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(72) Inventors:  
• **KURIHARA, Shigetoshi**  
Tokyo, 100-8280 (JP)  
• **KAYAMA, Masahiro**  
Tokyo, 100-8280 (JP)

(74) Representative: **MERH-IP Matias Erny Reichl Hoffmann**  
**Patentanwälte PartG mbB**  
**Paul-Heyse-Strasse 29**  
**80336 München (DE)**

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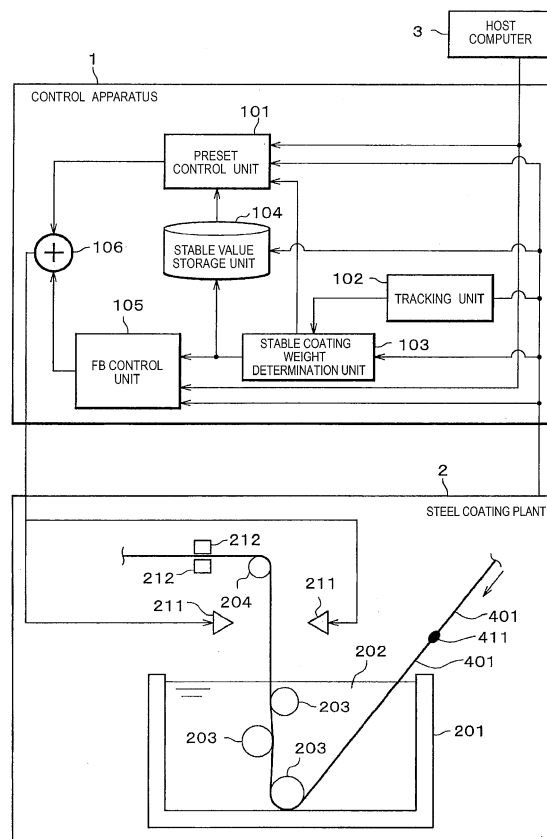
(71) Applicant: **Hitachi, Ltd.**  
**Tokyo 100-8280 (JP)**

(54) **COATING WEIGHT CONTROL APPARATUS AND COATING WEIGHT CONTROL METHOD**

(57) [Task] There is a problem in that a nozzle pressure control is performed with high accuracy in a coating weight control requiring nozzle opening and closing near a welding point 411.

[Solving means] A tracking unit 102 which determines whether or not it is the stable condition, by determining whether or not a coating weight acquired from a steel coating plant 2 is a coating weight based on a current nozzle pressure, a nozzle gap, and a strip speed, based on positional information of a strip 401 based on a movement distance of the strip 401, a preset control unit 101 which calculates a preset value for controlling the nozzle 211 based on a stable coating weight, a stable strip speed, and a stable nozzle gap at a timing of determining whether or not it is the stable condition, and an addition output unit 106 which outputs a control signal of the nozzle 211 based on the preset value, are included.

[Fig. 1]



**Description**

## Technical Field

5 **[0001]** The present invention relates to a technique of a coating weight control apparatus and a coating weight control method which control nozzles in a steel coating plant.

## Background Art

10 **[0002]** In a continuous coating line for coating steel, a weight of a coating attached to a strip is determined by a strip speed (strip speed), which is the speed of the strip referred to as a line speed, a nozzle gap (nozzle-strip distance) which is a distance between a nozzle and the strip, a nozzle pressure (gas pressure) which is a pressure of gas discharged from the nozzle, and the like. In many plants automatically controlling coating weights, with respect to the strip speed and the nozzle gap determined by an operator's manual operation, a nozzle pressure realizing a target coating weight  
15 that is transferred from a host computer is controlled by calculating the nozzle pressure using a coating weight prediction model. As a method in the related art for increasing the accuracy of the control of the coating weight, for example, a technique described in PTL 1 is disclosed.

**[0003]** PTL 1 discloses a preset control method of a control system and a control apparatus using a control model in which "a first preset unit that calculates a control reference corresponding to a set value using a control model and sets  
20 the control reference as a preset value and a second preset unit that calculates a value of a control reference that needs to be changed in accordance with the amount of change of a control specification, and adds or subtracts the value to or from a current control reference, thereby obtaining a preset value are provided, a preset unit, which is capable of performing an appropriate control using manufacturing information or control information obtained from a plant by focusing on a control error and a model error is selected, and the control reference is changed." (refer to the abstract).

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## Citation List

## Patent Literature

30 **[0004]** PTL 1: JP-A-2004-013393

## Summary of Invention

## Technical Problem

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**[0005]** In low-grade strips, there are many cases in which a strip shape in a vicinity of a welding point (head end and tail end of strip) is not favorable.

**[0006]** Accordingly, there is a concern that a nozzle may come into contact with the strip in the vicinity of the welding point. In order to avoid such a situation, a so-called nozzle opening and closing control in which, before the welding point  
40 passes through the nozzle position, the nozzle is opened (nozzle gap is increased), and, after the welding point passes through the nozzle position, the nozzle is closed again to an appropriate position is performed. Therefore, near a welding point where the preset calculation in PTL 1 is performed, the nozzle is positioned not in a normal operating position, but in a position greatly distant from the strip.

**[0007]** In many cases, the coating weight prediction model is used for preset calculation. The coating weight prediction model is constructed using data at the time of a stable condition. Here, the time of a stable condition means a time when a coating is performed in a condition in which the nozzle gap or the nozzle pressure does not change. In other words, a stable condition is a condition in which the coating weight acquired from the steel coating plant is a coating weight based on each of a current strip speed, a current nozzle pressure, and a current nozzle gap (each determined individually)  
45 imported from the steel coating plant. However, at the time of controlling the nozzle opening and closing, the coating weight has already been predicted when a nozzle gap which has become an abnormally large value is input. In the technique described in PTL 1, since there is no consideration with respect to this point, a prediction accuracy of the coating weight in the preset calculation at the time of controlling the nozzle opening and closing is degraded. As a result, in the technique described in PTL 1, there is a problem in that the accuracy of calculating the nozzle pressure is degraded.

**[0008]** In addition, at the time of opening the nozzle, generally, the nozzle pressure becomes a high pressure for  
50 keeping the coating weight, and thus it becomes a saturated pressure. In the technique described in PTL 1, at the time of a second preset control which calculates a relative value, a second preset unit, which performs the second preset control, performs adding and subtracting a control reference (nozzle pressure) corresponding to the change of amount of a control specification (target value of the coating weight) to or from a current control reference (nozzle pressure

control reference). That is, based on the current control reference (nozzle pressure control reference), the control reference (nozzle pressure) at a next timing is calculated. In a case in which the nozzle pressure reaches a saturated condition, based on the saturated pressure, the nozzle pressure in the next time is calculated. As a result, in the next time, there is a problem in that a greatly reduced nozzle pressure is calculated. That is, when the saturated pressure puts a limit, based on the current nozzle pressure which is greatly deteriorated further than an original nozzle pressure, the nozzle pressure in the next time is calculated, and thus there is a problem in that the nozzle pressure in the next time is greatly reduced to lower than that of a nozzle pressure needed to be calculated originally.

**[0009]** The invention has been made in view of such a background, and the invention has an object of allowing nozzle control to be performed with high accuracy.

#### Solution to Problem

**[0010]** In order to solve the problems described above, the invention provides a coating weight control apparatus which receives result information from a steel coating plant, which attaches a coating having a desired coating weight to a strip by immersing a continuously sent strip into a bath of a molten coating and spraying high pressure gas from a nozzle so as to peel an unnecessary coating off immediately after the strip is lifted, generates control information for controlling a coating weight which is a coating weight of a coating based on the received result information, and transfers the generated control information to the steel coating plant, the apparatus including a preset control unit that calculates at least the gas pressure as a set value for a control reference of the nozzle for attaching a coating having a desired coating weight, by calculation based on a coating weight prediction model indicating at least a relationship between a strip speed which is a moving speed of the strip, a gas pressure which is a pressure of the gas being sprayed from the nozzle, a nozzle-strip distance which is a distance between the nozzle and the strip, and the coating weight being attached to the strip, and/or a tracking unit that specifies positional information in the strip based on a movement distance of the strip obtained by importing the strip speed from the steel coating plant and integrating the imported strip speed, and/or a stable condition determination unit that determines whether or not the coating weight imported from the steel coating plant is a stably-detected coating weight by determining whether or not a current coating weight imported from the steel coating plant is a coating weight in accordance with each of a current strip speed, a current gas pressure, and a current nozzle-strip distance imported from the steel coating plant, based on the positional information of the strip specified by the tracking unit, and/or a stable value storage processing unit that stores a combination of a second coating weight, a second strip speed, a second gas pressure, and a second nozzle-strip distance, which are imported, when the coating weight imported from the steel coating plant is determined to be the stably-detected coating weight, by the stable condition determination unit, in a stable value storage unit. The preset control unit imports a first strip speed which is the current strip speed, a first nozzle-strip distance which is the current nozzle-strip distance, and a first target coating weight which is a target value of the current coating weight from the steel coating plant, calculates a first gas pressure of a set value which is the gas pressure for realizing the first target coating weight based on the coating weight prediction model, imports the second strip speed, the second nozzle-strip distance, and the second coating weight from the stable value storage unit, calculates a third gas pressure of a set value which is the gas pressure for realizing the coating weight corresponding to the second strip speed and the second nozzle-strip distance using the coating weight prediction model, adds the first gas pressure to the second gas pressure imported from the stable value storage unit, and calculates a fourth gas pressure which is a set value for a control reference of the nozzle by subtracting the third gas pressure.

**[0011]** The other solving means will be described in embodiments. Advantageous Effects of Invention

**[0012]** According to the invention, control of nozzles with high accuracy can be performed.

#### Brief Description of Drawings

**[0013]**

[Fig. 1] Fig. 1 is a diagram illustrating a configuration example of a coating weight control system according to a first embodiment.

[Fig. 2] Fig. 2 is a diagram illustrating a hardware configuration of a control apparatus according to the first embodiment.

[Fig. 3] Fig. 3 is a flow chart illustrating a sequence of a process in a preset control unit according to the first embodiment.

[Fig. 4] Fig. 4 is a flow chart illustrating a sequence of a process in a tracking unit according to the first embodiment.

[Fig. 5] Fig. 5 is a diagram schematically illustrating a stable condition established timing inside one strip.

[Fig. 6] Fig. 6 is a flow chart illustrating a process sequence of a stable coating weight determination unit according to the first embodiment.

[Fig. 7] Fig. 7 is a diagram illustrating an example of nozzle controlling according to the first embodiment.

[Fig. 8] Fig. 8 is a diagram illustrating a configuration example of a coating weight control system according to a second embodiment.

[Fig. 9] Fig. 9 is a diagram illustrating a hardware configuration of a control apparatus according to the second embodiment.

[Fig. 10] Fig. 10 is a flow chart illustrating a sequence of a process in an absolute value calculating unit according to the second embodiment.

[Fig. 11] Fig. 11 is a flow chart illustrating a process sequence in a welding point vicinity determination unit according to the second embodiment.

[Fig. 12] Fig. 12 is a flow chart illustrating a sequence of a process in a control method selecting unit according to the second embodiment.

[Fig. 13] Fig. 13 is a diagram illustrating an example of nozzle controlling according to the second embodiment.

**[0014]** Next, embodiments for realizing the invention (refer to as embodiment) will be described in detail with reference to appropriate drawings.

[First Embodiment]

**[0015]** Fig. 1 is a diagram illustrating a configuration example of a coating weight control system according to a first embodiment.

**[0016]** The coating weight control system includes a control apparatus (coating weight control apparatus) 1, a steel coating plant 2, and a host computer (external device) 3.

**[0017]** The control apparatus 1 controls the steel coating plant 2 which is a target to be controlled, and a coating having a desired coating weight is attached to a strip 401.

**[0018]** The steel coating plant 2 is the target to be controlled of the control apparatus 1 as described above, and attaches a coating to the strip 401 based on a control reference of the control apparatus 1.

**[0019]** The host computer 3 inputs information of a target coating weight, and the like to the control apparatus 1.

**[0020]** First, a configuration of the steel coating plant 2 will be described. The steel coating plant 2 immerses the strips 401, which are continuously sent, into a molten coating 202 accumulated in a pot 201. Accordingly, the strip 401 is plated. Also, the steel coating plant 2 peels an unnecessary coating off by spraying high pressure gas from a nozzle 211 immediately after the strip 401 is lifted from the molten coating 202. Accordingly, the steel coating plant 2 controls a coating weight of the coating attached to the strip 401 to be a desired value. The strips 401 (coil) are connected with each other in a welding manner, and have a configuration in which a continuous coating process is performed.

**[0021]** A welding point 411 is coincide with, in general, a change point of a target coating weight. However, there is a case in which a plurality of coils are produced from one strip 401. That is, there is a case in which another coating is performed on one strip 401. In this case, in addition to the welding point 411, a target value change point of the coating weight is present, and one strip 401 is controlled with another target coating weight. The coating weight W attached to the strip 401 is detected by a coating weight gauge 212. The coating weight gauge 212 is provided on a position apart away from a nozzle 211. In addition, as a detection method, it is general that the coating weight gauge 212 is traversed in a width direction of the strip 401, and an average value of the coating weight with respect to the width direction is output. Therefore, although a nozzle pressure (gas pressure) which is pressure of gas sprayed from the nozzle or a nozzle gap (nozzle-strip distance) which is a distance between the nozzle 211 and the strip 401 is operated, the coating weight can be detected as a result thereof after one or two minutes elapse. Accordingly, a preset control which predicts the coating weight and determines the nozzle pressure is a high importance target to be controlled.

**[0022]** A roll 203 and a top roll 204 support the strip 401. The coating weight W is changed when receiving influence of various factors, but is mainly determined by a strip speed (strip speed) V of the strip 401 which is a moving speed of the strip 401, a nozzle pressure P, and a nozzle gap D. Also, the strip speed V of the strip 401 is calculated on the basis of a rotation speed, or the like of the roll 203 or the top roll 204.

**[0023]** This relationship is expressed by, for example, Expression (1) as follows.

$$\ln (W) = a_0 + a_1 \cdot \ln (P) + a_2 \cdot \ln (V) + a_3 \cdot \ln (D) \dots (1)$$

**[0024]** Here,  $a_0$  to  $a_3$  are constants.

**[0025]** As illustrated in Fig. 1, in general, there are many cases in which the nozzles 211 are respectively provided in a front side and a back side of the strip 401. When the nozzle pressures P in the front side and the back side of the strip 401 are different from each other, an average value of both of them may be set to the nozzle pressure P. In the same

manner, when the nozzle gaps D in the front side and the back side of the strip 401 are different from each other, or a right side and a left side are different from each other, an average value of them may be set to the nozzle gap D. In addition, in actual, it is considered that the coating weight W is also changed due to a temperature of the molten coating or the strip 401, a height of the nozzle 211, an angle with respect to the strip 401 of the nozzle 211, and the like. However,

in a regression model like Expression (1), the temperature of the molten coating or the strip 401, the height of the nozzle 211, the angle with respect to the strip 401 of the nozzle 211, and the like are not served as significance, and often omitted. In the embodiment, hereinafter, the coating weight prediction model will be described as Expression (1).

**[0026]** Also, the strip 401, in which the coating weight is detected by the coating weight gauge 212, is cut by a cutting machine which is not illustrated finally, and is wound as a coil.

**[0027]** Next, a configuration of the control apparatus 1 will be described.

**[0028]** The control apparatus 1 receives manufacturing information of the types of a steel, a thickness of a strip, a width of a strip, and the like of the strip 401 from the host computer 3 by adding the target coating weight  $W^*$  corresponding to the strip 401 which will be processed next. There is a case in which an upper and lower limit value of the coating weight W or standard information of the strip 401 is included in the manufacturing information.

**[0029]** The control apparatus 1 includes a preset control unit 101, a tracking unit (stable condition determination unit) 102, a stable coating weight determination unit (stable value storage processing unit) 103, a stable value storage unit (storage unit) 104, a feed back (FB) control unit 105, and an addition output unit 106.

**[0030]** The preset control unit 101 uses a current target coating weight  $W^*c$  acquired from the host computer 3, a current nozzle pressure  $P_c$  acquired from the steel coating plant 2, a current strip speed  $V_c$ , a current nozzle gap  $D_c$ , stable data of the stable value storage unit 104, and the like, and calculates a control reference (preset value  $P_{ref}$ ) of the nozzle pressure P. The stable data will be described later. In addition, the preset control unit 101 starts a process at the timing of receiving one of a change of the target coating weight  $W^*$  from the host computer 3, a change of the nozzle gap D and a change of the strip speed V from the steel coating plant 2, and terminates the process when receiving a stable condition trigger from the stable coating weight determination unit 103.

**[0031]** The tracking unit 102 traces a movement distance of the strip 401 by integrating the strip speed V acquired from the steel coating plant 2. In addition, the tracking unit 102 issues the stable condition trigger in a case of the stable condition.

**[0032]** Here, the stable condition refers to a condition in which a coating is attached by being corresponded to the nozzle pressure P, the nozzle gap D, and the strip speed V, and then the nozzle pressure P, the nozzle gap D, and the strip speed V are detected as the coating weight W by the coating weight gauge 212 while being not changed as they are. On the contrary, when any one of the nozzle pressure P, the nozzle gap D, and the strip speed V is changed before the coating weight of that part is detected by the coating weight gauge 212, the stable condition is not recognized. In other words, the stable condition refers to a condition in which a result value of the current coating weight W acquired from the steel coating plant 2 is the coating weight W based on (each determined individually) the current strip speed V, the current nozzle pressure P, and the current nozzle gap D which are imported from the steel coating plant 2.

**[0033]** The stable coating weight determination unit 103 acquires the current coating weight  $W_c$ , the nozzle pressure  $P_c$ , the nozzle gap  $D_c$ , and the strip speed  $V_c$  from the steel coating plant 2. In addition, when receiving the stable condition trigger from the tracking unit 102, the stable coating weight determination unit 103 stores the acquired current coating weight  $W_c$ , the nozzle pressure  $P_c$ , the nozzle gap  $D_c$ , and the strip speed  $V_c$  in the stable value storage unit 104 as the coating weight  $W_s$ , the nozzle pressure  $P_s$ , the nozzle gap  $D_s$ , and the strip speed  $V_s$  in the stable condition. Hereinafter, the coating weight  $W_s$ , the nozzle pressure  $P_s$ , the nozzle gap  $D_s$ , and the strip speed  $V_s$  are respectively referred to as a stable coating weight  $W_s$ , a stable nozzle pressure  $P_s$ , a stable nozzle gap  $D_s$ , and a stable strip speed  $V_s$ . All of the stable coating weight  $W_s$ , the stable nozzle pressure  $P_s$ , the stable nozzle gap  $D_s$ , and the stable strip speed  $V_s$  are the result value. The stable coating weight  $W_s$ , the stable nozzle pressure  $P_s$ , the stable nozzle gap  $D_s$ , the stable strip speed  $V_s$ , and the like stored by the stable coating weight determination unit 103 are stored in the stable value storage unit 104.

**[0034]** When receiving the stable condition trigger from a stable condition coating weight determination unit 103, based on a deviation between the stable coating weight  $W_s$  acquired from the steel coating plant 2 and the current target coating weight  $W^*c$  acquired from a host computer 3, a FB control unit 105 changes the nozzle pressure P in a direction in which the deviation is decreased.

**[0035]** The addition output unit 106 outputs an output of the preset control unit 101 and an output of the FB control unit 105 by adding to each other.

**[0036]** Hereinafter, in the embodiment, simply, a case in which a target to be controlled of the steel coating plant 2 is the nozzle pressure P will be described as an example. In the control apparatus 1, the preset control unit 101 performs a preset-control at the timing when the strip speed V and the nozzle gap D acquired from the target coating weight  $W^*$  or the steel coating plant 2 are changed and switches the current nozzle pressure  $P_c$  to a nozzle pressure P realizing a desired coating weight.

**[0037]** Also, in the embodiment, although a case in which the target to be controlled is the nozzle pressure P has been

described; however, the target to be controlled is not limited to the nozzle pressure P, and the nozzle gap D, and the like may be the target to be controlled.

(Hardware Configuration)

**[0038]** Fig. 2 is a diagram illustrating a hardware configuration of the control apparatus according to the first embodiment.

**[0039]** The control apparatus 1 may be a personal computer (PC), and may be a programmable logic controller (PLC).

**[0040]** The control apparatus 1 includes a memory 501 such as a random access memory (RAM), and a storage device 503 such as a central processing unit (CPU) 502, or a hard disc (HD). Here, the storage device 503 corresponds to the stable value storage unit 104 of Fig. 1.

**[0041]** In the memory 501, the preset control unit 101, the tracking unit 102, the stable coating weight determination unit 103, the FB control unit 105, and the addition output unit 106 are implemented, when a program stored in the storage device 503 is load and the loaded program is executed by the CPU 502.

(Preset Control Process)

**[0042]** Fig. 3 is a flow chart illustrating a sequence of a process in the preset control unit according to the first embodiment. Fig. 1 is appropriately referred to.

**[0043]** Also, this process is a process which is performed when a nozzle opening and closing process is performed. Specifically, the process is a process which starts at the timing when the control apparatus 1 receives a change of the nozzle gap D, before and after the welding point 411 passes through the nozzle 211.

**[0044]** In addition, a process illustrated in Fig. 3 is terminated when the change of the nozzle gap D is terminated. Also, a process by the FB control unit 105 is stopped during performing the process by the preset control unit 101.

**[0045]** First, the preset control unit 101 acquires the current strip speed (first strip speed) Vc, the current nozzle gap (first nozzle-strip distance) Dc, and the current nozzle pressure Pc (S101) from the steel coating plant 2. Incidentally, the current nozzle pressure Pc is a setting value of the current nozzle pressure P. Also, in Step S101, the preset control unit 101 may not acquire the current nozzle pressure Pc.

**[0046]** Next, the preset control unit 101 acquires the current target coating weight W\*c from the host computer 3 (S102).

**[0047]** Next, the preset control unit 101 acquires the stable data from the stable value storage unit 104 (S103). The stable data is a combination of the stable strip speed (second strip speed) Vs, stable nozzle gap (second nozzle-strip distance) Ds, and the stable coating weight (information of coating weight) Ws.

**[0048]** A determination method of the stable condition or a storage of the stable data to the stable value storage unit 104 will be described later.

**[0049]** Also, the preset control unit 101 calculates the preset value Pref which is a control reference of the nozzle pressure based on the acquired stable data (S104).

**[0050]** Here, a calculating method of the preset value Pref in Step S104 will be described in detail.

**[0051]** In a case in which Expression (1) is assumed as the coating weight prediction model, Expression (1) can be rewritten in Expression (2) as follows.

$$W = f(P, V, D) = \exp(a_0 + a_1 \cdot \ln(P) + a_2 \cdot \ln(V) + a_3 \cdot \ln(D))$$

... (2)

**[0052]** When the strip speed is set to V, and the nozzle gap is set to D by Expression (2), the nozzle pressure P realizing a coating weight W can be expressed by Expression (3) as follows.

$$P = \exp\{(\ln(W) - a_0 - a_2 \cdot \ln(V) - a_3 \cdot \ln(D)) / a_1\} \dots (3)$$

**[0053]** Accordingly, the preset value Pref calculated by the preset control unit 101 is calculated by adding and subtracting deviations between the current target coating weight W\*c, the current strip speed Vc, the current nozzle gap Dc, and the stable coating weight Ws, the stable strip speed Vs, and the stable nozzle gap Ds stored in the stable value storage unit 104 to and from the stable nozzle pressure (second gas pressure) Ps stored in the stable value storage unit 104 by Expression (4) as follows.

$$P_{ref} = P_s + f^{-1}(W^*c, V_c, D_c) - f^{-1}(W_s, V_s, D_s) \dots (4)$$

**[0054]** A second term ( $f^{-1}(W^*c, V_c, D_c)$ ) in a right side of Expression (4) indicates a nozzle pressure (first gas pressure) corresponding to the current target coating weight (first coating weight)  $W^*c$ , the current strip speed  $V_c$ , and the current nozzle gap  $D_c$ . In addition, a third term ( $f^{-1}(W_s, V_s, D_s)$ ) on the right side in Expression (4) indicates a nozzle pressure (third gas pressure) corresponding to the stable coating weight (result value of coating weight)  $W_s$ , the stable strip speed  $V_s$ , the stable nozzle gap  $D_s$  stored in the stable value storage unit 104. The preset value  $P_{ref}$  (fourth gas pressure) is determined by Expression (5) as follows by proceeding with the second term and the third term of Expression (4).

$$P_{ref} = P_s + \exp\{(\ln(W^*c) - a_0 - a_2 \cdot \ln(V_c) - a_3 \cdot \ln(D_c)) / a_1\} - \exp\{(\ln(W_s) - a_0 - a_2 \cdot \ln(V_s) - a_3 \cdot \ln(D_s)) / a_1\} \dots (5)$$

**[0055]** An image of control in the preset control unit 101 will be described later. Also, information relating to the coating weight prediction model of Expression (5), and the like is stored in the stable value storage unit 104, and the like.

(Tracking Process)

**[0056]** Fig. 4 is a flow chart illustrating a sequence of a process in the tracking unit according to the first embodiment. Fig. 1 is appropriately referred to.

**[0057]** The tracking unit 102 determines whether or not the coating weight of the strip 401 detected by the coating weight gauge 212 is the stable coating weight. In order to determine the stable coating weight, the tracking unit 102 defines a tracking distance  $L$  which is a movement distance of the strip 401. The tracking distance  $L$  is added in accordance with a movement of the strip 401, and is reset at the timing when the welding point 411 passes through the nozzle 211 and at the timing of changing any one of the nozzle pressure  $P$ , the nozzle gap  $D$ , and the strip speed  $V$ .

**[0058]** Also, a process of Fig. 4 is executed during operating the steel coating plant 2.

**[0059]** First, the tracking unit 102 resets the tracking distance  $L$  as an initializing process (S201).

**[0060]** Next, the tracking unit 102 determines whether or not the welding point 411 passes through a position of the nozzle 211 (nozzle position) based on the tracking distance  $L$  (S211). In the steel coating plant 2, including a part which is not illustrated in Fig. 1, the movement of the strip 401 is consistently managed from beginning to the end. Accordingly, in Step S211, the tracking unit 102 is capable of easily determining whether or not the welding point 411 passes through the position of the nozzle 211 (nozzle position).

**[0061]** In Step S211, in a case in which it is determined that whether or not the welding point 411 does not pass through the nozzle position (S211→N), the tracking unit 102 proceeds a process to Step S213.

**[0062]** In Step S211, in a case in which it is determined that the welding point 411 passes through the nozzle position (S211→Y), the tracking unit 102 determines that new process of the strip 401 is started, resets the tracking distance  $L$  (S212), and proceeds the process to Step S213.

**[0063]** In Step S213, the tracking unit 102 acquires the current strip speed  $V_c$  from the steel coating plant 2.

**[0064]** Also, the tracking unit 102 calculates the tracking distance  $L$  of the strip 401 by integrating the acquired strip speed  $V_c$  (S214). That is, the tracking unit 102 calculates the tracking distance  $L$  by Expression (6) as follows.

$$L = \sum V_c \cdot \Delta t \dots (6)$$

**[0065]** Also,  $\Delta t$  in Expression (6) is an acquisition period of the strip speed  $V_c$ .

**[0066]** Next, the tracking unit 102 compares the current strip speed  $V_c$  with a reference speed  $V_o$ , and determines whether or not the strip speed  $V_c$  is less than the reference speed  $V_o$  (S221). The reference speed  $V_o$  is a determination index of whether or not the steel coating plant 2 is operated. That is, when the strip speed  $V_c$  is smaller than the reference speed  $V_o$ , the tracking unit 102 determines that a line is stopped.

**[0067]** As a result of Step S221, in a case in which the strip speed  $V_c$  is less than the reference speed  $V_o$  (S221→Y), the tracking unit 102 determines that operating of the steel coating plant 2 is terminated, and terminates the process.

**[0068]** As the result of Step S221, in a case in which the strip speed  $V_c$  is equal to or more than the reference speed  $V_o$  (S221→N), the tracking unit 102 determines whether or not the tracking distance  $L$  is greater than a reference distance  $L_s$  (S222). The reference distance  $L_s$  is a distance corresponding to a distance where the stable condition is established, and is defined as a value obtained by adding a distance corresponding to detection delay of the coating weight gauge

212 to a distance between the nozzle 211 and the coating weight gauge 212. That is, the reference distance  $L_s$  is a distance for determining whether or not the welding point 411 reaches the coating weight gauge 212.

**[0069]** As a result of Step S222, in a case in which the tracking distance  $L$  is equal to or less than the reference distance  $L_s$  (S222→N), the tracking unit 102 proceeds the process to Step S224.

**[0070]** As the result of Step S222, in a case in which the tracking distance  $L$  is greater than the reference distance  $L_s$  (S222→Y), the tracking unit 102 determines that the stable condition is established, and issues the stable condition trigger to the stable coating weight determination unit 103 (S223). An establishment condition of the stable condition is same as described above. The tracking distance  $L$  is greater than the reference distance  $L_s$  because a part of the strip 401 right under the nozzle 211 shows that any one of the nozzle pressure, the nozzle gap, and the strip speed is not changed until the coating weight gauge 212 detects the coating weight. That is, when the tracking distance  $L$  is greater than the reference distance  $L_s$ , it means that the welding point 411 passes through the coating weight gauge 212. Also, during this time, since the part of the strip 401 right under the nozzle 211 shows that any one of the nozzle pressure, the nozzle gap, and the strip speed is not changed until the coating weight gauge 212 detects the coating weight, the tracking unit 102 determines them to be the coating weight in accordance with each of a current strip speed, a current gas pressure, and a current nozzle-strip distance which are imported from the steel coating plant.

**[0071]** In this way, the tracking unit 102 determines whether or not the coating weight acquired from the steel coating plant 2 is the coating weight which is stably detected (whether or not the coating weight is in the stable condition) using a positional information of the strip 401 based on the tracking distance of the strip 401.

**[0072]** Also, in Step S224, the tracking unit 102 determines whether or not at least one of the nozzle pressure  $P$ , the nozzle gap  $D$ , and the strip speed  $V$  is changed.

**[0073]** As a result of Step S224, in a case in which at least one of the nozzle pressure  $P$ , the nozzle gap  $D$ , and the strip speed  $V$  is changed (S224→Y), the tracking unit 102 returns the process to Step S212 after waiting for a predetermined time ( $\Delta t$ ), and resets the tracking distance  $L$ . At this time, the tracking unit 102 performs a notification to the effect that the condition is not the stable condition to the preset control unit 101, and the preset control unit 101 which receives the notification may start the process illustrated in Fig. 3.

**[0074]** In a case in which any one of the nozzle pressure  $P$ , the nozzle gap  $D$ , and the strip speed  $V$  is not changed (S224→N), the tracking unit 102 returns the process to Step S211 after waiting for the predetermined time ( $\Delta t$ ), and repeats a process after Step S211.

**[0075]** In this way, determination whether or not the condition is the stable condition is performed in a period of the predetermined time ( $\Delta t$ ).

**[0076]** Fig. 5 is a diagram schematically illustrating a stable condition established timing inside one strip.

**[0077]** Here, a previous strip 401a and a next strip 401b are connected to the welding point 411 by welding. In an example of Fig. 5, in the previous strip 401a, after the welding point 411 passes through the position of the nozzle 211, an example in which four times stable conditions are established indicated by numerals 602a to 602d is illustrated. Here, a distance between the welding point 411 and the numeral 602a is great, because between the welding point and the numeral, for example, the nozzle gap is changed and the tracking distance  $L$  is reset. In the same manner, a distance between the numeral 602b and the numeral 602c is great, because between these numerals, for example, the strip speed is changed at a timing of the numeral 601 and the tracking distance  $L$  is reset.

(Stable Coating Weight Determination Process)

**[0078]** Fig. 6 is a flow chart illustrating a process sequence in the stable coating weight determination unit according to the first embodiment. Fig. 1 is appropriately referred to.

**[0079]** At the timing when a detection value of the coating weight is obtained from the coating weight gauge 212 of the steel coating plant 2, the stable coating weight determination unit 103 determines whether or not the obtained coating weight is a value of the stable condition according to an output of the tracking unit 102. Also, when the coating weight is the value of the stable condition, the stable coating weight determination unit 103 updates the stable data stored in the stable value storage unit 104 to be the value. Here, the stable coating weight  $W_s$  indicates the coating weight  $W$  when the nozzle pressure  $P$ , the nozzle gap  $D$ , and the strip speed  $V$  are not changed while a detection part of the coating weight is moved from the nozzle 211 to the coating weight gauge 212. In other words, the stable coating weight  $W_s$  indicates the coating weight  $W$  at the time of a condition in which the result value  $W$  of the current coating weight acquired from the steel coating plant 2 becomes the coating weight  $W$  based on each of the current strip speed  $V$ , the current nozzle pressure  $P$ , and the current nozzle gap  $D$  acquired from the steel coating plant 2. The coating weight (stable coating weight  $W_s$ ), the nozzle pressure (stable nozzle pressure  $P_s$ ), the strip speed (table strip speed  $V_s$ ), and the nozzle gap (stable nozzle gap  $D_s$ ) at this time are stored in the stable value storage unit 104 as a set of data items (stable data).

**[0080]** First, the stable coating weight determination unit 103 acquires the current coating weight  $W_c$ , the nozzle pressure  $P_c$ , the nozzle gap  $D_c$ , and the strip speed  $V_c$  from the steel coating plant 2 (S301).



**[0081]** Next, the stable coating weight determination unit 103 determines whether or not the tracking unit 102 issues the stable condition trigger (S302).

**[0082]** As a result of Step S302, in a case in which the tracking unit 102 does not issue the stable condition trigger (S302→N), the stable coating weight determination unit 103 terminates the process.

**[0083]** As the result of Step S302, in a case in which the tracking unit 102 issues the stable condition trigger (S302→Y), the stable coating weight determination unit 103 updates the stable data in which the coating weight  $W_c$ , the nozzle pressure  $P_c$ , the nozzle gap  $D_c$ , and the strip speed  $V_c$  acquired in Step S301 are respectively stored in the stable value storage unit 104 as the stable coating weight  $W_s$ , the stable nozzle pressure  $P_s$ , the stable nozzle gap  $D_s$ , the stable strip speed  $V_s$  (S303).

**[0084]** Also, the stable coating weight determination unit 103 performs feedback-controlling on the FB control unit 105 (S304). The FB control unit 105 calculates a correction amount  $\Delta P$  of the nozzle pressure for closing the stable coating weight  $W_s$  to the target coating weight  $W^*c$ , for example, by Expression (7) when comparing the stable coating weight  $W_s$  obtained in the stable condition with the current target coating weight  $W^*c$ .

$$\Delta P = \alpha \times (\partial P / \partial W) \times (W^*c - W_s) \dots (7)$$

**[0085]** Here,  $\alpha$  is a constant corresponding to a control gain, and  $(\partial P / \partial W)$  is a constant corresponding to an influence coefficient.

**[0086]** The addition output unit 106 outputs a value obtained by adding the preset value  $P_{ref}$  output by the preset control unit 101 and the correction amount  $\Delta P$  of the nozzle pressure output by the FB control unit 105 with respect to the nozzle 211 as the control reference (preset value) of the nozzle pressure.

(Modification Example of First Embodiment)

**[0087]** Also, in the embodiment, as the coating weight stored in the stable value storage unit 104, an example in which the result value of the coating weight detected by the coating weight gauge 212 is described, but the target coating weight acquired from the host computer 3 may be stored instead. The result value of the coating weight is controlled to be close to the target coating weight. Accordingly, at the timing of obtaining the stable coating weight, the coating weight and the target coating weight become a similar value. Accordingly, the target coating weight can be used instead of the result value of the coating weight.

**[0088]** Also, at the timing of acquiring the stable nozzle pressure  $P_s$ , the stable strip speed  $V_s$ , and the stable nozzle gap  $D_s$ , in a case in which the target coating weight (second coating weight)  $W^*s$  at the time of the stable condition is acquired instead of the result value of the coating weight at the time of the stable condition from the host computer 3, Expression (4) and Expression (5) are replaced by Expression (4a) and Expression (5a) as follows.

$$P_{ref} = P_s + f^{-1}(W^*c, V_c, D_c) - f^{-1}(W^*s, V_s, D_s) \dots (4a)$$

$$P_{ref} = P_s + \exp\{(\ln(W^*c) - a_0 - a_2 \cdot \ln(V_c) - a_3 \cdot \ln(D_c)$$

$$/a_1\} - \exp\{(\ln(W^*s) - a_0 - a_2 \cdot \ln(V_s) - a_3 \cdot \ln(D_s) /a_1\} \dots (5a)$$

**[0089]** Also, even when Expression (4a) and Expression (5a) are used, a same effect as that of a control using Expression (4) and Expression (5) can be obtained.

**[0090]** In addition, there are many cases in which a detector measuring distance between the nozzle 211 and the strip 401 is not provided in a general coating weight control apparatus. However, even in this case, since distance of a previous nozzle and a rear nozzle of the strip 401 can be checked from nozzle position information, the embodiment can be applied as it is by considering of 1/2 of the distance as the nozzle gap (nozzle-strip distance).

(Nozzle Control)

**[0091]** Fig. 7 is a diagram illustrating an example of a nozzle control according to the first embodiment.

**[0092]** In Fig. 7, when the nozzle is opened and closed in a vicinity of the welding point 411, a change of the nozzle

gap and the nozzle pressure by the preset control unit 101 is schematically illustrated.

[0093] In Fig. 7, the previous strip 401a and the next strip 401b are connected to the welding point 411. An opening and closing operation of the nozzle gap (change of nozzle gap) is illustrated by a line 701 of an upper side of Fig. 7, and a change of the nozzle pressure output by the preset control unit 101 is illustrated by a line 702 of a lower side thereof.

[0094] When the welding point 411 comes close, and the nozzle gap begins to open, the nozzle pressure is increased by a nozzle pressure calculation of the preset control unit 101, and an influence of opening of the nozzle gap on the coating weight is offset.

[0095] The numeral 611 indicates a timing where the stable condition is established in the previous strip 401a at the end, before the nozzle gap is changed.

[0096] The preset control unit 101 acquires the current nozzle gap  $D_c$ , the strip speed  $V_c$ , and the like from the steel coating plant 2 at the timing of calculating the nozzle pressure  $P$  after the numeral 611 (refer to Step S101 of Fig. 3).

[0097] In addition, the preset control unit 101 acquires a target value  $W^*c$  of the current coating weight from the host computer 3 at the timing of calculating the nozzle pressure  $P$  after the numeral 611 (refer to Step S102 of Fig. 3).

[0098] Also, the preset control unit 101 acquires the stable nozzle gap  $D_s$ , the stable strip speed  $V_s$ , a stable coating weight  $W_s$  acquired at the timing of the numeral 611 (refer to Step S103 of Fig. 3), at the timing of calculating the nozzle pressure  $P$  after the numeral 611.

[0099] Also, the preset control unit 101 calculates the preset value  $P_{ref}$  by Expression (5) at the timing of calculating the nozzle pressure  $P$  after the numeral 611 (refer to Step S104 of Fig. 3).

[0100] In general, since the nozzle gap  $D$  has a significant influence on the coating weight  $W$ , in order to eliminate this influence, as illustrated in Fig. 7, the nozzle pressure  $P$  increases in a process of the nozzle gap  $D$  opening and is saturated at the upper limit value before the nozzle gap is fully opened.

[0101] Also, the welding point 411 passes through the nozzle position, and the nozzle pressure  $P$  is also decreased according to closing of the nozzle gap  $D$ . The nozzle pressure after the nozzle closing is terminated is also preset-calculated, in the same manner, until next stable condition is established, based on the stable nozzle pressure  $P_s$ , the stable nozzle gap  $D_s$ , the stable strip speed  $V_s$ , and the stable coating weight  $W_s$  stored in the stable value storage unit 104.

[0102] That is, the preset control unit 101 calculates a subsequent nozzle pressure, based on the nozzle pressure 711 at a timing 611 where the stable condition is established in the end in the previous strip 401a as a referent point, as described in the numeral 712.

[0103] This condition is terminated when an opening and closing operation of the nozzle gap  $D$  is terminated.

[0104] Also, in the next strip 401b, after the stable condition is detected, feedback-controlling by the FB control unit 105 (refer to Fig. 2) is performed.

[0105] In the embodiment, as illustrated in Fig. 7, based on the stable nozzle pressure 711 at the timing 611 where the stable condition is established in the end in the previous strip 401a as a reference, a subsequent nozzle pressure is calculated. As seen from the above, the preset value of the calculated nozzle pressure does not affect a calculating result at an operating point where the nozzle gap is greatly opened. That is, even at the time where saturation outputting is terminated, since the nozzle pressure which becomes a reference point is the nozzle pressure 711 at the timing 611 as it is, the nozzle pressure can be stably controlled.

[0106] In addition, in the embodiment, based on the stable nozzle pressure 711 at the timing 611 where the stable condition is established in the end in the previous strip 401a as a reference, errors can be prevented from being accumulated by calculating a subsequent nozzle pressure, and therefore, making it possible to controlling the nozzle pressure with high accuracy.

[0107] Also, as illustrated in Fig. 7, based on the stable nozzle pressure 711 at the timing 611 where the stable condition is established in the end in the previous strip 401a as a reference, the control apparatus 1 illustrated in the embodiment calculates a subsequent nozzle pressure, but it is not limited thereto. According to the nozzle pressure when the stable condition is established, it may not be the stable nozzle pressure 711 at the timing 611 where the stable condition is established in the end.

[0108] At this time, the stable coating weight  $W_s$ , the target coating weight  $W^*s$  at the time of the stable condition, the stable strip speed  $V_s$ , the stable nozzle gap  $D_s$  which are used in Expression (4), Expression (5), Expression (4a), and Expression (5a), are acquired at the timing where the stable nozzle pressure  $P_s$  used in each Expression is acquired.

[0109] In the embodiment, an example in which a control target is the nozzle pressure  $P$  has been described; however, in actual plant, a control target may be the nozzle gap  $D$ , and may be both of the nozzle pressure  $P$  and the nozzle gap  $D$ . In any case, the method of the embodiment can be applied to.

[0110] Also, in the embodiment, the nozzle pressure is limited to be the saturated pressure, but if there is no need to limit, the nozzle pressure may not be limited to the saturated pressure.

[Second Embodiment]

(System)

**[0111]** Fig. 8 is a diagram illustrating a configuration of a coating weight control system according to a second embodiment.

**[0112]** Also, in Fig. 8, same numerals as those of Fig. 1 are given to configuration components which are the same as those of Fig. 1, and description thereof will be omitted.

**[0113]** First, a preset control unit 101a in a control apparatus 1a in Fig. 8 includes an absolute value calculating unit (first preset control unit) 111, a relative value calculating unit (second preset control unit) 112, a control method selecting unit (selecting unit) 113, and a switching unit 114.

**[0114]** The absolute value calculating unit 111 presets the nozzle pressure by calculating an absolute value of the nozzle pressure using the coating weight prediction model. Here, the absolute value of the nozzle pressure is a nozzle pressure which is calculated on the basis of only information at the current timing without referring to a nozzle pressure at a previous timing.

**[0115]** The relative value calculating unit 112 calculates the nozzle pressure which is need to be changed with respect to the amount of change of the target coating weight, and performs a preset by performing adding and subtracting with respect to the current nozzle pressure. That is, a preset process which is performed by the relative value calculating unit 112 is the same process as that of the preset control unit 101 in the first embodiment.

**[0116]** Hereinafter, a preset control executed by the absolute value calculating unit 111 is referred to as an absolute value preset, and a preset control executed by the relative value calculating unit 112 is referred to as a relative value preset. In addition, the preset value of the nozzle pressure calculated by the absolute value calculating unit 111 is appropriately referred to as an absolute preset value, and the preset value of the nozzle pressure calculated by the relative value calculating unit 112 is appropriately referred to as a relative preset value.

**[0117]** In addition, based on information, and the like transferred from a welding point vicinity determination unit 121, the control method selecting unit 113 selects which one of the absolute preset value calculated by the absolute value calculating unit 111 and a relative preset value calculated by the relative value calculating unit 112 is actually used.

**[0118]** The switching unit 114 switches an output of the preset control unit 101a to an output from the absolute value calculating unit 111 and an output from the relative value calculating unit 112 in accordance with the output of the control method selecting unit 113.

**[0119]** In addition, the control apparatus 1a illustrated in Fig. 8 includes the welding point vicinity determination unit 121.

**[0120]** The welding point vicinity determination unit 121 determines whether or not the welding point 411 comes close to the nozzle position from the current strip speed  $V_c$  acquired from the steel coating plant 2, the timing when the welding point 411 passes through the nozzle position, and the like, and notifies a condition to the preset control unit 101a at the time of being close.

**[0121]** Also, the preset control unit 101a is started as long as at a timing when the welding point 411 is determined to be near the nozzle position by the welding point vicinity determination unit 121. That is, when the preset control unit 101a receives a vicinity trigger issued by the welding point vicinity determination unit 121 in Steps S503 and S533 of Fig. 11 to be described later, the preset control unit 101a starts the process. In addition, when the preset control unit 101a receives a vicinity release trigger issued by the welding point vicinity determination unit 121 in Step S523 of Fig. 11 to be described later, the preset control unit 101a terminates the process.

(Hardware Configuration)

**[0122]** Fig. 9 is a diagram illustrating a hardware configuration of a control apparatus according to the second embodiment.

**[0123]** Also, in Fig. 9, same numerals are given to the same components as those of Fig. 2 and description thereof will be omitted.

**[0124]** In the control apparatus 1a, when a program stored in the storage device 503 is loaded by the memory 501, and executed by CPU 502, in addition to each unit 102, 103, 105, and 106 illustrated in Fig. 2, the welding point vicinity determination unit 121 or, the absolute value calculating unit 111, the relative value calculating unit 112, the control method selecting unit 113, the switching unit 114, and the like executed by the preset control unit 101a are implemented.

**[0125]** Hereinafter, processes of the absolute value calculating unit 111, the welding point vicinity determination unit 121, and the control method selecting unit 113 will be described. Processes of the tracking unit 102, the stable coating weight determination unit 103, the FB control unit 105, and the addition output unit 106 are the same as those of the first embodiment, and thus descriptions of those will be omitted here.

**[0126]** In addition, as described above, the process executed by the relative value calculating unit 112 is the same as the process executed by the preset control unit 101 of the first embodiment using Expression (4) and Expression (5),

and thus descriptions of those will be omitted here.

(Absolute Value Calculation Process)

5 **[0127]** Fig. 10 is a flow chart illustrating a sequence of a process in the absolute value calculating unit according to the second embodiment.

**[0128]** First, the absolute value calculating unit 111 acquires the current strip speed  $V_c$  and the current nozzle gap  $D_c$  from the steel coating plant 2, and acquires the current target coating weight  $W^*c$  from the host computer 3 (S401). Also, the absolute value calculating unit 111 acquires, for example, the current strip speed  $V_c$ , the current nozzle gap  $D_c$ , and the target coating weight  $W^*c$  for every constant time, and as illustrated in the first embodiment, it does not matter whether or not it is the stable condition.

**[0129]** Also, the absolute value calculating unit 111 calculates the preset value  $P_{ref}$  (fifth gas pressure) of the nozzle pressure by Expression (8) as follows (S402).

$$15 \quad P_{ref} = f^{-1} (W^*c, V_c, D_c) \dots (8)$$

**[0130]** Also, the target coating weight  $W^*c$  is expressed by Expression (9) as follows.

$$20 \quad W^*c = f (P_{ref}, V_c, D_c) = \exp (a_0 + a_1 \cdot \ln (P_{ref}) + a_2 \cdot \ln (V_c) + a_3 \cdot \ln (D_c)) \dots (9)$$

25 **[0131]** Accordingly, Expression (8) can be rewritten in Expression (10) as follows by Expression (9).

$$30 \quad P_{ref} = \exp \{ (\ln (W^*c) - a_0 - a_2 \cdot \ln (V_c) - a_3 \cdot \ln (D_c)) / a_1 \} \dots (10)$$

(welding point vicinity determination process)

35 **[0132]** Fig. 11 is a flow chart illustrating a process sequence in the welding point vicinity determination unit according to the second embodiment.

**[0133]** Here, an example in which a region including a range where the nozzle opening and closing is performed is determined using the tracking distance with respect to the welding point 411 of the strip 401 is shown.

**[0134]** First, the welding point vicinity determination unit 121 determines whether or not the current strip speed  $V_c$  is greater than the reference speed  $V_o$  (S501). The reference speed  $V_o$  is a determination index for determining whether or not the steel coating plant 2 is operated as described above, and when the strip speed  $V_c$  is greater than the reference speed  $V_o$ , it indicates that the steel coating plant 2 is performing the process of the strip 401.

**[0135]** As a result of Step S501, in a case in which the current strip speed  $V_c$  is equal to or less than the reference speed  $V_o$  (S501→N), the welding point vicinity determination unit 121 returns the process to Step S501.

40 **[0136]** As a result of Step S501, in a case in which the current strip speed  $V_c$  is greater than the reference speed  $V_o$  (S501→Y), the welding point vicinity determination unit 121 determines whether or not the welding point 411 passes through the nozzle position (S502). Determination whether or not the welding point 411 passes through the nozzle position is performed on the basis of the tracking distance  $L$  calculated by the tracking unit 102.

**[0137]** As a result of Step S502, in a case in which the welding point 411 does not pass through the nozzle position (S502→N), the welding point vicinity determination unit 121 returns the process to Step S501.

50 **[0138]** As a result of Step S502, in a case in which the welding point 411 passes through the position of the nozzle 211 (S502→Y), that is, according to a start of a process of new strip 401 (coil), the welding point vicinity determination unit 121 determines whether or not the nozzle position is near the welding point 411, issues the vicinity trigger (S503), and starts a process as follows.

**[0139]** Next, the welding point vicinity determination unit 121 determines whether or not the welding point 411 passes through the position of the nozzle 211 (S511).

**[0140]** As a result of Step S511, in a case in which the welding point 411 does not pass through the position of the nozzle 211 (S511→N), the welding point vicinity determination unit 121 proceeds the process to Step S513.

**[0141]** As the result of Step S511, in a case in which the welding point 411 passes through the position of the nozzle 211 (S511→Y), the welding point vicinity determination unit 121 resets the tracking distance L (S512), and proceeds the process to Step S513.

**[0142]** In Step S513, the welding point vicinity determination unit 121 acquires the strip speed  $V_c$  from the steel coating plant 2, and calculates the tracking distance L of the strip 401 by Expression (6) whenever the speed is acquired (S514).

**[0143]** Also, the welding point vicinity determination unit 121 determines whether or not the acquired strip speed  $V_c$  is greater than the reference speed  $V_o$  (S521).

**[0144]** As a result of Step S521, in a case in which the strip speed  $V_c$  is equal to or less than the reference speed  $V_o$  (S521→N), the welding point vicinity determination unit 121 determines that operating of the steel coating plant 2 is terminated, and terminates the process.

**[0145]** As the result of Step S521, in a case in which the strip speed  $V_c$  is greater than the reference speed  $V_o$  (S521→Y), the welding point vicinity determination unit 121 determines whether or not the tracking distance L is greater than a first reference distance  $L_d$  (S522). The first reference distance  $L_d$  is set in advance to a value which is sufficiently longer than a length between a timing when the nozzle opening and closing in the next strip 401 is terminated after the welding point 411 passes through, and the welding point 411. An example of the first reference distance  $L_d$  is illustrated in Fig. 13.

**[0146]** That is, in Step S522, the welding point vicinity determination unit 121 determines whether or not a part of the strip 401, which is a range of the first reference distance  $L_d$  in Fig. 13, when passing through the nozzle 211, already passed through the coating weight gauge 212.

**[0147]** As a result of Step S522, in a case in which the tracking distance L is equal to or less than the first reference distance  $L_d$  (S522→N), after waiting for a predetermined time ( $\Delta t$ ), the welding point vicinity determination unit 121 returns the process to Step S513.

**[0148]** As the result of Step S522, in a case in which the tracking distance L is greater than the first reference distance  $L_d$  (S522→Y), the welding point vicinity determination unit 121 determines whether or not it is not near the welding point 411, issues a vicinity release trigger (S523), and releases a welding point vicinity determination.

**[0149]** Also, the welding point vicinity determination unit 121 acquires the strip speed  $V_c$  from the steel coating plant 2 (S524), and calculates the tracking distance L of the strip 401 by Expression (6) whenever the speed is acquired (S525).

**[0150]** Next, the welding point vicinity determination unit 121 determines whether or not the acquired strip speed  $V_c$  is greater than the reference speed  $V_o$  (S531).

**[0151]** As a result of Step S531, in a case in which the strip speed  $V_c$  is equal to or less than the reference speed  $V_o$  (S531→N), the welding point vicinity determination unit 121 determines that operating of the steel coating plant 2 is terminated, and terminates the process.

**[0152]** As the result of Step S531, in a case in which the strip speed  $V_c$  is greater than the reference speed  $V_o$  (S531→Y), the welding point vicinity determination unit 121 determines whether or not a value ( $L_c - L$ ) which is obtained by subtracting the tracking distance L from a coil length  $L_c$  is less than a second reference distance  $L_e$  (S532). Here, the second reference distance  $L_e$  is set in advance to be a value which is sufficiently longer than a length between the timing when the nozzle opening and closing is started in the current strip 401 before passing through the welding point 411, and the welding point 411. The second reference distance  $L_e$  is illustrated in Fig. 13. In addition, here, the coil length  $L_c$  is a length from the welding point 411 to the welding point 411.

**[0153]** That is, in Step S532, the welding point vicinity determination unit 121 determines whether or not a part of the strip 401, which is a range of the second reference distance  $L_e$  in Fig. 13 at the time of passing through the nozzle 211, currently passes through the coating weight gauge 212.

**[0154]** As a result of Step S532, in a case in which a value ( $L_c - L$ ) which is obtained by subtracting the tracking distance L from the coil length  $L_c$  is equal to or more than  $L_e$  (S532→N), the welding point vicinity determination unit 121 returns the process to Step S524 after waiting for the predetermined time ( $\Delta t$ ).

**[0155]** In a case in which a value ( $L_c - L$ ) obtained by subtracting the tracking distance L from the coil length  $L_c$  is less than  $L_e$  (S532→Y), the welding point vicinity determination unit 121 determines that it is near the welding point 411, issues the vicinity trigger (S533), and returns the process to Step S511.

(Control Method Selecting Process)

**[0156]** Fig. 12 is a flow chart illustrating a sequence of a process in the control method selecting unit according to the second embodiment. The process is started at the same time when the process of the preset control unit 101a is started. That is, when the preset control unit 101a receives the vicinity trigger issued by the welding point vicinity determination unit 121 in Step S503 and S533 of Fig. 11, a process of Fig. 12 is started. In addition, when the preset control unit 101a receives a vicinity release trigger issued by the welding point vicinity determination unit 121 in Step S523 of Fig. 11, the process of Fig. 12 is terminated.

**[0157]** The control method selecting unit 113 selects which one of the absolute preset value and the relative preset

value is used according to whether or not the welding point 411 passes through the position of the nozzle 211 in addition to a degree of similarity of a control specification of a control value, and the like in a coating control. In the embodiment, an example is described of which the degree of similarity of the control specification after the welding point 411 passes is reprehensive of the target value of the coating weight.

**[0158]** First, the control method selecting unit 113 acquires the current target coating weight  $W^*c$  from the host computer 3, and further acquires the result value  $W$  of the coating weight obtained in the last controlling from the coating weight gauge 212 in the steel coating plant 2 (S601). Also, since the result value  $W$  of the coating weight obtained in the last controlling is actually considered to be a result value of the current coating weight, it is set to be the coating weight  $Wc$  here.

**[0159]** Next, the control method selecting unit 113 determines whether or not the welding point 411 passes through the position of the nozzle 211 (S602). The control method selecting unit 113 determines whether or not, the welding point vicinity determination unit 121 acquires a signal of resetting the tracking distance  $L$ , and the welding point 411 passes through the position of the nozzle 211 based on the signal in a process in Step S511 of Fig. 11.

**[0160]** As a result of Step S602, in a case in which the welding point 411 does not pass through the position of the nozzle 211 (S602→N), the control method selecting unit 113 instructs the switching unit 114 to select the relative value calculating unit 112 (S605).

**[0161]** As the result of Step S602, in a case in which the welding point 411 passes through the position of the nozzle 211 (S602→Y), the control method selecting unit 113 determines whether or not an absolute value (deviation) of a difference between the target coating weight  $W^*c$  and the coating weight  $Wc$  is greater than a certain value  $\Delta Z$  (S603).

**[0162]** As a result of Step S603, in a case in which an absolute value of a difference between the target coating weight  $W^*c$  and the result coating weight  $Wc$  is equal to or less than the certain value  $\Delta Z$  (S603→N), the control method selecting unit 113 instructs the switching unit 114 to select the relative value calculating unit 112 (S605).

**[0163]** As a result of Step S604, in a case in which the absolute value of the difference between the target coating weight  $W^*c$  and the result coating weight  $Wc$  is greater than the certain value  $\Delta Z$  (S603→Y), the control method selecting unit 113 instructs the switching unit 114 to select the absolute value calculating unit 111 (S604).

**[0164]** The switching unit 114 switches the output of the relative value calculating unit 112 and the output of the absolute value calculating unit 111, and outputs them according to the instruction of the control method selecting unit 113.

**[0165]** In the second embodiment, attention has been paid to the target coating weight as the index for the control method selecting unit 113 to select the output, but it is also possible to consider that the degree of similarity is calculated by adding the mutual difference or the like of the lower limit values of the coating weight in the previous strip 401a (Fig. 13) and a next strip 402b (Fig. 13).

(Nozzle Controlling)

**[0166]** Fig. 13 is a diagram illustrating an example of the nozzle controlling according to the second embodiment.

**[0167]** In Fig. 13, when opening and closing is performed near the welding point 411 with respect to the nozzle 211, the nozzle pressure output by the preset control unit 101a is schematically illustrated.

**[0168]** In Fig. 13, the previous strip 401a and the next strip 401b are connected to the welding point 411.

**[0169]** A vicinity range of the welding point 411 is defined to sufficiently include a range where the nozzle gap is opened and closed over the welding point 411. The opening and closing operation of the nozzle gap is illustrated by a line 801 of an upper side of Fig. 13, and nozzle pressure operation output by the preset control unit 101a is illustrated by a line 802 of a lower side of Fig. 13.

**[0170]** When the nozzle gap to which the welding point 411 comes close starts opening, the nozzle pressure becomes greater by calculating the nozzle pressure of the preset control unit 101a, and an influence of opening of the nozzle gap on the coating weight is offset. In addition, the welding point 411 passes through the nozzle position, and the nozzle pressure is also decreased as the nozzle gap is closed.

**[0171]** Here, the numeral 611 indicates a timing when the stable condition is established in the end in the previous strip 401a. As illustrated in Fig. 13, before the welding point 411 passes through the position of the nozzle 211, the relative value calculating unit 112 is selected in the preset control unit 101a. That is, in a time region 811 before the welding point 411 passes through the position of the nozzle 211, a process same as that of the first embodiment is performed.

**[0172]** After that, after the next strip 401b becomes a process target (time region 812), focusing on a difference between the current target coating weight  $W^*c$  and the result coating weight  $Wc$  acquired from the coating weight gauge 212, the preset control unit 101a calculates the nozzle pressure by an absolute preset using the absolute value calculating unit 111 when the difference is great, and by a relative value calculation using the stable data stored in the stable value storage unit 104 when the difference is small.

**[0173]** Also, the time regions 811 and 812 are respectively near the welding point 411, and include time when the nozzle opening and closing are controlled.

**[0174]** That is, in the second embodiment, when the welding point 411 passes through the nozzle position and the

next strip 401b is processed, a similarity is compared. In the second embodiment, a difference between the current target coating weight  $W^*c$  and the result coating weight  $Wc$  is applied as the similarity. Also, when a previous section number 401a and a process in the next strip 401b are similar to each other, the same process as that of the first embodiment is performed. In addition, when the previous strip 401a and the process in the next strip 401b are not similar to each other, since reliability is deteriorated if the stable data acquired at the time of the stable condition in the end in the previous strip 401a is used for the next strip 401b, the nozzle pressure control by the absolute preset value is performed.

**[0175]** In this way, reliability of the nozzle pressure control can be improved.

**[0176]** Incidentally, the tracking unit 102 and the welding point vicinity determination unit 121 in Fig. 8 may be combined into one.

**[0177]** The invention is not limited to the embodiment described above, and various modification examples are included therein. For example, the embodiment described above is described in detail in order to easily understand the invention, and the invention is not necessarily limited to apparatuses and methods including all of the described configurations. In addition, a part of a configuration of a certain embodiment can be replaced with a configuration of another embodiment, and the configuration of another embodiment can be also added to the configuration of a certain embodiment. In addition, addition, deleting, and substitutions of another configuration can be made to a part of a configuration of each embodiment.

**[0178]** In addition, in each configuration, function, units 101 to 103, 105, 106, 101a, 111 to 114, and 121, the stable value storage unit 104, and the like, some or all thereof may be implemented by, for example, hardware when being designed as an integrated circuit. In addition, as illustrated in Fig. 2 and Fig. 9, each configuration, function, and the like described above, may be implemented by software when a processor such as the CPU 502 interprets and executes a program realizing each function. Information of a program, table, file, and the like realizing each function can be stored in a recording device, such as a memory or a solid state drive (SSD), or a recording medium such as an integrated circuit (IC) card, a secure digital (SD) card, or a digital versatile disc (DVD), in addition to storing in a hard disk (HD).

**[0179]** In addition, in each embodiment, only a control line or a information line that are considered to be necessary for description are indicated and products may not indicate all of the control lines or information lines. Actually, almost all of the configurations may be considered to be connected to each other.

**[0180]** Features, components and specific details of the structures of the above-described embodiments may be exchanged or combined to form further embodiments optimized for the respective application. As far as those modifications are readily apparent for an expert skilled in the art they shall be disclosed implicitly by the above description without specifying explicitly every possible combination, for the sake of conciseness of the present description.

#### Reference Signs List

#### **[0181]**

- 1 control apparatus (coating weight control apparatus)
- 2 steel coating plant
- 3 host computer (external device)
- 101 preset control unit
- 102 tracking unit (stable condition determination unit)
- 103 stable coating weight determination unit (stable value storage processing unit)
- 104 stable value storage unit (storage unit)
- 105 FB control unit
- 106 addition output unit
- 111 absolute value calculating unit (first preset control unit)
- 112 relative value calculating unit (second preset control unit)
- 113 control method selecting unit (selecting unit)
- 114 switching unit
- 121 welding point vicinity determination unit
- 201 pot
- 202 molten coating
- 203 roll
- 204 top roll
- 211 nozzle
- 212 coating weight gauge
- 401 strip
- 401a previous strip
- 401b next strip

411 welding point

**Claims**

- 5 1. A coating weight control apparatus which receives result information from a steel coating plant (2), which attaches a coating having a desired coating weight to a strip (401) by immersing a continuously sent strip (401) into a bath of a molten coating (202) and spraying high pressure gas from a nozzle (211) so as to peel an unnecessary coating off immediately after the strip (401) is lifted, generates control information for controlling a coating weight which is  
10 a coating weight of the coating based on the received result information, and transfers the generated control information to the steel coating plant (2), the apparatus comprising:

15 a preset control unit (101) that calculates at least the gas pressure as a control reference for a control reference of the nozzle (211) for attaching the coating having a desired coating weight, by calculation based on a coating weight prediction model indicating at least a relationship between a strip speed which is a moving speed of the strip (401), a gas pressure which is a pressure of the gas being sprayed from the nozzle (211), a nozzle-strip distance which is a distance between the nozzle (211) and the strip (401), and the coating weight being attached to the strip (401);

20 a tracking unit (102) that specifies positional information of the strip (401) based on a movement distance of the strip (401) obtained by importing the strip speed from the steel coating plant (2) and integrating the imported strip speed;

25 a stable condition determination unit that determines whether or not the coating weight imported from the steel coating plant (2) is a stably-detected coating weight by determining whether or not a current coating weight imported from the steel coating plant (2) is a coating weight in accordance with each of a current strip speed, a current gas pressure, and a current nozzle-strip distance imported from the steel coating plant (2), based on the positional information of the strip (401) specified by the tracking unit; and

30 a stable value storage processing unit that stores a combination of a second coating weight, a second strip speed, a second gas pressure, and a second nozzle-strip distance, which are imported, when the coating weight imported from the steel coating plant (2) is determined to be the stably-detected coating weight, by the stable condition determination unit, in a stable value storage unit (104),

35 wherein the preset control unit (101) imports a first strip speed which is the current strip speed, a first nozzle-strip distance which is the current nozzle-strip distance, and a first target coating weight which is a target value of the current coating weight from the steel coating plant (2), calculates a first gas pressure of a control reference which is the gas pressure for realizing the first target coating weight based on the coating weight prediction model, imports the second strip speed, the second nozzle-strip distance, and the second coating weight from the stable value storage unit (104), calculates a third gas pressure of a control reference which is the gas pressure for realizing the coating weight corresponding to the second strip speed and the second nozzle-strip distance using the coating weight prediction model, adds the first gas pressure to the second gas pressure imported from the stable value storage unit (104), and calculates a fourth gas pressure which is a control reference of the nozzle (211) by subtracting the third gas pressure.

- 40 2. The coating weight control apparatus according to Claim 1, wherein the second coating weight is a result value of the coating weight imported from the steel coating plant (2) at a timing when the coating weight imported from the steel coating plant (2) is determined to be the stably-detected coating weight by the stable condition determination unit.
- 45 3. The coating weight control apparatus according to Claim 1, wherein the second coating weight is a target coating weight, which is a target value of the coating weight imported from an external device, at a determination timing when the coating weight imported from the steel coating plant (2) is determined to be the stably-detected coating weight, by the stable condition determination unit.
- 50 4. The coating weight control apparatus according to Claim 1, wherein the preset control unit (101) is a second preset control unit, and wherein the preset control unit (101) further includes  
55 a first preset control unit that calculates a fifth gas pressure for realizing a desired coating weight corresponding to at least the strip speed and the nozzle-strip distance imported from the steel coating plant (2), using the coating weight prediction model,



a selecting unit that calculates a deviation between the target value and the result value of the coating weight imported from the steel coating plant (2), selects the first preset control unit when the deviation is greater than a predetermined value, and selects the second preset control unit when the deviation is less than a predetermined value, and

a switching unit (114) that performs switching between the first preset control unit and the second preset control unit according to a determination result of the selecting unit.

5. A coating weight control method for a coating weight control apparatus which receives result information from a steel coating plant (2), which attaches a coating having a desired coating weight to a strip (401) by immersing a continuously sent strip (401) into a bath of a molten coating (202) and spraying high pressure gas from a nozzle (211) so as to peel an unnecessary coating off immediately after the strip (401) is lifted, generates control information for controlling a coating weight which is a coating weight of the coating based on the received result information, and transfers the generated control information to the steel coating plant (2), the method comprising:

storing a coating weight prediction model indicating a relationship between at least a strip speed which is a moving speed of the strip (401), a gas pressure which is a pressure of the gas sprayed from the nozzle (211), a nozzle-strip distance which is a distance between the nozzle (211) and the strip (401), and the coating weight attached to the strip (401), in a storage unit;

importing the strip speed from the steel coating plant (2), and specifying positional information in the strip (401), based on a movement distance of the strip (401) obtained by integrating the imported strip speed;

based on the specified positional information of the strip (401), determining whether or not the coating weight imported from the steel coating plant (2) is the stably-detected coating weight by determining whether or not the current coating weight imported from the steel coating plant (2) is the coating weight respectively based on a current strip speed, a current gas pressure, and a current nozzle-strip distance which are imported from the steel coating plant (2) ;

storing a combination of a second coating weight, a second strip speed, a second gas pressure, and a second nozzle-strip distance which are imported when the coating weight imported from the steel coating plant (2) is determined to be the stably-detected coating weight, in a stable value storage unit (104); and

importing a first strip speed which is the current strip speed, a first nozzle-strip distance which is the current nozzle-strip distance, and a first target coating weight which is a target value of the current coating weight from the steel coating plant (2), calculating the first gas pressure of a control reference which is the gas pressure for realizing the first target coating weight, importing a second strip speed, a second nozzle-strip distance, and a second coating weight from the stable value storage unit (104) based on the coating weight prediction model, calculating a third gas pressure of the control reference which is the gas pressure for realizing the coating weight corresponding to the second strip speed and the second nozzle-strip distance using the coating weight prediction model, adding the first gas pressure to the second gas pressure imported from the stable value storage unit (104), and calculating a fourth gas pressure which is a control reference of the nozzle (211) by subtracting the third gas pressure.

6. The coating weight control method according to Claim 5, wherein the second coating weight is the result value of the coating weight imported from the steel coating plant (2) at the timing when the coating weight imported from the steel coating plant (2) is determined to be the stably-detected coating weight.

7. The coating weight control method according to Claim 5, wherein the second coating weight is a target coating weight which is a target value of the coating weight imported from an external device at the timing when the coating weight imported from the steel coating plant (2) is determined to be the stably-detected coating weight.

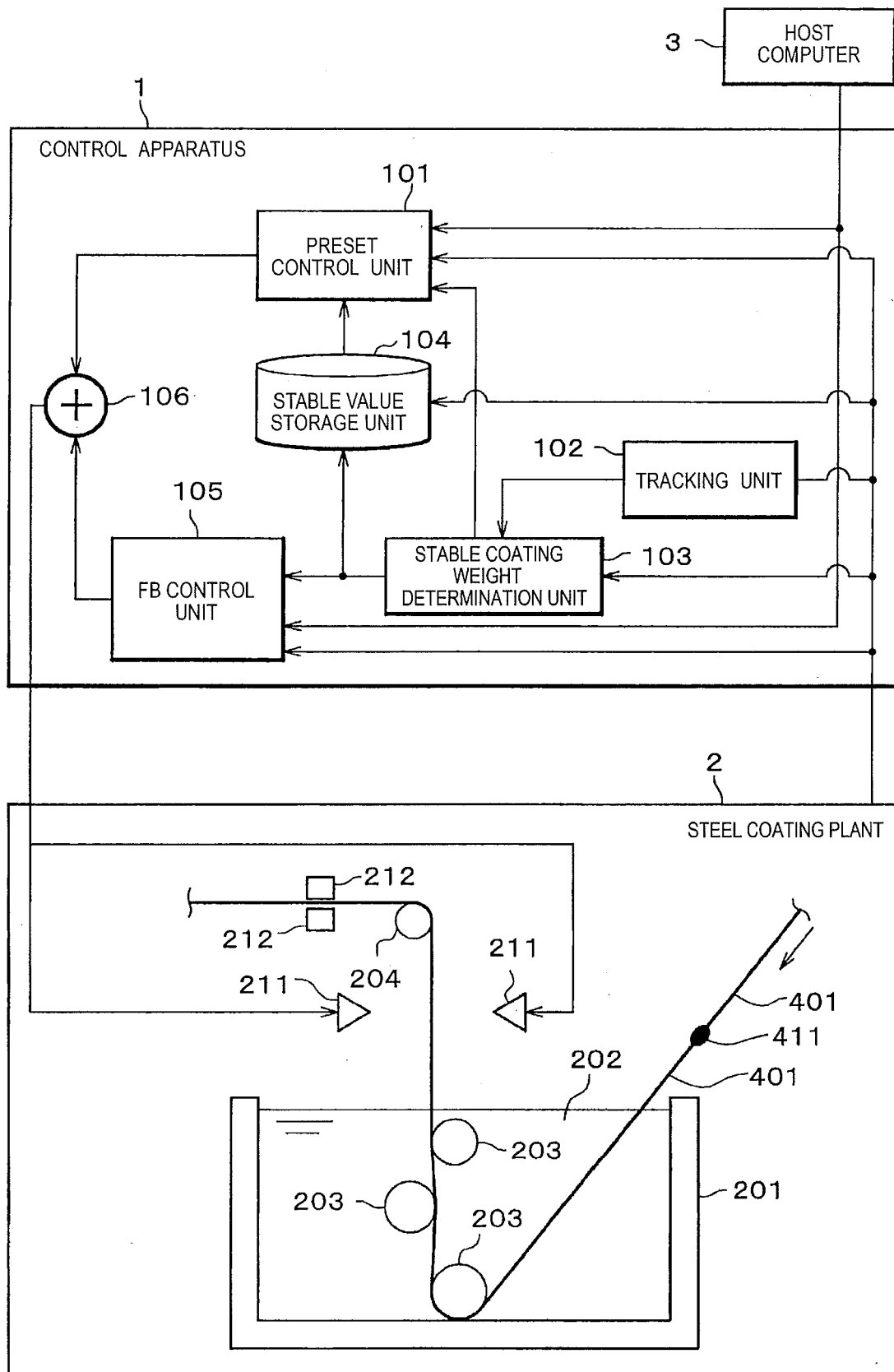
8. The coating weight control method according to Claim 5, the method further comprising:

calculating a deviation between a desired coating weight and the result value of the coating weight imported from the steel coating plant (2);

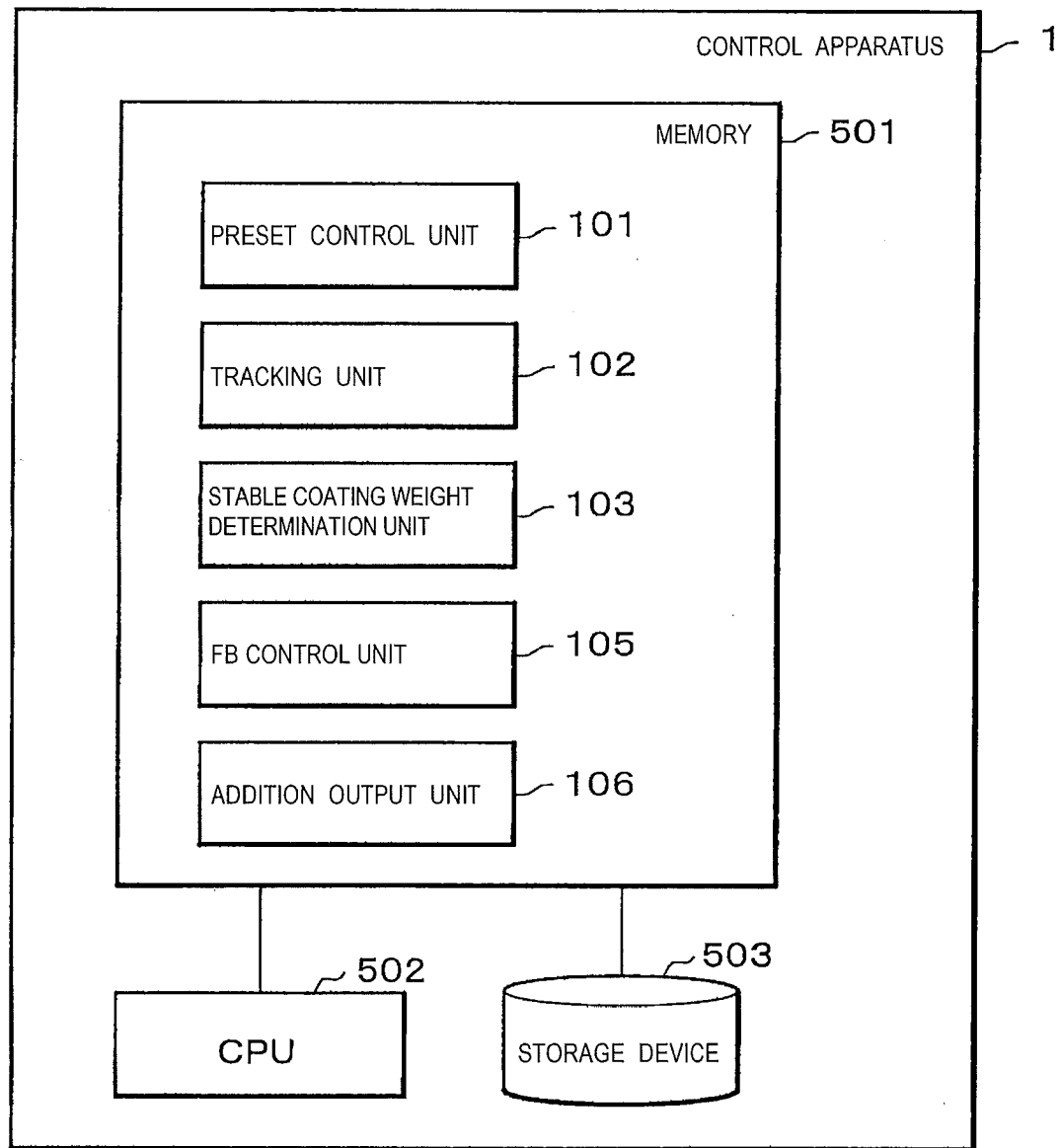
selecting a fifth gas pressure for realizing the desired coating weight corresponding to at least the strip speed and the nozzle-strip distance imported from the steel coating plant (2) when the deviation is greater than a predetermined value, as the control reference of the nozzle (211); and

selecting the fourth gas pressure as the set value of the control reference of the nozzle (211) when the deviation is less than the predetermined value.

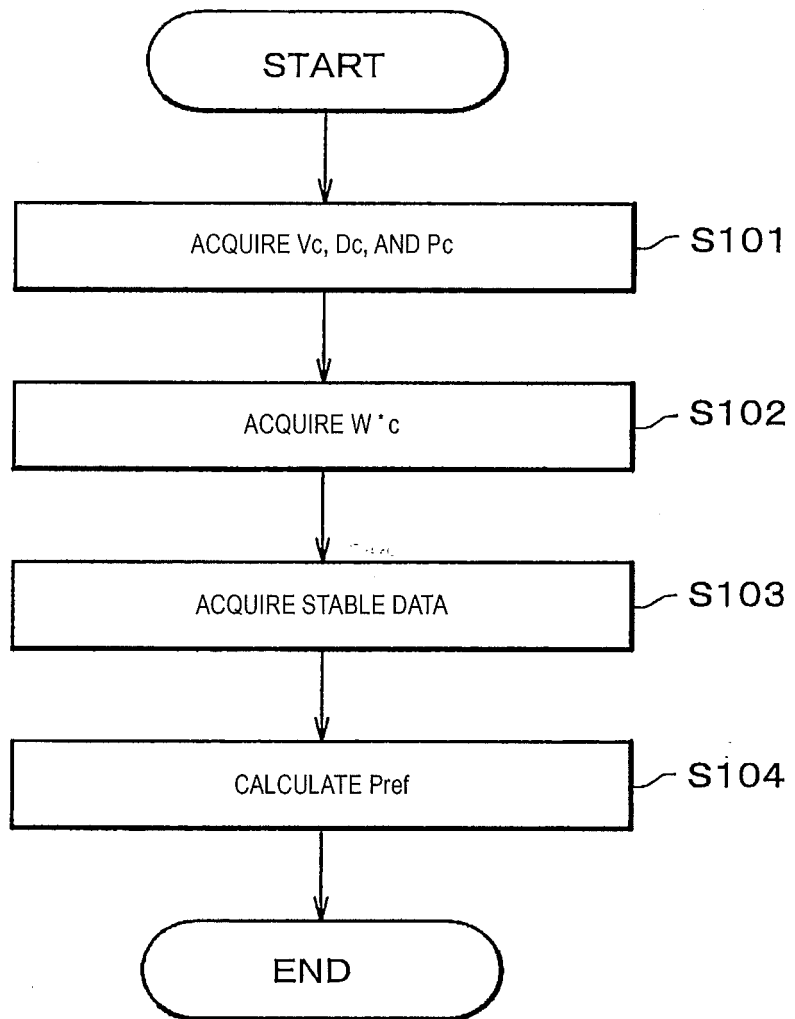
[Fig. 1]



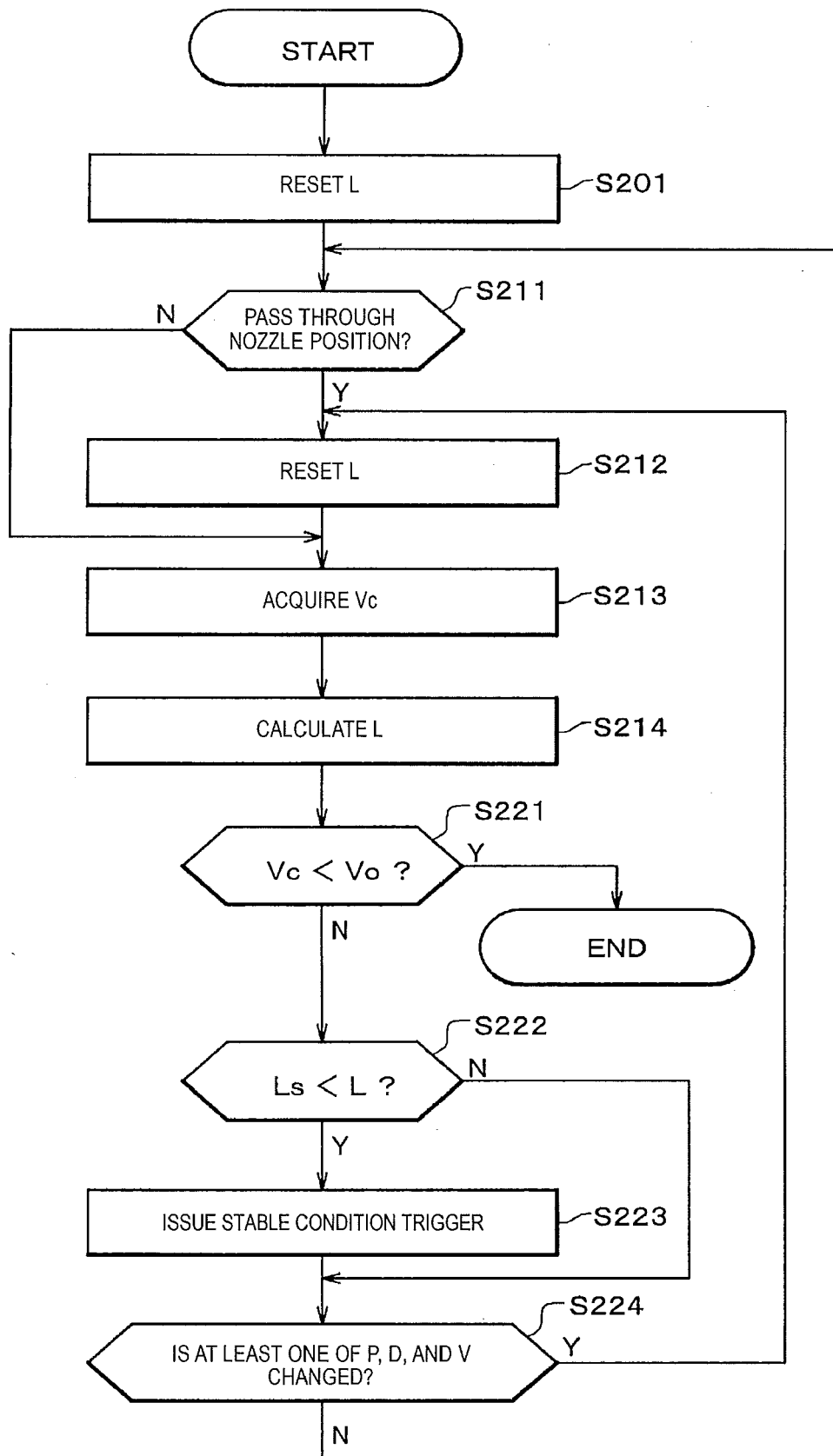
[Fig. 2]



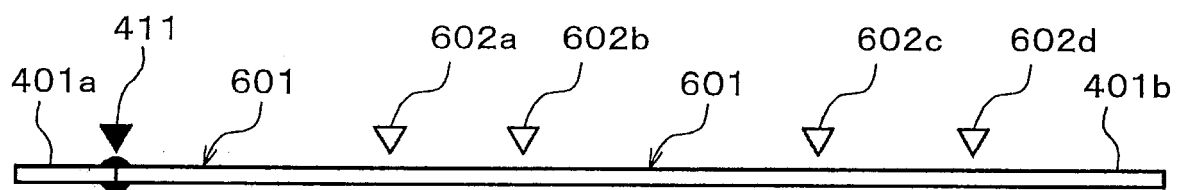
[Fig. 3]



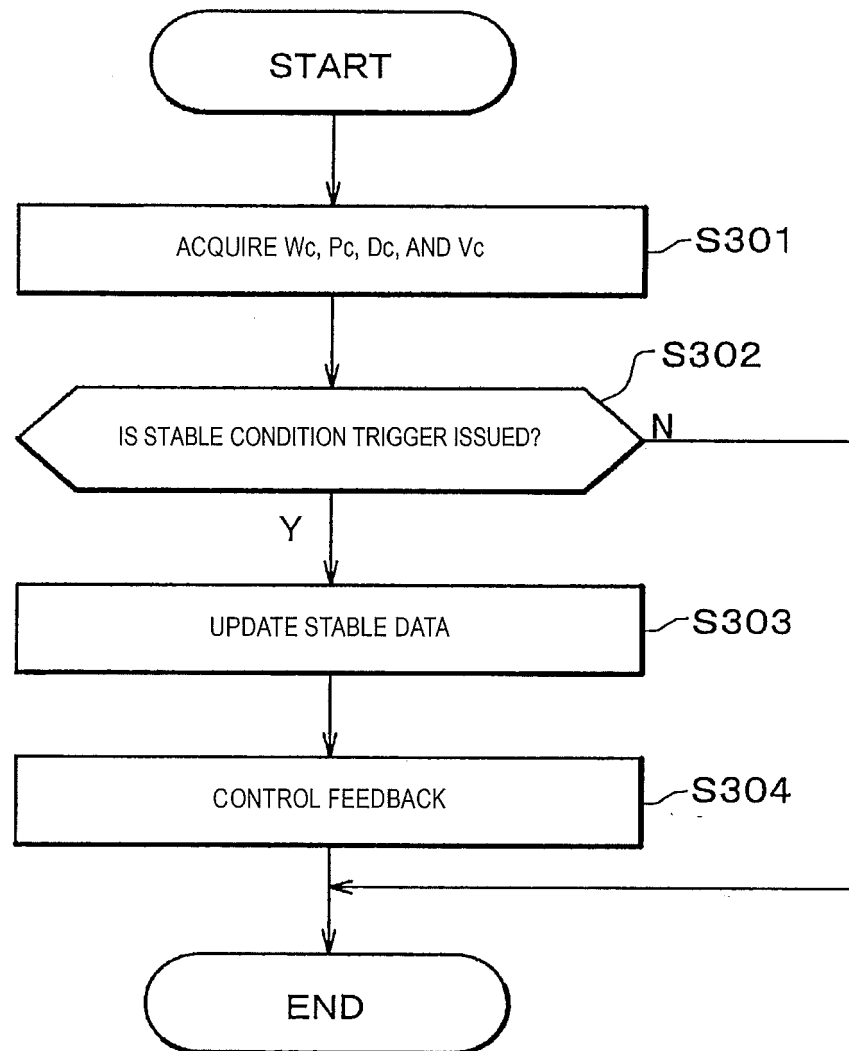
[Fig. 4]



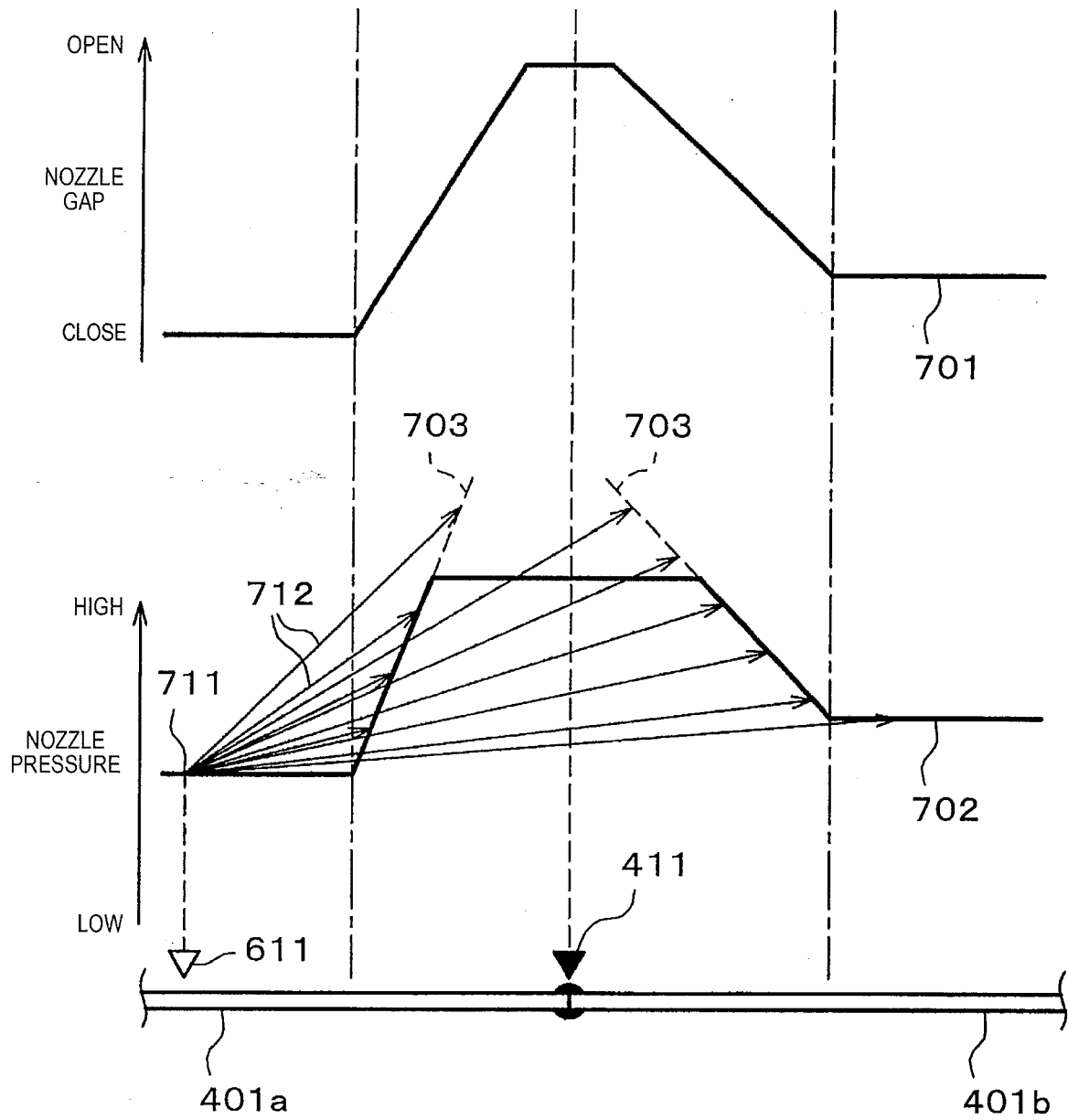
[Fig. 5]



[Fig. 6]

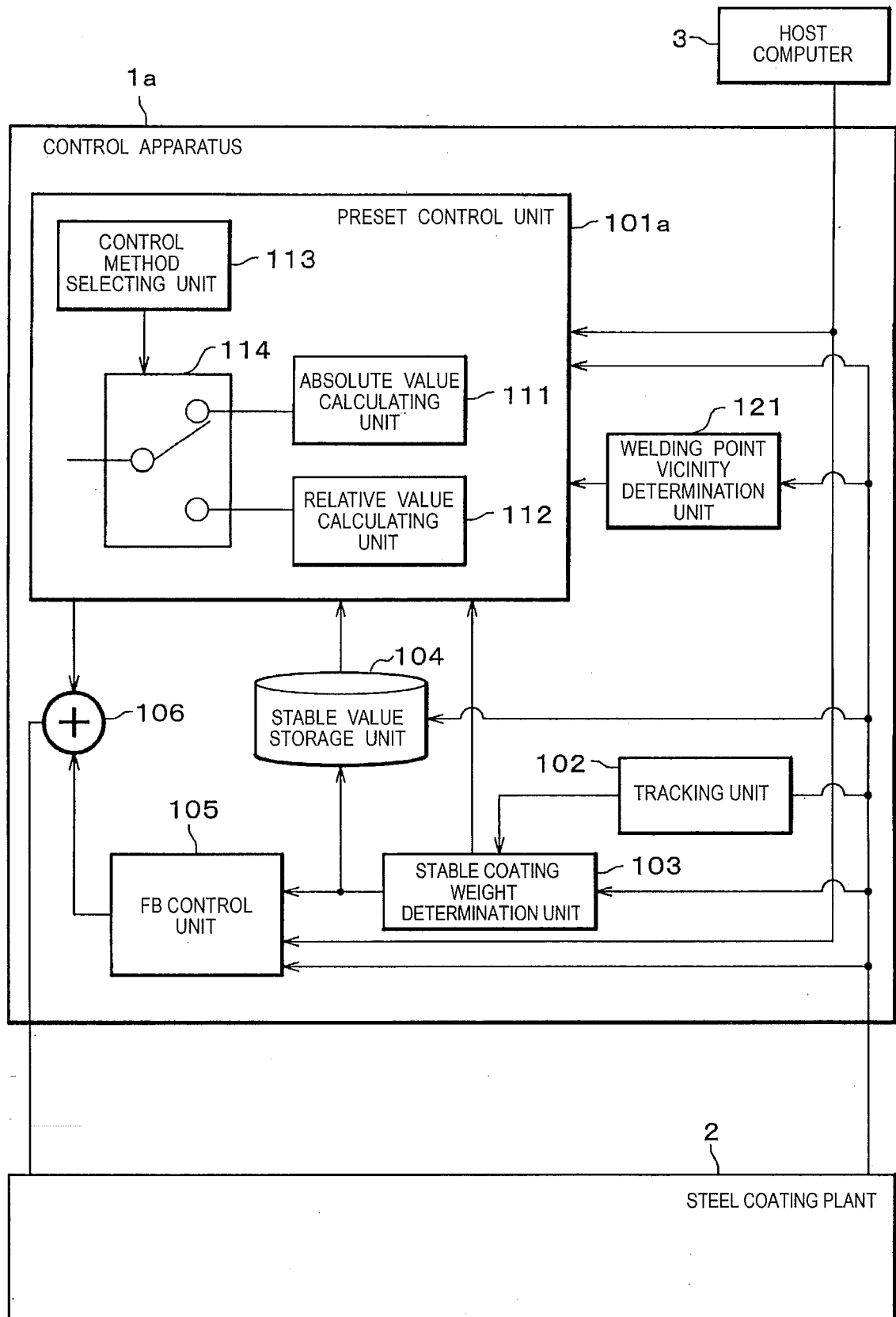


[Fig. 7]

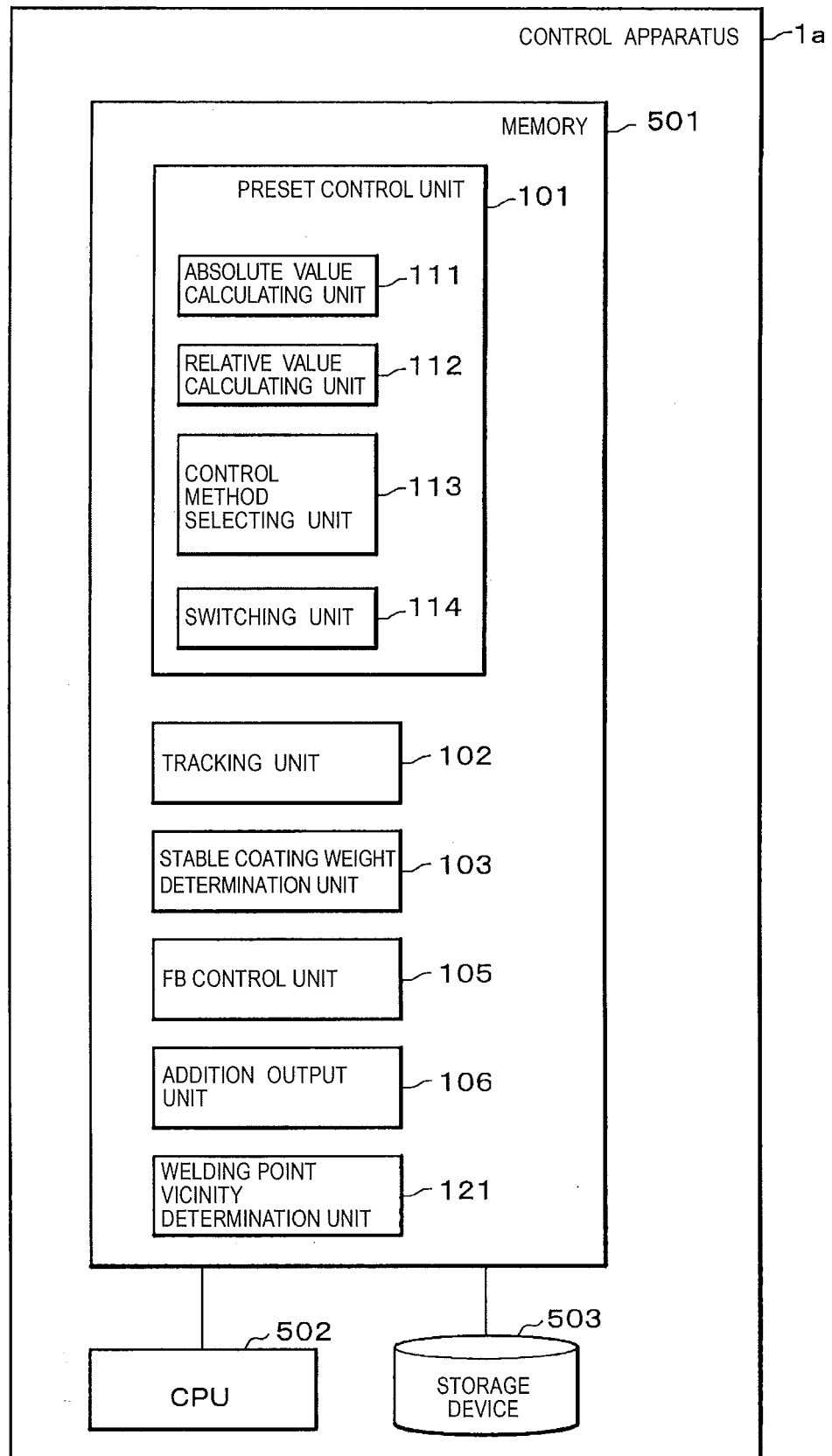




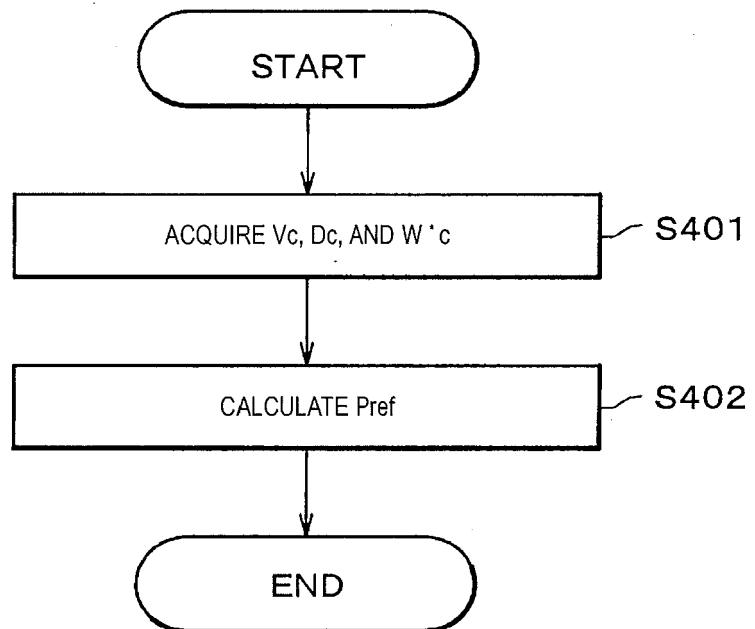
[Fig. 8]



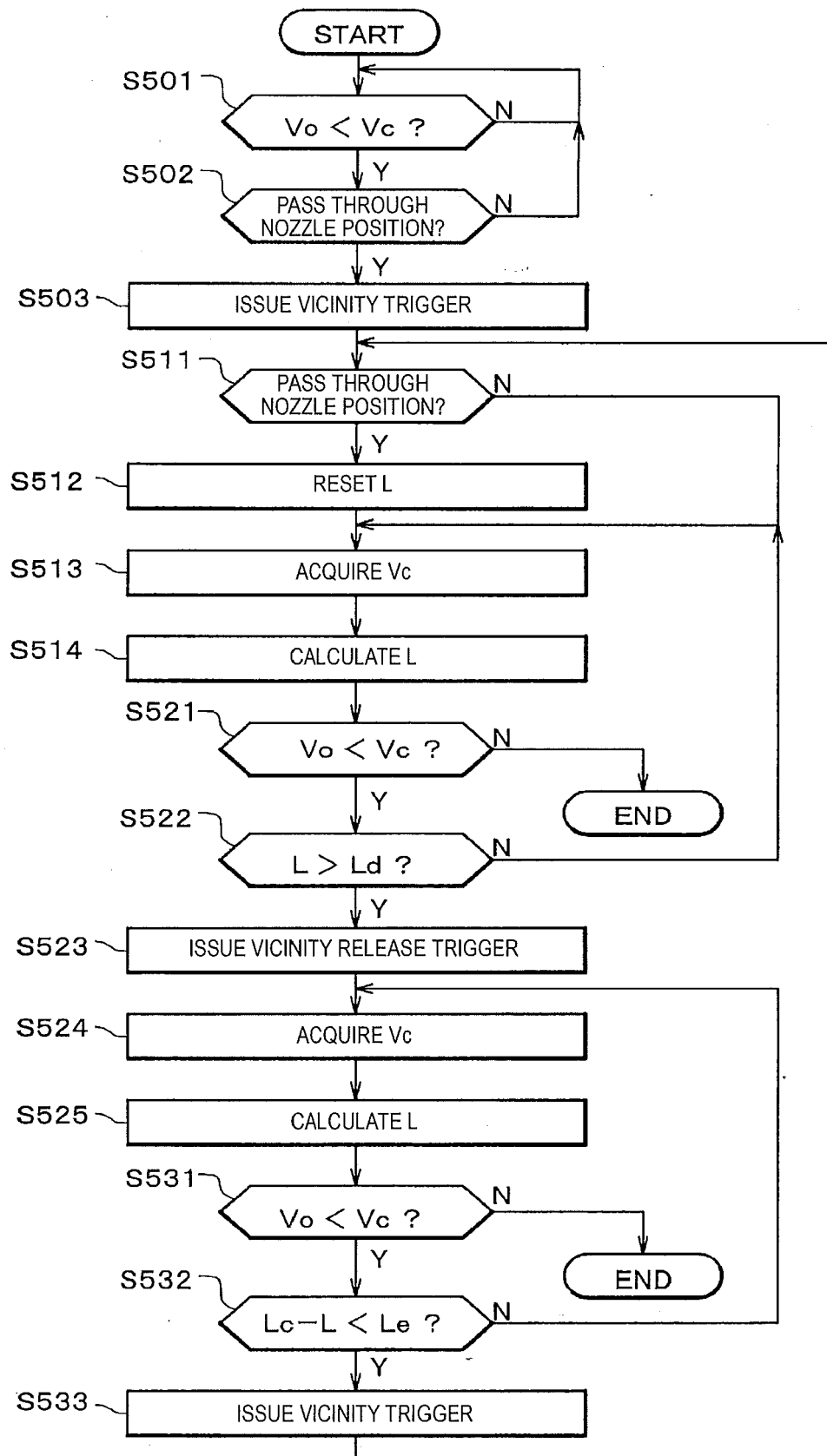
[Fig. 9]



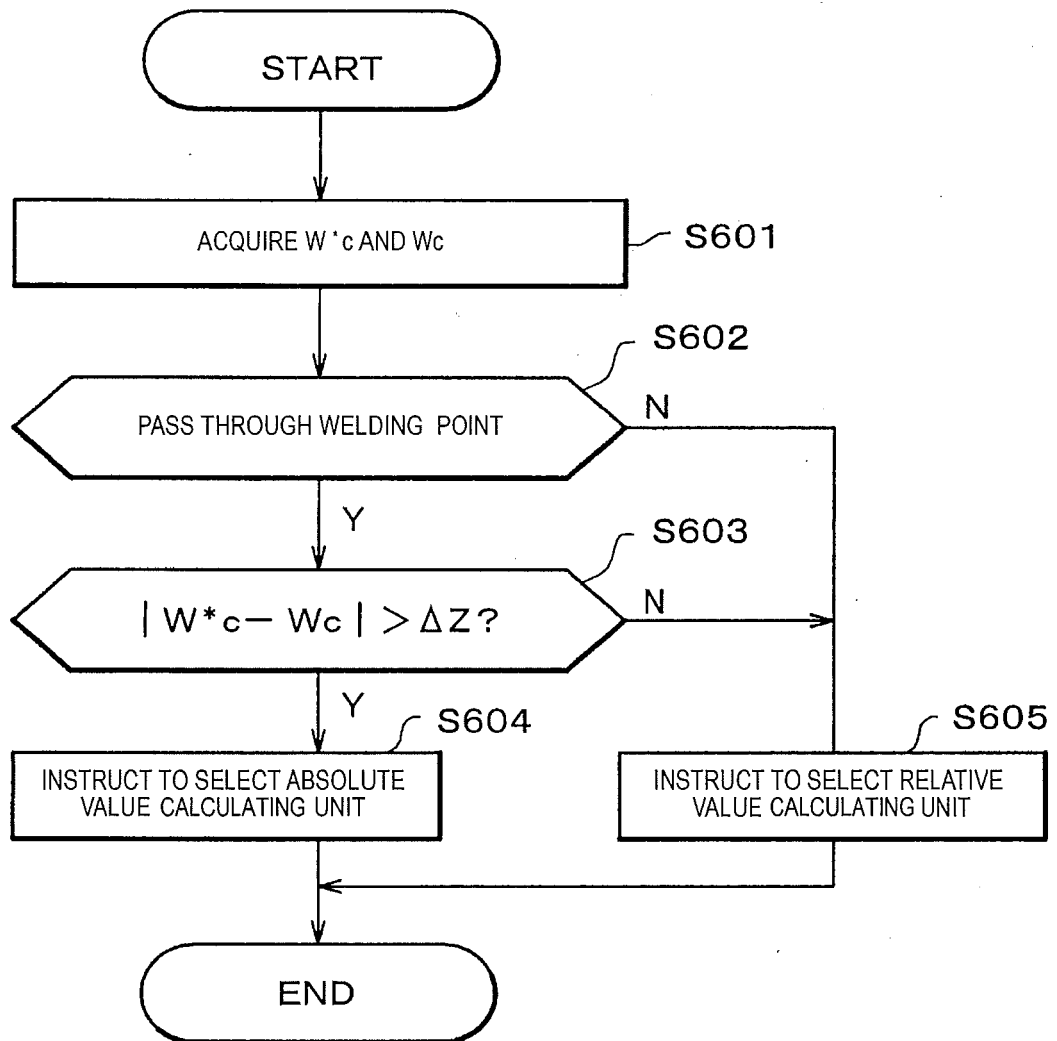
[Fig. 10]



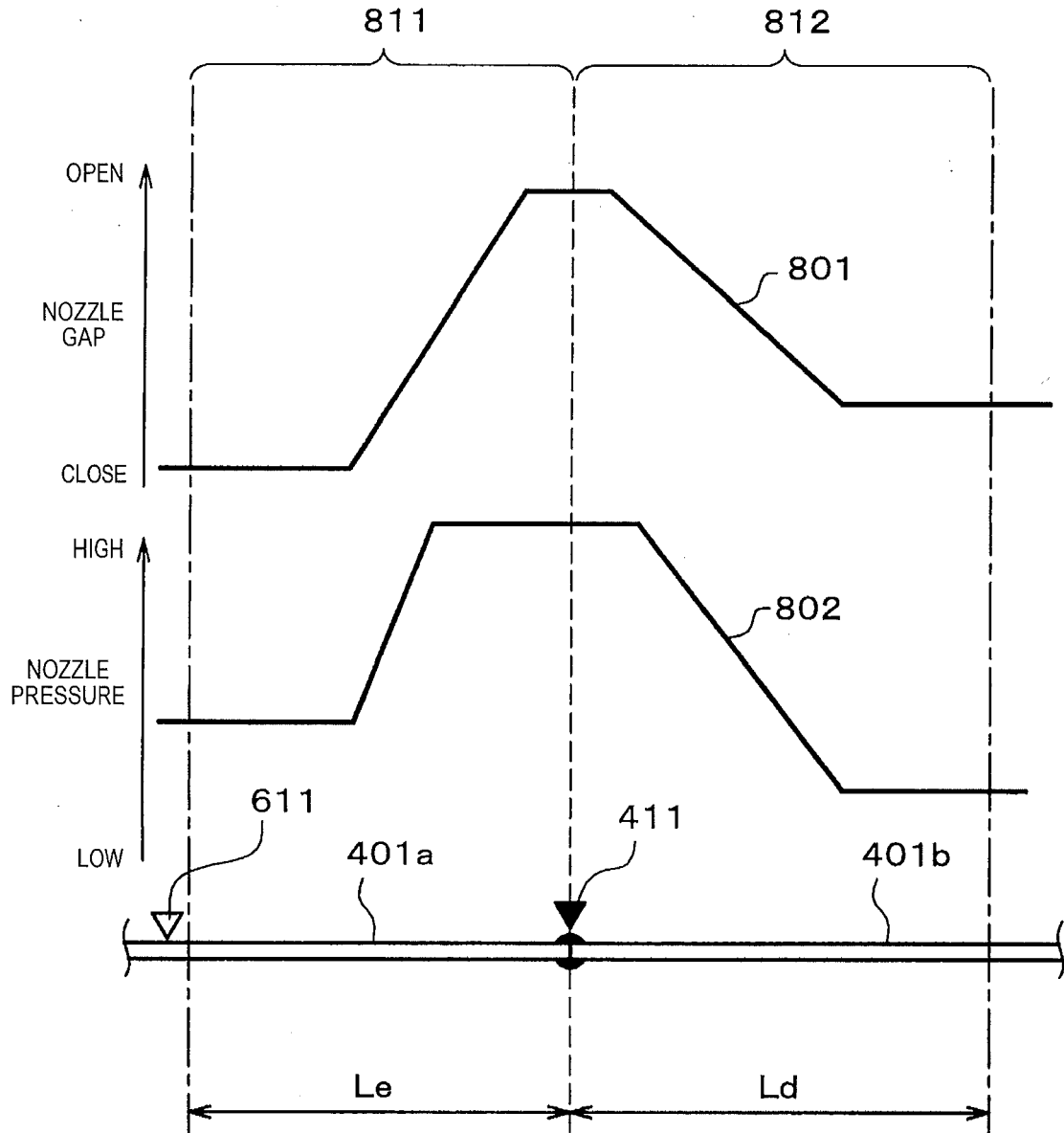
[Fig. 11]



[Fig. 12]



[Fig. 13]





## EUROPEAN SEARCH REPORT

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 EP 16 19 5854

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