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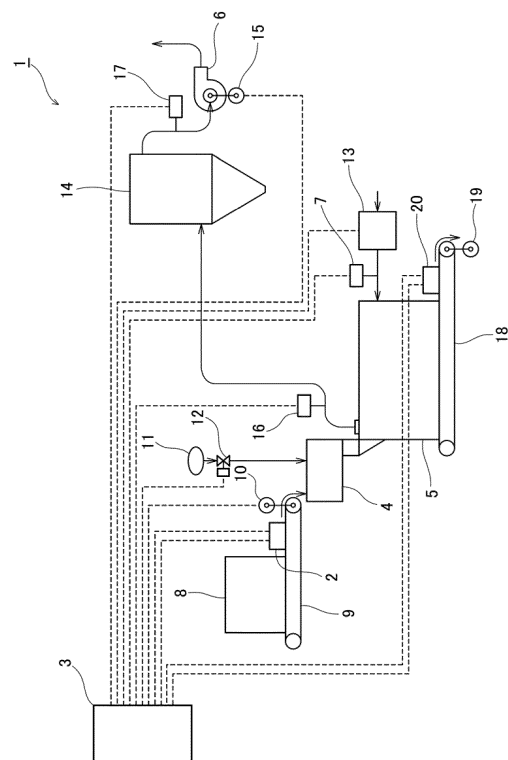
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(54) **RECOVERED-SAND COOLING SYSTEM AND RECOVERED-SAND COOLING METHOD**

(57) [Problem] To provide a return sand cooling system and return sand cooling method capable of reliably cooling return sand.

[Solution] Provided is a return sand cooling system 1 that cools return sand and adjusts the moisture content of cooled return sand, wherein the return sand cooling system 1 comprises: a sand moisture and temperature measuring instrument 2 that measures the moisture content and temperature of the return sand; a control device 3 that determines an appropriate water addition amount, which is an amount of water to be added to the return sand; a water-sprinkling cooling device 4, 5 that adds water of the appropriate water addition amount to the return sand and cools the return sand by the latent heat of vaporization of water to obtain the cooled return sand; an air introducing device 6 that introduces air into the water-sprinkling cooling device 4, 5; and an introduced air temperature and humidity measuring instrument 7 that measures the temperature and humidity of introduced air to be introduced into the water-sprinkling cooling device 4, 5; the control device 3 determining the appropriate water addition amount on the basis of the moisture content and temperature of the return sand, and the temperature and humidity of the introduced air.

[FIG. 1]



Description**TECHNICAL FIELD**

5 **[0001]** The present invention relates to a return sand cooling system and return sand cooling method suitable for green sand molds.

BACKGROUND

10 **[0002]** As seen in prior art, green sand casting, which is a casting method that uses green sand as molds, is widely practiced. In green sand casting, molten metal cast in a mold solidifies and then the casting is shaken out, separating the sand used as the mold from the casting. The separated sand is recovered as return sand, subjected to foreign matter removal as well as sand cooling, kneaded and adjusted, and then reused for molding green sand molds.

15 **[0003]** The sand temperature and moisture of return sand affect the subsequent kneading step and molding step. Sand adherence, which is caused by condensation of moisture on the inner walls of a hopper for storing green sand disposed before a kneading machine, occurs particularly in a state in which green sand is sent to the kneading step or molding step with the sand temperature of the return sand being high. In addition, the binding force between sand will decrease due to the faster drying of sand after kneading, which could cause molding defects such as mold drop-outs and sand inclusion.

20 **[0004]** The cooling of return sand is often performed using the latent heat of vaporization at the time the moisture contained in return sand evaporates into the air. In such cooling of return sand that uses the latent heat of vaporization of moisture, the return sand is sprinkled with water before cooling such that the return sand is cooled to a target temperature and the return sand after cooling has a certain moisture content. The water sprinkling amount is determined on the basis of the measurement values of the amount, temperature, and moisture content of the return sand before cooling. Patent Document 1 discloses determining the water sprinkling amount on the basis of the temperature of the return sand after cooling, in addition to the measurement values indicated above.

CITATION LIST30 **PATENT LITERATURE**

[0005] [Patent Document 1] JP S62-40098 B

SUMMARY OF INVENTION

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TECHNICAL PROBLEM

40 **[0006]** The evaporation amount of water largely depends on the state of the surrounding air. However, there are no disclosures in Patent Document 1 regarding taking into account the state of the air in a cooling device. Thus, in the method disclosed in Patent Document 1, the state of the air could cause variations in the extent to which return sand is cooled as well as the moisture content of the return sand after cooling. Thus, stable cooling and moisture content effects are not easily obtained, and it is difficult to always reliably perform the cooling of return sand.

[0007] The problem to be solved by the present invention is to provide a return sand cooling system and return sand cooling method capable of reliably cooling return sand.

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SOLUTION TO PROBLEM

50 **[0008]** The return sand cooling system according to the present invention cools return sand and adjusts the moisture content of cooled return sand, wherein the return sand cooling system comprises: a sand moisture and temperature measuring instrument that measures the moisture content and temperature of the return sand; a control device that determines an appropriate water addition amount, which is an amount of water to be added to the return sand; a water-sprinkling cooling device that adds water of the appropriate water addition amount to the return sand and cools the return sand by the latent heat of vaporization of water to obtain the cooled return sand; an air introducing device that introduces air into the water-sprinkling cooling device; and an introduced air temperature and humidity measuring instrument that measures the temperature and humidity of introduced air to be introduced into the water-sprinkling cooling device; the control device determining the appropriate water addition amount on the basis of the moisture content and temperature of the return sand, and the temperature and humidity of the introduced air.

55 **[0009]** In addition, the return sand cooling method according to the present invention cools return sand and adjusts

the moisture content of cooled return sand, wherein the return sand cooling method comprises: measuring the moisture content and temperature of the return sand; determining an appropriate water addition amount, which is an amount of water to be added to the return sand; adding water of the appropriate water addition amount to the return sand and cooling the return sand by the latent heat of vaporization of water while introducing air to obtain the cooled return sand; and measuring the temperature and humidity of the introduced air to be introduced; the return sand cooling method determining the appropriate water addition amount on the basis of the moisture content and temperature of the return sand, and the temperature and humidity of the introduced air.

[0010] In addition, the return sand cooling system according to the present invention cools return sand and adjusts the moisture content of cooled return sand, wherein the return sand cooling system comprises: a sand moisture and temperature measuring instrument that measures the moisture content and temperature of the return sand; a control device that determines an appropriate water addition amount, which is an amount of water to be added to the return sand; a water-sprinkling cooling device that adds water of the appropriate water addition amount to the return sand and cools the return sand by the latent heat of vaporization of water to obtain the cooled return sand; an air introducing device that introduces air into the water-sprinkling cooling device; and an introduced air temperature measuring instrument that measures the temperature of introduced air to be introduced into the water-sprinkling cooling device; the control device determining the appropriate water addition amount on the basis of the moisture content and temperature of the return sand, and the temperature of the introduced air.

[0011] In addition, the return sand cooling system according to the present invention cools return sand and adjusts the moisture content of cooled return sand, wherein the return sand cooling system comprises: a sand moisture and temperature measuring instrument that measures the moisture content and temperature of the return sand; a control device that determines an appropriate water addition amount, which is an amount of water to be added to the return sand; a water-sprinkling cooling device that adds water of the appropriate water addition amount to the return sand and cools the return sand by the latent heat of vaporization of water to obtain the cooled return sand; an air introducing device that introduces air into the water-sprinkling cooling device; and a cooled return sand moisture and temperature measuring instrument that measures the moisture content and temperature of the cooled return sand; the control device determining the appropriate water addition amount on the basis of the moisture content and temperature of the return sand, and the moisture content and temperature of the cooled return sand.

[0012] In addition, the return sand cooling method according to the present invention is a return sand cooling method that cools return sand and adjusts the moisture content of cooled return sand, wherein the return sand cooling method comprises: measuring the moisture content and temperature of the return sand; determining an appropriate water addition amount, which is an amount of water to be added to the return sand; adding water of the appropriate water addition amount to the return sand and cooling the return sand by the latent heat of vaporization of water while introducing air to obtain the cooled return sand; and measuring the temperature of the introduced air to be introduced; the return sand cooling method determining the appropriate water addition amount on the basis of the moisture content and temperature of the return sand, and the temperature of the introduced air.

[0013] In addition, the return sand cooling method according to the present invention is a return sand cooling method that cools return sand and adjusts the moisture content of cooled return sand, wherein the return sand cooling method comprises: measuring the moisture content and temperature of the return sand; determining an appropriate water addition amount, which is an amount of water to be added to the return sand; adding water of the appropriate water addition amount to the return sand and cooling the return sand by the latent heat of vaporization of water while introducing air to obtain the cooled return sand; and measuring the moisture content and temperature of the cooled return sand; the return sand cooling method determining the appropriate water addition amount on the basis of the moisture content and temperature of the return sand, and the moisture content and temperature of the cooled return sand.

ADVANTAGEOUS EFFECTS OF INVENTION

[0014] According to the present invention, it is possible to provide a return sand cooling system and return sand cooling method capable of reliably cooling return sand.

BRIEF DESCRIPTION OF DRAWINGS

[0015]

Fig. 1 is a schematic configuration view of a return sand cooling system shown as a first embodiment of the present invention.

Fig. 2 is a block diagram of a control device in the return sand cooling system shown as the first embodiment of the present invention.

Fig. 3 is a flow chart of a return sand cooling method shown as the first embodiment of the present invention.

Fig. 4 is a flow chart of the return sand cooling method shown as the first embodiment of the present invention.

5 Fig. 5 is a flow chart of the return sand cooling method shown as the first embodiment of the present invention.

Fig. 6 is a flow chart of the return sand cooling method shown as the first embodiment of the present invention.

10 Fig. 7 is a schematic configuration view of a return sand cooling system shown as a modified example of the first embodiment of the present invention.

Fig. 8 is a block diagram of a control device in the return sand cooling system shown as the modified example.

15 Fig. 9 is a flow chart of the return sand cooling method shown as the modified example.

Fig. 10 is a flow chart of the return sand cooling method shown as the modified example.

20 Fig. 11 is a schematic configuration view of a return sand cooling system shown as a second embodiment of the present invention.

Fig. 12 is a block diagram of a control device in the return sand cooling system shown as the second embodiment of the present invention.

25 Fig. 13 is a schematic configuration view of a return sand cooling system shown as a third embodiment of the present invention.

Fig. 14 is a block diagram of a control device in the return sand cooling system shown as the third embodiment of the present invention.

30 DESCRIPTION OF EMBODIMENTS

[0016] Embodiments of the present invention are described in detail below with reference to the drawings.

(First embodiment)

35 **[0017]** Fig. 1 is a schematic configuration view of a return sand cooling system 1 shown as an embodiment of the present invention. Return sand refers to sand, used as a mold in green sand casting, which is separated from a casting after molten metal cast in the mold has solidified. Return sand is subjected to foreign matter removal as well as sand cooling, kneaded and adjusted, and then reused for molding green sand molds. The return sand cooling system 1 is a system that cools green sand mold-return sand particularly in green sand casting and adjusts the moisture of cooled return sand.

40 **[0018]** The return sand cooling system 1 comprises: a sand moisture and temperature measuring instrument 2 that measures the moisture content and temperature of return sand; a control device 3 that determines an appropriate water addition amount, which is an amount of water to be added to the return sand; a water-sprinkling cooling device 4, 5 that adds water of the appropriate water addition amount to the return sand and cools the return sand by the latent heat of vaporization of water to obtain cooled return sand; an air introducing device 6 that introduces air into a sand cooling device; and an introduced air temperature and humidity measuring instrument 7 that measures the temperature and humidity of introduced air to be introduced into the sand cooling device.

45 **[0019]** The return sand cooling system 1 will be described in detail below. The return sand cooling system 1 comprises a hopper 8 and a belt feeder 9. Return sand separated from a casting is stored in the hopper 8. The belt feeder 9 is provided below the hopper 8. The return sand stored in the hopper 8 is supplied to the belt feeder 9 from a return sand supply port (not shown) provided in the hopper 8.

50 **[0020]** The belt feeder 9 comprises an inverter motor 10 and is driven by the inverter motor 10. The control device 3, which will be described later in more detail, is electrically connected to the inverter motor 10, and is configured such that the rotation speed of the inverter motor 10 changes according to a signal from the control device 3. Consequently, the return sand supplied to the belt feeder 9 is conveyed to the water-sprinkling cooling device 4, 5.

55 **[0021]** The sand moisture and temperature measuring instrument 2 is provided on the belt feeder 9. The moisture content and temperature of the return sand conveyed on the belt feeder 9 is measured by the sand moisture and

temperature measuring instrument 2. The control device 3, which will be described later in more detail, is electrically connected to the sand moisture and temperature measuring instrument 2. The moisture content and temperature of the return sand measured by the sand moisture and temperature measuring instrument 2 is transmitted to the control device 3.

[0022] The water-sprinkling cooling device 4, 5 comprises a water sprinkling device 4 and a sand cooling device 5.

The return sand cooling system 1 comprises a water source 11 and a water amount regulation valve 12. The water source 11 is connected to the water sprinkling device 4 and supplies water to the water sprinkling device 4. The water sprinkling device 4 sprinkles water supplied from the water source 11 onto the return sand fed from the belt feeder 9 and then agitates the return sand to disperse moisture throughout the return sand. This return sand, which has been sprinkled with water and has had moisture dispersed therethroughout, is hereinafter referred to as water-added return sand.

[0023] The water amount regulation valve 12 is interposed between the water source 11 and the water sprinkling device 4. The control device 3, which will be described later in more detail, is electrically connected to the water amount regulation valve 12. The water amount regulation valve 12 is controlled by the control device 3 such that the amount of water supplied from the water source 11 to the water sprinkling device 4 is equal to the value of the appropriate water addition amount, which is an appropriate amount of water calculated by the control device 3 to be added to the return sand. Consequently, the water sprinkling device 4 adds water of the appropriate water addition amount to the return sand to thus obtain water-added return sand.

[0024] The water-added return sand that has been agitated by the water sprinkling device 4 with moisture dispersed therethroughout is discharged from the water sprinkling device 4 and loaded into the sand cooling device 5. The sand cooling device 5 cools the water-added return sand by bringing the water-added return sand into contact with air inside the sand cooling device 5. Return sand that has been cooled is hereinafter referred to as cooled return sand.

[0025] The return sand cooling system 1 comprises an air heating device 13 and a dust collecting device 14. A single air passage is formed by the air heating device 13, the sand cooling device 5, the dust collecting device 14, and the air introducing device 6 such that air flows in this order. The air introducing device 6 provided at the terminal of the air passage is a suction-type device that creates a flow of air in the air passage by sucking air from the direction of the upstream air heating device 13 to introduce air into the sand cooling device 5.

[0026] The air heating device 13 is provided at the most upstream portion of the air passage. The air heating device 13 heats air, taken in from outside or the indoor atmosphere by suction of the air introducing device 6, as needed and air is introduced into the sand cooling device 5 as introduced air. The control device 3, which will be described later in more detail, is electrically connected to the air heating device 13. The air heating device 13 is controlled by the control device 3 and heats the introduced air such that the temperature of the introduced air to be introduced to the sand cooling device 5 is equal to an appropriate air temperature calculated by the control device 3.

[0027] In the sand cooling device 5, discharged air that has increased temperature and humidity due to the evaporation of water from the water-added return sand and heat transfer from sand is introduced into the dust collecting device 14. The dust collecting device 14 removes dust particles in the air passage including the sand cooling device 5 that is introduced into the dust collecting device 14. Air with dust particles removed therefrom is discharged outside via the air introducing device 6.

[0028] The air introducing device 6 comprises an inverter motor 15 and is driven by the inverter motor 15. The control device 3, which will be described later in more detail, is electrically connected to the inverter motor 15. The inverter motor 15 is controlled by the control device 3 such that the air suction amount of the air introducing device 6 is an appropriate airflow amount calculated by the control device 3.

[0029] To measure the state of the air in the air passage described above, the return sand cooling system 1 comprises the introduced air temperature and humidity measuring instrument 7, a discharged air temperature and humidity measuring instrument 16, and an airflow amount measuring instrument 17. The introduced air temperature and humidity measuring instrument 7 is provided between the air heating device 13 and the sand cooling device 5 and measures the temperature and humidity of introduced air to be introduced into the sand cooling device 5. The control device 3, which will be described later in more detail, is electrically connected to the introduced air temperature and humidity measuring instrument 7. The temperature and humidity of introduced air measured by the introduced air temperature and humidity measuring instrument 7 are transmitted to the control device 3.

[0030] The discharged air temperature and humidity measuring instrument 16 is provided between the sand cooling device 5 and the dust collecting device 14 and measures the temperature and humidity of discharged air discharged from the sand cooling device 5. The control device 3, which will be described later in more detail, is electrically connected to the discharged air temperature and humidity measuring instrument 16. The temperature and humidity of discharged air measured by the discharged air temperature and humidity measuring instrument 16 are transmitted to the control device 3.

[0031] The airflow amount measuring instrument 17 is provided between the dust collecting device 14 and the air introducing device 6, and measures the amount of air sucked in by the air introducing device 6. In other words, the airflow amount measuring instrument 17 measures the airflow amount of introduced air to be introduced into the sand

cooling device 5. The control device 3, which will be described later in more detail, is electrically connected to the airflow amount measuring instrument 17. The airflow amount of introduced air measured by the airflow amount measuring instrument 17 is transmitted to the control device 3.

[0032] The return sand cooling system 1 comprises a belt conveyor 18 below the cooled return sand discharge port (not shown) of the sand cooling device 5. The belt conveyor 18 comprises a motor 19 and is driven by the motor 19. The belt conveyor 18 conveys the cooled return sand discharged from the sand cooling device 5 to the next step, such as a kneading device (not shown).

[0033] The return sand cooling system 1 comprises a cooled return sand moisture and temperature measuring instrument 20. The cooled return sand moisture and temperature measuring instrument 20 measures the moisture content and temperature of cooled return sand conveyed on the belt conveyor 18. The control device 3, which will be described later in more detail, is electrically connected to the cooled return sand moisture and temperature measuring instrument 20. The moisture content and temperature of cooled return sand measured by the cooled return sand moisture and temperature measuring instrument 20 are transmitted to the control device 3.

[0034] As described above, the moisture content and temperature of the return sand measured by the sand moisture and temperature measuring instrument 2; the moisture content and temperature of the cooled return sand measured by the cooled return sand moisture and temperature measuring instrument 20; the temperature and humidity of the introduced air measured by the introduced air temperature and humidity measuring instrument 7; the temperature and humidity of the discharged air measured by the discharged air temperature and humidity measuring instrument 16; and the airflow amount of the introduced air measured by the airflow amount measuring instrument 17 are transmitted to the control device 3. The control device 3 receives these measurement values, performs computations that will be described later in more detail using fig. 3-6, and controls the inverter motor 10 of the belt feeder 9, the water amount regulation valve 12, the inverter motor 15 of the air introducing device 6, and the air heating device 13 on the basis of the computation results.

[0035] The control device 3 controls the operation of the return sand cooling system 1 by performing three kinds of processes, as in: an appropriate water addition amount determination and water sprinkling instruction; an action correction dependent on the moisture content and temperature of cooled return sand; and an action correction dependent on the temperature and humidity of discharged air. First, a configuration of the control device 3 needed to execute the appropriate water addition amount determination and water sprinkling instruction will be described.

(Configuration of control device 3 pertaining to appropriate water addition amount determination and water sprinkling instruction)

[0036] The control device 3 determines an appropriate water addition amount. In order to do so, the control device 3 comprises a required amount of water evaporation calculating unit 31, an allowable amount of water vapor evaporation calculating unit 32, an appropriate water addition amount determining unit 33, a comparison computation unit 34, and a control unit 35, as shown in fig. 2.

[0037] The required amount of water evaporation calculating unit 31 calculates a required amount of water evaporation on the basis of the temperature of the return sand and the loaded amount of the return sand. As described above, the water-added return sand is mainly cooled by the latent heat of vaporization due to the evaporation of water in the sand cooling device 5. The required amount of water evaporation is an amount of water evaporation per unit time required for cooling the water-added return sand to a target temperature by the latent heat of vaporization. If the temperature of the return sand measured by the sand moisture and temperature measuring instrument 2 is T_{s1} (K); the cooling target temperature of the water-added return sand is T_{s2} (K); the loaded amount of the return sand, that is, the amount of return sand per unit time loaded into the sand cooling device 5, is G_s (kg/min); the specific heat of the return sand is C_s (kJ/kg·K); and the latent heat of vaporization of water is L_w (kJ/kg), a required amount of water evaporation Q_v (kg/min) per unit time is represented by the following equation.

(Equation 1)

$$\text{Equation (1): } Q_v = G_s \cdot C_s \cdot (T_{s1} - T_{s2})/L_w$$

[0038] The required amount of water evaporation calculating unit 31 calculates the required amount of water evaporation Q_v per unit time using equation (1) indicated above.

[0039] Regarding the return sand amount G_s per unit time loaded into the sand cooling device 5, because in the present embodiment the amount of return sand supplied from the hopper 8 to the belt feeder 9 is constant per unit time and the control device 3 is connected to the inverter motor 10 of the belt feeder 9, allowing the driving speed of the inverter motor 10 to be recognized and controlled, the driving speed of the inverter motor 10 is converted and used as

the return sand amount G_s .

[0040] In addition, in the present embodiment, the water-added return sand is cooled by the latent heat of vaporization due to the evaporation of moisture in the water-added return sand as well as heat transfer from sand to air, but the cooling effect by the latent heat of vaporization is significantly dominant and the processes of the control device 3 are determined accordingly.

[0041] The allowable amount of water vapor evaporation calculating unit 32 calculates an allowable amount of water vapor evaporation on the basis of the temperature and humidity of the introduced air, as well as the airflow amount. As described above, because the water-added return sand is mainly cooled by the latent heat of vaporization due to the evaporation of water in the sand cooling device 5, the introduced air to be introduced into the sand cooling device 5 is discharged from the sand cooling device 5 as discharged air after receiving evaporated water vapor.

[0042] To cool the water-added return sand to the target temperature T_{s2} , the evaporation of moisture of an amount corresponding to the required amount of water evaporation Q_v per unit time shown as equation (1) is required. Thus, to effectively perform cooling in the sand cooling device 5, the control device 3 determines, by means of the comparison computation unit 34 to be described later in more detail, whether the introduced air is capable of receiving water vapor corresponding to the required amount of water evaporation Q_v per unit time. To make this determination, the allowable amount of water vapor evaporation calculating unit 32 calculates the water vapor amount per unit time that can be evaporated by the sand cooling device 5 by means of the current introduced air. In other words, the allowable amount of water vapor evaporation calculating unit 32 calculates an allowable amount of water vapor evaporation W_a (kg/min) per unit time, which is the water vapor amount that the introduced air to be introduced per unit time can hold in addition to the humidity that the introduced air already has.

[0043] As a stage before the allowable amount of water vapor evaporation W_a per unit time is calculated, a total amount W_{max} (kg/min) of the water vapor amount per unit time that the current introduced air can hold is considered. The humidity, or in other words the water vapor amount, that the introduced air can hold is 100% in terms of relative humidity, but the absolute humidity corresponding thereto differs depending on the air temperature. Thus, if the temperature of introduced air measured by the introduced air temperature and humidity measuring instrument 7 is T_{a1} (K); the absolute humidity corresponding to 100% relative humidity at the temperature T_{a1} is X_{max} (kg/kg-air); and the airflow amount, that is, the amount of introduced air measured by the airflow amount measuring instrument 17 is G_a (kg-air/min), the total amount W_{max} of the water vapor amount per unit time that the current introduced air can hold is represented by the following equation.

(Equation 2)

$$\text{Equation (2): } W_{max} = G_a \cdot X_{max}$$

[0044] The expression "kg-air" in the system of units of X_{max} and G_a above refers to the amount of air, and is for distinguishing from the unit "kg" used to represent the amount of water.

[0045] The corresponding relationship between the temperature T_{a1} and the absolute humidity X_{max} of the introduced air may for example be retained internally in the control device 3 in a form such as a table or function, and may be appropriately referred to at the time of calculation of the total amount W_{max} of the water vapor amount that the introduced air can hold.

[0046] Because the total W_{max} of the water vapor amount per unit time that the introduced air can hold is represented in the manner shown in equation (2) above, if the absolute humidity of the introduced air measured by the introduced air temperature and humidity measuring instrument 7 is X_1 (kg/kg-air), the allowable amount of water vapor evaporation W_a (kg/min) per unit time can be calculated by the following equation.

(Equation 3)

$$\text{Equation (3): } W_a = G_a \cdot (X_{max} - X_1)$$

[0047] The comparison computation unit 34 performs a comparison of the required amount of water evaporation Q_v (kg/min) per unit time represented by equation (1) and the allowable amount of water vapor evaporation W_a (kg/min) per unit time represented by equation (3). This allows a determination to be made as to whether cooling in the sand cooling device 5 can reliably be performed, that is, whether the introduced air to be introduced per unit time can receive water vapor of an amount that is equivalent to the required amount of water evaporation Q_v per unit time.

[0048] The comparison computation unit 34 determines one or more control operations for controlling the airflow amount, the loaded amount of the return sand, or the temperature of the introduced air, or any combination thereof, on the basis of the comparison result. More specifically, a comparison of the required amount of water evaporation Q_v per

unit time and the allowable amount of water vapor evaporation W_a per unit time should result in one of the following states: when $Q_v > W_a$ (state 1); when $Q_v = W_a$ (state 2); and when $Q_v < W_a$ (state 3). Depending on which relationship of states 1-3 that Q_v and W_a are in, the comparison computation unit 34 controls the inverter motor 15 of the air introducing device 6, the inverter motor 10 of the belt feeder 9, or the air heating device 13, or any combination thereof, and determines one or more control operations for controlling the airflow amount, the loaded amount of the return sand, or the temperature of the introduced air, or any combination thereof. The one or more control operations determined for each of the states 1-3 will be described in detail below.

[0049] First, the case of state 2 will be described. In state 2, $Q_v = W_a$, which is a state in which the water vapor amount to be evaporated per unit time is equal to the water vapor amount that the introduced air to be introduced per unit time can hold in addition to the humidity that the introduced air already has. State 2 is the most ideal state. Thus, the comparison computation unit 34 does not determine any particular control operations, and transmits to the control unit 35 an instruction to maintain the current state.

[0050] Next, the case of state 1 will be described. In state 1, $Q_v > W_a$, which is a state in which the water vapor amount to be evaporated per unit time is greater than the water vapor amount that the introduced air to be introduced per unit time can hold in addition to the humidity that the introduced air already has. This is a state in which the introduced air is unable to receive all of the water vapor amount to be evaporated and the cooling of the water-added return sand by the sand cooling device 5 is not sufficiently performed. Thus, the state of state 2 described above needs to be achieved by reducing the water vapor amount to be evaporated per unit time, or increasing the water vapor amount that the introduced air to be introduced per unit time can hold in addition to the humidity that the introduced air already has. In other words, if the required amount of water evaporation is greater than the allowable amount of water vapor evaporation, one or more control operations, which are operations for increasing the airflow, reducing the loaded amount of the return sand, or increasing the temperature of the introduced air, or any combination thereof, are determined.

[0051] More specifically, first, the comparison computation unit 34 considers increasing the water vapor amount that the introduced air to be introduced per unit time can hold by increasing the rotation speed of the inverter motor 15 of the air introducing device 6 to increase the airflow amount, which increases the amount of introduced air to be introduced per unit time. To achieve the state of state 2, the relationship of $Q_v = W_a$ needs to be achieved. Thus, the comparison computation unit 34 calculates an appropriate value of the airflow amount by creating an equality such that equation (1) and equation (3) are equal, substituting the measurement values therein, and then solving an equation that derives the airflow amount, that is, a value of the amount of introduced air G_a introduced per unit time. Thereafter, the comparison computation unit 34 transmits to the control unit 35 a control operation for adjusting the inverter motor 15 of the air introducing device 6 such that the airflow amount is equal to the calculated value.

[0052] If the value of the airflow amount calculated by the comparison computation unit 34 exceeds the capacity limit of the inverter motor 15 of the air introducing device 6, or when the value is increased to a value equivalent to the capacity limit of the inverter motor 15 of the air introducing device 6 but is still insufficient for achieving the relationship of $Q_v = W_a$, the comparison computation unit 34 further considers reducing the water vapor amount to be evaporated per unit time by reducing the rotation speed of the inverter motor 10 of the belt feeder 9 to reduce the loaded amount of the return sand. For this reason, as in the case of the airflow amount described above, the loaded amount of the return sand, that is, an appropriate value of the return sand amount G_s per unit time, is calculated by solving the equation according to equation (1) and equation (3). Thereafter, the comparison computation unit 34 sends to the control unit 35 a control operation for adjusting the inverter motor 10 of the belt feeder 9 such that the loaded amount of the return sand is equal to the calculated value, in addition to the control operation regarding the inverter motor 15 of the air introducing device 6.

[0053] However, if the loaded amount of the return sand is excessively reduced, the sand amount would be less than the sand amount required at the subsequent molding step, and it would not be possible to secure the minimum sand amount to be supplied to the molding machine to be able to maintain a determined molding speed. Thus, if a calculated value is calculated that is below a lower limit G_{sL} , which was set beforehand for the return sand amount G_s per unit time, the lower limit G_{sL} is used as a setting value. The setting of the lower limit G_{sL} is set by, for example, an operator inputting a lower limit G_{sL} into the control device 3 beforehand.

[0054] If the comparison computation unit 34 determines that the above is still insufficient for achieving the relationship of $Q_v = W_a$, the comparison computation unit 34 further considers increasing the water vapor amount that the introduced air to be introduced per unit time can hold by increasing the set temperature in the air heating device 13 to increase the temperature of the introduced air. This is performed by solving the equation according to equation (1) and equation (3), as in the case described above, to calculate an appropriate value of the absolute humidity X_1 of the introduced air, which is a value that is dependent on the temperature T_{a1} of the introduced air. Thereafter, the comparison computation unit 34 transmits to the control unit 35 a control operation for controlling the air heating device 13 to increase the temperature of the introduced air to the calculated value, in addition to the control operation pertaining to the inverter motor 15 of the air introducing device 6 and the control operation pertaining to the inverter motor 10 of the belt feeder 9.

[0055] However, when increasing the set temperature of the air heating device 13, if the introduced air is excessively

heated, the temperature of the sand cooling device 5 will increase, meaning the sand cooling device 5 will not be able to efficiently cool the water-added return sand. Thus, the upper limit of the temperature of the introduced air is preferably set so as to be, for example, around 45°C.

[0056] Finally, the case of state 3 will be described. In state 3, $Q_v < W_a$, which is a state in which the water vapor amount to be evaporated per unit time is less than the water vapor amount that the introduced air to be introduced per unit time can hold in addition to the humidity that the introduced air already has. That is, state 3 is a state in which the introduced air to be introduced per unit time can sufficiently absorb water vapor. Essentially, the return sand is sufficiently cooled even if this state is maintained. However, state 3 is in other words a state in which an excessively large amount of introduced air in proportion to the return sand is being introduced. Thus, it is possible to reduce lighting and heating expenses and increase the amount that is cooling-treated per unit time by achieving the state of state 2 by for example reducing the airflow amount and increasing the loaded amount of the return sand. In other words, if the required amount of water evaporation is less than the allowable amount of water vapor evaporation, one or more control operations, which are operations for either or both reducing the airflow amount and increasing the loaded amount of the return sand, are determined.

[0057] More specifically, first, the comparison computation unit 34 considers reducing the water vapor amount that the introduced air to be introduced per unit time can hold by reducing the rotation speed of the inverter motor 15 of the air introducing device 6 to reduce the airflow amount, which reduces the introduced air amount to be introduced per unit time. An appropriate value of the airflow amount is calculated in a similar manner as in state 1. Thereafter, the comparison computation unit 34 transmits to the control unit 35 the control operation for adjusting the inverter motor 15 of the air introducing device 6 such that the airflow amount is equal to the calculated value.

[0058] However, the airflow amount must not be lower than a value that still allows the dust particles in the sand cooling device 5 to be collected in order to prevent being unable to collect the dust particles generated in the sand cooling device 5 as a result of excessive reduction of the airflow amount.

[0059] If the value of the airflow amount calculated by the comparison computation unit 34 is insufficient for achieving the relationship of $Q_v = W_a$, the comparison computation unit 34 further considers increasing the water vapor amount to be evaporated per unit time by increasing the rotation speed of the inverter motor 10 of the belt feeder 9 to increase the loaded amount of the return sand. For this reason, as in the case of state 1 described above, the loaded amount of the return sand, that is, an appropriate value of the return sand amount G_s per unit time, is calculated. Thereafter, the comparison computation unit 34 transmits to the control unit 35 the control operation for adjusting the inverter motor 10 of the belt feeder 9 such that the loaded amount of the return sand is equal to the calculated value, in addition to the control operation pertaining to the inverter motor 15 of the air introducing device 6.

[0060] The control unit 35 executes the control operations transmitted from the comparison computation unit 34. More specifically, the control unit 35 controls the inverter motor 10 of the belt feeder 9, the inverter motor 15 of the air introducing device 6, and the air heating device 13. The control unit 35 also receives a control operation transmitted by the appropriate water addition amount determining unit 33, which will be described later in more detail, and controls the water amount regulation valve 12.

[0061] The appropriate water addition amount determining unit 33 determines an appropriate water addition amount per unit time on the basis of the required amount of water evaporation per unit time calculated by the required amount of water evaporation calculating unit 31. Because the cooled return sand, which is return sand after being cooled, is reused as a sand mold, the cooled return sand preferably has a certain moisture content at the stage before being kneaded and adjusted. In other words, the water-added return sand is cooled by the latent heat of vaporization in the sand cooling device 5 and the evaporated moisture is lost, but the cooled return sand thereafter preferably still has the certain moisture content. The appropriate water addition amount is the water sprinkling amount per unit time in the water sprinkling device 4 required for the cooled return sand to have this certain moisture content. If the moisture content of return sand measured by the sand moisture and temperature measuring instrument 2 is W_{s1} (%) and the target moisture content of cooled return sand is W_{s2} (%), the appropriate water addition amount Q_w (kg/min) per unit time is represented by the following equation.

(Equation 4)

$$\text{Equation (4): } Q_w = \{G_s \cdot (W_{s2} - W_{s1})\} + Q_v$$

[0062] The appropriate water addition amount determining unit 33 determines the appropriate water addition amount Q_w per unit time using equation (4).

[0063] The determination of the appropriate water addition amount Q_w per unit time by the appropriate water addition amount determining unit 33 is performed after the required amount of water evaporation Q_v per unit time is calculated twice, as described later in more detail using fig. 3. Strictly speaking, after the required amount of water evaporation Q_v

per unit time is calculated for the first time, control operations such as those described above are transmitted to the inverter motor 10 of the belt feeder 9, the inverter motor 15 of the air introducing device 6, and the air heating device 13, and the control unit 35 controls these devices. The appropriate water addition amount Q_w per unit time is determined on the basis of the measurement values that were measured again after the control operations. In other words, in a state in which conditions have been appropriately changed by means of a control operation, the measurement values are measured again by the measuring instruments, the required amount of water evaporation Q_v per unit time is calculated again from the measurement values that were measured again, and the appropriate water addition amount Q_w per unit time is determined on the basis of the required amount of water evaporation Q_v per unit time that was calculated again and the measurement values that were measured again. This allows the appropriate water addition amount Q_w per unit time to be determined as an appropriate value.

[0064] As described above, the control device 3 determines an appropriate water addition amount on the basis of the moisture and temperature of the return sand, the temperature and humidity of the introduced air, and the airflow amount.

(Appropriate water addition amount determination and water sprinkling instruction method)

[0065] Next, an appropriate water addition amount determination and water sprinkling instruction method in a return sand cooling method that uses the return sand cooling system 1 described above will be described using fig. 1-4. The present method cools return sand and adjusts the moisture of cooled return sand. Note that fig. 2 shows a first correction amount calculating unit 36 and a second correction amount calculating unit 37 of the control device 3. These units, as well as the process methods that use these units, will be described later in more detail.

[0066] The present method comprises: measuring the moisture content and temperature of return sand; determining an appropriate water addition amount, which is an amount of water to be added to the return sand; adding water of the appropriate water addition amount to the return sand and cooling the return sand by the latent heat of vaporization of water while introducing air to obtain cooled return sand; and measuring the temperature and humidity of introduced air to be introduced; wherein the method determines the appropriate water addition amount on the basis of the moisture content and temperature of the return sand, and the temperature and humidity of the introduced air. In addition, the present method comprises measuring the airflow amount of the introduced air; wherein the method determines the appropriate water addition amount further on the basis of the airflow amount.

[0067] More specifically, first, return sand separated from a casting is loaded into the hopper 8. The hopper 8 supplies the return sand to the belt feeder 9. The belt feeder 9 conveys the return sand to the water sprinkling device 4. The sand moisture and temperature measuring instrument 2 measures the moisture content and temperature of the return sand conveyed on the belt feeder 9, and transmits the measurement results to the control device 3. The driving speed of the inverter motor 10 of the belt feeder 9 is controlled by the control device 3 (step S1).

[0068] The required amount of water evaporation calculating unit 31 of the control device 3 calculates the required amount of water evaporation Q_v per unit time using equation (1) on the basis of the temperature (T_{s1}) of the return sand received from the sand moisture and temperature measuring instrument 2 and the loaded amount of the return sand, that is, the return sand amount (G_s) per unit time, which is obtained by converting the driving speed of the inverter motor 10 managed by the control device 3 (step S2).

[0069] Next, the air introducing device 6 is driven by the inverter motor 15 and air flows through the air passage formed by the air heating device 13, the sand cooling device 5, the dust collecting device 14, and the air introducing device 6. This introduces introduced air into the sand cooling device 5. The introduced air temperature and humidity measuring instrument 7 measures the temperature and humidity of the introduced air, and transmits the measurement results to the control device 3. In addition, the airflow amount measuring instrument 17 measures the airflow amount of the introduced air to be introduced into the sand cooling device 5, and transmits the measurement result to the control device 3 (step S3).

[0070] The allowable amount of water vapor evaporation calculating unit 32 of the control device 3 calculates the allowable amount of water vapor evaporation W_a per unit time using equation (2) and equation (3) on the basis of the temperature (T_{a1}) and absolute humidity (X_1) of the introduced air received from the introduced air temperature and humidity measuring instrument 7, and the airflow amount (G_a) received from the airflow amount measuring instrument 17 (step S4).

[0071] The comparison computation unit 34 of the control device 3 performs a comparison of the required amount of water evaporation Q_v per unit time calculated in step S2 and the allowable amount of water vapor evaporation W_a per unit time calculated in step S4 (step S5). This allows a determination to be made as to whether cooling can reliably be performed in the sand cooling device 5, that is, whether the introduced air to be introduced per unit time can receive water vapor of an amount that is the required amount of water evaporation Q_v per unit time.

[0072] When the comparison results in $Q_v > W_a$ (state 1), the water vapor amount to be evaporated per unit time is greater than the water vapor amount that the introduced air to be introduced per unit time can hold in addition to the humidity that the introduced air already has. Thus, one or more control operations are determined for achieving state 2,

the state in which Q_v is equal to W_a , by decreasing the water vapor amount to be evaporated per unit time or increasing the water vapor amount that the introduced air to be introduced per unit time can hold in addition to the humidity that the introduced air already has (step S6).

[0073] More specifically, first, the comparison computation unit 34 considers increasing the water vapor amount that the introduced air to be introduced per unit time can hold by increasing the rotation speed of the inverter motor 15 of the air introducing device 6 to increase the airflow amount, which increases the introduced air amount to be introduced per unit time. The comparison computation unit 34 calculates an appropriate value of the airflow amount using equations (1)-(4) in the same manner as described above. Thereafter, the comparison computation unit 34 transmits to the control unit 35 the control operation for adjusting the inverter motor 15 of the air introducing device 6 such that the airflow amount is equal to the calculated value.

[0074] If the value of the airflow amount calculated by the comparison computation unit 34 exceeds the capacity limit of the inverter motor 15 of the air introducing device 6, or when the value is increased to a value equivalent to the capacity limit of the inverter motor 15 of the air introducing device 6 but is still insufficient for achieving the relationship of $Q_v = W_a$, the comparison computation unit 34 further considers reducing the water vapor amount to be evaporated per unit time by reducing the rotation speed of the inverter motor 10 of the belt feeder 9 to reduce the loaded amount of the return sand. For this reason, as in the case of the airflow amount described above, an appropriate value of the return sand amount per unit time is calculated. Thereafter, the comparison computation unit 34 transmits to the control unit 35 the control operation for adjusting the inverter motor 10 of the belt feeder 9 such that the loaded amount of the return sand is equal to the calculated value, in addition to the control operation pertaining to the inverter motor 15 of the air introducing device 6.

[0075] However, if the loaded amount of the return sand is excessively reduced, the sand amount would be less than the sand amount required at the subsequent molding step, and it would not be possible to secure the minimum sand amount to be supplied to the molding machine to be able to maintain a determined molding speed. Thus, if a calculated value is calculated that is below a lower limit G_{sL} , which was set beforehand for the return sand amount G_s per unit time, the lower limit G_{sL} is used as a setting value. The setting of the lower limit G_{sL} is set by, for example, an operator inputting a lower limit G_{sL} into the control device 3 beforehand.

[0076] If the comparison computation unit 34 determines that the above is still insufficient for achieving the relationship of $Q_v = W_a$, the comparison computation unit 34 further considers increasing the water vapor amount that the introduced air to be introduced per unit time can hold by increasing the set temperature in the air heating device 13 to increase the temperature of the introduced air. For this reason, an appropriate value of the absolute humidity of the introduced air is calculated, as above. Thereafter, the comparison computation unit 34 transmits to the control unit 35 the control operation for controlling the air heating device 13 to increase the temperature of the introduced air to the calculated value, in addition to the control operation pertaining to the inverter motor 15 of the air introducing device 6 and the control operation pertaining to the inverter motor 10 of the belt feeder 9.

[0077] The control unit 35 receives the control operations and controls the inverter motor 10 of the belt feeder 9, the inverter motor 15 of the air introducing device 6, and the air heating device 13 on the basis of the control operations.

[0078] When the comparison in step S5 results in $Q_v = W_a$ (state 2), the water vapor amount to be evaporated per unit time is equal to the water vapor amount that the introduced air to be introduced per unit time can hold in addition to the humidity that the introduced air already has. Because this is the most ideal state, the comparison computation unit 34 does not determine any particular control operations, and transmits to the control unit 35 an instruction to maintain the current state (step S7).

[0079] The control unit 35 receives the instruction to maintain the current state as a control operation. The control unit 35 continues to control the inverter motor 10 of the belt feeder 9, the inverter motor 15 of the air introducing device 6, and the air heating device 13 such that the current state is maintained.

[0080] When the comparison in step S5 results in $Q_v < W_a$ (state 3), the water vapor amount to be evaporated per unit time is less than the water vapor amount that the introduced air to be introduced per unit time can hold in addition to the humidity that the introduced air already has. Thus, one or more control operations are determined for achieving state 2 by either or both reducing the airflow amount and increasing the loaded amount of the return sand in order to reduce lighting and heating expenses and increase the amount that is cooling-treated per unit time (step S8).

[0081] More specifically, first, the comparison computation unit 34 considers reducing the water vapor amount that the introduced air to be introduced per unit time can hold by reducing the rotation speed of the inverter motor 15 of the air introducing device 6 to reduce the airflow amount, which reduces the introduced air amount to be introduced per unit time. The appropriate value of the airflow amount is calculated in a similar manner as in state 1. Thereafter, the comparison computation unit 34 transmits to the control unit 35 the control operation for adjusting the inverter motor 15 of the air introducing device 6 such that the airflow amount is equal to the calculated value.

[0082] However, the airflow amount must not be lower than a value that still allows the dust particles in the sand cooling device 5 to be collected in order to prevent being unable to collect the dust particles generated in the sand cooling device 5 as a result of excessive reduction of the airflow amount.

[0083] If the value of the airflow amount calculated by the comparison computation unit 34 is insufficient for achieving the relationship of $Q_v = W_a$, the comparison computation unit 34 further considers increasing the water vapor amount to be evaporated per unit time by increasing the rotation speed of the inverter motor 10 of the belt feeder 9 to increase the loaded amount of the return sand. For this reason, as in the case of state 1, the loaded amount of the return sand, that is, an appropriate value of the return sand amount G_s per unit time, is calculated. Thereafter, the comparison computation unit 34 transmits to the control unit 35 the control operation for adjusting the inverter motor 10 of the belt feeder 9 such that the loaded amount of the return sand is equal to the calculated value, in addition to the control operation pertaining to the inverter motor 15 of the air introducing device 6.

[0084] The control unit 35 receives the control operations and controls the inverter motor 10 of the belt feeder 9 and the inverter motor 15 of the air introducing device 6 on the basis of the control operations.

[0085] After the controlling of the inverter motor 10 of the belt feeder 9, the inverter motor 15 of the air introducing device 6, and the air heating device 13 in steps S6-S8, the loaded amount of the return sand, the airflow amount of the introduced air, and the temperature of the introduced air in the return sand cooling system 1 are being changed so as to meet the relationship of $Q_v = W_a$, or in other words, so as to achieve the ideal state in which the water vapor amount to be evaporated per unit time is equal to the water vapor amount that the introduced air to be introduced per unit time can hold in addition to the humidity that the introduced air already has. In the steps from step S9 onwards to be described next, the measurement values in the state in which the conditions have been changed to be closer to the ideal state by means of the control operations are measured again by the measuring instruments, the required amount of water evaporation Q_v per unit time is calculated again from the measurement values that were measured again, and the appropriate water addition amount Q_w per unit time in this ideal state is determined on the basis of the required amount of water evaporation Q_v per unit time that was calculated again and the measurement values that were measured again.

[0086] Specifically, first, the sand moisture and temperature measuring instrument 2 measures the moisture content and temperature of the return sand conveyed on the belt feeder 9, and transmits the measurement results to the control device 3. The driving speed of the inverter motor 10 of the belt feeder 9 is controlled by the control device 3 such that return sand is loaded at the speed calculated by steps S6-S8 (step S9).

[0087] The required amount of water evaporation calculating unit 31 of the control device 3 calculates the required amount of water evaporation Q_v per unit time using equation (1) on the basis of the temperature (T_{s1}) of the return sand received from the sand moisture and temperature measuring instrument 2 and the loaded amount of the return sand, that is, the return sand amount (G_s) per unit time, which is obtained by converting the driving speed of the inverter motor 10 managed by the control device 3 (step S10).

[0088] Next, the introduced air temperature and humidity measuring instrument 7 measures the temperature and humidity of the introduced air, and transmits the measurement results to the control device 3. In addition, the airflow amount measuring instrument 17 measures the airflow amount of the introduced air to be introduced into the sand cooling device 5, and transmits the measurement result to the control device 3. The temperature and airflow amount of the introduced air is controlled by the control device 3 so as to be the values calculated by steps S6-S8 (step S11).

[0089] The allowable amount of water vapor evaporation calculating unit 32 of the control device 3 calculates the allowable amount of water vapor evaporation W_a per unit time using equation (2) and equation (3) on the basis of the temperature (T_{a1}) and absolute humidity (X_1) of the introduced air received from the introduced air temperature and humidity measuring instrument 7 and the airflow amount (G_a) received from the airflow amount measuring instrument 17 (step S12).

[0090] The appropriate water addition amount determining unit 33 of the control device 3 determines an appropriate water addition amount Q_w per unit time on the basis of the required amount of water evaporation Q_v per unit time, which was calculated as described above. The appropriate water addition amount Q_w per unit time is calculated using equation (4) as described above by summing the required amount of water evaporation Q_v per unit time and the moisture content to be added to return sand in addition to the moisture content of the return sand at the time of loading thereof. Because the conditions of the return sand cooling system 1 have been adjusted by the processes of steps S6-S8 and the required amount of water evaporation Q_v per unit time is an appropriate value, the appropriate water addition amount Q_w per unit time determined on the basis of equation (4) thereby also has an appropriate value. The appropriate water addition amount determining unit 33 transmits to the control unit 35 a control operation for adjusting the water amount regulation valve 12 such that the appropriate water addition amount Q_w per unit time is equal to the value that was determined (step S13).

[0091] The control unit 35 controls the water amount regulation valve 12 on the basis of the control operation received from the appropriate water addition amount determining unit 33. This adjusts the water amount per unit time supplied from the water source 11 to the water sprinkling device 4 to the appropriate water addition amount Q_w , and water-added return sand having an appropriate moisture content is generated (step S14).

[0092] The water sprinkling device 4 agitates the water-added return sand and disperses moisture therethroughout. The sand cooling device 5 brings the agitated water-added return sand discharged by the water sprinkling device 4 into contact with the introduced air that was introduced into the sand cooling device 5, and cools the sand by the latent heat

of vaporization of water.

[0093] The sand cooling device 5 discharges cooled return sand that has been cooled onto the belt conveyor 18, which is being driven by the motor 19. The belt conveyor 18 conveys the cooled return sand discharged from the sand cooling device 5 to the next step, such as a kneading device (not shown).

[0094] In the sand cooling device 5, discharged air having increased temperature and humidity due to the evaporation of water and heat transfer from sand is introduced into the dust collecting device 14. The dust collecting device 14 removes dust particles from the air that was introduced, and discharges the air from which dust particles have been removed outside.

[0095] In fig. 4, after the process of step S14, a determination is being made whether to perform an action correction dependent on the moisture content and temperature of the cooled return sand. This action correction will be described later in more detail. Whether the action correction is performed is determined on the basis of, for example, the setting value of the return sand cooling system 1 that was input into the control device 3 by the operator beforehand. If the action correction is to be performed, the process proceeds to the action correction process shown as step S21 (step S20).

[0096] If the action correction dependent on the moisture content and temperature of the cooled return sand is not to be performed, then a determination is being made whether to perform a later-described action correction dependent on the temperature and humidity of the discharged air. Whether the action correction is performed is determined on the basis of, for example, the setting value of the return sand cooling system 1 that was input into the control device 3 by the operator beforehand. If the action correction is to be performed, the process proceeds to the action correction process shown as step S41 (step S40).

[0097] If the action correction dependent on the temperature and humidity of the discharged air is not to be performed, a determination is made whether to continue the present series of processes of the return sand cooling system 1. Whether the processes are to be continued is determined on the basis of the setting value that was input into, for example, the control device 3, of the return sand cooling system 1 by the operator beforehand. If the processes are to be continued and executed, then after returning to step S1, the processes from step S1 onwards are repeated. If, by returning to step S1, the return sand amount and airflow amount and the like are changed by later-described correction operations and the like, the measurement values are measured again and the required amount of water evaporation Q_v per unit time and the allowable amount of water vapor evaporation W_a per unit time are calculated again, which update the values. If the processes are not to be executed, the present series of processes of the return sand cooling system 1 end (step S60).

(Additional configuration of control device 3 pertaining to action correction dependent on moisture content and temperature of cooled return sand)

[0098] Next, a configuration of the control device 3 pertaining to an action correction dependent on the moisture content and temperature of cooled return sand will be described. In order to perform the action correction dependent on the moisture content and temperature of cooled return sand, the control device 3 comprises the first correction amount calculating unit 36 as shown in fig. 2.

[0099] In an appropriate water addition amount determination and water sprinkling instruction, such as those described above, the required amount of water evaporation Q_v per unit time and the allowable amount of water vapor evaporation W_a per unit time are compared; the airflow amount of the introduced air, the loaded amount of the return sand, or the temperature of the introduced air, or any combination thereof, is adjusted on the basis of the result of the comparison; and then the appropriate water addition amount Q_w per unit time is determined. However, this process does not consider the actual capacity of the sand cooling device 5, such as the cooling efficiency thereof.

[0100] To consider the actual capacity of the sand cooling device 5, after the processes corresponding to step S14 in fig. 3 in which the appropriate water addition amount determining unit 33 determines the appropriate water addition amount Q_w , the water amount regulation valve 12 is controlled, and the water amount supplied from the water source 11 to the water sprinkling device 4 is adjusted to the appropriate water addition amount Q_w , the first correction amount calculating unit 36 calculates a correction amount of the airflow amount, the loaded amount of the return sand, or the appropriate water addition amount, or any combination thereof, on the basis of the moisture content and temperature of the cooled return sand discharged by the sand cooling device 5.

[0101] The first correction amount calculating unit 36 receives the moisture content W_{s3} (%) and temperature T_{s3} (K) of the cooled return sand from the cooled return sand moisture and temperature measuring instrument 20. The first correction amount calculating unit 36 compares the values with a target moisture content W_{s2} (%) and a cooled target temperature T_{s2} (K) of the cooled return sand, respectively.

[0102] As shown in fig. 5, which will be used later to describe an action correction method by means of the first correction amount calculating unit 36, the comparison could result in, for example, any of the following states: when $W_{s3} > W_{s2}$ and $T_{s3} > T_{s2}$ are true (state A); when $W_{s3} < W_{s2}$ and $T_{s3} > T_{s2}$ are true (state B); when $W_{s3} > W_{s2}$ and $T_{s3} < T_{s2}$ are true (state C); and when $W_{s3} < W_{s2}$ and $T_{s3} < T_{s2}$ are true (state D). Depending on the specific relationship of W_{s3} and W_{s2} as well as T_{s3} and T_{s2} , the first correction amount calculating unit 36 controls the inverter motor 15 of the air

introducing device 6, the inverter motor 10 of the belt feeder 9, or the water amount regulation valve 12, or any combination thereof, calculates a correction amount of the airflow amount, the loaded amount of the return sand, or the appropriate water addition amount, or any combination thereof, and determines one or more correction control operations for controlling each device in accordance with the calculated correction amount. The one or more correction control operations determined for each of states A-D will be described in detail below.

[0103] In state A, $W_{s3} > W_{s2}$ and $T_{s3} > T_{s2}$, which is a state in which the moisture content and temperature of the cooled return sand discharged by the sand cooling device 5 are higher than the target values. This is a state in which the water sprinkling amount in the water sprinkling device 4 is sufficient, but because the water-added return sand and the introduced air are not in sufficient contact with each other, there is insufficient evaporation of water in the sand cooling device 5, and the water-added return sand is not being sufficiently cooled by the latent heat of vaporization.

[0104] In state A, first, the first correction amount calculating unit 36 considers increasing the water vapor amount that the introduced air to be introduced per unit time can hold by increasing the rotation speed of the inverter motor 15 of the air introducing device 6 to increase the airflow amount. The amount by which the airflow amount is increased may be set to an amount such that W_{s3} is equal to W_{s2} and T_{s3} is equal to T_{s2} after the airflow amount is increased. Thus, the amount by which the airflow amount is increased is calculated on the basis of equations (1)-(4) as well as the relationships of $W_{s3} = W_{s2}$ and $T_{s3} = T_{s2}$. Thereafter, the first correction amount calculating unit 36 transmits to the control unit 35 a correction control operation for adjusting the inverter motor 15 of the air introducing device 6 such that the airflow amount is equal to the calculated value.

[0105] If the value of the airflow amount calculated by the first correction amount calculating unit 36 exceeds the capacity limit of the inverter motor 15 of the air introducing device 6, or when the value is increased to a value equivalent to the capacity limit of the inverter motor 15 of the air introducing device 6 but is still insufficient for achieving the target values, the first correction amount calculating unit 36 further considers reducing the loaded amount of the return sand by reducing the rotation speed of the inverter motor 10 of the belt feeder 9. The loaded amount of the return sand is calculated on the basis of equations (1)-(4). Thereafter, the first correction amount calculating unit 36 transmits to the control unit 35 a correction control operation for adjusting the inverter motor 10 of the belt feeder 9 such that the loaded amount of the return sand is equal to the calculated value, in addition to the correction control operation pertaining to the inverter motor 15 of the air introducing device 6.

[0106] However, if the loaded amount of the return sand is excessively reduced, the sand amount would be less than the sand amount required at the subsequent molding step, and it would not be possible to secure the minimum sand amount to be supplied to the molding machine to be able to maintain a determined molding speed. Thus, if a calculated value is calculated that is below a lower limit G_{sL} , which was set beforehand for the return sand amount G_s per unit time, the lower limit G_{sL} is used as a setting value. The setting of the lower limit G_{sL} is set by, for example, an operator inputting a lower limit G_{sL} into the control device 3 beforehand.

[0107] In state B, $W_{s3} < W_{s2}$ and $T_{s3} > T_{s2}$, which is a state in which the moisture content of the cooled return sand discharged by the sand cooling device 5 is lower than the target value, and the temperature of the sand is higher than the target value. Because the water sprinkling amount in the water sprinkling device 4 is insufficient, this is a state in which moisture is not being sufficiently evaporated in the sand cooling device 5 and there is insufficient cooling of the water-added return sand by the latent heat of vaporization.

[0108] In state B, the first correction amount calculating unit 36 considers increasing the degree of opening of the water amount regulation valve 12 to increase the water amount supplied to the water sprinkling device 4. The water amount is calculated on the basis of equations (1)-(4), as in the case of state A. Thereafter, the first correction amount calculating unit 36 transmits to the control unit 35 a correction control operation for increasing the degree of opening of the water amount regulation valve 12 such that the water amount is equal to the calculated value.

[0109] In state C, $W_{s3} > W_{s2}$ and $T_{s3} < T_{s2}$, which is a state in which the moisture content of the cooled return sand discharged by the sand cooling device 5 is higher than the target value, and the temperature of the sand is lower than the target value. Because the water sprinkling amount in the water sprinkling device 4 is too large, this is a state in which the water-added return sand in the sand cooling device 5 is being sufficiently cooled while a lot of the excess moisture above the target is being left on the cooled return sand.

[0110] In state C, the first correction amount calculating unit 36 considers decreasing the degree of opening of the water amount regulation valve 12 to reduce the water amount supplied to the water sprinkling device 4. The water amount is calculated on the basis of equations (1)-(4), as in the case of state A. Thereafter, the first correction amount calculating unit 36 transmits to the control unit 35 a correction control operation for decreasing the degree of opening of the water amount regulation valve 12 such that the water amount is equal to the calculated value.

[0111] In state D, $W_{s3} < W_{s2}$ and $T_{s3} < T_{s2}$, which is a state in which, in the sand cooling device 5, the water-added return sand is being sufficiently cooled but because the water sprinkling amount is low, the moisture content of the cooled return sand is low.

[0112] In state D, the first correction amount calculating unit 36 considers increasing the degree of opening of the water amount regulation valve 12 to increase the water amount supplied to the water sprinkling device 4. The water

amount is calculated on the basis of equations (1)-(4), as in the case of state A. Thereafter, the first correction amount calculating unit 36 transmits to the control unit 35 the correction control operation for increasing the degree of opening of the water amount regulation valve 12 such that the water amount is equal to the calculated value.

[0113] Alternatively, the first correction amount calculating unit 36 considers reducing the evaporation amount by reducing the rotation speed of the inverter motor 15 of the air introducing device 6 to reduce the airflow amount. The amount by which the airflow amount is reduced is calculated on the basis of equations (1)-(4), as in the case of state A. Thereafter, the first correction amount calculating unit 36 transmits to the control unit 35 the correction control operation for adjusting the inverter motor 15 of the air introducing device 6 such that the airflow amount is equal to the calculated value.

[0114] However, the airflow amount must not be lower than a value that still allows the dust particles in the sand cooling device 5 to be collected in order to prevent being unable to collect the dust particles generated in the sand cooling device 5 as a result of excessive reduction of the airflow amount.

[0115] The control unit 35 receives and executes one or more correction control operations transmitted from the first correction amount calculating unit 36, and controls the inverter motor 10 of the belt feeder 9, the water amount regulation valve 12, or the inverter motor 15 of the air introducing device 6, or any combination thereof.

(Action correction method dependent on moisture content and temperature of cooled return sand)

[0116] Next, an action correction method dependent on the moisture content and temperature of cooled return sand using the first correction amount calculating unit 36 in the return sand cooling system 1 described above will be described using fig. 1-5. The present method corresponds to step S21 described in fig. 4, and is executed after steps S1-S20 described in the appropriate water addition amount determination and water sprinkling instruction method.

[0117] First, the appropriate water addition amount determination and water sprinkling instruction method (steps S1-S20) are executed. In step S20, a determination is made as to whether the action correction dependent on the moisture content and temperature of the cooled return sand is performed. If a setting to perform the action correction has been made, a correction process described as step S21 is performed. Fig. 5 illustrates the details of correction process S21.

[0118] In correction process S21, first, the cooled return sand moisture and temperature measuring instrument 20 measures the moisture content and temperature of the cooled return sand conveyed on the belt conveyor 18, and transmits the measurement results to the control device 3 (step S22).

[0119] The first correction amount calculating unit 36 of the control unit 35 receives the moisture content W_{s3} (%) and temperature T_{s3} (K) of the cooled return sand from the cooled return sand moisture and temperature measuring instrument 20, and compares the values with the target moisture content W_{s2} (%) and cooled target temperature T_{s2} (K) of the cooled return sand, respectively, as described above (step S23). This allows a determination to be made as to, for example, whether the sand cooling device 5 is cooling the water-added return sand so as to meet the target temperature and moisture content of the cooled return sand, as well as whether, even if the targets are being met, the sand is being cooled excessively beyond the targets.

[0120] If the comparison results in $W_{s3} > W_{s2}$ and $T_{s3} > T_{s2}$ (state A), this is a state in which the water sprinkling amount in the water sprinkling device 4 is sufficient, but because the water-added return sand and the introduced air are not in sufficient contact with each other, there is insufficient evaporation of moisture in the sand cooling device 5, and the water-added return sand is not being sufficiently cooled by the latent heat of vaporization. Thus, one or more control operations are determined for achieving the state in which W_{s3} is equal to W_{s2} and T_{s3} is equal to T_{s2} (step S24).

[0121] More specifically, first, the first correction amount calculating unit 36 considers increasing the water vapor amount that the introduced air to be introduced per unit time can hold by increasing the rotation speed of the inverter motor 15 of the air introducing device 6 to increase the airflow amount. The amount by which the airflow amount is increased is calculated on the basis of equations (1)-(4). Thereafter, the first correction amount calculating unit 36 transmits to the control unit 35 the correction control operation for adjusting the inverter motor 15 of the air introducing device 6 such that the airflow amount is equal to the calculated value.

[0122] If the value of the airflow amount calculated by the first correction amount calculating unit 36 exceeds the capacity limit of the inverter motor 15 of the air introducing device 6, or when the value is increased to a value equivalent to the capacity limit of the inverter motor 15 of the air introducing device 6 but is still insufficient for achieving the target values, the first correction amount calculating unit 36 further considers reducing the loaded amount of the return sand by reducing the rotation speed of the inverter motor 10 of the belt feeder 9. The loaded amount of the return sand is calculated on the basis of equations (1)-(4). Thereafter, the first correction amount calculating unit 36 transmits to the control unit 35 the correction control operation for adjusting the inverter motor 10 of the belt feeder 9 such that the loaded amount of the return sand is equal to the calculated value, in addition to the correction control operation pertaining to the inverter motor 15 of the air introducing device 6.

[0123] However, if the loaded amount of the return sand is excessively reduced, the sand amount would be less than the sand amount required at the subsequent molding step, and it would not be possible to secure the minimum sand

amount to be supplied to the molding machine to be able to maintain a determined molding speed. Thus, if a calculated value is calculated that is below a lower limit G_{sL} , which was set beforehand for the return sand amount G_s per unit time, the lower limit G_{sL} is used as a setting value. The setting of the lower limit G_{sL} is set by, for example, an operator inputting a lower limit into the control device 3 beforehand.

[0124] If the comparison in step S23 results in $W_{s3} < W_{s2}$ and $T_{s3} > T_{s2}$ (state B), this is a state in which moisture in the sand cooling device 5 is not sufficiently evaporating because the water sprinkling amount in the water sprinkling device 4 is insufficient, and the cooling of the water-added return sand by the latent heat of vaporization is insufficient. In this case as well, a control operation is determined for achieving the state in which W_{s3} is equal to W_{s2} and T_{s3} is equal to T_{s2} (step S25).

[0125] More specifically, the first correction amount calculating unit 36 considers increasing the water amount supplied to the water sprinkling device 4 by increasing the degree of opening of the water amount regulation valve 12. The water amount is calculated on the basis of equations (1)-(4). Thereafter, the first correction amount calculating unit 36 transmits to the control unit 35 the correction control operation for increasing the degree of opening of the water amount regulation valve 12 such that the water amount is equal to the calculated value.

[0126] If the comparison in step S23 results in $W_{s3} > W_{s2}$ and $T_{s3} < T_{s2}$ (state C), this is a state in which, because the water sprinkling amount in the water sprinkling device 4 is too much, the water-added return sand in the sand cooling device 5 is being sufficiently cooled while a lot of excess moisture above the target that was not evaporated is being left on the cooled return sand. In this case as well, a control operation is determined for achieving the state in which W_{s3} is equal to W_{s2} and T_{s3} is equal to T_{s2} (step S26).

[0127] More specifically, the first correction amount calculating unit 36 considers decreasing the water amount supplied to the water sprinkling device 4 by decreasing the degree of opening of the water amount regulation valve 12. The water amount is calculated on the basis of equations (1)-(4). Thereafter, the first correction amount calculating unit 36 transmits to the control unit 35 the correction control operation for decreasing the degree of opening of the water amount regulation valve 12 such that the water amount is equal to the calculated value.

[0128] If the comparison in step S23 results in $W_{s3} < W_{s2}$ and $T_{s3} < T_{s2}$ (state D), this is a state in which the water-added return sand in the sand cooling device 5 is being sufficiently cooled, but because the water sprinkling amount is low, the moisture content of the cooled return sand is low. In this case as well, one or more control operations are determined for achieving the state in which W_{s3} is equal to W_{s2} and T_{s3} is equal to T_{s2} (step S27).

[0129] More specifically, the first correction amount calculating unit 36 considers increasing the water amount supplied to the water sprinkling device 4 by increasing the degree of opening of the water amount regulation valve 12. The water amount is calculated on the basis of equations (1)-(4). Thereafter, the first correction amount calculating unit 36 transmits to the control unit 35 the correction control operation for increasing the degree of opening of the water amount regulation valve 12 such that the water amount is equal to the calculated value.

[0130] Alternatively, the first correction amount calculating unit 36 considers reducing the evaporation amount by reducing the rotation speed of the inverter motor 15 of the air introducing device 6 to reduce the airflow amount. The amount by which the airflow amount is reduced is calculated on the basis of equations (1)-(4). Thereafter, the first correction amount calculating unit 36 transmits to the control unit 35 the correction control operation for adjusting the inverter motor 15 of the air introducing device 6 such that the airflow amount is equal to the calculated value.

[0131] However, the airflow amount must not be lower than a value that still allows the dust particles in the sand cooling device 5 to be collected in order to prevent being unable to collect the dust particles generated in the sand cooling device 5 as a result of excessive reduction of the airflow amount.

[0132] The control unit 35 receives the correction control operation and controls the inverter motor 10 of the belt feeder 9, the water amount regulation valve 12, or the inverter motor 15 of the air introducing device 6, or any combination thereof, on the basis of the correction control operation (step S28).

[0133] Thereafter, step S40 illustrated in fig. 4 is executed. As described above, in step S20, even if a determination is made to not execute correction process S21 described using fig. 5, step S40 is executed as described above. In step S40, a determination is made whether to perform an action correction dependent on the temperature and humidity of the discharged air, which will be described later in more detail. Whether the action correction is performed is determined on the basis of, for example, the setting value of the return sand cooling system 1 that was input into the control device 3 by the operator beforehand. If the action correction is to be performed, the process proceeds to an action correction process shown as step S41, which will be described later in more detail.

[0134] If the action correction dependent on the temperature and humidity of the discharged air is not to be performed, then a determination is made whether to continue the present series of processes of the return sand cooling system 1. Whether the processes are to be continued is determined on the basis of the setting value that was input into, for example, the control device 3, of the return sand cooling system 1 by the operator beforehand. If the processes are to be continued and executed, the processes from step S1 onwards are repeated. If, by returning to step S1, the return sand amount and airflow amount and the like are changed by the present correction operations and the like, the measurement values are measured again and the required amount of water evaporation Q_v per unit time as well as the allowable amount of

water vapor evaporation W_a per unit time are calculated again, which update the values. If the processes are not to be executed, then the present series of processes of the return sand cooling system 1 end (step S60).

[0135] Note that suddenly changing the conditions in the return sand cooling system 1 may result in degraded return sand quality as well as system malfunctions and damages and the like. Thus, in the execution of the action correction processes, the correction controls for the devices are performed at a rate of around 0.5-2.0% of the correction values in a period of time of about 2-10 seconds.

(Additional configuration of control device 3 pertaining to action correction dependent on temperature and humidity of discharged air)

[0136] Next, a configuration of the control device 3 pertaining to an action correction dependent on the temperature and humidity of discharged air will be described. To perform the action correction dependent on the temperature and humidity of discharged air, the control device 3 comprises a second correction amount calculating unit 37, as shown in fig. 2.

[0137] In the present embodiment, after the appropriate water addition amount determination and water sprinkling instruction corresponding to steps S1-S14 in fig. 3, or after the action correction dependent on the moisture and temperature of cooled return sand corresponding to step S21 in fig. 4, the second correction amount calculating unit 37 calculates a correction amount of the airflow amount, the loaded amount of the return sand, or the temperature of the introduced air, or any combination thereof, on the basis of the temperature and humidity of the discharged air discharged by the sand cooling device 5.

[0138] More specifically, the second correction amount calculating unit 37 receives the temperature and humidity of the discharged air from the discharged air temperature and humidity measuring instrument 16. The second correction amount calculating unit 37 calculates the value of the relative humidity at the temperature from these values.

[0139] If the value of the relative humidity is at a value close to 100%, such as 95% or more, condensation may occur in the sand cooling device 5 as well as the air blowing pipes forming the air passage. To prevent condensation, first, the second correction amount calculating unit 37 considers reducing the relative humidity of the discharged air to for example around 90-95% by increasing the rotation speed of the inverter motor 15 of the air introducing device 6 to increase the airflow amount. The amount by which the airflow amount is increased is calculated on the basis of equations (1)-(4). Thereafter, the second correction amount calculating unit 37 transmits to the control unit 35 the correction control operation for adjusting the inverter motor 15 of the air introducing device 6 such that the airflow amount is equal to the calculated value.

[0140] If condensation cannot be sufficiently prevented by the changing of the airflow amount by means of the correction operation of the inverter motor 15 of the air introducing device 6, the second correction amount calculating unit 37 further considers reducing the loaded amount of the return sand by reducing the rotation speed of the inverter motor 10 of the belt feeder 9. The loaded amount of the return sand is calculated on the basis of equations (1)-(4). Thereafter, the second correction amount calculating unit 37 transmits to the control unit 35 the correction control operation for adjusting the inverter motor 10 of the belt feeder 9 such that the loaded amount of the return sand is equal to the calculated value, in addition to the correction control operation pertaining to the inverter motor 15 of the air introducing device 6.

[0141] However, if the loaded amount of the return sand is excessively reduced, the sand amount would be less than the sand amount required at the subsequent molding step, and it would not be possible to secure the minimum sand amount to be supplied to the molding machine to be able to maintain a determined molding speed. Thus, if a calculated value is calculated that is below a lower limit G_{sL} , which was set beforehand for the return sand amount G_s per unit time, the lower limit G_{sL} is used as a setting value. The setting of the lower limit G_{sL} is set by, for example, an operator inputting a lower limit into the control device 3 beforehand.

[0142] If condensation still cannot be sufficiently prevented, the second correction amount calculating unit 37 further considers increasing the set temperature in the air heating device 13. The temperature of the introduced air is calculated on the basis of equations (1)-(4). Thereafter, the second correction amount calculating unit 37 transmits to the control unit 35 the control operation for controlling the air heating device 13 to increase the temperature of the introduced air to the calculated value, in addition to the correction control operations pertaining to the inverter motor 15 of the air introducing device 6 and the inverter motor 10 of the belt feeder 9.

[0143] The control unit 35 receives and executes the correction control operations sent from the second correction amount calculating unit 37 and controls the inverter motor 15 of the air introducing device 6, the inverter motor 10 of the belt feeder 9, or the air heating device 13, or any combination thereof.

[0144] The correction amounts are calculated on the basis of equations (1)-(4) as described above, but because prior to this calculation the absolute humidity is used as the humidity in equations (1)-(4), the second correction amount calculating unit 37 converts the relative humidity of the discharged air to the absolute humidity.

(Action correction method dependent on temperature and humidity of discharged air)

[0145] Next, an action correction method dependent on the temperature and humidity of discharged air using the second correction amount calculating unit 37 in the return sand cooling system 1 described above will be described using fig. 1-4 and 6. The present method corresponds to step S41 described in fig. 4, and is executed after steps S1-S14 in fig. 3 described in the appropriate water addition amount determination and water sprinkling instruction method, or is executed after step S21 described in the action correction method dependent on the moisture content and temperature of the cooled return sand.

[0146] First, the appropriate water addition amount determination and water sprinkling instruction method (steps S1-S20) and the action correction method dependent on the moisture and temperature of the cooled return sand (steps S21, S40) are executed. In step S40, a determination is made whether to perform the action correction dependent on the temperature and humidity of the discharged air. If a setting has been made to perform the action correction, the present correction process described as step S41 is performed. Fig. 6 illustrates the details of correction process S41.

[0147] In correction process S41, first, the discharged air temperature and humidity measuring instrument 16 measures the temperature and humidity of the discharged air discharged from the sand cooling device 5, and transmits the measurement results to the control device 3 (step S42).

[0148] The second correction amount calculating unit 37 of the control unit 35 receives the temperature and humidity of the discharged air from the discharged air temperature and humidity measuring instrument 16, and calculates the value of the relative humidity at the temperature from these values. Further, the second correction amount calculating unit 37 determines whether the calculated value of the relative humidity is for example 95% or more (step S43).

[0149] If the value of the relative humidity is a value close to 100%, such as 95% or more, a correction amount of the airflow amount, the loaded amount of the return sand, or the temperature of the introduced air, or any combination thereof, is calculated that is appropriate for the prevention of condensation (step S44). First, the second correction amount calculating unit 37 considers reducing the relative humidity of the discharged air to for example around 90-95% by increasing the rotation speed of the inverter motor 15 of the air introducing device 6. The amount by which the airflow amount is increased is calculated on the basis of equations (1)-(4). Thereafter, the second correction amount calculating unit 37 transmits to the control unit 35 the correction control operation for adjusting the inverter motor 15 of the air introducing device 6 such that the airflow amount is equal to the calculated value.

[0150] If condensation cannot be sufficiently prevented by the changing of the airflow amount by means of the correction operation of the inverter motor 15 of the air introducing device 6, the second correction amount calculating unit 37 further considers reducing the loaded amount of the return sand by reducing the rotation speed of the inverter motor 10 of the belt feeder 9. The loaded amount of the return sand is calculated on the basis of equations (1)-(4). Thereafter, the second correction amount calculating unit 37 transmits to the control unit 35 the correction control operation for adjusting the inverter motor 10 of the belt feeder 9 such that the loaded amount of the return sand is equal to the calculated value, in addition to the correction control operation pertaining to the inverter motor 15 of the air introducing device 6.

[0151] However, if the loaded amount of the return sand is excessively reduced, the sand amount would be less than the sand amount required at the subsequent molding step, and it would not be possible to secure the minimum sand amount to be supplied to the molding machine to be able to maintain a determined molding speed. Thus, if a calculated value is calculated that is below a lower limit G_{sL} , which was set beforehand for the return sand amount G_s per unit time, the lower limit G_{sL} is used as a setting value. The setting of the lower limit G_{sL} is set by, for example, an operator inputting a lower limit into the control device 3 beforehand.

[0152] If condensation still cannot be sufficiently prevented, the second correction amount calculating unit 37 further considers increasing the set temperature in the air heating device 13. The temperature of the introduced air is calculated on the basis of equations (1)-(4). Thereafter, the second correction amount calculating unit 37 transmits to the control unit 35 the control operation for controlling the air heating device 13 to increase the temperature of the introduced air to the calculated value, in addition to the correction control operations pertaining to the inverter motor 15 of the air introducing device 6 and the inverter motor 10 of the belt feeder 9.

[0153] The control unit 35 receives the correction control operations and controls the inverter motor 15 of the air introducing device 6, the inverter motor 10 of the belt feeder 9, or the air heating device 13, or any combination thereof, on the basis of the correction control operations (step S45).

[0154] After step S45, or if a determination is made at step S43 that the value of the relative humidity is for example 95% or less and a correction to prevent condensation is unnecessary, then immediately thereafter, step S60 illustrated in fig. 4 as previously described is executed. If the processes are to be continued and executed in S60, the processes from step S1 onwards are repeated. If, by returning to step S1, the return sand amount and airflow amount and the like are changed by later-described correction operations and the like, the measurement values are measured again and the required amount of water evaporation Q_v per unit time as well as the allowable amount of water vapor evaporation W_a per unit time are calculated again, which update the values.

[0155] Note that in the execution of the present action correction processes, the correction controls for the airflow

amount and the loaded amount of the return sand are preferably performed at a rate of around 0.5-2.0% of the correction amounts in a period of time of about 2-10 seconds, as in the action correction dependent on the moisture and temperature of the cooled return sand. In addition, regarding the temperature of the introduced air, control operations therefor are preferably performed at a rate of around 0.5-3% of the correction amounts in a period of time of 2-10 seconds.

[0156] Next, the functions and effects of the return sand cooling system 1 and method described above will be described.

[0157] In configurations and methods such as those described above, in the appropriate water addition amount determination and water sprinkling instruction, the comparison computation unit 34 performs a comparison of the allowable amount of water vapor evaporation W_a (kg/min) per unit time based on the temperature and humidity of the introduced air calculated by equation (3) and the required amount of water evaporation Q_v (kg/min) per unit time calculated by equation (1), and determines whether the introduced air per unit time can receive water vapor corresponding to the required amount of water evaporation Q_v in order to efficiently perform cooling of the water-added return sand.

[0158] If this results in for example the required amount of water evaporation per unit time being greater than the allowable amount of water vapor evaporation per unit time (state 1), a control operation is performed so as to reduce the required amount of water evaporation per unit time or increase the allowable amount of water vapor evaporation per unit time. The amount by which each device is controlled according to the control operation is performed such that the required amount of water evaporation per unit time and the allowable amount of water vapor evaporation per unit time are equal on the basis of equations (1)-(4).

[0159] In other words, a determination is made as to the specific amount of water vapor that the introduced air can hold per unit time on the basis of the temperature and humidity of the introduced air, and in accordance with the result, the conditions in the return sand cooling system, such as the loaded amount of the return sand, the water sprinkling amount, and the temperature and airflow amount of the introduced air, are controlled and changed. This allows appropriate conditions in the return sand cooling system to be achieved that take into account the temperature and humidity of the introduced air, enabling stable cooling and moisture content effects to be achieved even under conditions such as seasonal changes in temperatures and humidity. Thus, return sand can be reliably cooled to a target temperature regardless of the state of introduced air.

[0160] In addition, the operation amount of each device for obtaining cooled return sand that has been cooled to a target temperature, or in other words, for achieving the conditions necessary and sufficient for cooling return sand to a target temperature, is obtained by computation, and each device is controlled according to the operation amount. This makes it possible to reduce the number of times each device is controlled. In other words, when empirically controlling each device, there would be a need to repeatedly perform control adjustments for each device as well as the measurements that were taken again by the measuring instruments under conditions that were changed by such control adjustments and converge the conditions in the return sand cooling system. However, such repetitions do not need to be repeatedly performed in the present embodiment. Thus, the cooling of return sand can be performed more easily.

[0161] In addition, even if the required amount of water evaporation per unit time is less than the allowable amount of water vapor evaporation per unit time (state 3), or in other words, even in a state in which the introduced air can sufficiently absorb the water vapor, one or more control operations are performed such that the required amount of water evaporation per unit time and the allowable amount of water vapor evaporation per unit time are equal. As one of these control operations, the loaded amount of the return sand may be increased to increase the amount that is cooling-treated per unit time. Thus, the cooling of return sand can be efficiently performed.

[0162] In addition, in state 3, the control operation for reducing the airflow amount can also be performed. In this case, lighting and heating expenses can be reduced.

[0163] In addition, the appropriate water addition amount Q_w per unit time is determined by computation using equation (4) in the return sand cooling system once the conditions of the system have been adjusted, as described above. Equation (4) obtains an appropriate water addition amount by adding the difference between the target moisture of the cooled return sand and the moisture of the return sand before water sprinkling to the required amount of water evaporation Q_v per unit time after adjustment. In other words, the moisture of the cooled return sand has been adjusted to be around the target moisture, and the adjustment of the moisture content of the cooled return sand can be efficiently performed.

[0164] In addition, in the appropriate water addition amount determination and water sprinkling instruction process, there are cases in which an appropriate water addition amount Q_w that is appropriate is determined, and the moisture content and temperature of the cooled return sand differ from the target values regardless of whether water has been sprinkled. This is considered to be a case in which the contemplated capacity and the actual capacity of the sand cooling device 5, such as cooling capacity, are different, but even in such cases, after the appropriate water addition amount determination and water sprinkling instruction process, the action correction dependent on the moisture content and temperature of the cooled return sand is performed, and one or more corrections are performed to bring the moisture content and temperature of the cooled return sand closer to the targets. Thus, even in such cases, it becomes possible to cool and add water to the return sand to achieve the target temperature.

[0165] In addition, in the action correction dependent on the temperature and humidity of the discharged air, after the appropriate water addition amount Q_w is determined and if the relative humidity of the introduced air is a value that is

close to 100%, such as 95% or more, on the basis of the temperature and humidity of the discharged air, a correction amount is calculated for the airflow amount, the loaded amount of the return sand, or the temperature of introduced air, or any combination thereof, to for example achieve around 90-95%, and correction controls are performed for the devices. This allows for the prevention of condensation in the sand cooling device 5 as well as in the air blowing pipes forming the air passage.

(Modified example of first embodiment)

[0166] Next, a modified example of the first embodiment will be described.

[0167] Fig. 7 is a schematic configuration view of a return sand cooling system 61 shown as a modified example of the first embodiment, and fig. 8 is a block diagram of a control device in the return sand cooling system 61.

[0168] In these figures, the same reference signs are used for structural components that are the same as those shown in fig. 1 and 2, which were described in the first embodiment, and thus, the descriptions will be omitted.

[0169] This embodiment differs from the previously discussed first embodiment in that the humidity of the discharged air is not measured and is instead obtained by calculation, and in accordance therewith, the process details of a second correction amount calculating unit 67 differ.

[0170] The return sand cooling system 61 of the present modified example comprises a discharged air temperature measuring instrument 66 that measures the temperature of discharged air discharged from the water-sprinkling cooling device 4, 5, as shown in fig. 7, instead of the discharged air temperature and humidity measuring instrument 16 shown in fig. 1.

[0171] The discharged air temperature measuring instrument 66 is provided between the sand cooling device 5 and the dust collecting device 14 and measures the temperature of the discharged air discharged from the sand cooling device 5. A control device 63, which will be described later in more detail, is electrically connected to the discharged air temperature measuring instrument 66. The temperature of the discharged air measured by the discharged air temperature measuring instrument 66 is transmitted to the control device 63.

[0172] The moisture content and temperature of return sand measured by the sand moisture and temperature measuring instrument 2; the moisture content and temperature of cooled return sand measured by the cooled return sand moisture and temperature measuring instrument 20; the temperature and humidity of introduced air measured by the introduced air temperature and humidity measuring instrument 7; the temperature of discharged air measured by the discharged air temperature measuring instrument 66; and the airflow amount of introduced air measured by the airflow amount measuring instrument 17 are transmitted to the control device 63. The control device 63 receives the measurement values, performs computations to be described later in more detail, and controls the inverter motor 10 of the belt feeder 9, the water amount regulation valve 12, the inverter motor 15 of the air introducing device 6, and the air heating device 13 on the basis of the computation results.

[0173] The control device 63 controls the operation of the return sand cooling system 61 by performing three kinds of processes, as in: appropriate water addition amount determination and water sprinkling instruction; operation correction dependent on the moisture content and temperature of cooled return sand; and operation correction dependent on the temperature of discharged air.

[0174] Fig. 9 is a flow chart of a return sand cooling method shown as the present modified example, and follows the appropriate water addition amount determination and water sprinkling instruction of the first embodiment described using fig. 3. In the present modified example, the appropriate water addition amount determination and water sprinkling instruction shown in fig. 3 and the action correction dependent on the moisture content and temperature of the cooled return sand shown as step S21 in fig. 9 are executed, as in the first embodiment. The processes are the same as in the first embodiment, so the descriptions will here be omitted. Here, an action correction dependent on the temperature of the discharged air shown as step S51, which differs from the first embodiment, will be discussed.

[0175] Note that in the first embodiment, whether the action correction dependent on the moisture content and temperature of the cooled return sand (step S21) and the action correction dependent on the temperature and humidity of the discharged air (step S41) are executed was determined by the determination processes according to steps S20 and S40, as described using fig. 4. In the present modified example, these determination processes are not executed, and the action correction dependent on the moisture content and temperature of the cooled return sand (step S21) and the action correction dependent on the temperature of the discharged air (step S51) are configured to be continuously and sequentially executed.

(Additional configuration of control device 63 pertaining to action correction dependent on temperature of discharged air)

[0176] In the present modified example, after the action correction dependent on the moisture and temperature of the cooled return sand corresponding to step S21 in fig. 9, the second correction amount calculating unit 67 calculates the humidity of the discharged air on the basis of the temperature of the discharged air discharged by the sand cooling

device 5, and calculates, if the humidity of the discharged air is greater than or equal to a prescribed value, a correction amount of the airflow amount, the loaded amount of the return sand, or the temperature of the introduced air, or any combination thereof.

[0177] More specifically, the second correction amount calculating unit 67 receives the temperature of the discharged air from the discharged air temperature measuring instrument 66. The second correction amount calculating unit 67 calculates the moisture content held by the discharged air and, from the values of the moisture content and received temperature of the discharged air, calculates the value of the relative humidity at the temperature.

[0178] The second correction amount calculating unit 67 calculates the moisture content held by the discharged air as follows.

[0179] First, the absolute humidity of the introduced air is calculated from the temperature and humidity of the introduced air measured by the introduced air temperature and humidity measuring instrument 7, and then the moisture content held by the introduced air per unit time is calculated on the basis of the airflow amount of the introduced air measured by the airflow amount measuring instrument 17 and the calculated absolute humidity of the introduced air.

[0180] Next, the moisture content held by the return sand per unit time is calculated on the basis of the moisture content of the return sand measured by the sand moisture and temperature measuring instrument 2 and the return sand amount per unit time loaded into the sand cooling device 5.

[0181] Then, the sum of the calculated moisture content held by the introduced air per unit time and moisture content held by the return sand per unit time is calculated, the water amount per unit time that was supplied to the water sprinkling device 4 via the water amount regulation valve 12 is added to this sum, and the total sum of these values is calculated.

[0182] Consequently, the total sum of the moisture content that was introduced into the water-sprinkling cooling device 4, 5 is derived.

[0183] Meanwhile, the moisture in the water-sprinkling cooling device 4, 5 is discharged from the sand cooling device 5 while being held by both the cooled return sand and the discharged air. In other words, the moisture content held by the discharged air can be calculated by subtracting the moisture content held by and discharged from the cooled return sand from the total sum of the moisture content that was introduced into the water-sprinkling cooling device 4, 5, which was calculated as described above.

[0184] Thus, the second correction amount calculating unit 67 calculates the moisture content held by the cooled return sand per unit time on the basis of the moisture content of the cooled return sand measured by the cooled return sand moisture and temperature measuring instrument 20 and the cooled return sand amount per unit time discharged from the sand cooling device 5.

[0185] The second correction amount calculating unit 67 further subtracts the moisture content held by the cooled return sand per unit time from the total sum of the moisture content that was introduced into the water-sprinkling cooling device 4, 5 and calculates the moisture content of the discharged air.

[0186] The second correction amount calculating unit 67 calculates, on the basis of the moisture content of the discharged air that was calculated in such a manner as well as the temperature of the discharged air, the value of the relative humidity at the temperature.

[0187] The relative humidity of the discharged air calculated as described above is used instead of the value of the humidity of the discharged air measured by the discharged air temperature and humidity measuring instrument 16 in the first embodiment. If the value of the relative humidity is at a value close to 100%, such as 95% or more, condensation may occur in the sand cooling device 5 as well as the air blowing pipes forming the air passage. Thus, for the prevention of condensation, the second correction amount calculating unit 67 considers one or more correction controls such as increasing the airflow amount by means of the increasing of the rotation speed of the inverter motor 15 of the air introducing device 6, reducing the loaded amount of return sand by means of the decreasing of the rotation speed of the inverter motor 10 of the belt feeder 9, and increasing the set temperature in the air heating device 13, and transmits the one or more control operations to the control unit 35, as in the second correction amount calculating unit 37 in the first embodiment.

[0188] The correction amounts are calculated on the basis of equations (1)-(4) as in the first embodiment, but because prior to this calculation the absolute humidity is used as the humidity in equations (1)-(4), the second correction amount calculating unit 67 converts the calculated relative humidity of the discharged air to the absolute humidity.

(Action correction method dependent on temperature of discharged air)

[0189] Next, an action correction method dependent on the temperature of discharged air using the second correction amount calculating unit 67 of the return sand cooling system 61 described above will be described. The present method corresponds to step S51 described in fig. 9 and is executed after the action correction method dependent on the moisture content and temperature of the cooled return sand (step S21).

[0190] First, the appropriate water addition amount determination and water sprinkling instruction method (steps S1-S14) and the action correction method dependent on the moisture and temperature of the cooled return sand (step S21)

are executed, and then the present correction process described as step S51 is performed. Fig. 10 illustrates the details of correction process S51.

[0191] In correction process S51, first, the discharged air temperature measuring instrument 66 measures the temperature of the discharged air discharged from the sand cooling device 5, and transmits the measurement result to the control device 63 (step S52).

[0192] The second correction amount calculating unit 67 of the control unit 35 receives the temperature of the discharged air from the discharged air temperature measuring instrument 66, and calculates the value of the relative humidity at the temperature (step S53). This is performed as follows.

[0193] First, the absolute humidity of the introduced air is calculated from the temperature and humidity of the introduced air measured by the introduced air temperature and humidity measuring instrument 7, and then the moisture content held by the introduced air per unit time is calculated on the basis of the airflow amount of the introduced air measured by the airflow amount measuring instrument 17 and the calculated absolute humidity of the introduced air.

[0194] Next, the moisture content held by the return sand per unit time is calculated on the basis of the moisture content of the return sand measured by the sand moisture and temperature measuring instrument 2 and the return sand amount per unit time loaded into the sand cooling device 5.

[0195] Then, the sum of the calculated moisture content held by the introduced air per unit time and moisture content held by the return sand per unit time is calculated, the water amount per unit time that was supplied to the water sprinkling device 4 via the water amount regulation valve 12 is added to this sum, and the total sum of these values is calculated.

[0196] In addition, the moisture content held by the cooled return sand per unit time is calculated on the basis of the moisture content of the cooled return sand measured by the cooled return sand moisture and temperature measuring instrument 20 and the cooled return sand amount per unit time discharged from the sand cooling device 5.

[0197] Furthermore, the moisture content held by the cooled return sand per unit time is subtracted from the total sum of the moisture content that was introduced into the water-sprinkling cooling device 4, 5, and the moisture content of the discharged air is calculated.

[0198] The second correction amount calculating unit 67 calculates, on the basis of the moisture content of the discharged air that was calculated in such a manner as well as the temperature of the discharged air, the value of the relative humidity at the temperature.

[0199] Further, the second correction amount calculating unit 67 determines whether the value of the relative humidity of the discharged air calculated as described above is greater than or equal to a prescribed value, such as 95% (step S54). This is a process equivalent to step S43 described using fig. 6. Subsequently, steps S55 and S56, which are equivalent to steps S44 and S45 in fig. 6, are sequentially executed.

[0200] Of course, the present modified example provides effects similar to those of the first embodiment.

[0201] In the present modified example in particular, because in the action correction dependent on the temperature of the discharged air the humidity of the discharged air is obtained by calculation, a hygrometer for measuring the humidity of discharged air is not needed. Because dust particles and the like are mixed with the discharged air discharged from the sand cooling device 5, if a hygrometer for measuring the humidity of discharged air has been provided, maintenance tasks such as routine cleaning of the hygrometer become necessary in order to maintain the accuracy of measurement values. Thus, the configuration of the return sand cooling system can be simplified and the costs needed for maintenance can be reduced by obtaining the humidity of discharged air by calculation.

(Second embodiment)

[0202] Next, a second embodiment of the present invention will be described.

[0203] Fig. 11 is a schematic configuration view of a return sand cooling system 71 shown as the second embodiment of the present invention, and fig. 12 is a block diagram of a control device in the return sand cooling system 71.

[0204] In these figures, the same reference signs are used for structural components that are the same as those shown in fig. 1 and 2, which were described in the first embodiment, and thus, the descriptions will be omitted.

[0205] The present embodiment differs from the previously discussed first embodiment in that in the present embodiment, the determination of the appropriate water addition amount by a control device 73 is performed on the basis of the moisture content and temperature of the return sand and the temperature of the introduced air. In other words, in the second embodiment, the humidity of the introduced air does not need to be used when determining the appropriate water addition amount.

[0206] The return sand cooling system 71 of the second embodiment comprises an introduced air temperature measuring instrument 77 that measures the temperature of introduced air to be introduced into the water-sprinkling cooling device 4, 5, as shown in fig. 11, instead of the introduced air temperature and humidity measuring instrument 7 shown in fig. 1.

[0207] Furthermore, in the second embodiment, the humidity of the discharged air is not used. Thus, the return sand cooling system 71 of the second embodiment comprises a discharged air temperature measuring instrument 76 that

measures the temperature of discharged air discharged from the water-sprinkling cooling device 4, 5, as shown in fig. 11, instead of the discharged air temperature and humidity measuring instrument 16 shown in fig. 1.

[0208] In this manner, the return sand cooling system 71 comprises the introduced air temperature measuring instrument 77 and the discharged air temperature measuring instrument 76 in addition to the airflow amount measuring instrument 17 in order to measure the state of air in the air passage described above.

[0209] The introduced air temperature measuring instrument 77 is provided between the air heating device 13 and the sand cooling device 5 and measures the temperature of the introduced air to be introduced into the sand cooling device 5. The control device 73, which will be described later in more detail, is electrically connected to the introduced air temperature measuring instrument 77. The temperature of the introduced air measured by the introduced air temperature measuring instrument 77 is transmitted to the control device 73.

[0210] The discharged air temperature measuring instrument 76 is provided between the sand cooling device 5 and the dust collecting device 14 and measures the temperature of the discharged air discharged from the sand cooling device 5. The control device 73, which will be described later in more detail, is electrically connected to the discharged air temperature measuring instrument 76. The temperature of the discharged air measured by the discharged air temperature measuring instrument 76 is transmitted to the control device 73.

[0211] The moisture content and temperature of return sand measured by the sand moisture and temperature measuring instrument 2; the moisture content and temperature of cooled return sand measured by the cooled return sand moisture and temperature measuring instrument 20; the temperature and humidity of introduced air measured by the introduced air temperature measuring instrument 77; the temperature of discharged air measured by the discharged air temperature measuring instrument 76; and the airflow amount of introduced air measured by the airflow amount measuring instrument 17 are transmitted to the control device 73. The control device 73 receives the measurement values and controls the inverter motor 10 of the belt feeder 9, the water amount regulation valve 12, the inverter motor 15 of the air introducing device 6, and the air heating device 13 on the basis of the measurement values.

[0212] In this embodiment, the control device 73 determines an appropriate water addition amount on the basis of the moisture content and temperature of the return sand and the temperature of the introduced air, and performs a water sprinkling instruction.

[0213] In addition, the control device 73 performs an action correction of the system on the basis of the moisture content and temperature of the cooled return sand and the like.

[0214] The return sand cooling system 71 configured as described above comprises: a sand moisture and temperature measuring instrument 2 that measures the moisture content and temperature of return sand; a control device 73 that determines an appropriate water addition amount, which is an amount of water to be added to the return sand; a water-sprinkling cooling device 4, 5 that adds water of the appropriate water addition amount to the return sand and cools the return sand by the latent heat of vaporization of water to obtain cooled return sand; an air introducing device 6 that introduces air into the water-sprinkling cooling device 4, 5; and an introduced air temperature measuring instrument 77 that measures the temperature of air to be introduced into the water-sprinkling cooling device 4, 5; the control device 73 determining the appropriate water addition amount on the basis of the moisture content and temperature of the return sand and the temperature of the introduced air.

[0215] This allows appropriate conditions in the return sand cooling system to be achieved that take into account the temperature of the introduced air, which enables stable cooling and moisture content effects to be achieved even under conditions such as seasonal changes in temperatures and humidity. Thus, return sand can be reliably cooled to a target temperature regardless of the state of introduced air.

(Third embodiment)

[0216] Next, a third embodiment of the present invention will be described.

[0217] Fig. 13 is a schematic configuration view of a return sand cooling system 81 shown as the third embodiment of the present invention, and fig. 14 is a block diagram of a control device in the return sand cooling system 81.

[0218] In these figures, the same reference signs are used for structural components that are the same as those shown in fig. 11 and 12, which were described in the second embodiment, and thus, the descriptions will be omitted.

[0219] The third embodiment differs from the previously discussed second embodiment in that in the third embodiment, the determination of an appropriate water addition amount by a control device 83 is performed on the basis of the moisture content and temperature of the return sand, and the moisture content and temperature of the cooled return sand.

[0220] In other words, in this embodiment, the return sand cooling system 81 that cools return sand and adjusts the moisture content of cooled return sand shown in fig. 13 comprises: a sand moisture and temperature measuring instrument 2 that measures the moisture content and temperature of the return sand; a control device 83 that determines an appropriate water addition amount, which is an amount of water to be added to the return sand; a water-sprinkling cooling device 4, 5 that adds water of the appropriate water addition amount to the return sand and cools the return sand by the latent heat of vaporization of water to obtain the cooled return sand; an air introducing device 6 that introduces air into

the water-sprinkling cooling device 4, 5; and a cooled return sand moisture and temperature measuring instrument 20 that measures the moisture content and temperature of the cooled return sand; the control device 83 determining the appropriate water addition amount on the basis of the moisture content and temperature of the return sand, and the moisture content and temperature of the cooled return sand.

[0221] In the present embodiment, an appropriate water addition amount is determined by the output of the sand moisture and temperature measuring instrument 2 and the output of the cooled return sand moisture and temperature measuring instrument 20. Thus, the system does not comprise the introduced air temperature measuring instrument 77 and the discharged air temperature measuring instrument 76 shown in fig. 11, which are structural components of the second embodiment.

[0222] In the present embodiment as well, effects similar to those of the previously discussed second embodiment can be obtained, and return sand can be cooled to a target temperature.

[0223] The return sand cooling system and return sand cooling method of the present invention are not to be construed as being limited to the embodiments disclosed above that were explained with reference to drawings, and various other modified examples may be contemplated within the technical scope thereof.

[0224] For example, in the appropriate water addition amount determination and water sprinkling instruction of the first embodiment, in the case of state 1, the increasing of the airflow amount, the reducing of the loaded amount of the return sand, and the increasing of the temperature of the introduced air were carried out in this order, but the order is not limited thereto and alternative orders can be contemplated. For example, the increasing of the temperature of the introduced air may be attempted first. In addition, in this case, one or more control operations may be determined so as to control three kinds of devices, as in the inverter motor 15 of the air introducing device 6, the inverter motor 10 of the belt feeder 9, and the air heating device 13, and one or more control operations may be determined so as to control one or two kinds of devices among these devices.

[0225] The same applies to other cases in which there are a plurality of devices to be controlled, such as state 3 of the water sprinkling instruction determination and water sprinkling instruction, states A and D in the action correction dependent on the moisture and temperature of the cooled return sand, and the processes in the action correction dependent on the temperature and humidity of the discharged air.

[0226] In addition, in each of the embodiments described above, the water sprinkling device 4 and the sand cooling device 5 were individually arranged, and the water-added return sand to which water was added in the water sprinkling device 4 was supplied to the sand cooling device 5, but a water-sprinkling cooling device in which these devices are integrated may be used so long as the water sprinkled onto the return sand is dispersed throughout the return sand by means of agitation and mixing and the contact between the air that was introduced and the return sand is sufficiently performed.

[0227] In addition, in each of the embodiments described above, the airflow amount in the air introducing device 6 was adjusted by the inverter motor 15, but instead, a damper may be provided in the air passage to adjust the airflow amount by means of the damper.

[0228] In addition to the above, it is possible to mix and match the configurations indicated in the embodiments described above and to appropriately modify the configurations to other configurations, without departing from the spirit of this invention.

REFERENCE SIGNS LIST

[0229]

1, 61, 71, 81	Return sand cooling system
2	Sand moisture and temperature measuring instrument
3, 63, 73, 83	Control device
4	Water-sprinkling device (water-sprinkling cooling device)
5	Sand cooling device (water-sprinkling cooling device)
6	Air introducing device
7	Introduced air temperature and humidity measuring instrument
8	Hopper
9	Belt feeder
10	Inverter motor
11	Water source
12	Water amount regulation valve
13	Air heating device
14	Dust collecting device
15	Inverter motor

16	Discharged air temperature and humidity measuring instrument
17	Airflow amount measuring instrument
18	Belt conveyor
19	Motor
5 20	Cooled return sand moisture and temperature measuring instrument
31	Required amount of water evaporation calculating unit
32	Allowable amount of water vapor evaporation calculating unit
33	Appropriate water addition amount determining unit
34	Comparison computation unit
10 35	Control unit
36	First correction amount calculating unit
37, 67	Second correction amount calculating unit
66, 76	Discharged air temperature measuring instrument
77	Introduced air temperature measuring instrument
15	

Claims

1. A return sand cooling system that cools return sand and adjusts the moisture content of cooled return sand, wherein the return sand cooling system comprises:
 - a sand moisture and temperature measuring instrument that measures the moisture content and temperature of the return sand;
 - a control device that determines an appropriate water addition amount, which is an amount of water to be added to the return sand;
 - a water-sprinkling cooling device that adds water of the appropriate water addition amount to the return sand and cools the return sand by the latent heat of vaporization of water to obtain the cooled return sand;
 - an air introducing device that introduces air into the water-sprinkling cooling device; and
 - an introduced air temperature and humidity measuring instrument that measures the temperature and humidity of introduced air to be introduced into the water-sprinkling cooling device;
 - the control device determining the appropriate water addition amount on the basis of the moisture content and temperature of the return sand, and the temperature and humidity of the introduced air.
2. The return sand cooling system according to claim 1, comprising an airflow amount measuring instrument that measures the airflow amount of the introduced air; wherein the control device determines the appropriate water addition amount further on the basis of the airflow amount.
3. The return sand cooling system according to claim 2, wherein the control device comprises:
 - a required amount of water evaporation calculating unit that calculates a required amount of water evaporation on the basis of the temperature of the return sand and the loaded amount of the return sand;
 - an allowable amount of water vapor evaporation calculating unit that calculates an allowable amount of water vapor evaporation on the basis of the temperature and humidity of the introduced air and the airflow amount;
 - a comparison computation unit that performs a comparison of the required amount of water evaporation and the allowable amount of water vapor evaporation, and determines a control operation for controlling the airflow amount, the loaded amount of the return sand, or the temperature of the introduced air, or any combination thereof, on the basis of the result of the comparison; and
 - a control unit that executes the control operation.
4. The return sand cooling system according to claim 3, wherein if the required amount of water evaporation is greater than the allowable amount of water vapor evaporation, the control operation is an operation for increasing the airflow amount, reducing the loaded amount of the return sand, or increasing the temperature of the introduced air, or any combination thereof.
5. The return sand cooling system according to claim 3, wherein if the required amount of water evaporation is less than the allowable amount of water vapor evaporation, the control operation is an operation for either or both reducing the airflow amount and increasing the loaded amount of the return sand.

6. The return sand cooling system according to claim 4 or 5, wherein the control device comprises an appropriate water addition amount determining unit that determines the appropriate water addition amount on the basis of the required amount of water evaporation that was calculated again from measurement values measured again in each measuring instrument after the control operation.

7. The return sand cooling system according to any one of claims 1-6, comprising a cooled return sand moisture and temperature measuring instrument that measures the moisture content and temperature of the cooled return sand; wherein the control device comprises a first correction amount calculating unit that calculates a correction amount of the airflow amount of the introduced air, the loaded amount of the return sand, or the appropriate water addition amount, or any combination thereof, on the basis of the moisture content and temperature of the cooled return sand.

8. The return sand cooling system according to any one of claims 1-7, comprising a discharged air temperature and humidity measuring instrument that measures the temperature and humidity of discharged air discharged from the water-sprinkling cooling device; wherein the control device comprises a second correction amount calculating unit that calculates a correction amount of the airflow amount of the introduced air, the loaded amount of the return sand, or the temperature of the introduced air, or any combination thereof, on the basis of the temperature and humidity of the discharged air.

9. The return sand cooling system according to any one of claims 1-6, comprising a discharged air temperature measuring instrument that measures the temperature of discharged air discharged from the water-sprinkling cooling device; wherein the control device:

calculates the humidity of the discharged air on the basis of the temperature of the discharged air; and corrects, if the humidity of the discharged air is greater than or equal to a prescribed value, the airflow amount of the introduced air, the loaded amount of the return sand, or the temperature of the introduced air, or any combination thereof.

10. The return sand cooling system according to claim 9, comprising a cooled return sand moisture and temperature measuring instrument that measures the moisture content and temperature of the cooled return sand; wherein the control device calculates a total sum of the moisture content held by the introduced air per unit time based on the humidity of the introduced air, the moisture content held by the return sand per unit time based on the moisture content of the return sand, and the water amount per unit time supplied to the water-sprinkling cooling device, and subtracts the moisture content held by the cooled return sand per unit time based on the moisture content of the cooled return sand from the total sum to calculate the humidity of the discharged air.

11. The return sand cooling system according to claim 10, wherein the control device comprises a first correction amount calculating unit that calculates a correction amount of the airflow amount of the introduced air, the loaded amount of the return sand, or the appropriate water addition amount, or any combination thereof, on the basis of the moisture content and temperature of the cooled return sand.

12. A return sand cooling method that cools return sand and adjusts the moisture content of cooled return sand, wherein the return sand cooling method comprises:

measuring the moisture content and temperature of the return sand;
determining an appropriate water addition amount, which is an amount of water to be added to the return sand;
adding water of the appropriate water addition amount to the return sand and cooling the return sand by the latent heat of vaporization of water while introducing air to obtain the cooled return sand; and
measuring the temperature and humidity of introduced air to be introduced;
the return sand cooling method determining the appropriate water addition amount on the basis of the moisture content and temperature of the return sand, and the temperature and humidity of the introduced air.

13. The return sand cooling method according to claim 12, further comprising measuring the airflow amount of the introduced air; wherein the return sand cooling method determines the appropriate water addition amount further on the basis of the airflow amount.

14. The return sand cooling method according to claim 12 or 13, further comprising measuring the temperature of discharged air discharged at the time of cooling of the return sand;

wherein the return sand cooling method calculates the humidity of the discharged air on the basis of the temperature of the discharged air; and
 corrects, if the humidity of the discharged air is greater than or equal to a prescribed value, the airflow amount of the introduced air, the loaded amount of the return sand, or the temperature of the introduced air, or any combination thereof.

15. A return sand cooling system that cools return sand and adjusts the moisture content of cooled return sand, wherein the return sand cooling system comprises:

a sand moisture and temperature measuring instrument that measures the moisture content and temperature of the return sand;
 a control device that determines an appropriate water addition amount, which is an amount of water to be added to the return sand;
 a water-sprinkling cooling device that adds water of the appropriate water addition amount to the return sand and cools the return sand by the latent heat of vaporization of water to obtain the cooled return sand;
 an air introducing device that introduces air into the water-sprinkling cooling device; and
 an introduced air temperature measuring instrument that measures the temperature of air to be introduced into the water-sprinkling cooling device;
 the control device determining the appropriate water addition amount on the basis of the moisture content and temperature of the return sand, and the temperature of the introduced air.

16. A return sand cooling system that cools return sand and adjusts the moisture content of cooled return sand, wherein the return sand cooling system comprises:

a sand moisture and temperature measuring instrument that measures the moisture content and temperature of the return sand;
 a control device that determines an appropriate water addition amount, which is an amount of water to be added to the return sand;
 a water-sprinkling cooling device that adds water of the appropriate water addition amount to the return sand and cools the return sand by the latent heat of vaporization of water to obtain the cooled return sand;
 an air introducing device that introduces air into the water-sprinkling cooling device; and
 a cooled return sand moisture and temperature measuring instrument that measures the moisture content and temperature of the cooled return sand;
 the control device determining the appropriate water addition amount on the basis of the moisture content and temperature of the return sand, and the moisture content and temperature of the cooled return sand.

17. The return sand cooling system according to claim 15 or 16, comprising an airflow amount measuring instrument that measures the airflow amount of introduced air to be introduced into the water-sprinkling cooling device; wherein the control device determines the appropriate water addition amount further on the basis of the airflow amount.

18. A return sand cooling method that cools return sand and adjusts the moisture content of cooled return sand, wherein the return sand cooling method comprises:

measuring the moisture content and temperature of the return sand;
 determining an appropriate water addition amount, which is an amount of water to be added to the return sand;
 adding water of the appropriate water addition amount to the return sand and cooling the return sand by the latent heat of vaporization of water while introducing air to obtain the cooled return sand; and
 measuring the temperature of air to be introduced;
 the return sand cooling method determining the appropriate water addition amount on the basis of the moisture content and temperature of the return sand, and the temperature of the introduced air.

19. A return sand cooling method that cools return sand and adjusts the moisture content of cooled return sand, wherein the return sand cooling method comprises:

measuring the moisture content and temperature of the return sand;
 determining an appropriate water addition amount, which is an amount of water to be added to the return sand;
 adding water of the appropriate water addition amount to the return sand and cooling the return sand by the

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latent heat of vaporization of water while introducing air to obtain the cooled return sand; and
measuring the moisture content and temperature of the cooled return sand;
the return sand cooling method determining the appropriate water addition amount on the basis of the moisture
content and temperature of the return sand, and the moisture content and temperature of the cooled return sand.

- 5
- 20.** The return sand cooling method according to claim 18 or 19, further comprising measuring the airflow amount of
air to be introduced;
wherein the return sand cooling method determines the appropriate water addition amount further on the basis of
the airflow amount.
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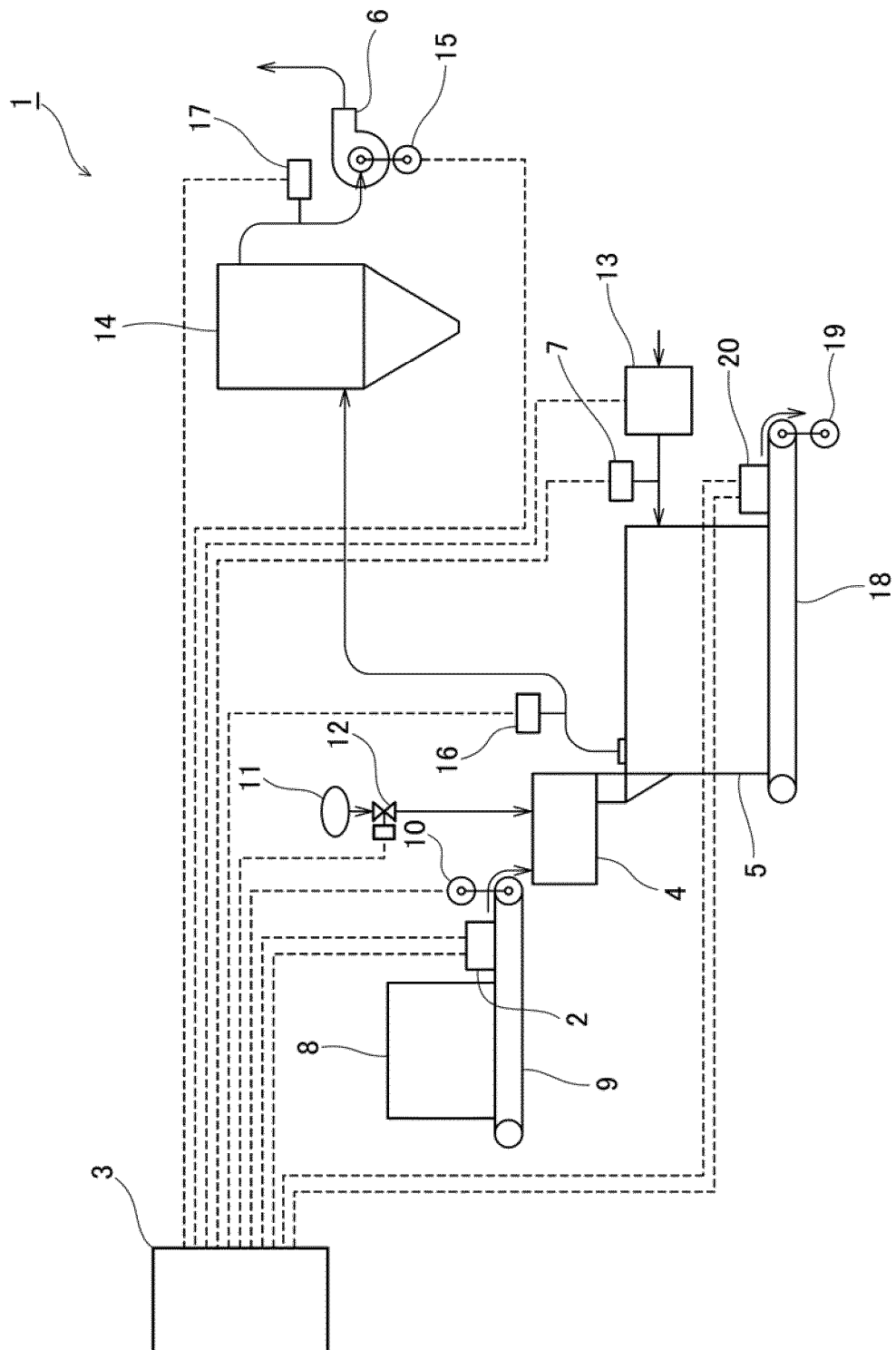
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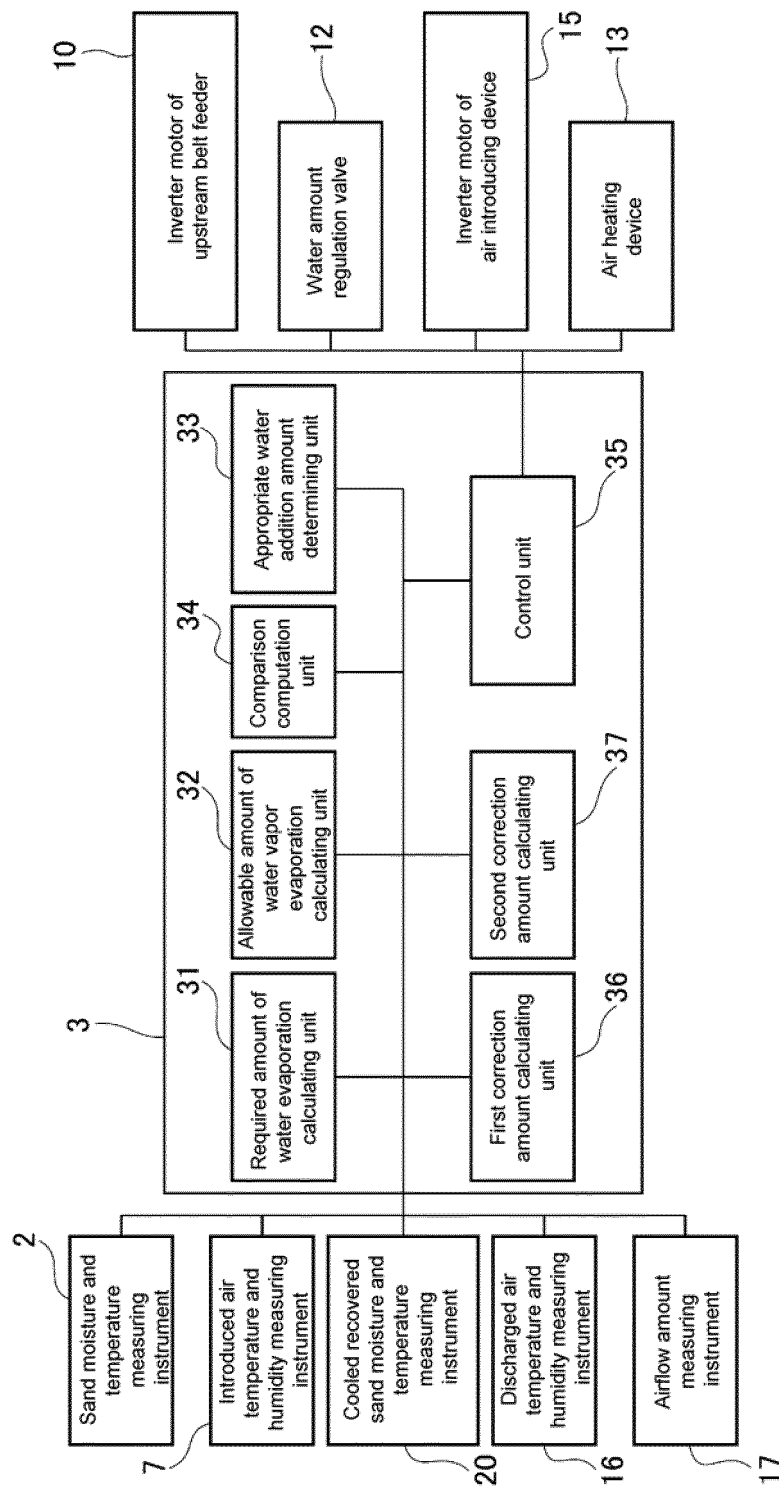
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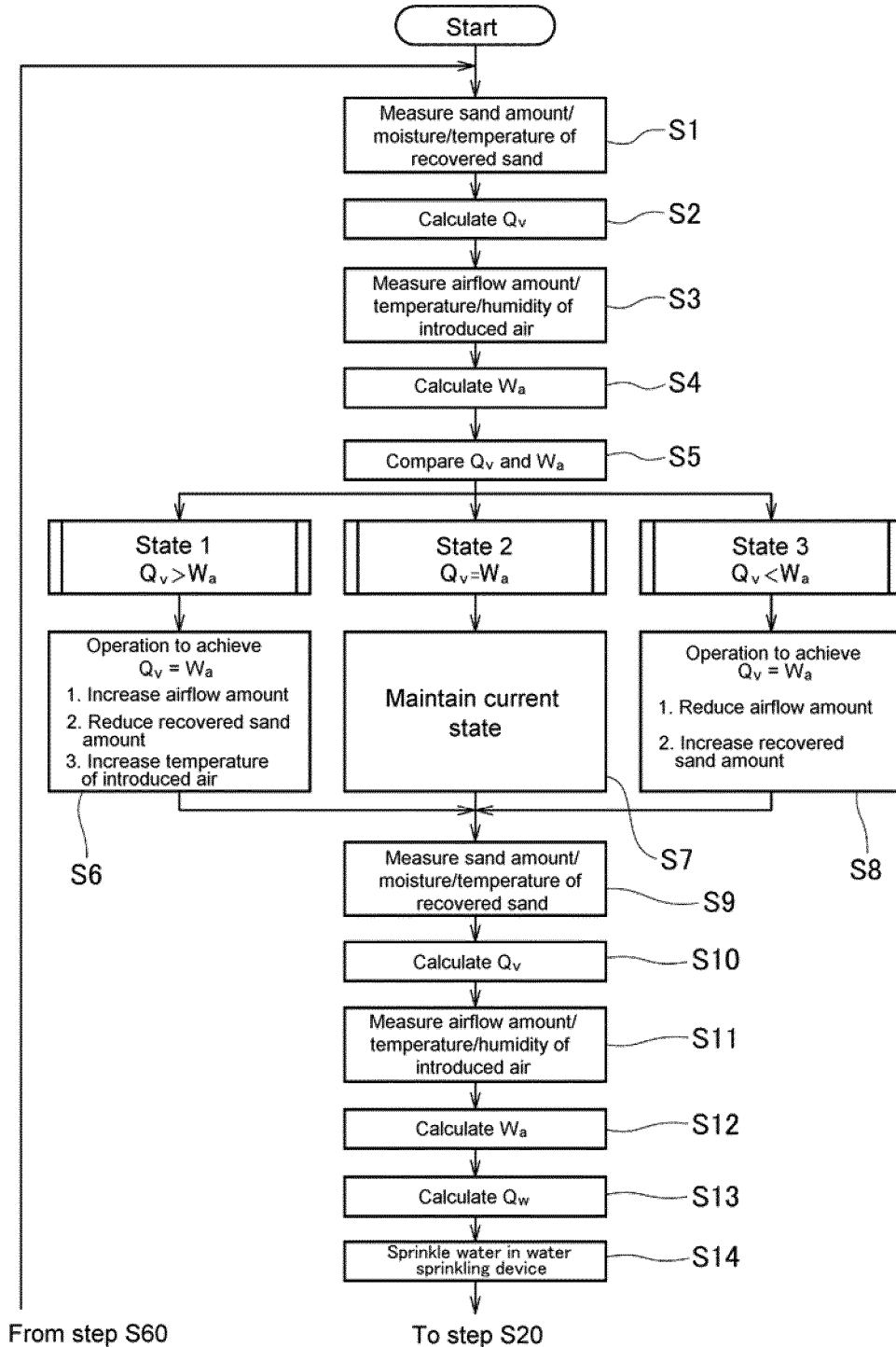
[FIG. 1]



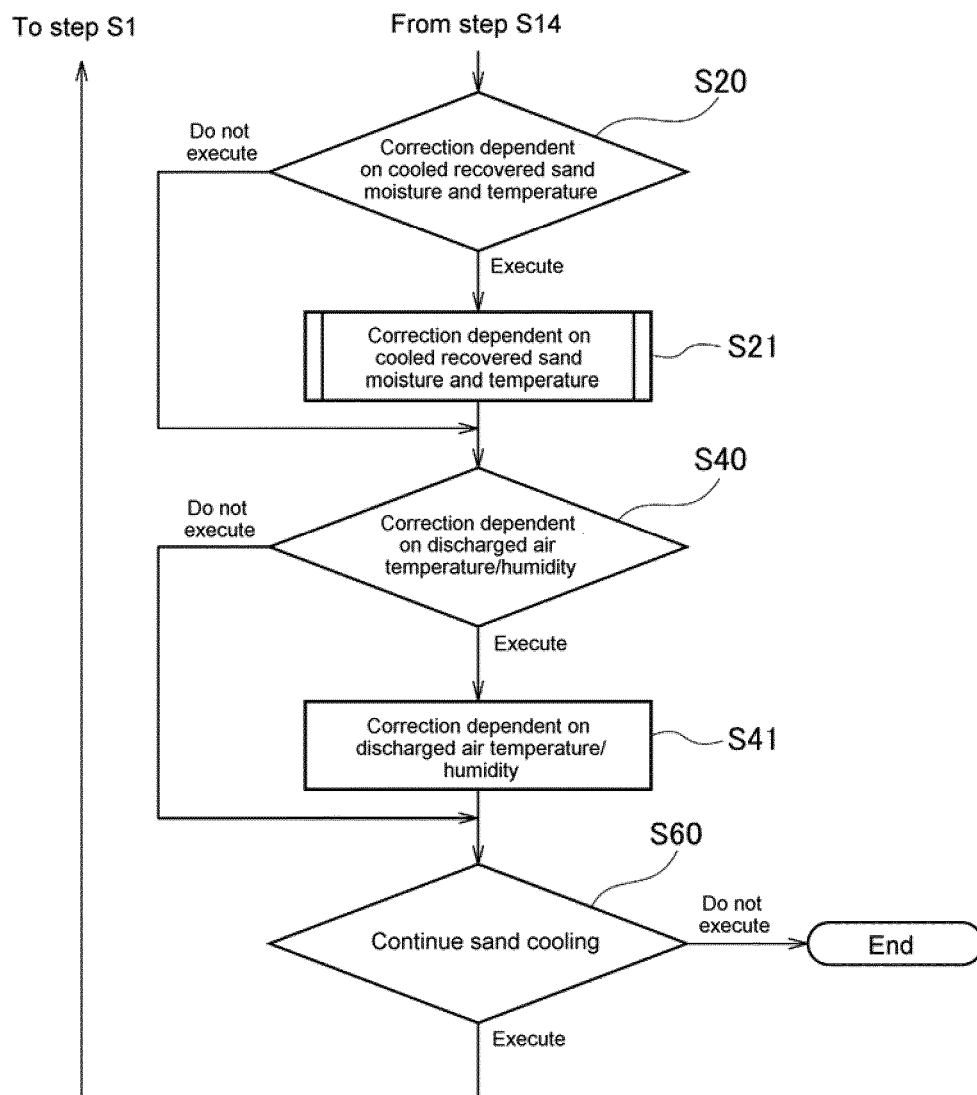
[FIG. 2]



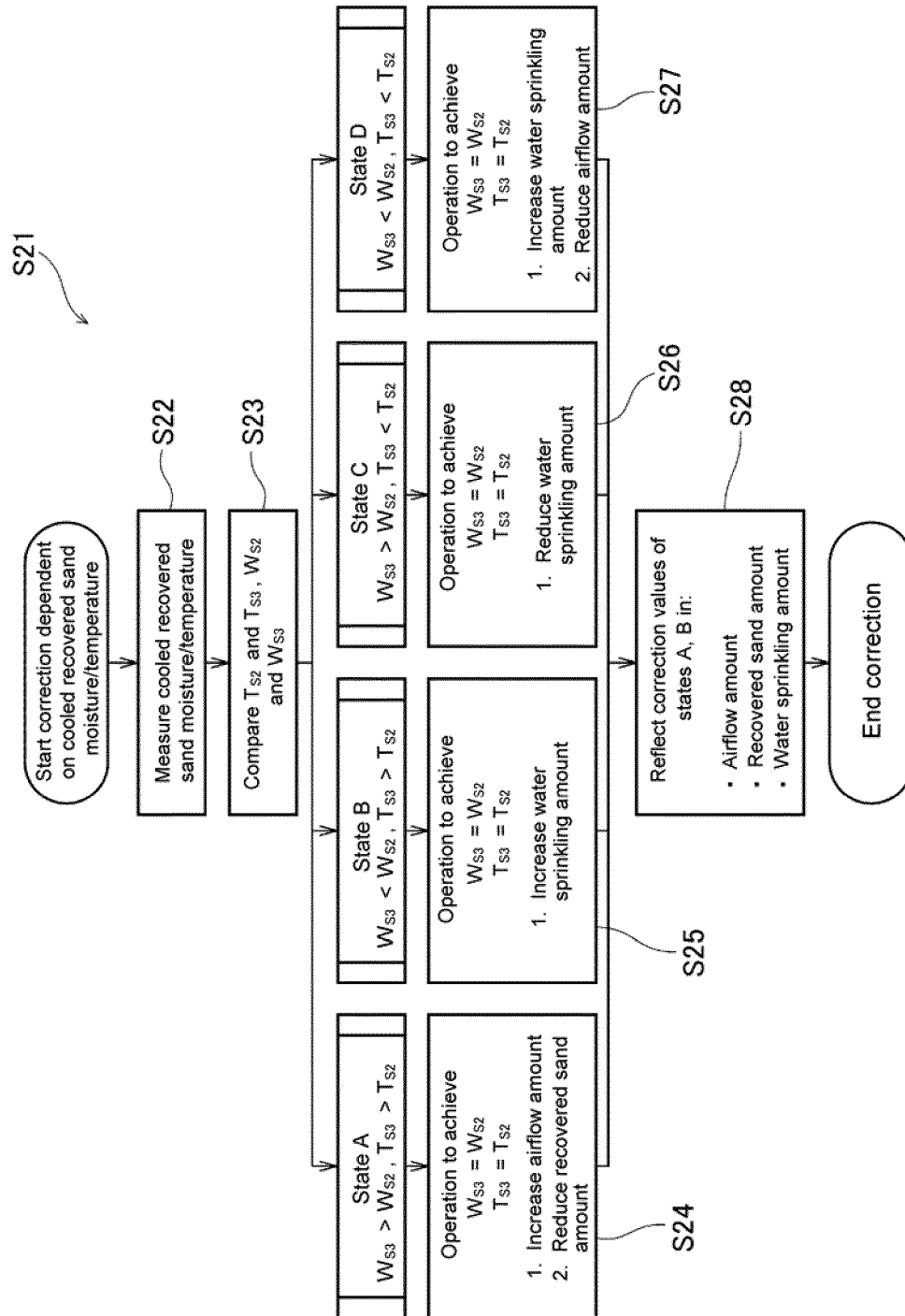
[FIG. 3]



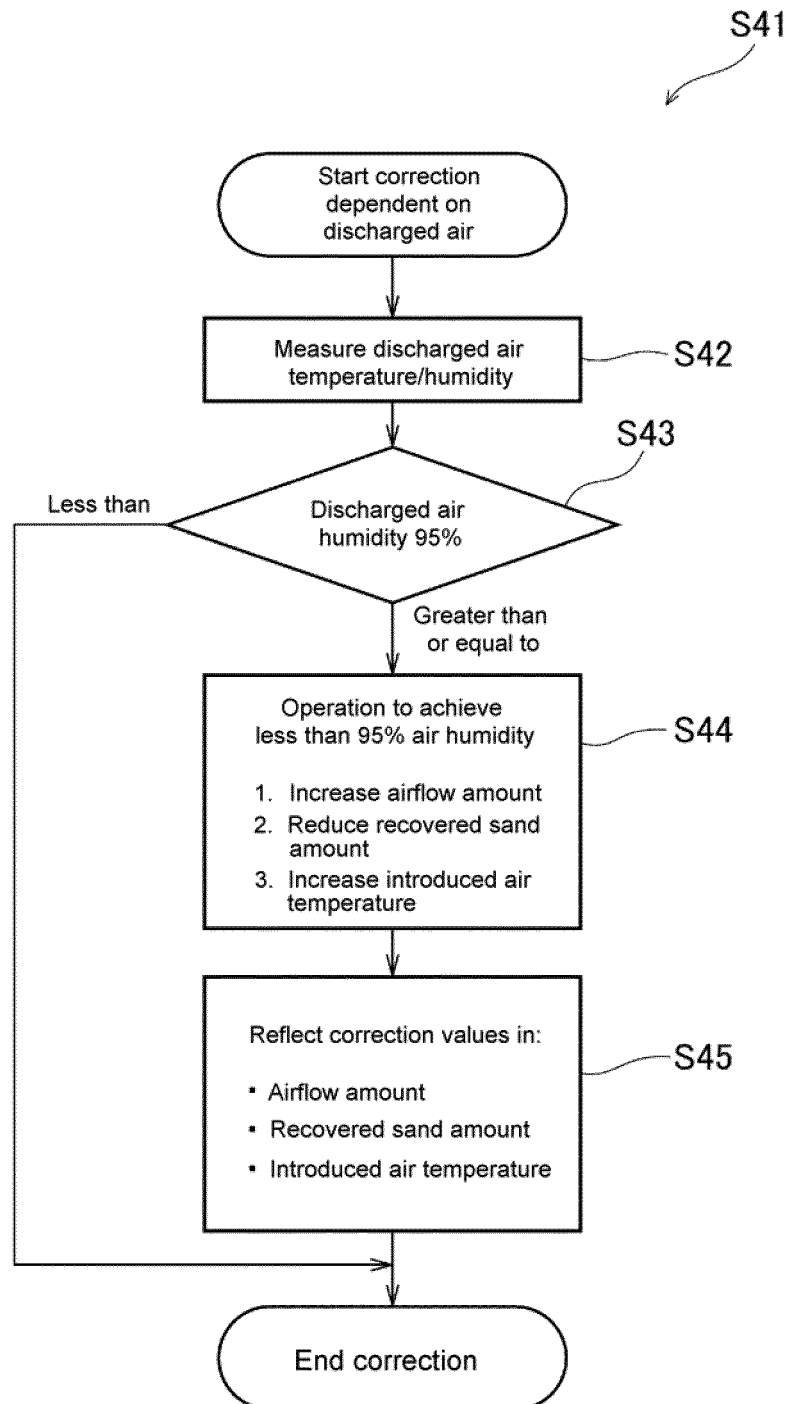
[FIG. 4]



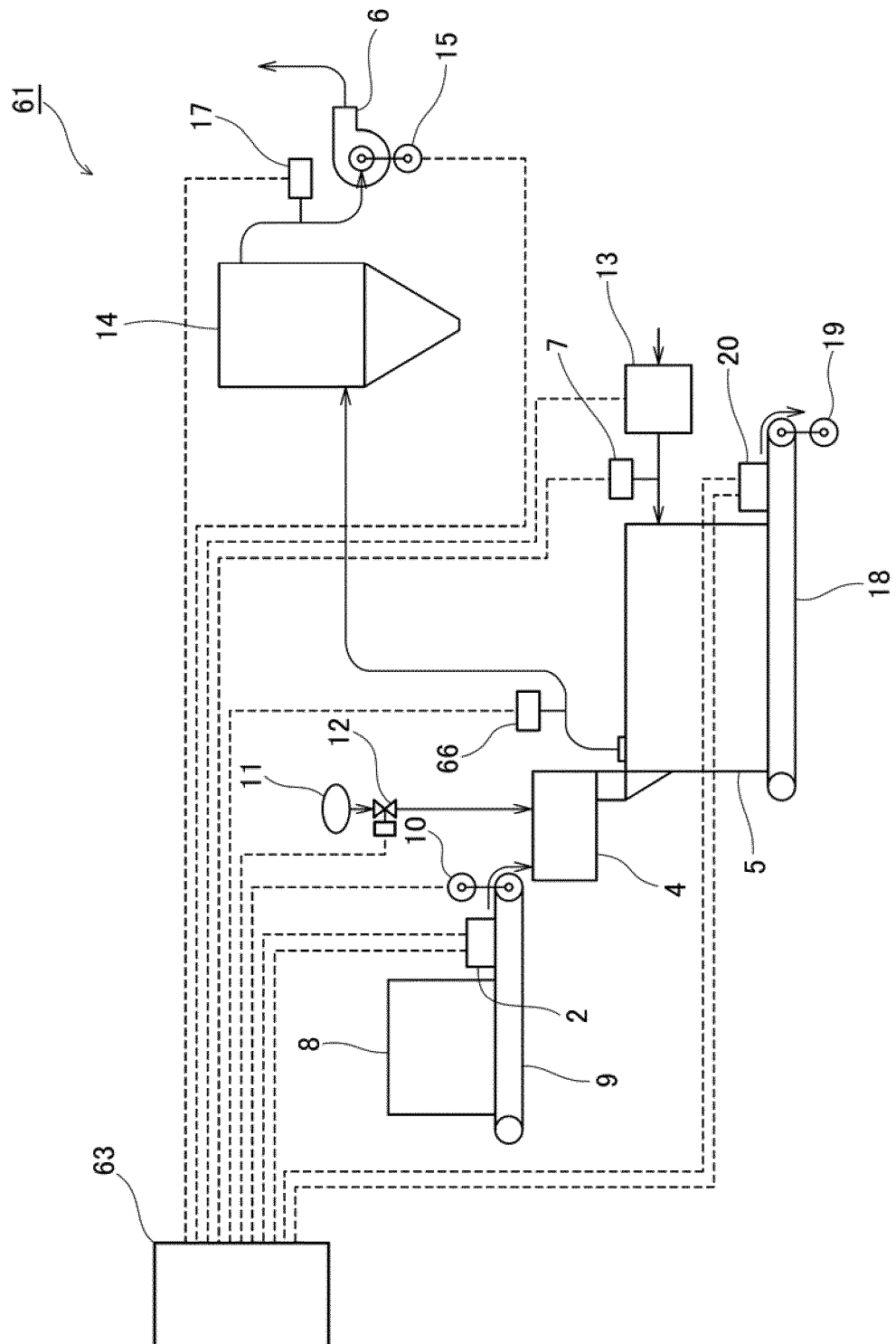
[FIG. 5]



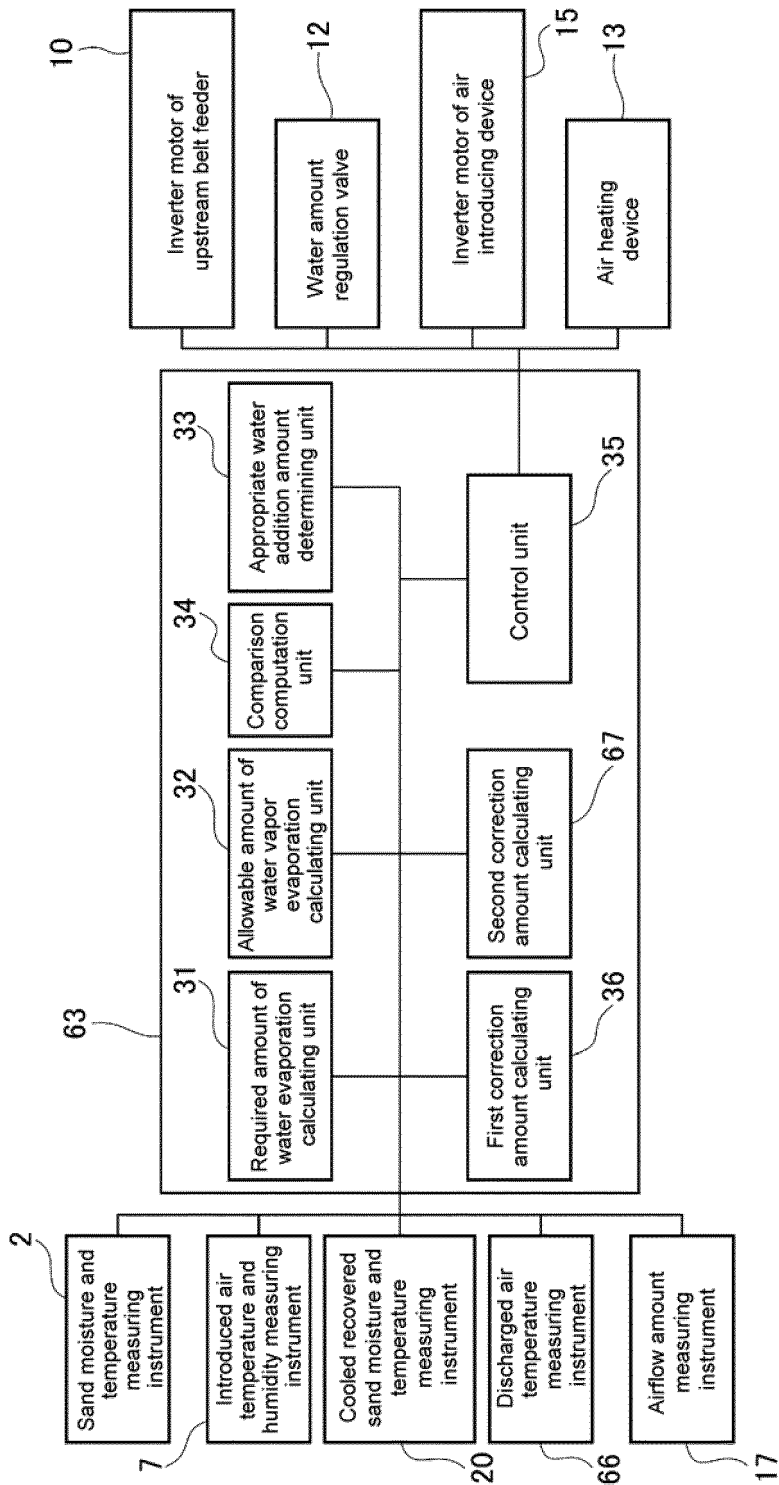
[FIG. 6]



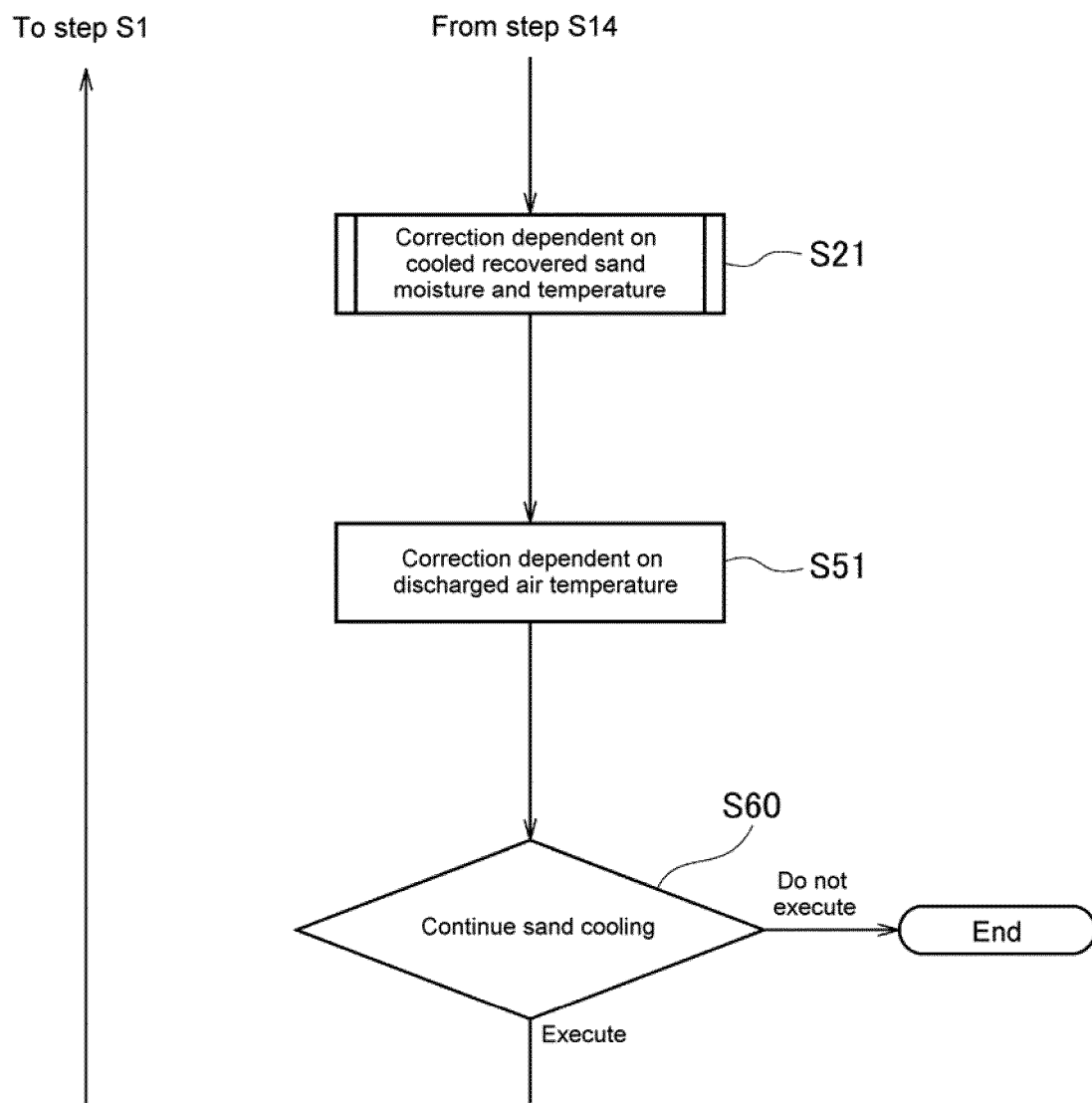
[FIG. 7]



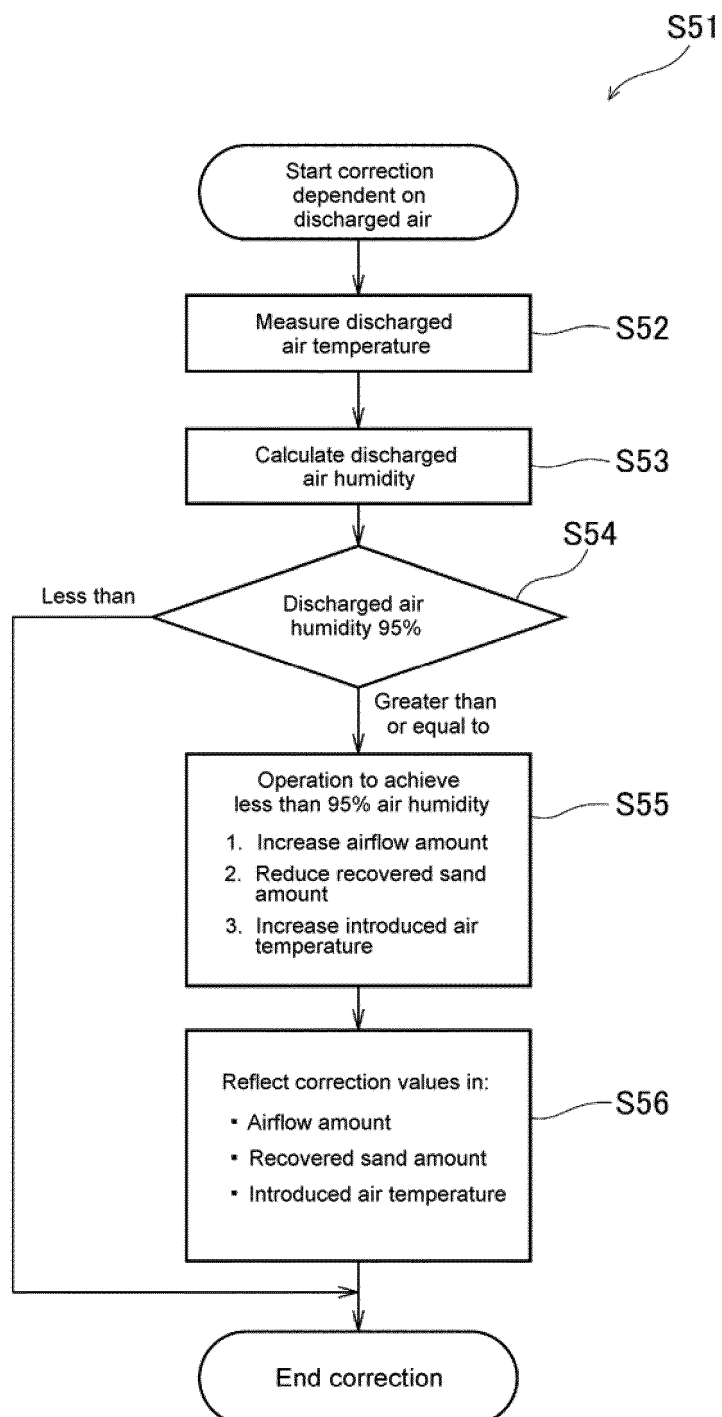
[FIG. 8]



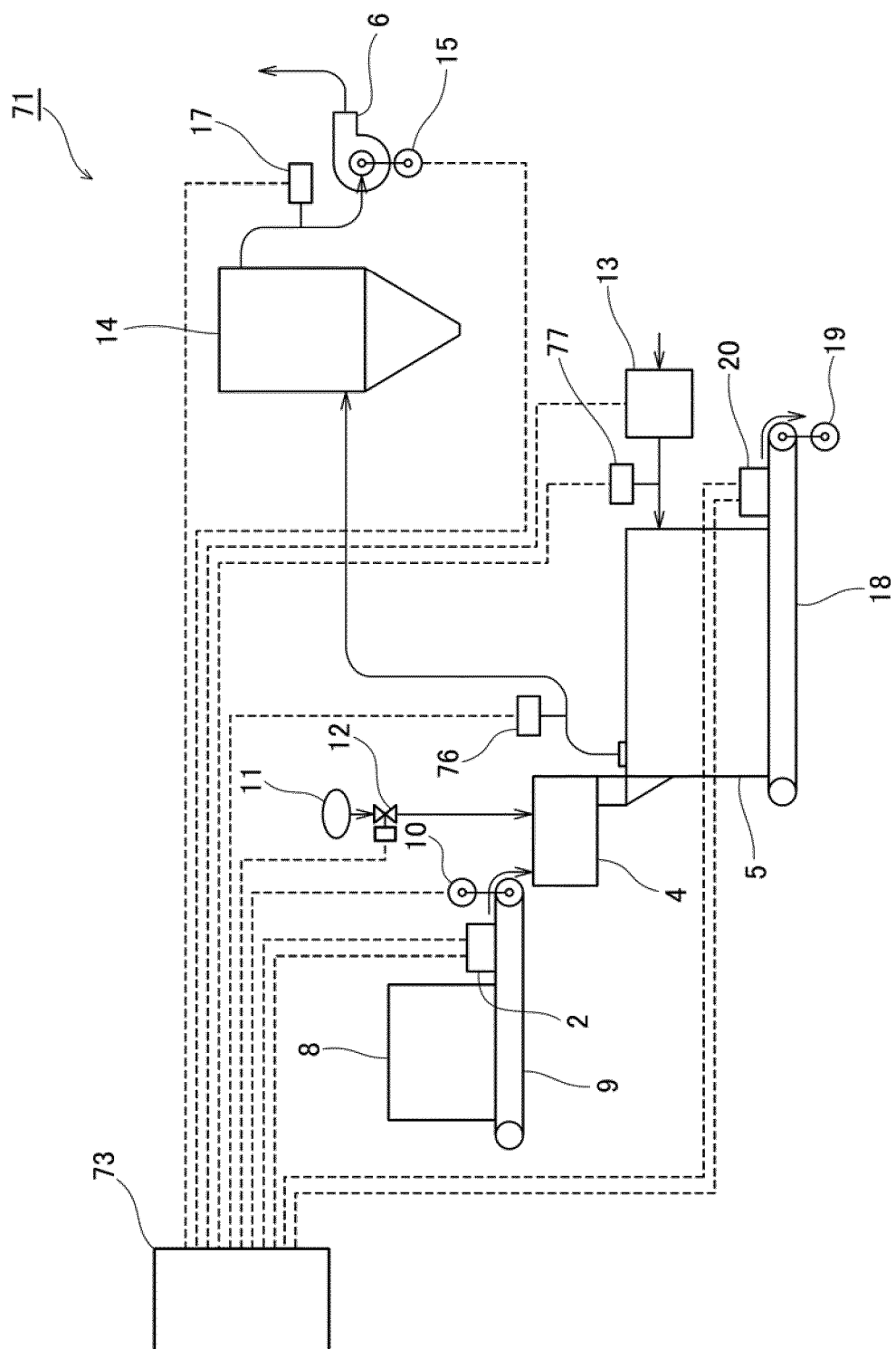
[FIG. 9]



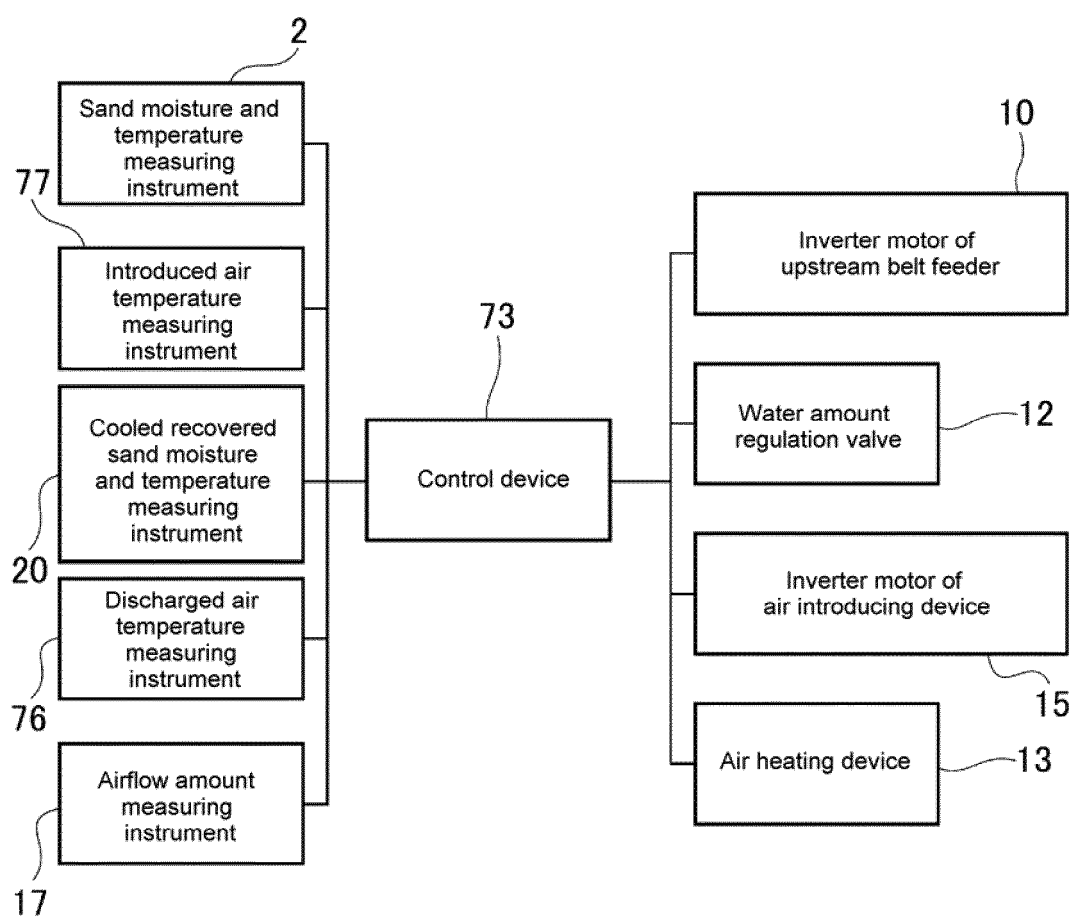
[FIG. 10]



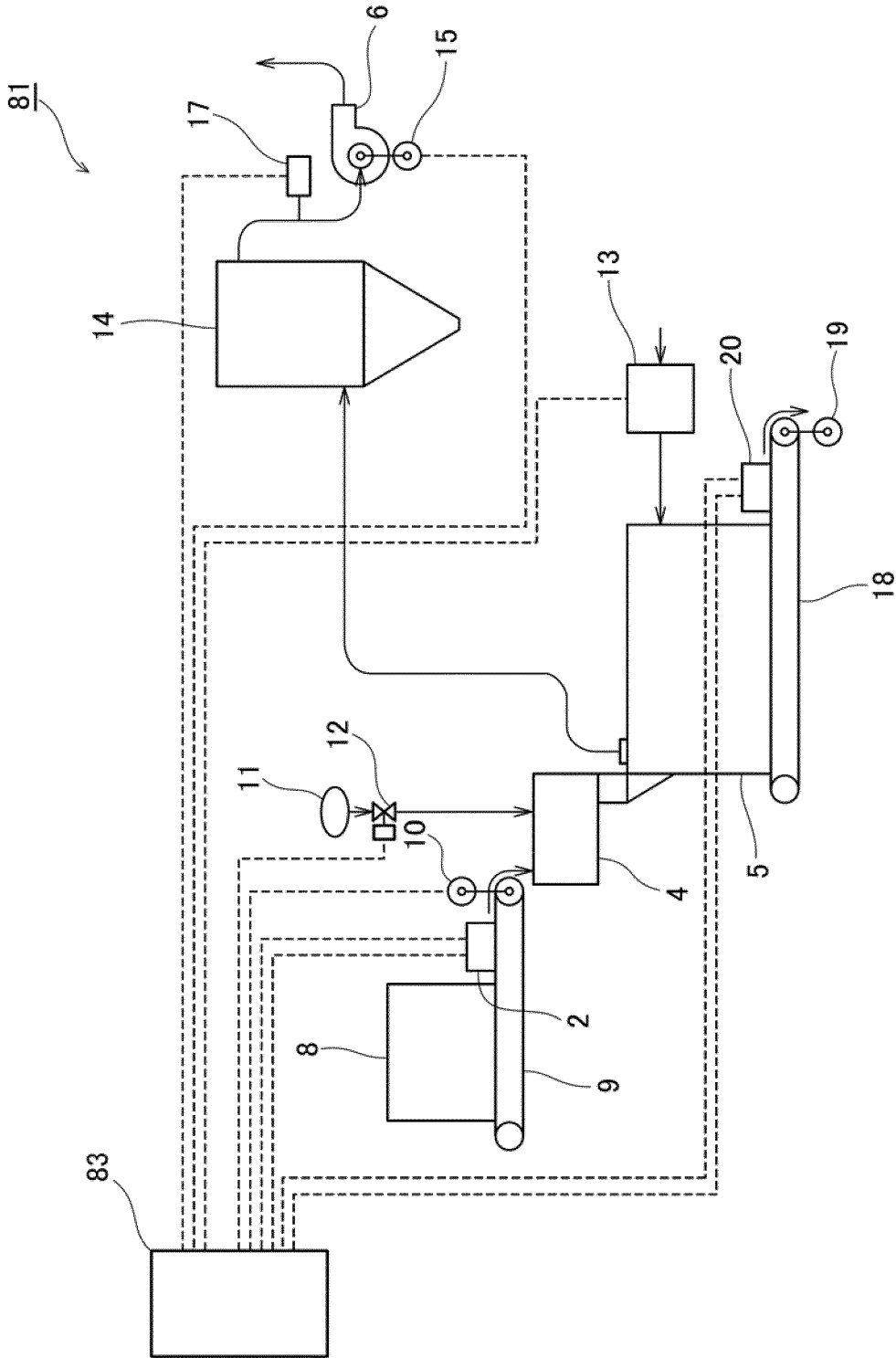
[FIG. 11]



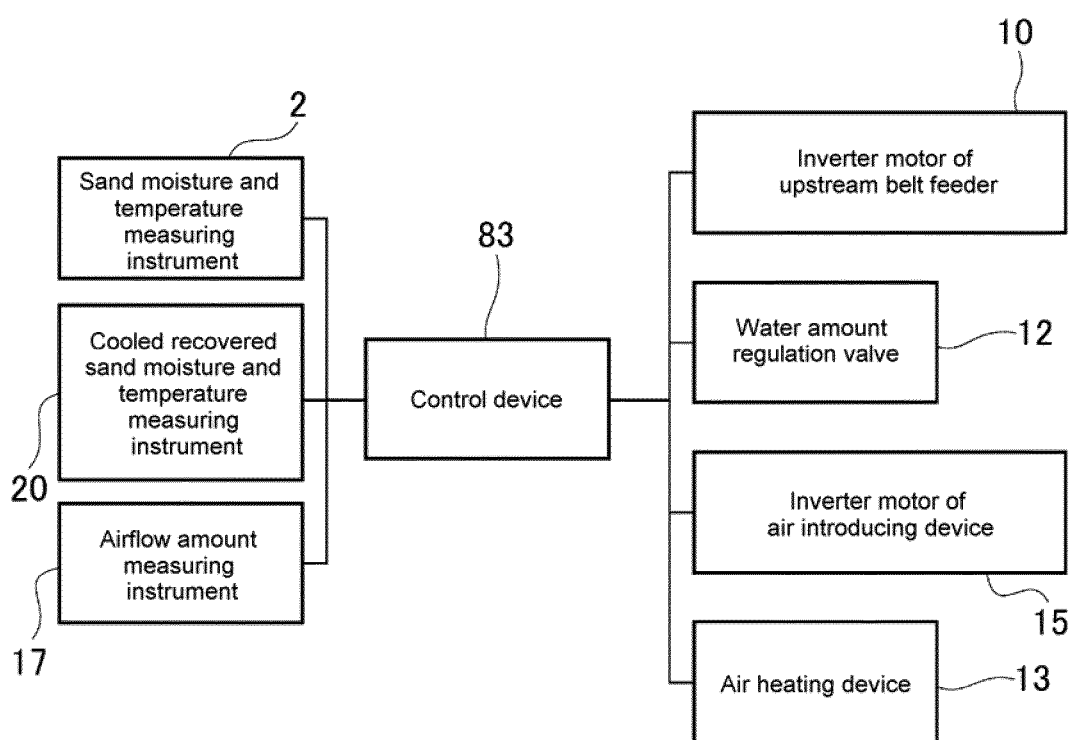
[FIG. 12]



[FIG. 13]



[FIG. 14]



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2017/032307

A. CLASSIFICATION OF SUBJECT MATTER

B22C5/08(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

B22C5/00-B22C5/18

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho 1922-1996 Jitsuyo Shinan Toroku Koho 1996-2017

Kokai Jitsuyo Shinan Koho 1971-2017 Toroku Jitsuyo Shinan Koho 1994-2017

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	WO 2013/118477 A1 (Nara Machinery Co., Ltd.), 15 August 2013 (15.08.2013), paragraphs [0032] to [0088]; fig. 1 to 12 (Family: none)	16-17, 19-20 <u>1-2, 7, 12-13,</u> <u>15, 18</u>
Y	JP 57-50236 A (Amano Co., Ltd.), 24 March 1982 (24.03.1982), page 2, lower left column, line 14 to page 4, lower right column, line 18; fig. 1 to 3 (Family: none)	1-2, 7, 12-13, 15, 18
A	JP 2011-224622 A (Sinto Kogyo Ltd.), 10 November 2011 (10.11.2011), paragraphs [0016] to [0031]; fig. 1 to 3 (Family: none)	1-20

☒ Further documents are listed in the continuation of Box C.
 ☐ See patent family annex.

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07 November 2017 (07.11.17)Date of mailing of the international search report
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Japan Patent Office
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C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 8-309477 A (Sinto Kogyo Ltd.), 26 November 1996 (26.11.1996), paragraphs [0005] to [0011]; fig. 1 (Family: none)	1-20
A	JP 59-127948 A (Toyoda Automatic Loom Works, Ltd.), 23 July 1984 (23.07.1984), entire text; fig. 1 to 7 (Family: none)	1-20

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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP S6240098 B [0005]