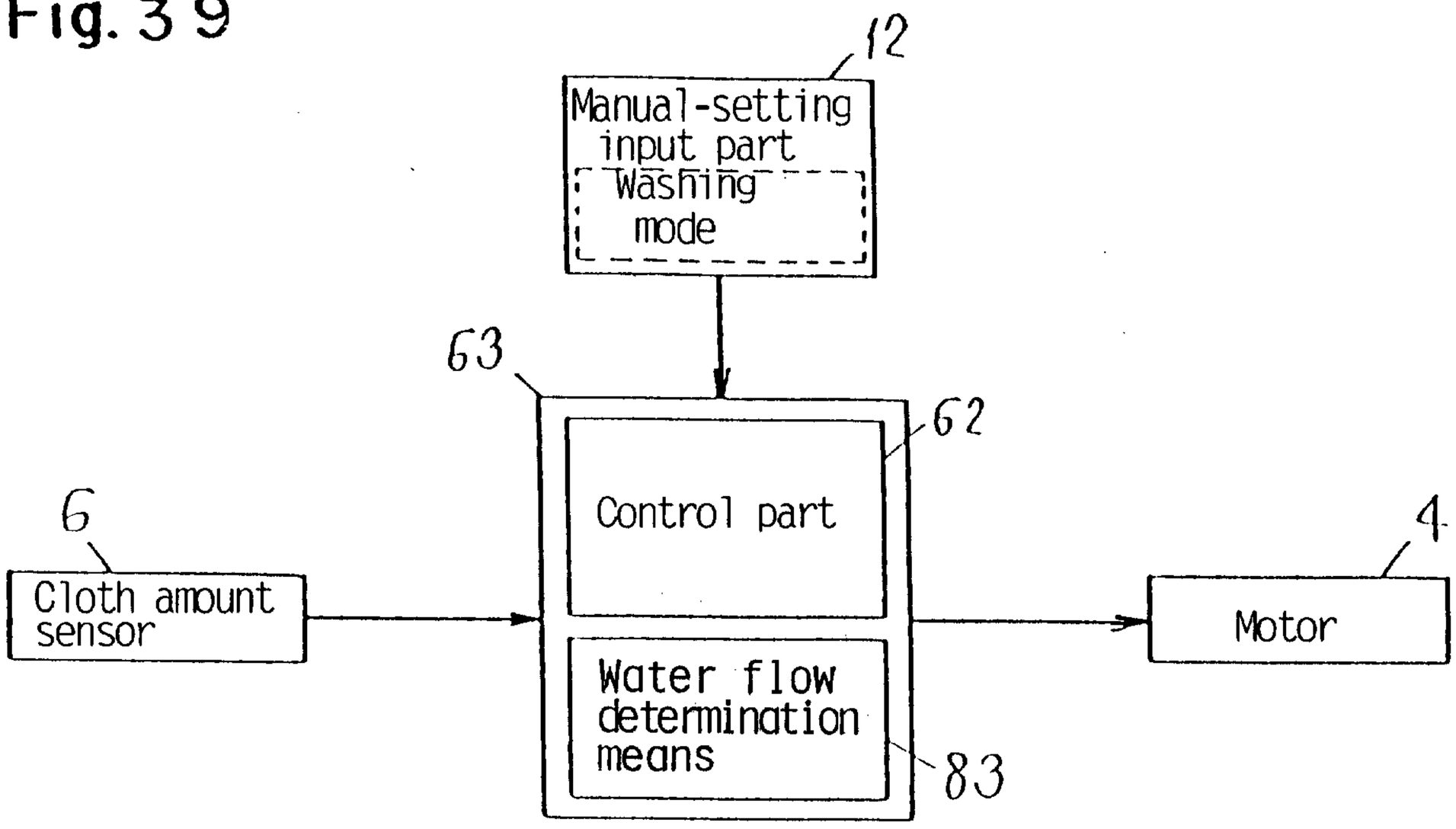
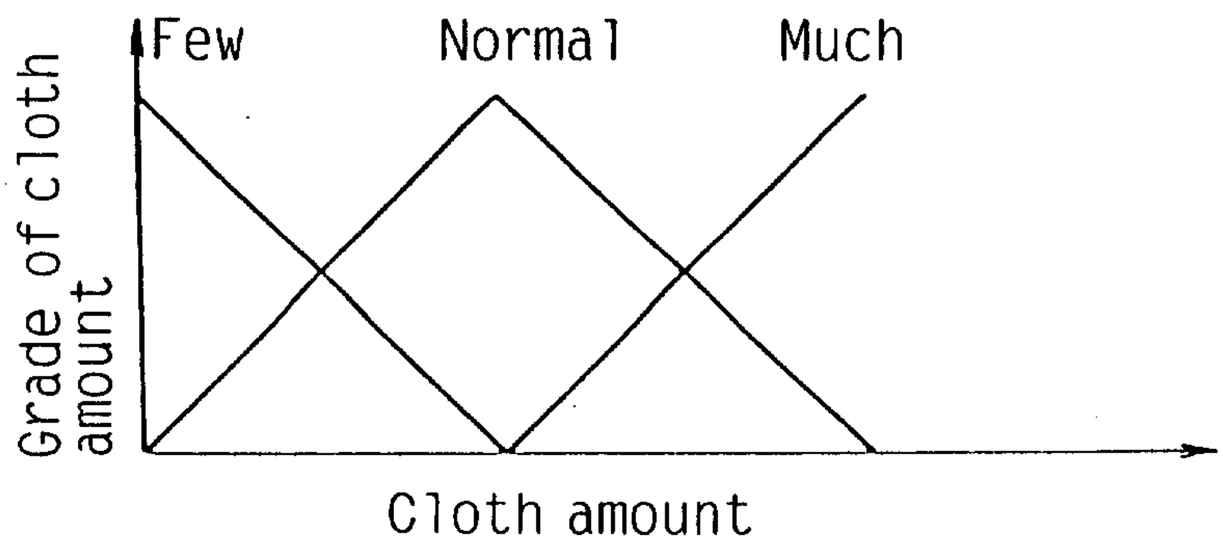


Fig. 40

Cloth amount / Washing mode	Few	Normal	Much
Weak	Very weak	Slightly weak	Slightly strong
Normal	Weak	Normal	Strong
Strong	Slightly weak	Slightly strong	Very strong

Fig.4 l

(a)


Few
Normal
Much
Grade of cloth amount
Cloth amount

(b)

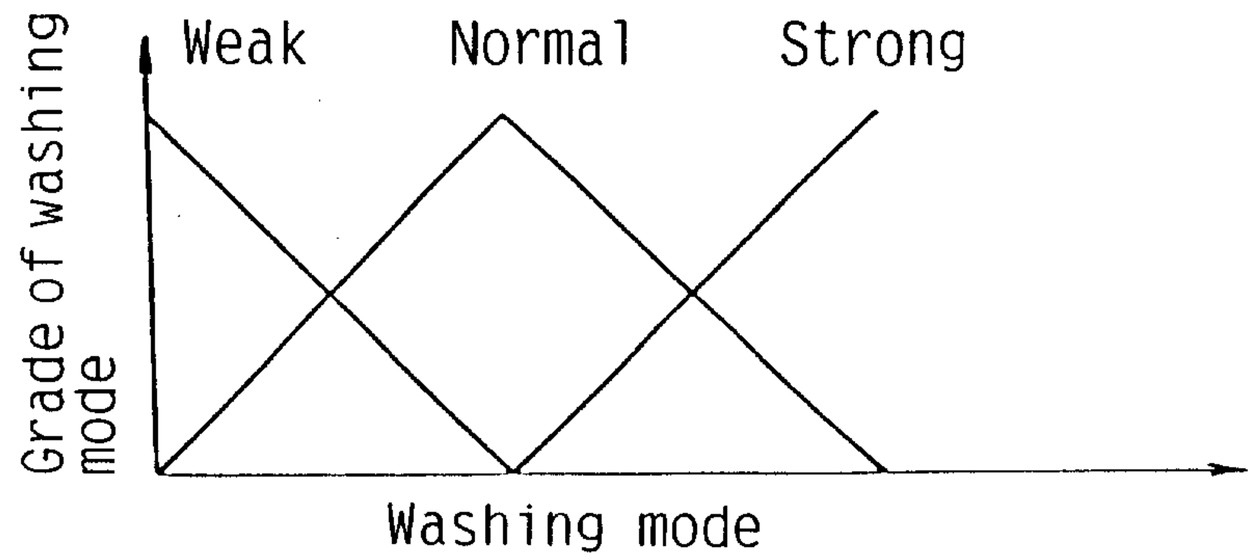
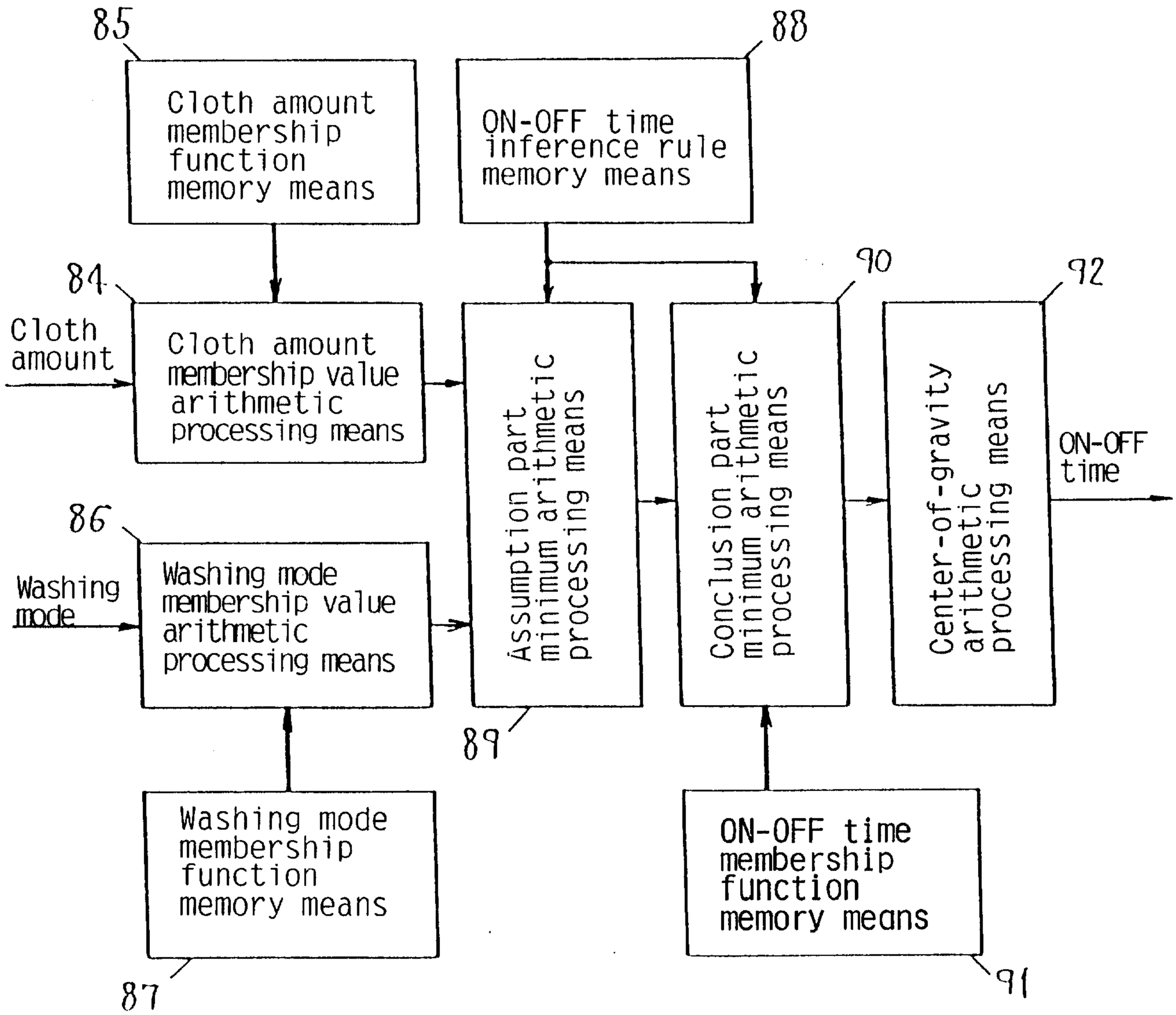

Weak
Normal
Strong
Grade of washing mode
Washing mode

Fig.42


85
Cloth amount membership function memory means
88
ON-OFF time inference rule memory means
84
Cloth amount
Cloth amount membership value arithmetic processing means
86
Washing mode
Washing mode membership value arithmetic processing means
Assumption part minimum arithmetic processing means
89
90
Conclusion part minimum arithmetic processing means
92
Center-of-gravity arithmetic processing means
ON-OFF time
Washing mode membership function memory means
87
ON-OFF time membership function memory means
91

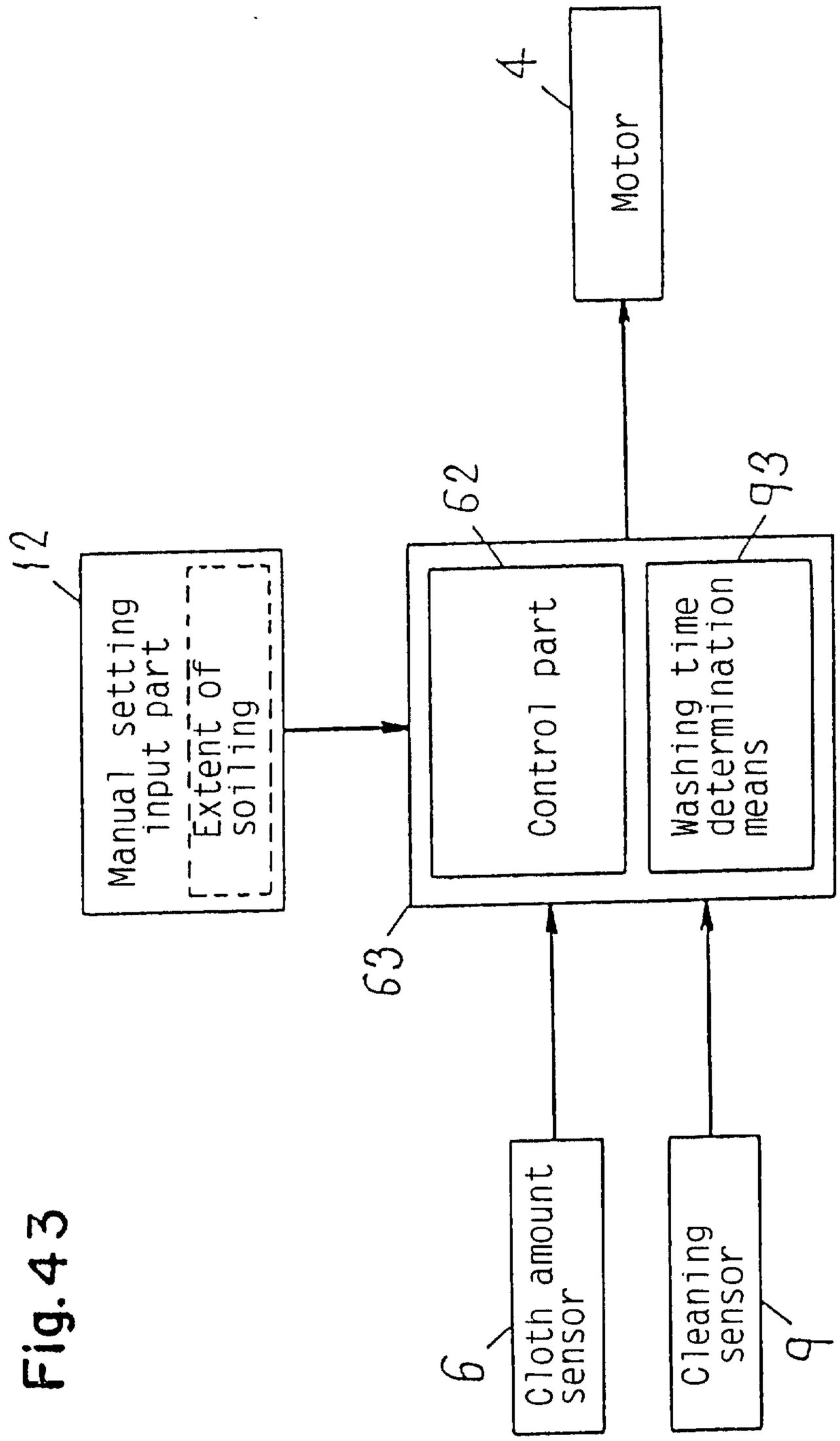

4
Motor
62
93
Control part
Washing time determination means
12
Manual setting input part
Extent of soiling
63
6
Cloth amount sensor
Cleaning sensor
9

Fig.43

Washing time	Cloth amount	Few	Small	Short	Few	Fairly short
					Normal	Slightly short
					Much	Normal
				Long	Few	Slightly short
					Normal	Normal
					Much	Slightly long
			Large	Short	Few	Very short
					Normal	Fairly short
					Much	Fairly short
				Long	Few	Fairly short
					Normal	Fairly short
					Much	Slightly short
		Much	Small	Short	Few	Normal
					Normal	Slightly long
					Much	Long
				Long	Few	Slightly long
					Normal	Fairly long
					Much	Very long
			Large	Short	Few	Short
					Normal	Slightly short
					Much	Normal
				Long	Few	Slightly short
					Normal	Normal
					Much	Slightly long
	Cloth amount	Light-transmittance	Saturation time	Extent of soiling		Washing time

Fig.44

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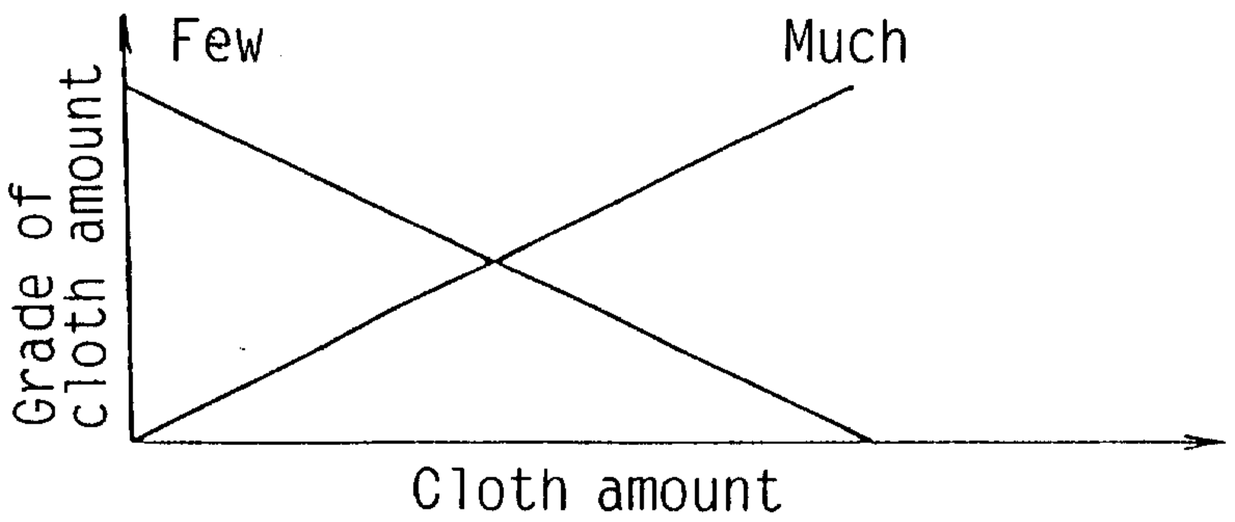
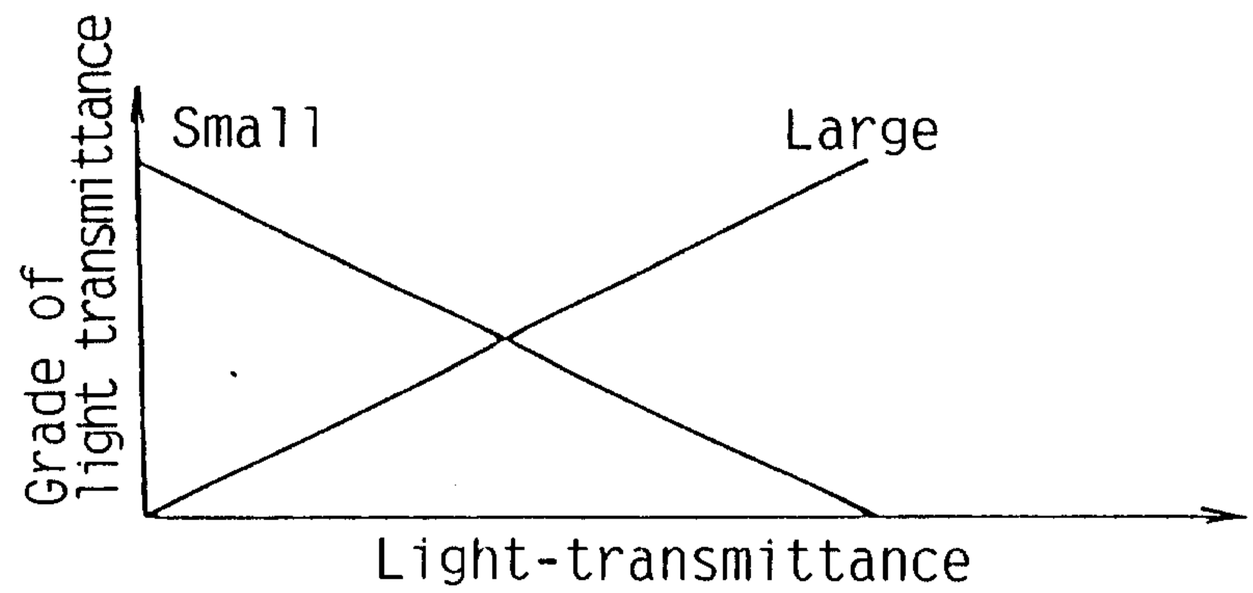
Fig.45

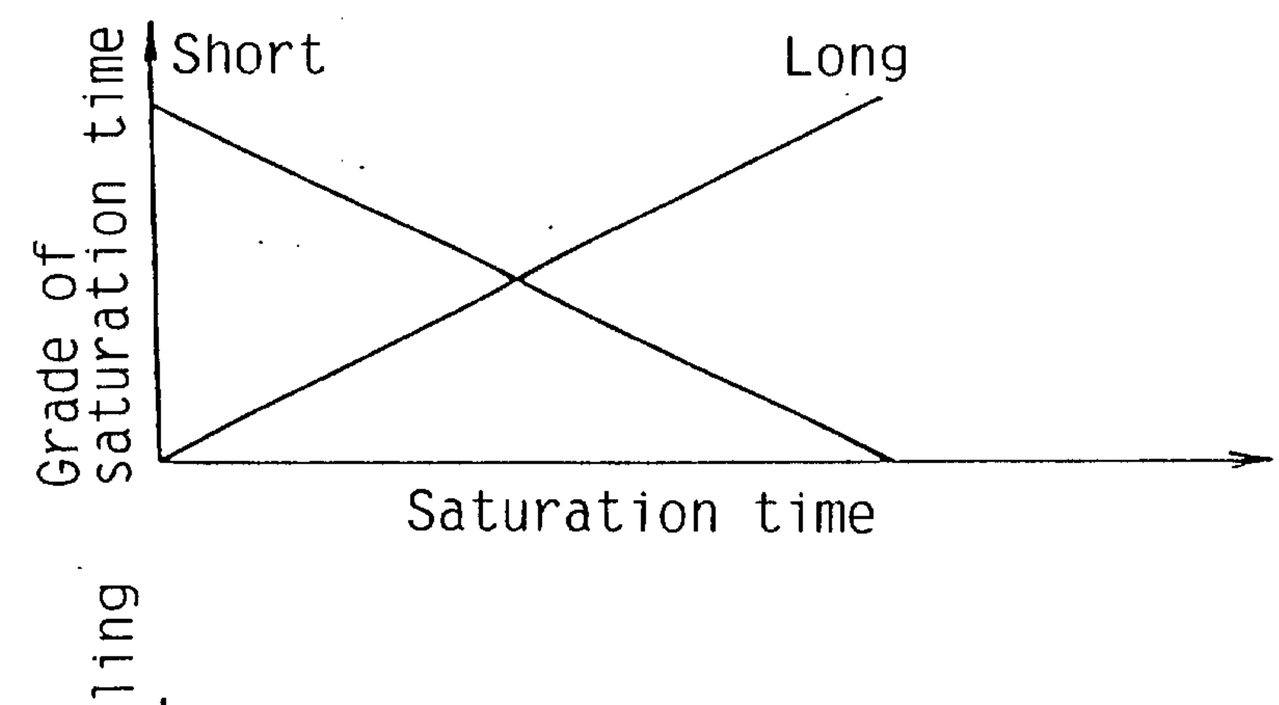
(a)


Few
Much
Grade of cloth amount
Cloth amount

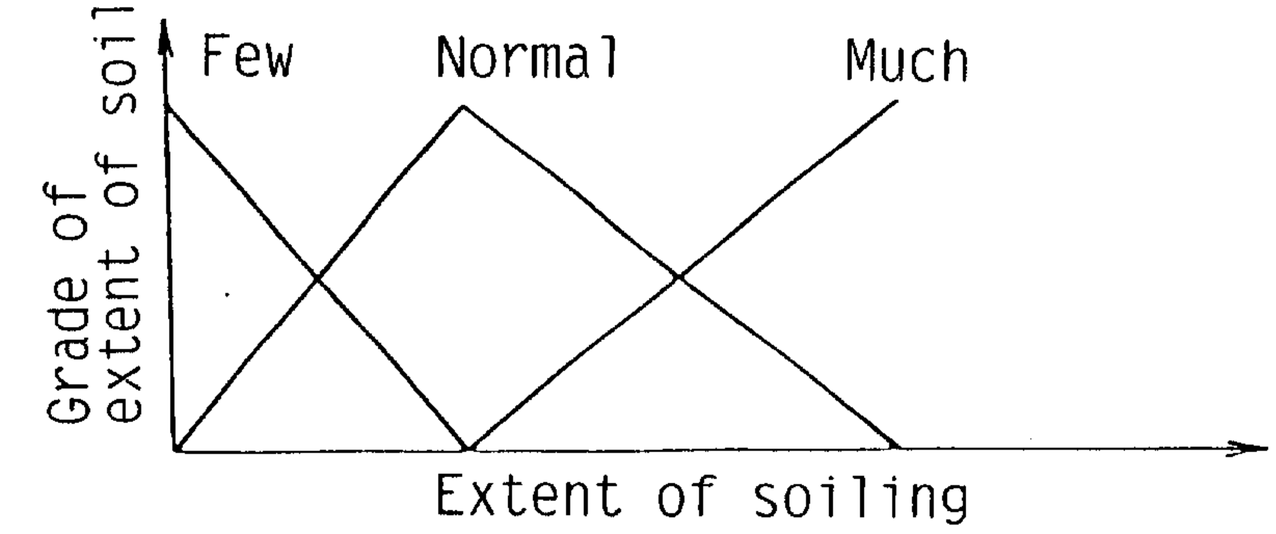
(b)


Small
Large
Grade of light transmittance
Light-transmittance

(C)


Short
Long
Grade of saturation time
Saturation time
ng

(d)


Few
Normal
Much
Grade of extent of soili
Extent of soiling

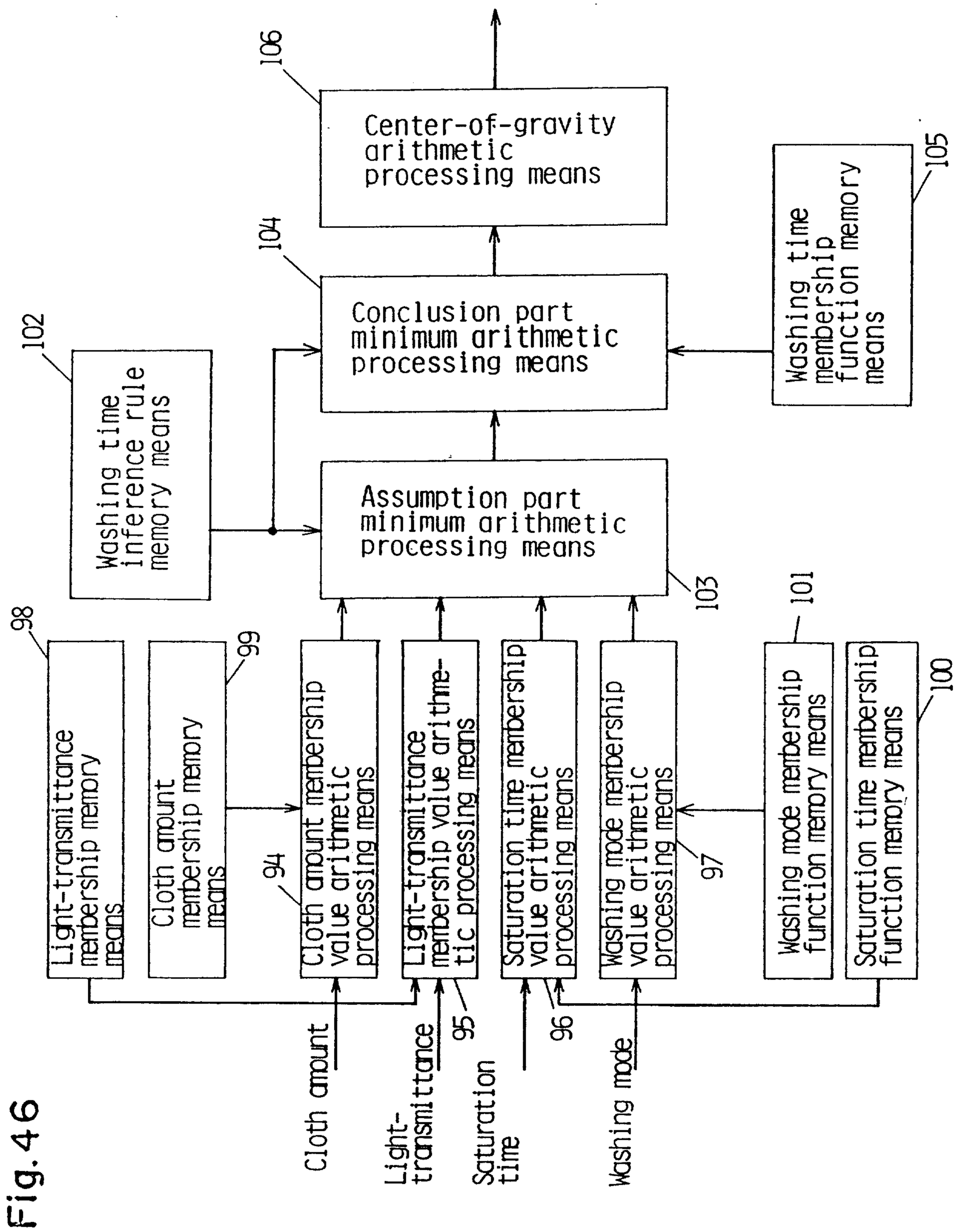

106
Center-of-gravity arithmetic processing means
104
Conclusion part minimum arithmetic processing means
105
Washing time membership function memory means
102
Washing time inference rule memory means
Assumption part minimum arithmetic processing means
103
98
Light-transmittance membership memory means
99
Cloth amount membership memory means
94
Cloth amount membership value arithmetic processing means
Light-transmittance membership value arithmetic processing means
95
Saturation time membership value arithmetic processing means
96
Washing mode membership value arithmetic processing means
97
101
Washing mode membership function memory means
Saturation time membership function memory means
100
Cloth amount
Light-transmittance
Saturation time
Washing mode

Fig.46

Fig.47

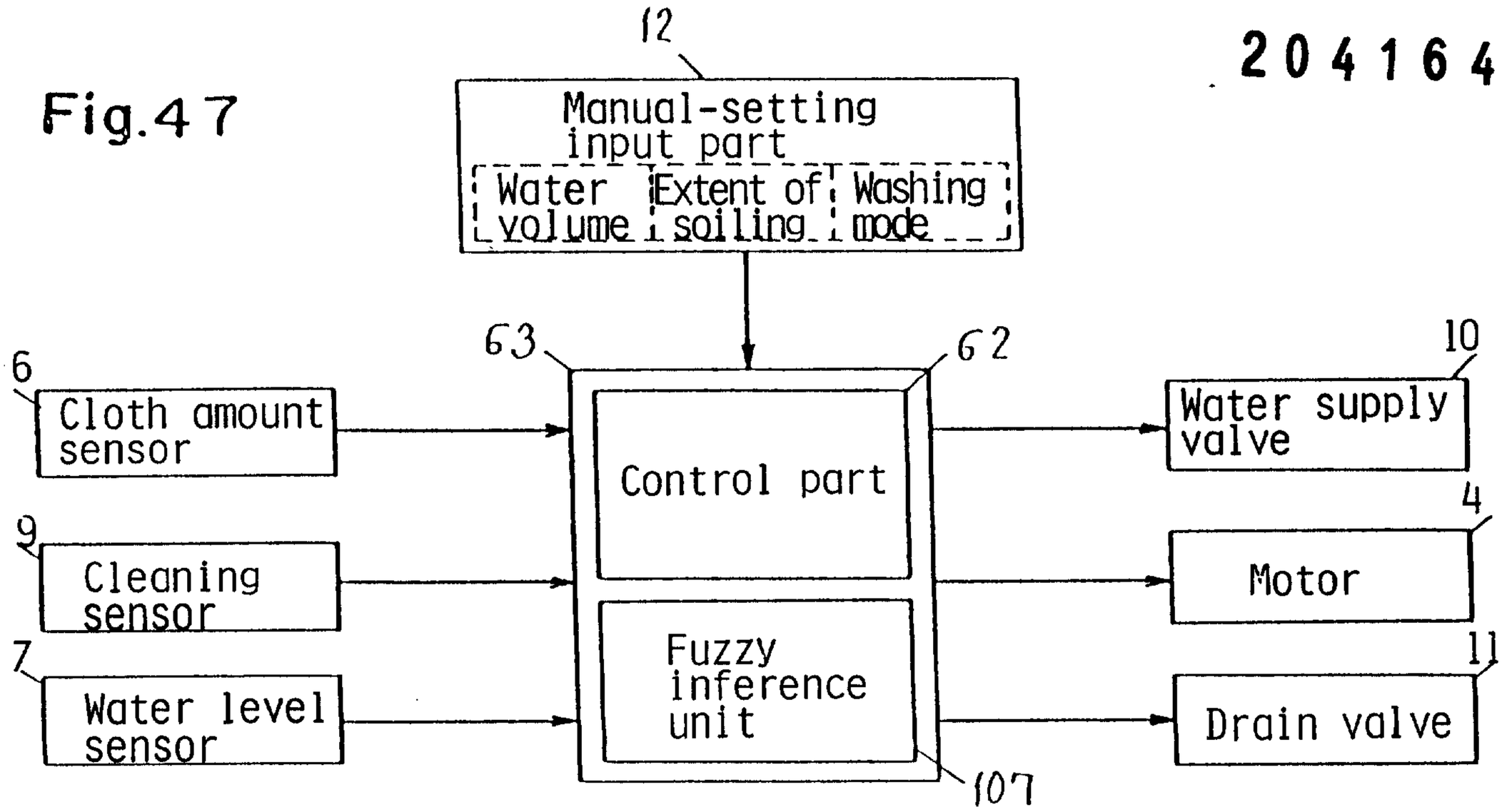

12
Manual-setting input part
Water volume
Extent of soiling
Washing mode
63
62
6
Cloth amount sensor
9
Cleaning sensor
7
Water level sensor
Control part
Fuzzy inference unit
107
10
Water supply valve
4
Motor
11
Drain valve

Fig. 48

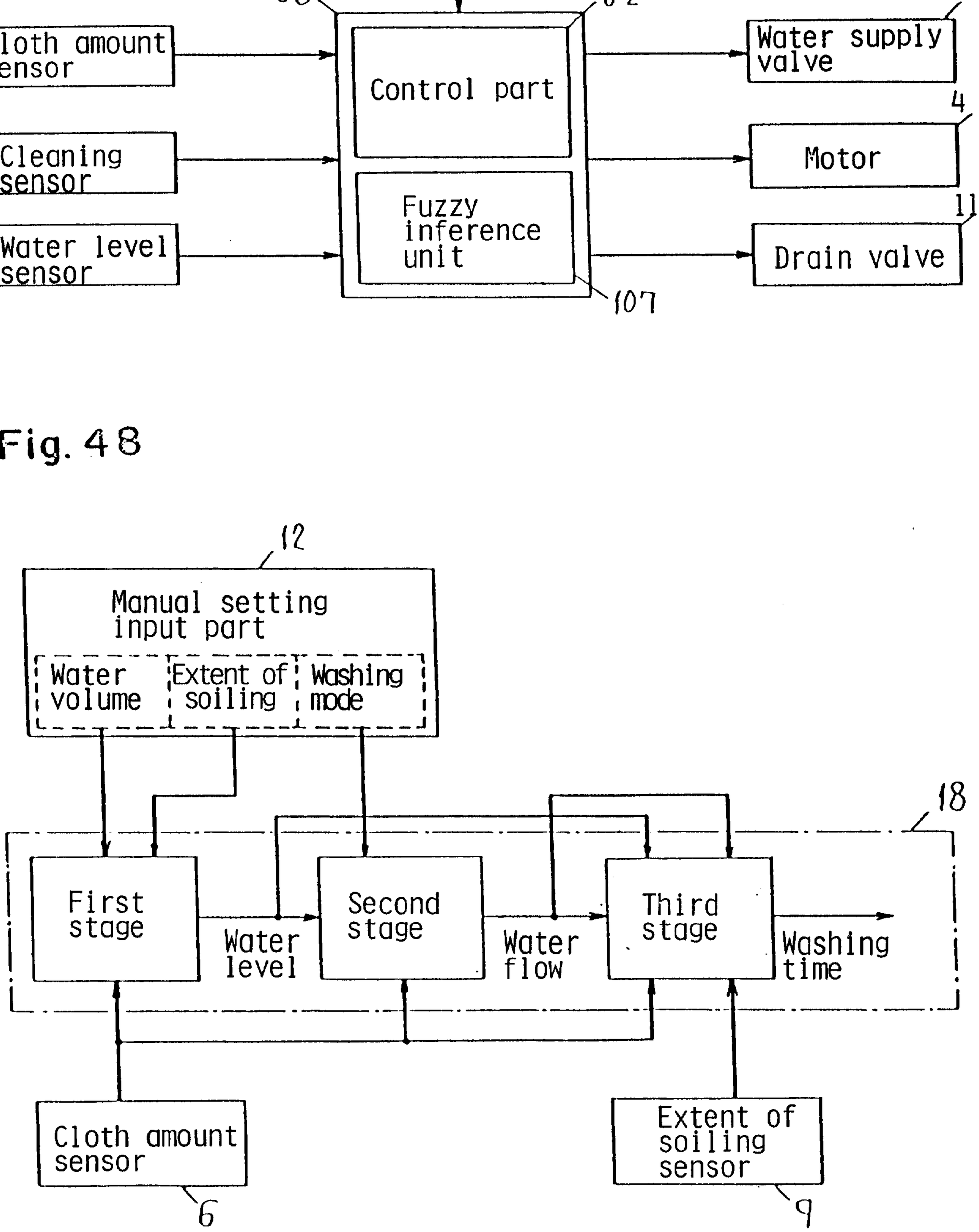

12
Manual setting input part
Water volume
Extent of soiling
Washing mode
18
First stage
Second stage
Third stage
Water level
Water flow
Washing time
Cloth amount sensor
6
Extent of soiling sensor
9

Fig.49

Cloth amount	Wear level	Washing mode	Water flow
Few	Low	Weak	Very weak
		Normal	Weak
		Strong	Slightly strong
	High	Weak	Slightly weak
		Normal	Normal
		Strong	Strong
Much	Low	Weak	Slightly weak
		Normal	Normal
		Strong	Slightly strong
	High	Weak	Slightly strong
		Normal	Strong
		Strong	Very strong

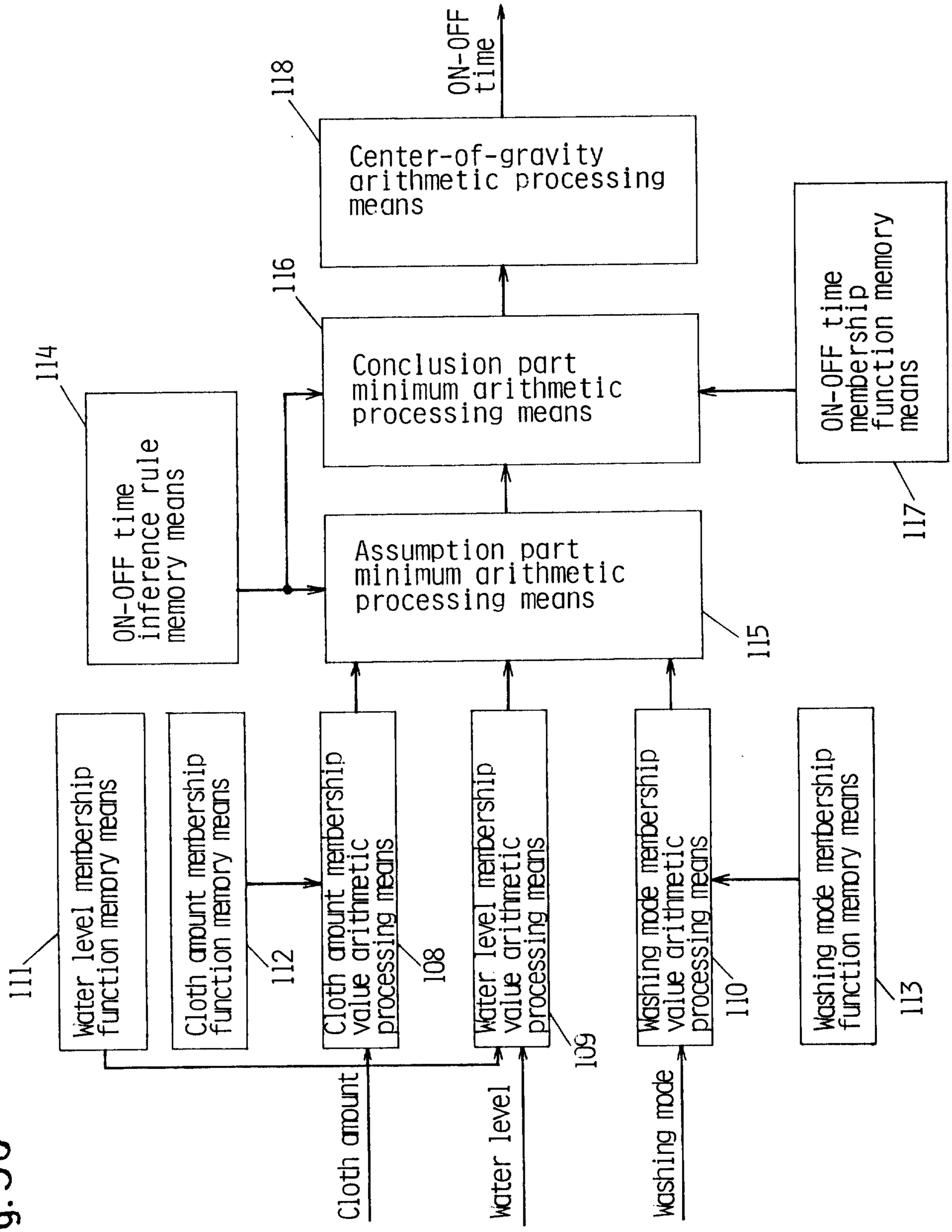

ON-OFF time
118
Center-of-gravity arithmetic processing means
116
Conclusion part minimum arithmetic processing means
114
ON-OFF time inference rule memory means
Assumption part minimum arithmetic processing means
115
ON-OFF time membership function memory means
117
Water level membership function memory means
111
Cloth amount membership function memory means
112
Cloth amount membership value arithmetic processing means
108
Water level membership value arithmetic processing means
109
Washing mode membership value arithmetic processing means
110
Washing mode membership function memory means
113
Cloth amount
Water level
Washing mode

Fig.50

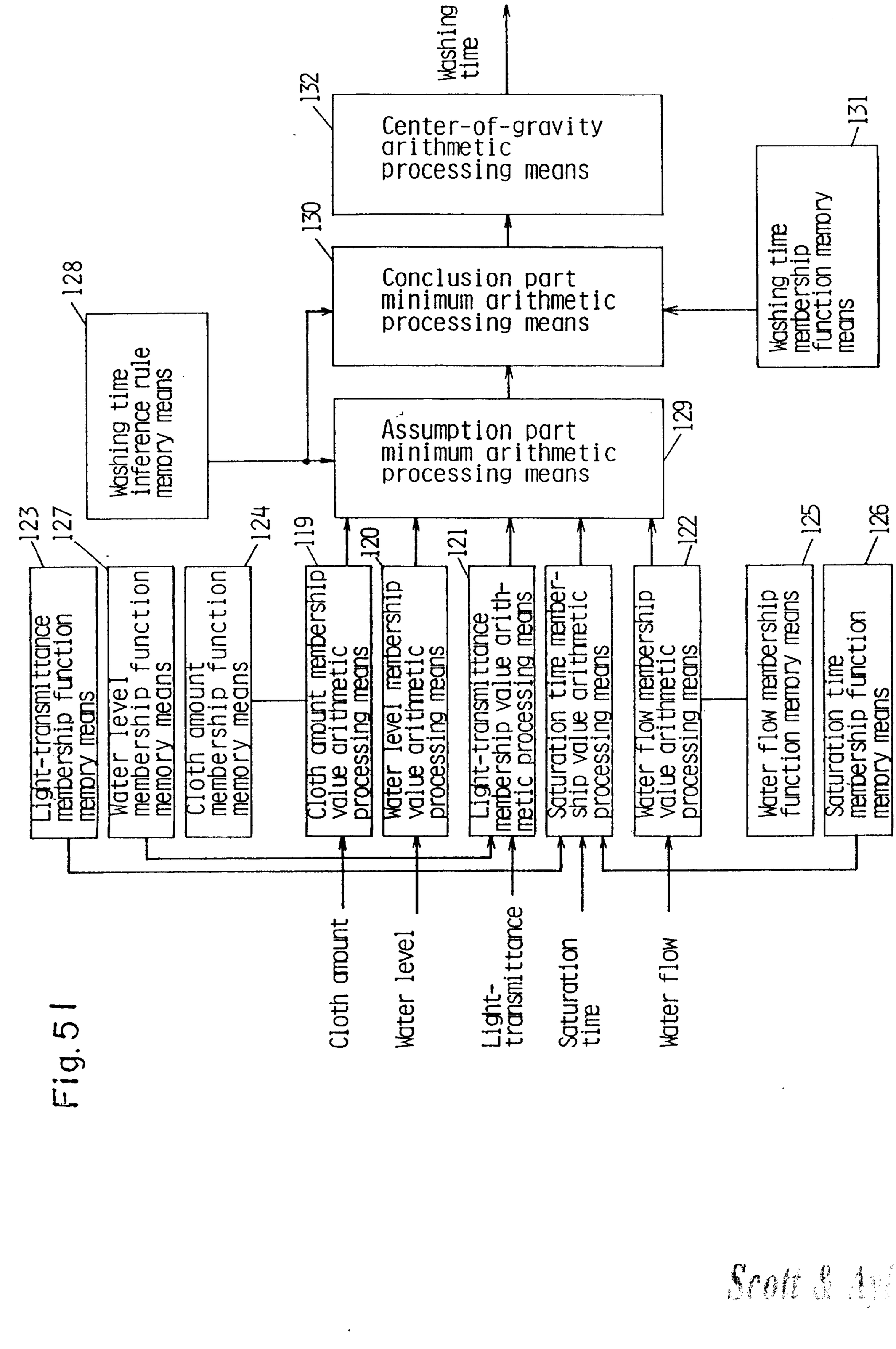


Fig.5 l

B

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