(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 4 524 218 A1

(12) **EUROPEAN PATENT APPLICATION**
published in accordance with Art. 153(4) EPC

(43) Date of publication:
19.03.2025 Bulletin 2025/12

(21) Application number: **23842752.0**

(22) Date of filing: **23.06.2023**

(51) International Patent Classification (IPC):
C10B 53/08 *(2006.01)* ***C10B 41/00*** *(2006.01)*
C10B 47/20 *(2006.01)*

(52) Cooperative Patent Classification (CPC):
C10B 41/00; C10B 47/20; C10B 53/08

(86) International application number:
PCT/JP2023/023272

(87) International publication number:
WO 2024/018821 (25.01.2024 Gazette 2024/04)

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC ME MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA
Designated Validation States:
KH MA MD TN

(30) Priority: **21.07.2022 JP 2022116231**

(71) Applicant: **JFE Steel Corporation**
Tokyo 100-0011 (JP)

(72) Inventors:
- **KIMURA, Yuki**
  Tokyo 100-0011 (JP)
- **HIROIKE, Syoichiro**
  Tokyo 100-0011 (JP)

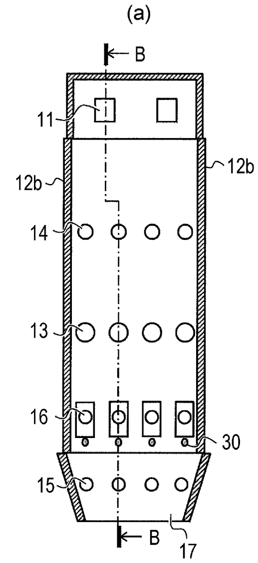
(74) Representative: **Hoffmann Eitle**
Patent- und Rechtsanwälte PartmbB
Arabellastraße 30
81925 München (DE)

(54) **OPERATION METHOD OF VERTICAL DRY DISTILLATION FURNACE, PRODUCTION METHOD OF FERROCOKE AND VERTICAL DRY DISTILLATION FURNACE EQUIPMENT**

(57) Provided are a method of operating a vertical carbonization furnace that is capable of detecting an operation abnormality of the vertical carbonization furnace caused by a loss of a gas permeability balance in the furnace, a method of producing ferro coke, and a control device of the vertical carbonization furnace.

A method of operating a vertical carbonization furnace that produces ferro coke is a method in which the vertical carbonization furnace 10 includes a carbonization-furnace main body 12; one or more high-temperature tuyeres 13 that blow high-temperature gas into the carbonization-furnace main body; and two or more extraction tuyeres 16 that are provided at positions differing in a height direction from a position of the one or more high-temperature tuyeres 13, and that discharge gas in the carbonization-furnace main body, and in which the two or more extraction tuyeres 16 are provided at positions at a same height and differing from each other in a width direction, the method of operating the vertical carbonization furnace including an obtaining step of obtaining a flow rate of the gas that is discharged from each of the extraction tuyeres 16; and a determining step of determining that an operation abnormality has occurred when the flow rate obtained in the obtaining step falls outside a predetermined flow rate range.

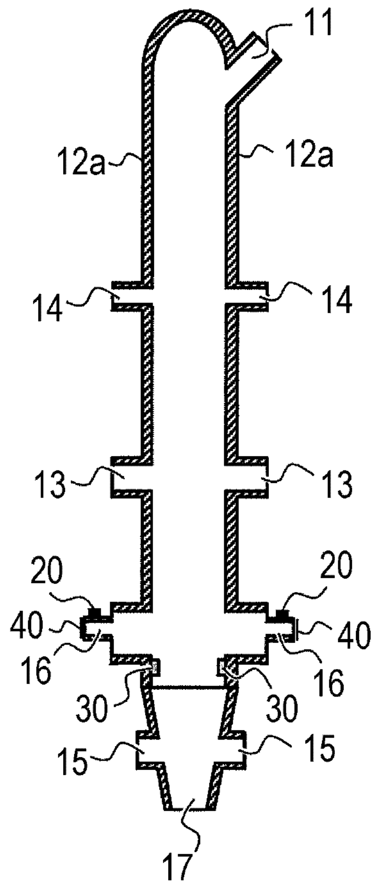
FIG. 2



EP 4 524 218 A1

FIG. 2

(b)



Description

Technical Field

[0001] The present invention relates to a method of operating a vertical carbonization furnace that produces ferro coke, a method of producing ferro coke, and a vertical-carbonization-furnace facility.

Background Art

[0002] Ferro coke is produced by carbonizing coal, together with an iron-containing substance, such as iron ore, and contains therein metal iron in the form of fine particles produced by reduction of the iron-containing substance. The metal iron has the function of a catalyst that accelerates a reaction in which CO_2 produced by the progression of a reaction in a blast furnace reacts with coke (C) and reproduces CO that is a reducing gas. Therefore, when the ferro coke is used, since a gasification reaction of the coke starts from a low-temperature portion in the blast furnace, it is possible to decrease the temperature of a thermal reserve zone. Consequently, it is thought that it is possible to, by largely decreasing a reducing agent ratio by using the ferro coke, contribute to energy conservation and to a reduction in the emission of CO_2. Due to such usefulness, research regarding a ferro coke production technology is progressing.

[0003] An ordinary chamber coke oven consists of silica bricks. Therefore, when iron ore is charged and carbonized, silica, which is a main component of the silica bricks, reacts with iron ore, and fayalite having a low melting point is produced. Since there is a problem in that the silica bricks are damaged by this reaction, the production of ferro coke by using a chamber coke oven of a related art is not industrially carried out. Therefore, as a method of producing ferro coke, a production method using a vertical carbonization furnace is being proposed as an alternative to the production method using a chamber coke oven.

[0004] In this production method, a vertical carbonization furnace that is formed from chamotte bricks instead of silica bricks is used. Coal and iron ore, which are raw materials, are formed into a molded product obtained by mixing the coal and the iron ore with a binder and molding them into a predetermined size, and then the molded product is charged into the vertical carbonization furnace. Then, heat transfer gas is blown into the vertical furnace for heating, to thereby carbonize the molded product and produce molded ferro coke. It is possible to, by using this method, evenly carbonize molded charcoal without damaging the bricks by the iron ore.

[0005] As a vertical carbonization furnace that is used in producing ferro coke, Patent Literature 1 discloses a vertical carbonization furnace that is capable of evenly heating a molded product by controlling the flow of high-temperature gas by providing a gas discharge port in a carbonization-furnace main body.

[0006] Patent Literature 2 discloses a heating rate designing method for carbonizing a molded product under an optimal heating condition. According to Patent Literature 2, it is possible to, by carbonizing the molded product by using an optimal heat pattern, prevent cracking or heat cracking of the molded product occurring during the carbonization and suppress quality deterioration of the ferro coke.

Citation List

Patent Literature

[0007]

PTL 1: Japanese Patent No. 6274126
PTL 2: Japanese Patent No. 5087868

Summary of Invention

Technical Problem

[0008] When fine powder becomes mixed in a vertical carbonization furnace, since a gas permeability balance in the furnace is lost, it no longer becomes possible to control the flow of high-temperature gas even if the gas discharge port is provided. Similarly, when the gas permeability balance in the furnace is lost due to the mixing of the fine powder, it no longer becomes possible to control even the heat pattern. When the temperature difference in the furnace in a horizontal direction becomes large due to the loss of the gas permeability balance in the furnace, carbonization failure of the molded product carbonized in a low temperature region occurs, and ferro coke that has low strength and that thus can no longer be used as a blast-furnace raw material is produced.

[0009] The present invention has been made in view of such problems of the related art, and it is an object of the present invention to provide a method of operating a vertical carbonization furnace that is capable of detecting an operation abnormality of the vertical carbonization furnace caused by a loss of a gas permeability balance in the furnace, a method of producing ferro coke, and a control device of the vertical carbonization furnace.

Solution to Problem

[0010] The spirit of the present invention that is capable of solving the problems above is as follows.

[1] A method of operating a vertical carbonization furnace that produces ferro coke is a method in which the vertical carbonization furnace includes a carbonization-furnace main body; one or more high-temperature tuyeres that blow high-temperature gas into the carbonization-furnace main body; and two or more extraction tuyeres that are provided at positions differing in a height direction from a position of the one or more high-temperature tuyeres, and that discharge gas in the carbonization-furnace main body, and in which the two or more extraction tuyeres are provided at positions at a same height and differing from each other in a width direction, the method of operating the vertical carbonization furnace including an obtaining step of obtaining a flow rate of the gas that is discharged from each of the extraction tuyeres; and a determining step of determining that an operation abnormality has occurred when the flow rate obtained in the obtaining step falls outside a predetermined flow rate range.

[2] In the method of operating the vertical carbonization furnace according to [1], in the obtaining step, by measuring vibration of each of the extraction tuyeres, the flow rate of the gas that is discharged from each of the extraction tuyeres is obtained.

[3] In the method of operating the vertical carbonization furnace according to [2], in the obtaining step, the flow rate of the gas that is discharged from each of the extraction tuyeres is obtained from each of the vibrations whose frequency component of vibration that becomes a disturbance is removed, and the frequency component of the vibration that becomes the disturbance is determined by previously performing principal component analysis of the frequency component of the vibration that becomes the disturbance and by determining a principal component loading.

[4] In the method of operating the vertical carbonization furnace according to [3], the frequency component of the vibration that becomes the disturbance is determined by evaluating for every frequency an existence ratio in which the principal component loading determined by the analysis in terms of the principal component becomes greater than or equal to a predetermined value.

[5] In the method of operating the vertical carbonization furnace according to any one of [1] to [4], in the obtaining step, temperatures in the furnace at two or more positions that are same in the height direction and that differ from each other in the width direction are further obtained, and that an operation abnormality has occurred is determined when a difference between the temperatures in the furnace is greater than or equal to a predetermined temperature difference.

[6] The method of operating the vertical carbonization furnace according to any one of [1] to [5], further includes an adjusting step of, when it is determined that an operation abnormality has occurred in the determining step, adjusting the flow rate of the gas that is discharged from each of the extraction tuyeres such that the flow rate falls within the predetermined flow rate range.

[7] A method of producing ferro coke is a method in which the ferro coke is produced by operating a vertical carbonization furnace by the method of operating the vertical carbonization furnace according to [6].

[8] A vertical-carbonization-furnace facility that produces ferro coke includes a vertical carbonization furnace; two or more flow rate sensors that measure flow rates of gas; and a control device that controls the vertical carbonization furnace, in which the vertical carbonization furnace includes a carbonization-furnace main body; a charging port into which a molded product that becomes a raw material of the ferro coke is charged; one or more high-temperature tuyeres that blow high-temperature gas into the carbonization-furnace main body; two or more extraction tuyeres that are provided at positions differing in a height direction from a position of the one or more high-temperature tuyeres, and that discharge gas in the carbonization-furnace main body; and a discharge port that discharges the molded product that has been carbonized, in which the two or more extraction tuyeres are provided at positions differing from each other in a width direction, in which the two or more flow rate sensors are each provided at a corresponding one of the two or more extraction tuyeres, and in which the control device includes an obtaining section that obtains from each of the flow rate sensors data indicating the flow rate of the gas that is discharged from each of the extraction tuyeres, a computing section that calculates from the data the flow rate of the gas that is discharged from each of the extraction tuyeres, and a determining section that determines that an operation abnormality has occurred when the flow rate falls outside a predetermined flow rate range.

[9] In the vertical-carbonization-furnace facility according to [8], each of the flow rate sensors is a vibration meter.

[10] The vertical-carbonization-furnace facility according to [9], further includes a disturbance removing filter, in which the disturbance removing filter removes a predetermined frequency component of vibration measured by each of the vibration meters.

[11] In the vertical-carbonization-furnace facility according to [10], the frequency component is previously determined by performing principal component analysis of a frequency component of vibration that becomes a disturbance and by evaluating for every frequency an existence ratio in which a principal component loading becomes greater than or equal to a predetermined value.

[12] The vertical-carbonization-furnace facility according to any one of [8] to [11], further includes two or more temperature sensors that measure temperatures in the furnace, in which the two or more temperature sensors are provided at positions at a same height in the vertical carbonization furnace and differing from each other in the width direction, and in which the obtaining section obtains the temperature in the furnace from each of the temperature sensors and the determining section determines that an operation abnormality has occurred when a difference between the temperatures in the furnace obtained from the temperature sensors is greater than or equal to a predetermined temperature difference.

[13] In the vertical-carbonization-furnace facility according to any one of [8] to [12], when the determining section determines that an operation abnormality has occurred, the determining section adjusts the flow rate of the gas that is discharged from each of the extraction tuyeres such that the flow rate falls within the predetermined flow rate range.

Advantageous Effects of Invention

[0011] It is possible to, by carrying out the method of operating the vertical carbonization furnace according to the present invention, detect an operation abnormality of the vertical carbonization furnace caused by a loss of a gas permeability balance in the furnace. In this way, when an operation abnormality of the vertical carbonization furnace can be detected, measures to restore the gas permeability balance in the furnace can be taken to thereby make it possible to suppress production of ferro coke having low strength caused by carbonization failure.

Brief Description of Drawings

[0012]

[Fig. 1] Fig. 1 is a perspective schematic view of a vertical-carbonization-furnace facility 100 that makes it possible to carry out a method of operating a vertical carbonization furnace according to an embodiment.

[Fig. 2] Fig. 2 is a sectional schematic view of a vertical carbonization furnace 10.

[Fig. 3] Fig. 3 is a sectional schematic view of an extraction tuyere 16.

[Fig. 4] Fig. 4 is a schematic view showing flow paths of gases discharged from extraction tuyeres 16.

[Fig. 5] Fig. 5 is a block diagram showing a structure of a control device 50.

[Fig. 6] Fig. 6 is a graph showing the relationship between an acceleration effective value and a gas flow rate.

[Fig. 7] Fig. 7 is a graph showing the relationship between an acceleration effective value and a total flow rate in the extraction tuyeres 16.

[Fig. 8] Fig. 8 is a graph showing an existence ratio of a high correlation coefficient of gas and vibration that becomes a disturbance.

[Fig. 9] Fig. 9 is a graph showing an existence ratio of a high correlation coefficient of vibration that becomes a disturbance.

[Fig. 10] Fig. 10 is a flowchart showing an example of a process of the method of operating the vertical carbonization furnace according to the embodiment.

[Fig. 11] Fig. 11 is a flowchart showing another example of a process of the method of operating the vertical carbonization furnace according to the embodiment.

[Fig. 12] Fig. 12 is a graph showing changes in temperatures in a furnace at units A and B.

Description of Embodiments

[0013] The present invention is described below by way of an embodiment of the present invention. Fig. 1 is a perspective schematic view of a vertical-carbonization-furnace facility 100 that makes it possible to carry out a method of operating a vertical carbonization furnace according to the embodiment. Fig. 2 is a sectional schematic view of a vertical carbonization furnace 10. Fig. 2(a) is a sectional view along line A-A of Fig. 1, and Fig. 2(b) is a sectional view along B-B of Fig. 2(a).

[0014] The vertical-carbonization-furnace facility 100 is a facility that produces ferro coke by carbonizing a molded product that becomes a raw material of the ferro coke. The molded product that becomes a raw material of the ferro coke is produced by cold-briquetting with a briquetting machine the molded product out of an iron-containing raw material, such as iron ore, a carbon-containing raw material, such as coal, and a binder-containing raw material.

[0015] As shown in Figs. 1 and 2, the vertical-carbonization-furnace facility 100 includes the vertical carbonization furnace 10, acceleration sensors 20, temperature sensors 30, flow-rate regulating valves 40, and a control device 50. The vertical carbonization furnace 10 includes charging port 11, a carbonization-furnace main body 12, high-temperature tuyeres 13, low-temperature tuyeres 14, cooling tuyeres 15, extraction tuyeres 16, and a discharge port 17. The charging ports 11 are provided at an upper portion of the carbonization-furnace main body 12. Each charging port 11 is an opening for charging into the carbonization-furnace main body 12 a molded product that becomes a raw material of ferro coke. The vertical carbonization furnace 10 includes two charging ports 11.

[0016] The carbonization-furnace main body 12 is a furnace whose horizontal cross section has a rectangular cylindrical shape, and includes two furnace walls 12a that are provided at positions of long sides of the horizontal cross section, and two furnace walls 12b that are provided at positions of short sides of the horizontal cross section. A refractory is provided on inner sides of the furnace walls 12a and 12b, and a shell serving as an external structure is provided on outer sides of the furnace walls 12a and 12b.

[0017] The discharge port 17 is provided on a lower end of the carbonization-furnace main body 12. Ferro coke carbonized and produced in the furnace is discharged from the discharge port 17. The ferro coke discharged from the discharge port 17 is conveyed to a product hopper by a conveyor (not shown), and is used as a blast-furnace raw material.

[0018] Eight high-temperature tuyeres 13 in total are provided, four at one of the two furnace walls 12a and four at the other of the two furnace walls 12a. Four high-temperature tuyeres 13 are provided at equal intervals at positions at the same height and differing from each other in a width direction. By using a heating device that is provided outside the furnace, for example, high-temperature gas heated to 800°C to 1100°C is blown into the furnace from the high-temperature tuyeres 13. It is preferable that high-temperature gas heated to 900°C to 1000°C be blown into the furnace from the high-temperature tuyeres 13. Note that, in the present embodiment, the width direction means a direction in which sides of the horizontal cross section of the carbonization-furnace main body 12 become long sides.

[0019] Eight low-temperature tuyeres 14 in total are provided at positions corresponding to the positions of the high-temperature tuyeres 13 in the width direction of the two furnace walls 12a, four at one of the two furnace walls 12a and four at the other of the two furnace walls 12a so as to be situated above the high-temperature tuyeres 13 in a height direction. By using a heating device that is provided outside the furnace, for example, low-temperature gas heated to 400°C to 700°C is blown into the furnace from the low-temperature tuyeres 14. In this way, the high-temperature tuyeres 13 and the low-temperature tuyeres 14 are provided in two positions above and below each other at the vertical carbonization furnace 10, and high-temperature gas and low-temperature gas are blown in from these tuyeres. Therefore, compared with a case in which high-temperature gas is blown in from one position of high-temperature tuyeres, it is possible to heat a molded product in a wide range and the vertical carbonization furnace becomes a furnace that is capable of efficiently carbonizing a molded product.

[0020] Eight cooling tuyeres 15 in total are provided near the discharge port 17, four at one of the two furnace walls 12a and four at the other of the two furnace walls 12a. Cooling gas of 25°C to 80°C is blown into the furnace from the cooling tuyeres 15. In this way, it is possible to, by blowing in the cooling gas from the cooling tuyeres 15, decrease the temperature of the carbonized ferro coke that is discharged from the discharge port 17, and thus continuously carbonize the molded product. When the temperature of the ferro coke can be decreased in this way, it is no longer necessary to provide a cooling facility that cools the ferro coke, and thus it is possible to reduce facility costs of the cooling facility and transportation costs for transporting the ferro coke to the cooling facility.

[0021] Eight extraction tuyeres 16 in total are provided at positions corresponding to the positions of the high-temperature tuyeres 13 in the width direction of the two furnace walls 12a, four at one of the two furnace walls 12a and four at the other of the two furnace walls 12a so as to be situated between the cooling tuyeres 15 and the high-temperature tuyeres 13 in the height direction. Gas of 0°C to 500°C at which the high-temperature gas, the low-temperature gas, and the cooling gas have merged, is discharged to the outside of the furnace from the extraction tuyeres 16. In this way, by providing the high-temperature tuyeres 13, the low-temperature tuyeres 14, and the extraction tuyeres 16 at equal intervals at positions that differ from each other in the width direction of the two furnace walls 12a such that they face each other, the temperature in the furnace in the horizontal cross section in the carbonization-furnace main body 12 is made uniform.

[0022] Fig. 3 is a sectional schematic view of an extraction tuyere 16. The flow-rate regulating valves 40 are provided at end portions of the respective extraction tuyeres 16. By adjusting the openings of the flow-rate regulating valves 40, the flow rates of gases that are discharged from the extraction tuyeres 16 are adjusted. Two branching portions 19 are provided at each extraction tuyere 16. By providing two branching portions 19, dust or foreign substances contained in the gas that is discharged from each extraction tuyere 16 can be separated into the branching portions 19.

[0023] Each acceleration sensor 20 is provided at an outer wall surface of its corresponding extraction tuyere 16. Each acceleration sensor 20 measures vibration data of the outer wall surface of its corresponding extraction tuyere 16 as data indicating the flow rate of the gas that is discharged from its corresponding extraction tuyere 16. Each acceleration sensor 20 outputs to the control device 50 the measured vibration data together with identification data of the acceleration sensor. Note that, in the present embodiment, each acceleration sensor 20 is one example of a vibration meter.

[0024] Fig. 2 is referred to again. Eight temperature sensors 30 in total are provided at inner wall surfaces of the two furnace walls 12a at equal intervals so as to be situated at positions at the same height and differing from each other in the width direction. In the example shown in Fig. 2, the temperature sensors 30 are provided at positions corresponding to the positions of the extraction tuyeres 16 in the width direction so as to be situated near the extraction tuyeres 16. Each temperature sensor 30 measures the temperature of the inside of the furnace at its corresponding position, and outputs to the control device 50 the measured temperature data together with identification data of the temperature sensor. Note that the positions where the temperature sensors 30 are provided are not limited to positions near the extraction tuyeres 16. The temperature sensors 30 may be provided at positions in the carbonization-furnace main body 12 that differ from each other in the height direction.

[0025] The control device 50 obtains the data indicating the flow rate of the gas from each acceleration sensor 20, and calculates the flow rate of the gas that is discharged from each extraction tuyere 16 from this data. The control device 50 determines whether or not each calculated flow rate of the gas is outside a predetermined flow rate range.

[0026] When the gas permeability of a part of a region in the vertical carbonization furnace 10 deteriorates and the gas permeability balance in the furnace is lost, the flow of gas that is discharged from an extraction tuyere 16 provided at a position in the width direction that corresponds to the region where the gas permeability has deteriorated is decreased, and the flow rates of gases that are discharged from the other extraction tuyeres 16 are increased. Therefore, it is possible to, by determining whether or not the flow rate of the gas that is discharged from the extraction tuyere 16 is outside the predetermined flow rate range, detect an operation abnormality of the vertical carbonization furnace 10 caused by the loss of the gas permeability balance in the furnace. Note that the predetermined flow rate range is determined to be a flow rate range in which a temperature difference in the furnace in a horizontal direction can be maintained to be less than 50°C by using a flow rate of gas that is discharged from an extraction tuyere 16 in a normal operation state and a flow rate of gas that is discharged from the extraction tuyere 16 when the gas permeability balance is experimentally lost and the temperature difference in the furnace in the horizontal direction becomes 50°C.

[0027] The control device 50 determines that the vertical carbonization furnace 10 is operationally abnormal when the flow rate of gas that is discharged from an extraction tuyere 16 is outside the predetermined flow rate range. On the other hand, the control device 50 determines that the vertical carbonization furnace 10 is operationally normal when the flow rate of the gas that is discharged from the extraction tuyere 16 is within the predetermined flow rate range. Therefore, the control device 50 is capable of detecting an operation abnormality of the vertical carbonization furnace 10 caused by the loss of the gas permeability balance in the furnace.

[0028] When the control device 50 determines that the vertical carbonization furnace 10 is operationally abnormal, the control device 50 adjusts the flow rate of the gas that is discharged from the extraction tuyere 16 by adjusting the opening of the flow-rate regulating valve 40 such that the flow rate of the gas that is discharged from the extraction tuyere 16 is within the predetermined flow rate range. For example, when the flow rate of gas that is discharged from a particular extraction tuyere 16 exceeds the predetermined flow rate range, the control device 50 narrows the opening of the flow-rate regulating valve 40 of the particular extraction tuyere 16 and decreases the flow rate of the gas that is discharged from the extraction tuyere 16. Therefore, the flow rate of the gas that is discharged from the particular extraction tuyere 16 is decreased and the flow rate of the gas can be caused to be within the predetermined flow rate range.

[0029] Note that the predetermined flow rate range is not limited to the flow rate range of gas, and may be an upper limit of the flow rate of gas or a lower limit of the flow rate of the gas. When the upper limit is determined, it is determined that the flow rate is outside the flow rate range when the upper limit is exceeded. When the lower limit is determined, it is determined that the flow rate is outside the flow rate range when the flow rate is less than the lower limit. Note that, when the flow rate (reference flow rate) of gas that is discharged from an extraction tuyere 16 during normal operation is 100, the upper limit as the predetermined flow rate range is, for example, 114. That is, the control device 50 determines that the furnace is operationally abnormal when the flow rate of gas is greater than 1.14 times the reference flow rate. Note that the upper limit is determined from flow-rate increase ranges of gases of the other extraction tuyeres 16 when one extraction tuyere 16 of the eight extraction tuyeres 16 is closed.

[0030] When the flow rate of gas that is discharged from an extraction tuyere 16 is less than the predetermined flow rate range, the control device 50 widens the opening of the flow-rate regulating valve 40 and increases the flow rate of the gas that is discharged from the extraction tuyere 16. Therefore, the flow rate of gas that is discharged from a particular extraction tuyere 16 is increased, and the flow rate can be caused to be within the predetermined flow rate range.

[0031] The control device 50 may obtain the temperatures in the furnace from the temperature sensors 30. The control device 50 may determine that the furnace is operationally abnormal when a temperature difference in the furnace obtained from the temperature sensors 30 provided at the same height is greater than or equal to a predetermined temperature difference. That is, in this case, the control device 50 may determine that the vertical carbonization furnace 10 is operationally abnormal when the gas flow rate is outside the predetermined flow rate range and the temperature difference in the furnace is greater than or equal to the predetermined temperature difference. Note that, in the present embodiment, the predetermined temperature difference is, for example, 50°C.

[0032] When the temperature difference in the furnace in a horizontal method of a lower portion of the furnace becomes greater than or equal to 50°C, uneven cooling of a molded product occurs, and high-temperature ferro coke is discharged from the discharge port 17 and thus generation of heat or ignition may occur in a product hopper. Therefore, in order to reliably maintain at less than 50°C the temperature difference in the furnace in a horizontal cross section, the flow rate range is set taking into consideration a prescribed safety factor. Consequently, even if the flow rate of gas that is discharged from an extraction tuyere 16 is outside the predetermined flow rate range, the temperature difference in the furnace in the horizontal cross section is not necessarily greater than or equal to the predetermined temperature difference. In contrast, it becomes possible to, by detecting an operation abnormality of the vertical carbonization furnace 10 on the basis of the temperature difference in the furnace, more reliably detect an operation abnormality of the vertical carbonization furnace 10.

[0033] In the vertical carbonization furnace 10, when a circulation amount of gas is increased, the temperature in the furnace is decreased, and when the circulation amount of the gas is decreased, the temperature in the furnace is increased. When the flow rate of gas that is discharged from an extraction tuyere 16 is increased, a circulation amount of cooling gas is increased, and thus the temperature in the furnace near the extraction tuyere 16 is decreased. On the other hand, when the flow rate of the gas that is discharged from the extraction tuyere 16 is decreased, the circulation amount of the cooling gas is decreased, and thus a high-temperature molded product passes through, as a result of which the temperature in the furnace near the extraction tuyere 16 is increased.

[0034] Therefore, when the control device 50 determines that the vertical carbonization furnace 10 is operationally abnormal, the control device 50 adjusts the flow rate of gas that is discharged from an extraction tuyere 16 by adjusting the opening of the flow-rate regulating valve 40 such that the temperature difference in the furnace is less than a predetermined temperature. For example, the control device 50 widens the opening of the flow-rate regulating valve 40 situated at the position of the temperature sensor where a high temperature in the furnace is output, and increases the flow rate of the gas that is discharged from the extraction tuyere 16. Therefore, since it is possible to decrease the temperature in the furnace at the position where the high temperature in the furnace is output, it is possible to cause the temperature difference in the furnace to be less than the predetermined temperature.

[0035] Fig. 4 is a schematic view showing flow paths of gases discharged from extraction tuyeres 16. As shown in Fig. 4, the gases discharged from eight extraction tuyeres 16 merge at one flow path 70 and are discharged. At the flow path 70, as pieces of operation data of the vertical carbonization furnace 10, the pressure of the gas is measured by a pressure sensor 72, the flow rate of the gas is measured by a flow-rate sensor 74, and the temperature of the gas is measured by a temperature sensor 76. The pieces of operation data are output to the control device 50, and are stored in the control device 50.

[0036] Fig. 5 is a block diagram showing a structure of the control device 50. The control device 50 is, for example, a general-purpose computer, such as a work station or a personal computer. The control device 50 includes a control section 52, an input section 54, an output section 56, and a storage section 58. The control section 52 is, for example, a CPU, and the control section 52 is caused to function as an obtaining section 60, a computing section 62, and a determining section 64 by executing a program that is read from the storage section 58.

[0037] The input section 54 is, for example, a keyboard or a touch panel integrated with a display. The output section 56 is, for example, an LCD or a CRT display. The storage section 58 is, for example, an information recording medium, such as an updatable and recordable flash memory, a built-in hard disk or a hard disk connected to a data communication terminal, or a memory card; or a read-write device for the information recording medium. The storage section 58 stores, for example, a program for execution of each function by the control section 52 or data that is used by the program.

[0038] The pieces of vibration data that are output from the acceleration sensors 20 provided at the respective extraction tuyeres 16 are amplified by an amplifier 22, and low-frequency components are removed by an HPF (high-pass filter) 24. The obtaining section 60 obtains the amplified pieces of vibration data whose low-frequency components have been removed and the pieces of identification data of the acceleration sensors 20. The obtaining section 60 outputs the obtained pieces of vibration data and the obtained pieces of identification data to the computing section 62.

[0039] The computing section 62 converts the obtained pieces of vibration data into acceleration effective values. The computing section 62 reads out from the storage section 58 a regression equation indicating a correspondence relationship between the gas flow rates and the acceleration effective values, and calculates the flow rate of gas discharged from each of the extraction tuyeres 16 by using the acceleration effective value and the regression equation.

[0040] Here, the relationship between a gas flow rate and vibration data is described. Here, the acceleration sensors were attached to a steel pipe of JIS standard 25A, and vibration data when air was caused to flow at a speed of 0 L/min to 25 L/min in the steel pipe was obtained to confirm the relationship between the flow rate of gas flowing in the steel pipe and the vibration data. As the vibration data, the acceleration effective value was used. The acceleration effective value at 0 to T sections in the vibration data represented by f(t) can be calculated by using the following Formula (1).

[Formula 1]

$$\text{acceleration effective value} = \sqrt{\frac{1}{T}\int_0^T f(t)^2\,dt} \quad \cdots (1)$$

[0041] Fig. 6 is a graph showing the relationship between the acceleration effective value and the gas flow rate. In Fig. 6, the horizontal axis represents the flow rate (L/min) and the vertical axis represents the acceleration effective value (m/s^2). As shown in Fig. 6, as the gas flow rate increases, the acceleration effective value also increases. From this result, it was confirmed that there was a correlation between the gas flow rate and the acceleration effective value.

[0042] Accordingly, the relationship between the vibration data and the flow rate when each acceleration sensors 20 was set at the outer wall surface of the corresponding extraction tuyere 16 by using the vertical carbonization furnace 10 and when the flow rate of the gas discharged from each extraction tuyere 16 was changed was confirmed. Note that since it was difficult to perform the measurements using an ordinary flowmeter because gas immediately after being discharged from the extraction tuyeres 16 contained powder formed by pulverizing molded charcoal or volatile matter volatilized from the molded charcoal and because the temperature of the gas was a high temperature near 500°C, the measurements were performed with an orifice flowmeter by measuring the gas flow rate after merging the gases discharged from the eight extraction tuyeres 16 and removing, for example, dust contained in the gas.

[0043] Fig. 7 is a graph showing the relationship between the acceleration effective value and the total flow rate in the extraction tuyeres 16. In Fig. 7, the horizontal axis represents the total flow rate (L/min) and the vertical axis represents the acceleration effective value (m/s^2). The acceleration effective value is the total value of the effective values of vibrations measured at the eight acceleration sensors 20 shown in Fig. 4. As shown in Fig. 7, it was confirmed that the acceleration effective value increased in proportion to the total flow rate. In this way, since the acceleration effective value and the total flow rate have a correspondence relationship, when the regression equation indicating the correspondence relationship between the gas flow rate and the acceleration effective value is previously determined, it is possible to calculate the flow rate of the gas discharged from each extraction tuyere 16 by using the acceleration effective value and the regression equation.

[0044] Therefore, when the regression equation indicating the correspondence relationship between the gas flow rate and the acceleration effective value is previously determined and when the regression equation is stored in the storage section 58, the computing section 62 is capable of calculating the flow rate of the gas discharged from each extraction tuyere 16 by using the acceleration effective value and the regression equation. The computing section 62 outputs the gas flow rate calculated in this way to the determining section 64.

[0045] Note that the vibration data that is output from each acceleration sensor 20 includes not only the vibration caused by the gas that is discharged from each extraction tuyere 16, but also the vibration of the carbonization-furnace main body 12. Since the frequency of the vibration of the carbonization-furnace main body 12 often appears in a low frequency band, for example, by removing a low frequency component of the vibration data by the HPF 24 described above, calculation precision of the gas flow rate is increased. Note that the HPF 24 is an example of a disturbance removing filter that removes a frequency component of the vibration that becomes a disturbance.

[0046] Next, a frequency component that is removed by the HPE 24 is described. The vibration data that is output from each acceleration sensor 20 includes not only the vibration of gas but also vibration that becomes a disturbance of, for example, a peripheral facility. Therefore, when the vibration data is used as it is, the calculation precision of the gas flow rate may be reduced. Consequently, the vibration obtained by varying the production amount of ferro coke so as to change the flow rate of gas discharged from each extraction tuyere 16 and the vibration that became a disturbance, and vibration obtained by changing the vibration that became a disturbance, such as the vibration of a peripheral facility, without discharging the gas were measured. Then, a frequency analysis (FFT) result of these pieces of vibration data was subjected to principal component analysis, and an existence ratio of a high correlation coefficient in which the loading of a first principal component became greater than or equal to 0.7 was determined. Here, the existence ratio of a high correlation coefficient means a ratio obtained when a signal intensity is analyzed for every 1 Hz in a range of up to 12.5 kHz by the frequency analysis, the obtained frequency analysis data is subjected to principal component analysis, and the loading of a first principal component becomes greater than or equal to 0.7 for every 100 Hz.

[0047] Fig. 8 is a graph showing the existence ratio of a high correlation coefficient of gas and vibration that becomes a disturbance. Fig. 9 is a graph showing the existence ratio of a high correlation coefficient of vibration that becomes a disturbance. In Figs. 8 and 9, the horizontal axis represents the frequency (Hz) and the vertical axis represents the existence ratio of a high correlation coefficient (%).

[0048] As shown in Fig. 8, in the case of the gas and the vibration that becomes a disturbance, the high correlation coefficient in which the loading of the first principal component becomes greater than or equal to 0.7 existed over an entire frequency band. From this result, it was confirmed that a wide frequency component contributed to the vibration of the gas and the vibration that became a disturbance. On the other hand, as shown in Fig. 9, in the case of the vibration that became a disturbance, the high correlation coefficient in which the loading of the first principal component became greater than or equal to 0.7 existed in a frequency band of less than or equal to 5 kHz and did not exist much in a frequency band greater than 5 kHz. From this result, it was confirmed that the frequency component less than or equal to 5 kHz contributed to the vibration that became a disturbance. Note that the loading of 0.7 of the first principal component, which is a high correlation value, is an example of a predetermined principal component loading.

[0049] As described above, since the frequency component of less than or equal to 5 kHz contributes to the vibration that becomes a disturbance, when the frequency component of less than or equal to 5 kHz in the vibration data is removed by using the HPF 24, the influence of the vibration that becomes a disturbance is reduced, and thus the calculation precision of the gas flow rate is increased. In this way, in the method of operating the vertical carbonization furnace according to the present embodiment, the frequency components, obtained by frequency analysis of the vibration that becomes a disturbance and is not correlated with the gas flow rate, are subjected to principal component analysis in advance, and the existence ratio in which the loading of the first principal component becomes greater than or equal to a predetermined value is evaluated for every frequency. Therefore, it is possible to previously determine a frequency component that contributes to the vibration that becomes a disturbance and to remove the frequency component from the vibration data by using a disturbance removing filter, as a result of which it is possible to increase the calculation precision of the gas flow rate.

[0050] In the example above, an example in which the frequency component of less than or equal to 5 kHz that becomes a disturbance is removed by using the HPE 24 has been described, but it is not limited thereto. The frequency component of the vibration that becomes a disturbance may change due to the type of peripheral facility and the size of the facility. Therefore, the disturbance removing filter that removes the frequency component of the vibration that becomes a disturbance is not limited to the HPE, and may be a bandpass filter or a low-pass filter that removes a prescribed frequency component. The principal component whose loading is to be evaluated is not limited to the first principal component, and a second and subsequent principal components may be evaluated. It is only necessary to evaluate the principal component loading that is correlated with the vibration that becomes a disturbance.

[0051] The determining section 64 determines whether or not the gas flow rate obtained from the computing section 62 is outside a predetermined flow rate range. As described above, the predetermined flow rate range is previously determined by using the flow rate of gas that is discharged from each extraction tuyere 16 in a normal operation state and the flow rate of gas that is discharged from each extraction tuyere 16 when the gas permeability balance is experimentally lost such that the temperature difference in the furnace in the width direction becomes 50°C; and the predetermined flow rate range is stored in the storage section 58.

[0052] The determining section 64 reads out the predetermined flow rate range from the storage section 58, and determines whether or not the gas flow rate obtained from the computing section 62 is outside the predetermined flow rate range. When the gas flow rate obtained from the computing section 62 is outside the predetermined flow rate range, the determining section 64 determines that an operation abnormality caused by a loss of a gas permeability balance in the furnace is occurring. On the other hand, when the gas flow rate obtained from the computing section 62 is within the predetermined flow rate range, the computing section 62 determines that an operation abnormality caused by a loss of a gas permeability balance in the furnace is not occurring. When the computing section 62 determines that an operation abnormality caused by a loss of a gas permeability balance in the furnace is occurring, the output section 56 may be caused to display an image indicating that an operation abnormality is occurring. In this way, the vertical-carbonization-furnace facility 100 according to the present embodiment detects an operation abnormality of the vertical carbonization furnace 10 caused by a loss of a gas permeability balance in the furnace.

[0053] When the determining section 64 determines that an operation abnormality caused by a loss of a gas permeability balance in the furnace is occurring, it is preferable that the determining section 64 adjust the opening of a flow-rate regulating value 40 and adjust the flow rate of gas that is discharged from an extraction tuyere 16. When the flow rate of gas that is discharged from a particular extraction tuyere 16 exceeds the predetermined flow rate range, the determining section 64 reads out a table indicating a correspondence relationship between a setting position and identification data stored in the storage section 58, refers to the table, and determines the setting position of the particular extraction tuyere 16. The determining section 64 outputs a signal that narrows the opening of the flow-rate regulating valve 40 to the flow-rate regulating valve 40 where the particular extraction tuyere 16 is provided, and narrows the opening. Therefore, since it is possible to decrease the flow rate of the gas that is discharged from the particular extraction tuyere 16, it is possible to adjust the flow rate of the gas that is discharged from the particular extraction tuyere 16 such that the flow rate is within the predetermined flow rate range.

[0054] The control device 50 may obtain temperature data from each temperature sensor 30. In this case, the obtaining section 60 obtains the temperature data from each temperature sensor 30. The obtaining section 60 outputs the obtained pieces of temperature data to the computing section 62. Of the four pieces of temperature data provided at the same furnace wall 12a and at the same height, the computing section 62 determines highest temperature data and lowest temperature data. The computing section 62 calculates the temperature difference in the furnace by calculating the difference between these two pieces of temperature data. The computing section 62 outputs the calculated temperature difference in the furnace to the determining section 64.

[0055] The determining section 64 determines whether or not the temperature difference in the furnace obtained from the computing section 62 is greater than or equal to 50°C that has been previously determined. When the temperature difference in the furnace obtained from the computing section 62 is greater than or equal to 50°C, the determining section 64 determines that an operation abnormality is occurring. On the other hand, when the temperature difference obtained from the computing section 62 is less 50°C, the computing section 62 determines that an operation abnormality is not occurring. When the computing section 62 determines that an operation abnormality is occurring, the output section 56 may be caused to display an image indicating that an operation abnormality is occurring.

[0056] When the determining section 64 determines that an operation abnormality is occurring, the determining section 64 adjusts the opening of a flow-rate regulating valve 40 and adjusts the flow rate of the gas that is discharged from an extraction tuyere 16. The determining section 64 determines the temperature sensor that outputs the highest temperature data and the temperature sensor that outputs the lowest temperature data, and obtains pieces of identification data of these sensors. For example, when the highest temperature is to be decreased, the determining section 64 identifies the extraction tuyere 16 that is provided at a position in the width direction that is in correspondence with the position of the temperature sensor that has output the highest temperature data. The determining section 64 outputs a signal that widens the opening to the flow-rate regulating valve 40 that is provided at the identified extraction tuyere 16, and widens the opening of the flow-rate regulating valve 40. Therefore, since a circulation amount of low-temperature gas that circulates at the position where the highest temperature in the furnace is output is large, the position is cooled and the temperature is decreased, as a result of which it is possible to cause the temperature difference in the furnace to be less than 50°C. When the lowest temperature in the furnace is to be increased, a signal that narrows the opening of a flow-rate regulating valve 40 is output. Therefore, it is possible to cause the temperature difference in the furnace to be less than 50°C.

[0057] Fig. 10 is a flowchart showing an example of a process of the method of operating the vertical carbonization furnace according to the embodiment. By using Fig. 10, the process of detecting an operation abnormality of the vertical carbonization furnace 10 from a gas flow rate and eliminating the operation abnormality is described. In the flowchart shown in Fig. 10, the input section 54 starts operating on the condition that the input section 54 has accepted an input from an operator for starting control using the control device 50.

[0058] First, the obtaining section 60 obtains vibration data from each acceleration sensor 20 (Step S101). This processing operation corresponds to an obtaining step. The obtaining section 60 outputs the obtained pieces of vibration data to the computing section 62.

[0059] The computing section 62 converts the obtained pieces of vibration data into acceleration effective values and uses a regression equation indicating the correspondence relationship between the acceleration effective values and the gas flow rates, to thereby calculate the flow rate of gas that is discharged from each extraction tuyere 16 (Step S102). The computing section 62 outputs the calculated gas flow rates to the determining section 64.

[0060] The determining section 64 reads out from the storage section 58 the flow rate range previously determined from the storage section 58. The determining section 64 determines whether or not any of the gas flow rates obtained from the computing section 62 are outside the predetermined flow rate range (Step S103). When the gas flow rates obtained from the computing section 62 are within the predetermined flow rate range (Step S103: No), the determining section 64 returns to the processing operation of Step S101 and repeats the processing operation of Step S101 and the processing operation of Step S102 until any gas flow rate that is outside the predetermined flow rate range is obtained. On the other hand, when any of the gas flow rates are outside the predetermined flow rate range (Step S103: Yes), the determining section 64 determines that the operation of the vertical carbonization furnace 10 is an abnormal operation, and detects the operation abnormality of the vertical carbonization furnace 10 (Step S104). The processing operations of Steps S103 and S104 correspond to a determining step.

[0061] The determining section 64 adjusts the opening of a flow-rate regulating valve 40 to adjust the flow rate of gas discharged from an extraction tuyere 16 where the gas flow rate has fallen outside the predetermined flow rate range (Step S105). This processing operation corresponds to an adjusting step.

[0062] The determining section 64 determines whether or not the input section 54 has received an input from the operator for ending control by the control device 50 (Step S106). When the input section 54 has received an input from the operator for ending control by the control device 50 (Step S106: Yes), the determining section 64 ends a processing operation of detecting an operation abnormality of the vertical carbonization furnace 10 and eliminating the operation abnormality. On the other hand, when the input section 54 has not received an input from the operator for ending control by the control device 50 (Step S106: No), the determining section 64 returns to the processing operation of Step S101, and repeats the processing operations from Step S101. Even if the operation abnormality cannot be eliminated by one adjustment of the gas flow rate, when these processing operations are repeated, the operation abnormality of the vertical carbonization furnace 10 is eliminated by repeating the processing operations two to three times.

[0063] By performing such processing operations, the control device 50 is capable of detecting an operation abnormality caused by a loss of a gas permeability balance in the vertical carbonization furnace 10. Further, the control section 50 is capable of adjusting the flow rates of gases of gases that are discharged from the extraction tuyeres 16 so as to eliminate the operation abnormality.

[0064] Fig. 11 is a flowchart showing another example of a process of the method of operating the vertical carbonization furnace according to the embodiment. By using Fig. 11, the process of detecting an operation abnormality of the vertical carbonization furnace 10 from a gas flow rate and the temperature in the furnace and eliminating the operation abnormality is described. Even in the flowchart shown in Fig. 11, the input section 54 starts operating on the condition that the input section 54 has accepted an input from an operator for starting control using the control device 50.

[0065] First, the obtaining section 60 obtains vibration data from each acceleration sensor 20, and obtains temperature data from each temperature sensor 30 (Step S201). This processing operation corresponds to an obtaining step. The obtaining section 60 outputs the obtained pieces of vibration data and the obtained pieces of temperature data to the computing section 62.

[0066] The computing section 62 converts the obtained pieces of vibration data into acceleration effective values and uses the acceleration effective values and the regression equation indicating a correspondence relationship between the acceleration effective values and the gas flow rates, to thereby calculate the flow rate of gas that is discharged from each extraction tuyere 16. Further, the computing section 62 calculates a temperature difference using the obtained pieces of temperature data (Step S202). The computing section 62 outputs the gas flow rates and the temperature difference to the determining section 64.

[0067] The determining section 64 reads out from the storage section 58 the flow rate range previously determined from the storage section 58. The determining section 64 determines whether or not any of the gas flow rates obtained from the computing section 62 are outside the predetermined flow rate range (Step S203). When the gas flow rates are within the predetermined flow rate range (Step S203: No), the determining section 64 returns to the processing operation of Step S201 and repeats the processing operation of Step S201 and the processing operation of Step S202 until any gas flow rate that is outside the predetermined flow rate range is obtained. On the other hand, when any of the gas flow rates are outside the predetermined flow rate range (Step S203: Yes), the determining section 64 proceeds to the processing operation of Step S204.

[0068] The determining section 64 determines whether or not the temperature difference obtained from the computing section 62 is greater than or equal to 50°C (Step S204). When the determining section 64 determines that the temperature difference obtained from the computing section 62 is less than 50°C (Step S204: No), the determining section 64 returns to the processing operation of Step S201. On the other hand, when the temperature difference is greater than or equal to 50°C (Step S204: Yes), the determining section 64 determines that the operation of the vertical carbonization furnace 10 is an abnormal operation, and detects the operation abnormality of the vertical carbonization furnace 10 (Step S205). In the example shown in Fig. 11, the processing operations of Steps S203 to S205 correspond to a determining step.

[0069] The determining section 64 adjusts the opening of a flow-rate regulating valve 40 to adjust, for example, the flow rate of gas discharged from an extraction tuyere 16 that is provided at a position that corresponds to the position in the width direction of a temperature sensor 30 that has outputted the highest temperature data (Step S206). This processing operation corresponds to an adjusting step.

[0070] The determining section 64 determines whether or not the input section 54 has received an input from the operator for ending control by the control device 50 (Step S207). When the input section 54 has received an input from the operator for ending control by the control device 50 (Step S207: Yes), the determining section 64 ends a processing operation of detecting an operation abnormality of the vertical carbonization furnace 10 and eliminating the operation abnormality. On the other hand, when the input section 54 has not received an input from the operator for ending control by the control device 50 (Step S207: No), the determining section 64 returns to the processing operation of Step S201, and repeats the processing operations from Step S102.

[0071] By performing such processing operations, the control device 50 is capable of detecting an operation abnormality of the vertical carbonization furnace 10 based on an operation abnormality in which a carbonization failure where the temperature difference in the furnace in the horizontal cross section is greater than or equal to 50°C may occur. The control device 50 is capable to adjusting the flow rate of gas that is discharged from an extraction tuyere 16 so as to eliminate the operation abnormality.

[0072] As described above, it is possible to, by using the vertical-carbonization-furnace facility 100 according to the present embodiment, detect an operation abnormality of the vertical carbonization furnace 10 caused by a loss of a gas permeability balance in the furnace. In this way, when an operation abnormality of the vertical carbonization furnace 10 can be detected, measures to restore the gas permeability balance in the furnace, such as adjusting a flow-rate regulating valve 40, can be taken to thereby make it possible to suppress production of ferro coke having low strength caused by carbonization failure and to thereby make it possible to suppress generation of heat or ignition from occurring in a product hopper. Further, since the gas permeability balance in the furnace can be restored without changing the amount of heat that is introduced from the high-temperature tuyeres 13 and the low-temperature tuyeres 14, it is possible to maintain a proper production temperature and to suppress deformation or cracking of a molded product.

[0073] Note that although the vertical-carbonization-furnace facility 100 according to the present embodiment has been described using the vertical carbonization furnace 10 including eight high-temperature tuyeres 13, eight low-temperature tuyeres 14, eight extraction tuyeres 16, and eight cooling tuyeres 15, the vertical-carbonization-furnace facility 100 is not limited thereto. The vertical carbonization furnace 10 need not include low-temperature tuyeres 14 and cooling tuyeres 15, and only needs to include one or more high-temperature tuyeres 13 or two or more extraction tuyeres 16.

[0074] Although an example in which the extraction tuyeres 16 are provided at the same height and at equal intervals at the furnace walls 12a has been described, the extraction tuyeres 16 are not limited thereto. The extraction tuyeres 16 need not be provided at the same height or need not be provided at equal intervals. In this way, when the extraction tuyeres 16 are not provided at the same height or at equal intervals, since the flow rate range for determining an operation abnormality differs for each extraction tuyere, the gas flow rate during normal operation and the gas flow rate during abnormal operation are determined for each extraction tuyere 16, and the flow rate range that makes it possible to determine whether or not an operation abnormality has occurred is previously determined for each extraction tuyere 16.

[0075] Although, in the present embodiment, an example in which the acceleration sensors 20 are used as flow rate sensors has been described, the flow rate sensors are not limited thereto. As long as the flow rate sensors are capable of measuring the flow rates of gases that are discharged from the extraction tuyeres 16, any type of flow rate sensor may be used. Note that when the data that is output from each flow rate sensor is flow rate data, the computing section 62 outputs the flow rate data obtained from the obtaining section 60 as it is to the determining section 64.

EXAMPLES

[0076] In an example, as with the vertical carbonization furnace 10 shown in Figs. 1 and 2, eight thermocouple temperature sensors 30 were set at positions corresponding to each other in a horizontal direction near the extraction tuyeres 16. As components for estimating flow rates, acceleration sensors 20 were set at the eight extraction tuyeres 16, and as flow-rate regulating devices, flow-rate regulating valves were set.

[0077] Fig. 12 is a graph showing changes in temperatures in a furnace at units A and B. In Fig. 12, the horizontal axis represents time (hr) and the vertical axis represents the temperature (°C) in the furnace. The unit A is one of the four extraction tuyeres provided at the same furnace wall 12a, and the unit B is another one of the four extraction tuyeres. As shown in Fig. 10, during the operation of the vertical carbonization furnace 10, the flow rate of gas discharged from the unit A decreased and the temperature in the furnace increased, and at a little past 9:00, the flow rate difference between the gas of the unit A and gas of the unit B fell outside a predetermined range and the temperature difference in the furnace became 50°C. Therefore, the opening of the flow-rate regulating valve provided at the unit A was widened and the flow rate of the gas discharged from the unit A was increased. Consequently, the temperature in the furnace at the unit A decreased, and the temperature difference in the furnace at the units A and B decreased. As a result, the flow rate difference between the gas at the unit A and the gas at the unit B fell within the predetermined range, and the temperature difference of the furnace became less than 50°C, as a result of which it was possible to eliminate an operation failure of the vertical carbonization furnace 10.

Reference Signs List

[0078]

10	vertical carbonization furnace
11	charging port
12	carbonization-furnace main body
13	high-temperature tuyere
14	low-temperature tuyere
15	cooling tuyere
16	extraction tuyere
17	discharge port
19	branching portion
20	acceleration sensor
22	amplifier
24	HPF
30	temperature sensor
40	flow-rate regulating valve
50	control device
52	control section
54	input section
56	output section
58	storage section
60	obtaining section
62	computing section

64 determining section
70 flow path
72 pressure sensor
74 flow rate sensor
76 temperature sensor
100 vertical-carbonization-furnace facility

Claims

1. A method of operating a vertical carbonization furnace that produces ferro coke,

    wherein the vertical carbonization furnace includes
    a carbonization-furnace main body;
    one or more high-temperature tuyeres that blow high-temperature gas into the carbonization-furnace main body; and
    two or more extraction tuyeres that are provided at positions differing in a height direction from a position of the one or more high-temperature tuyeres, and that discharge gas in the carbonization-furnace main body, and
    wherein the two or more extraction tuyeres are provided at positions at a same height and differing from each other in a width direction,
    the method of operating the vertical carbonization furnace comprising:

        an obtaining step of obtaining a flow rate of the gas that is discharged from each of the extraction tuyeres; and
        a determining step of determining that an operation abnormality has occurred when the flow rate obtained in the obtaining step falls outside a predetermined flow rate range.

2. The method of operating the vertical carbonization furnace according to claim 1, wherein, in the obtaining step, by measuring vibration of each of the extraction tuyeres, the flow rate of the gas that is discharged from each of the extraction tuyeres is obtained.

3. The method of operating the vertical carbonization furnace according to claim 2,

    wherein, in the obtaining step, the flow rate of the gas that is discharged from each of the extraction tuyeres is obtained from each of the vibrations whose frequency component of vibration that becomes a disturbance is removed, and
    wherein the frequency component of the vibration that becomes the disturbance is determined by previously performing principal component analysis of the frequency component of the vibration that becomes the disturbance and by determining a principal component loading.

4. The method of operating the vertical carbonization furnace according to claim 3, wherein the frequency component of the vibration that becomes the disturbance is determined by evaluating for every frequency an existence ratio in which the principal component loading becomes greater than or equal to a predetermined value.

5. The method of operating the vertical carbonization furnace according to any one of claims 1 to 4, wherein, in the obtaining step, temperatures in the furnace at two or more positions that are same in the height direction and that differ from each other in the width direction are further obtained, and that an operation abnormality has occurred is determined when a difference between the temperatures in the furnace is greater than or equal to a predetermined temperature difference.

6. The method of operating the vertical carbonization furnace according to any one of claims 1 to 4, further comprising: an adjusting step of, when it is determined that an operation abnormality has occurred in the determining step, adjusting the flow rate of the gas that is discharged from each of the extraction tuyeres such that the flow rate falls within the predetermined flow rate range.

7. The method of operating the vertical carbonization furnace according to claim 5, further comprising: an adjusting step of, when it is determined that an operation abnormality has occurred in the determining step, adjusting the flow rate of the gas that is discharged from each of the extraction tuyeres such that the difference between the temperatures in the furnace becomes less than a predetermined temperature.

8. A method of producing ferro coke,
wherein the ferro coke is produced by operating a vertical carbonization furnace by the method of operating the vertical carbonization furnace according to claim 6.

9. A method of producing ferro coke,
wherein the ferro coke is produced by operating a vertical carbonization furnace by the method of operating the vertical carbonization furnace according to claim 7.

10. A vertical-carbonization-furnace facility that produces ferro coke, comprising:

a vertical carbonization furnace;
two or more flow rate sensors that measure flow rates of gas; and
a control device that controls the vertical carbonization furnace,
wherein the vertical carbonization furnace includes

a carbonization-furnace main body;
a charging port into which a molded product that becomes a raw material of the ferro coke is charged;
one or more high-temperature tuyeres that blow high-temperature gas into the carbonization-furnace main body;
two or more extraction tuyeres that are provided at positions differing in a height direction from a position of the one or more high-temperature tuyeres, and that discharge gas in the carbonization-furnace main body; and
a discharge port that discharges the molded product that has been carbonized,
wherein the two or more extraction tuyeres are provided at positions differing from each other in a width direction,
wherein the two or more flow rate sensors are each provided at a corresponding one of the two or more extraction tuyeres, and
wherein the control device includes an obtaining section that obtains from each of the flow rate sensors data indicating the flow rate of the gas that is discharged from each of the extraction tuyeres, a computing section that calculates from the data the flow rate of the gas that is discharged from each of the extraction tuyeres, and a determining section that determines that an operation abnormality has occurred when the flow rate falls outside a predetermined flow rate range.

11. The vertical-carbonization-furnace facility according to claim 10,
wherein each of the flow rate sensors is a vibration meter.

12. The vertical-carbonization-furnace facility according to claim 11, further comprising:

a disturbance removing filter,
wherein the disturbance removing filter removes a predetermined frequency component of vibration measured by each of the vibration meters.

13. The vertical-carbonization-furnace facility according to claim 12,
wherein the frequency component is previously determined by performing principal component analysis of a frequency component of vibration that becomes a disturbance and by evaluating for every frequency an existence ratio in which a principal component loading becomes greater than or equal to a predetermined value.

14. The vertical-carbonization-furnace facility according to any one of claims 10 to 13, further comprising:

two or more temperature sensors that measure temperatures in the furnace,
wherein the two or more temperature sensors are provided at positions at a same height in the vertical carbonization furnace and differing from each other in the width direction, and
wherein the obtaining section obtains the temperature in the furnace from each of the temperature sensors, and the determining section determines that an operation abnormality has occurred when a difference between the temperatures in the furnace obtained from the temperature sensors is greater than or equal to a predetermined temperature difference.

15. The vertical-carbonization-furnace facility according to any one of claims 10 to 13, wherein, when the determining section determines that an operation abnormality has occurred, the determining section adjusts the flow rate of the gas that is discharged from each of the extraction tuyeres such that the flow rate falls within the predetermined flow rate range.

16. The vertical-carbonization-furnace facility according to claim 14,
wherein, when the determining section determines that an operation abnormality has occurred, the determining section adjusts the flow rate of the gas that is discharged from each of the extraction tuyeres such that the difference between the temperatures in the furnace becomes less than a predetermined temperature.

FIG. 1

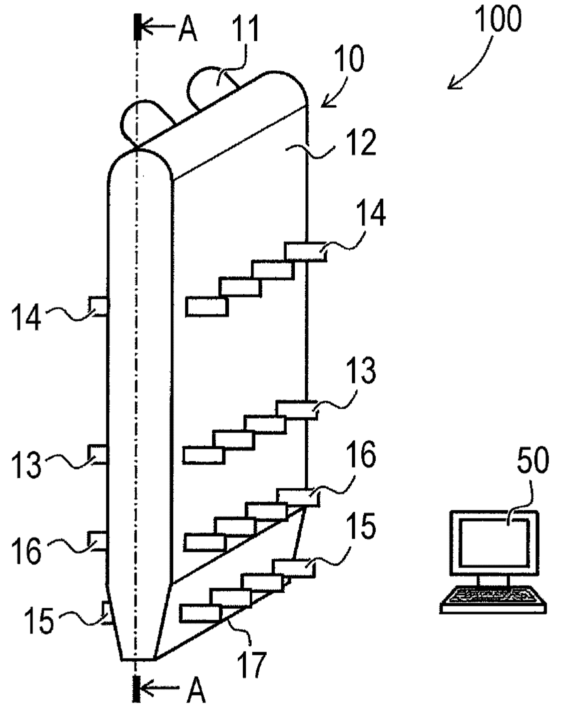

A
11
100
10
12
14
14
13
13
16
16
15
15
17
A
50

FIG. 2

(a) (b)

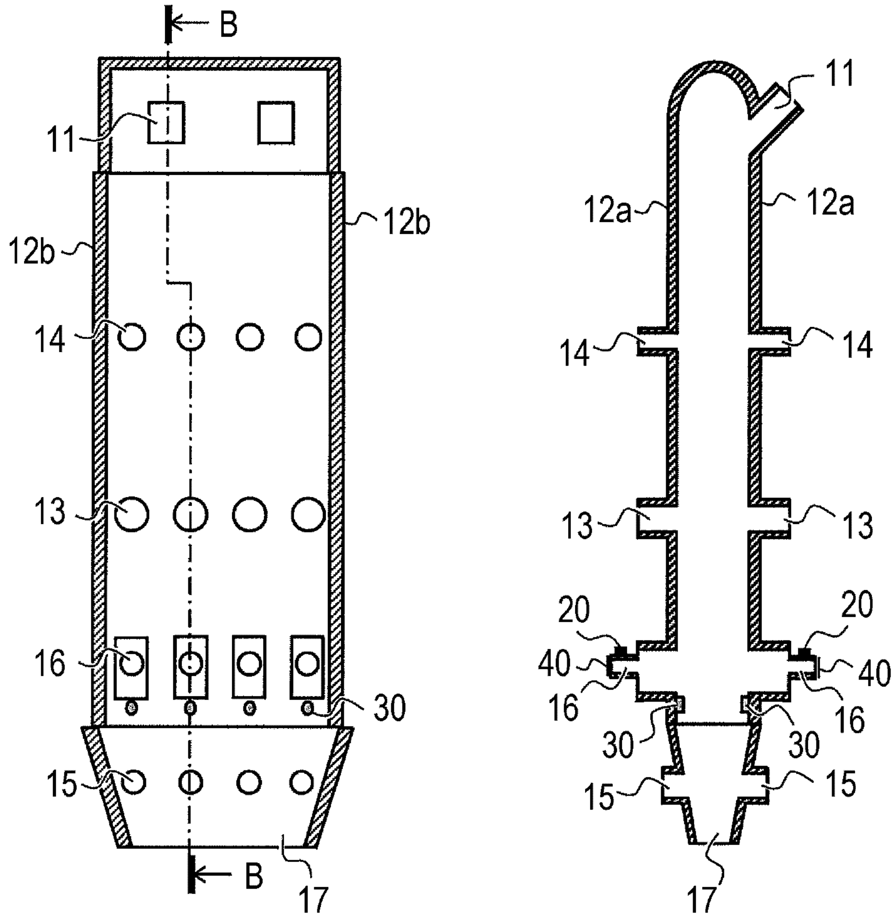

B
11
12b
12b
14
13
16
30
15
B
17
11
12a
12a
14
14
13
13
20
20
40
40
16
16
30
30
15
15
17

FIG. 3

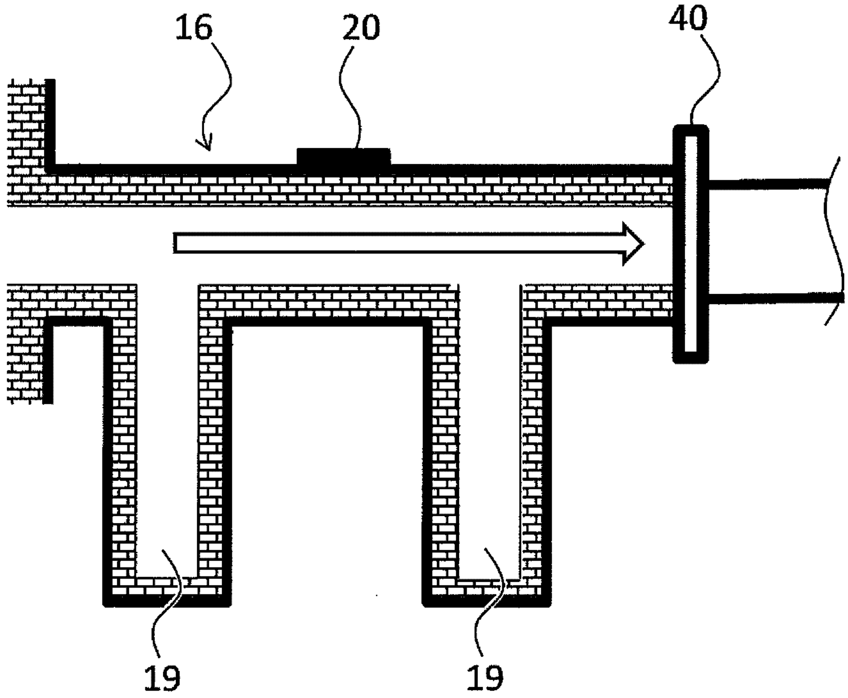


FIG. 4

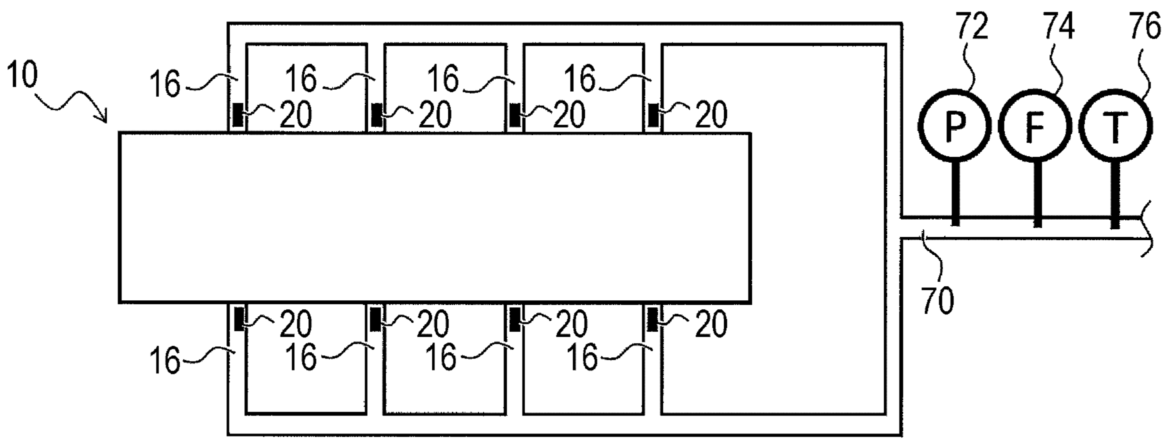


FIG. 5

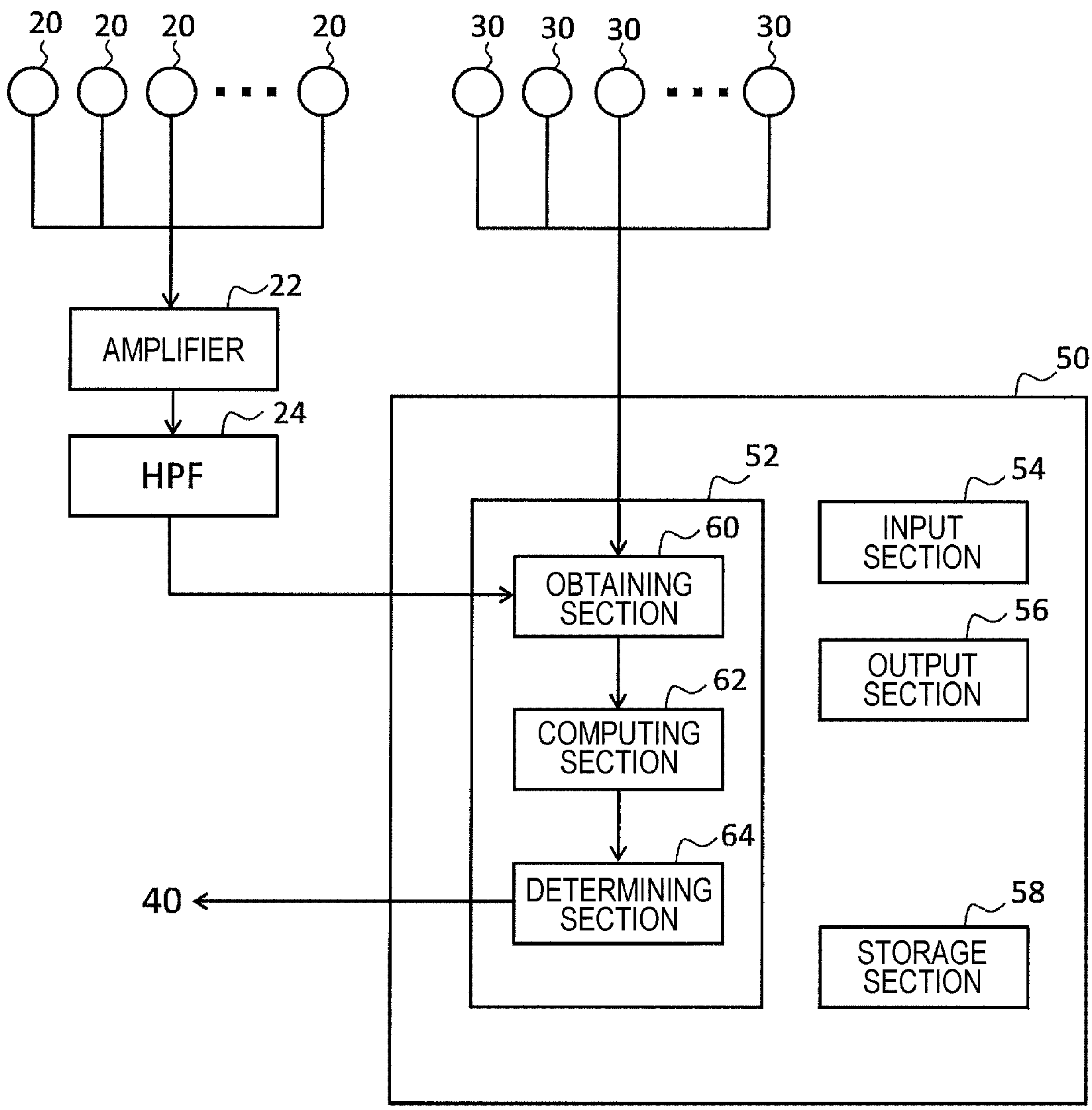

20
20
20
20
30
30
30
30
22
AMPLIFIER
24
HPF
50
52
54
INPUT SECTION
60
OBTAINING SECTION
56
OUTPUT SECTION
62
COMPUTING SECTION
64
40
DETERMINING SECTION
58
STORAGE SECTION

FIG. 6

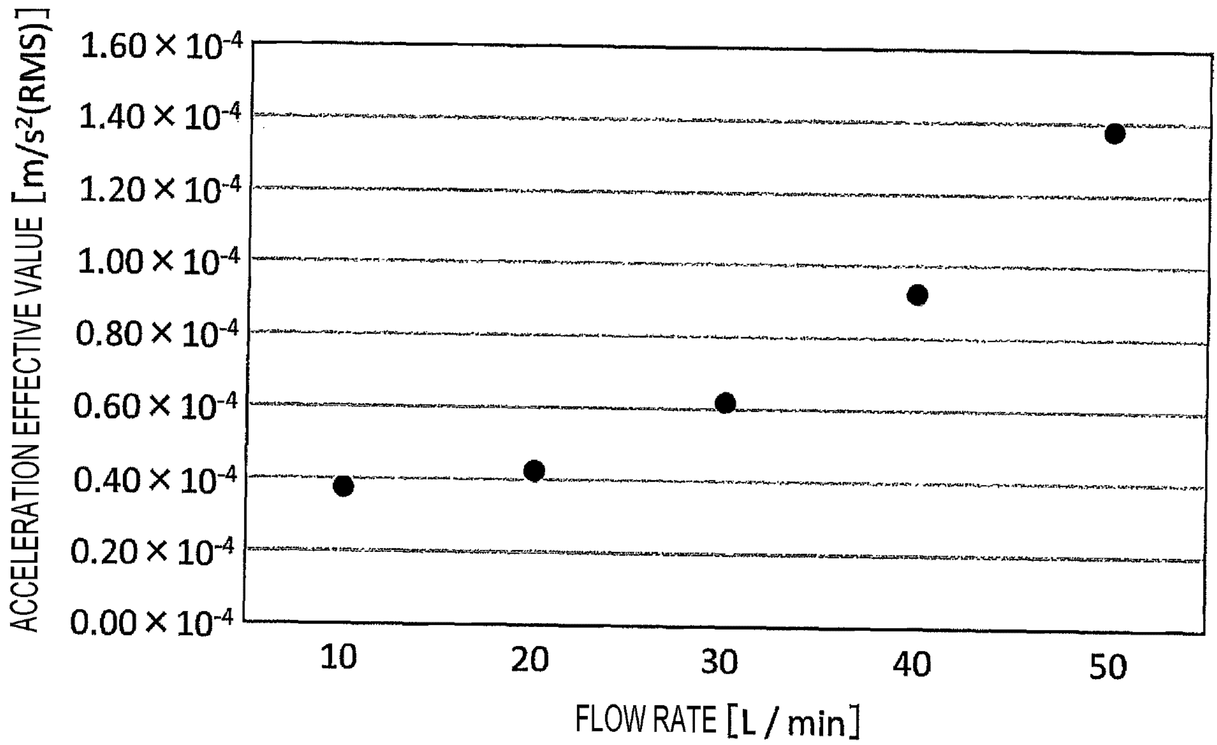

ACCELERATION EFFECTIVE VALUE [m/s²(RMS)]
1.60 × 10-4
1.40 × 10-4
1.20 × 10-4
1.00 × 10-4
0.80 × 10-4
0.60 × 10-4
0.40 × 10-4
0.20 × 10-4
0.00 × 10-4
10
20
30
40
50
FLOW RATE [L / min]

FIG. 7

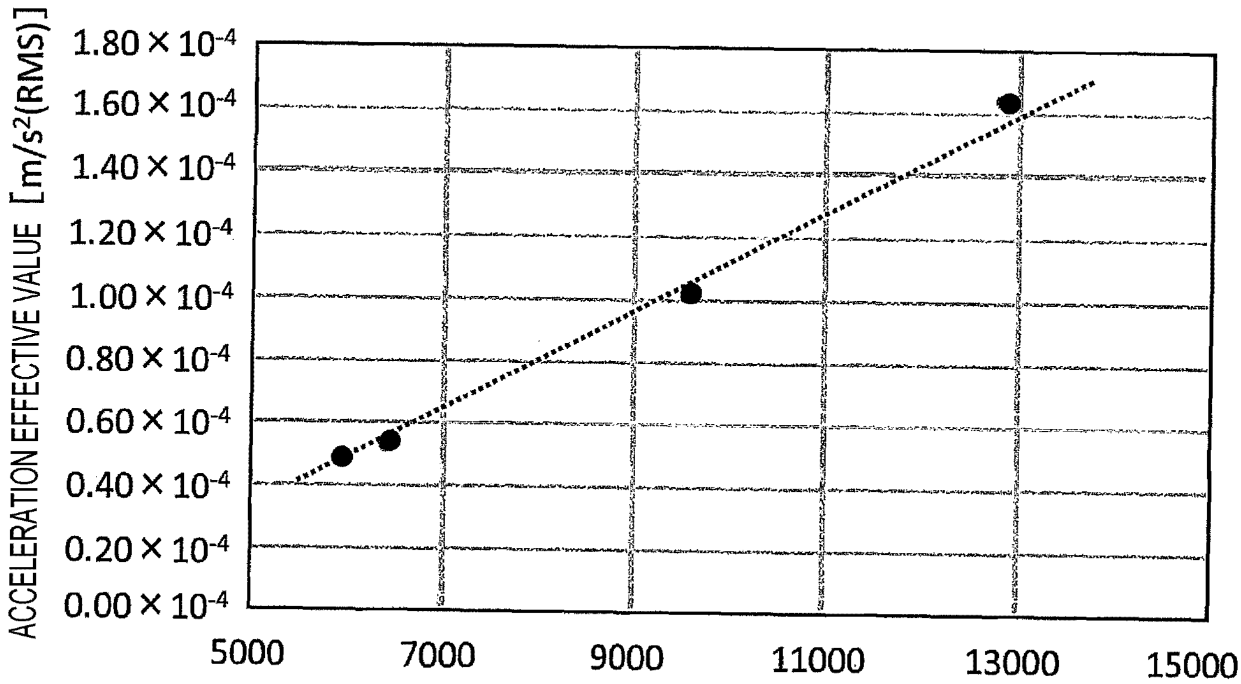

ACCELERATION EFFECTIVE VALUE [m/s²(RMS)]
1.80 × 10-4
1.60 × 10-4
1.40 × 10-4
1.20 × 10-4
1.00 × 10-4
0.80 × 10-4
0.60 × 10-4
0.40 × 10-4
0.20 × 10-4
0.00 × 10-4
5000
7000
9000
11000
13000
15000

FIG. 8

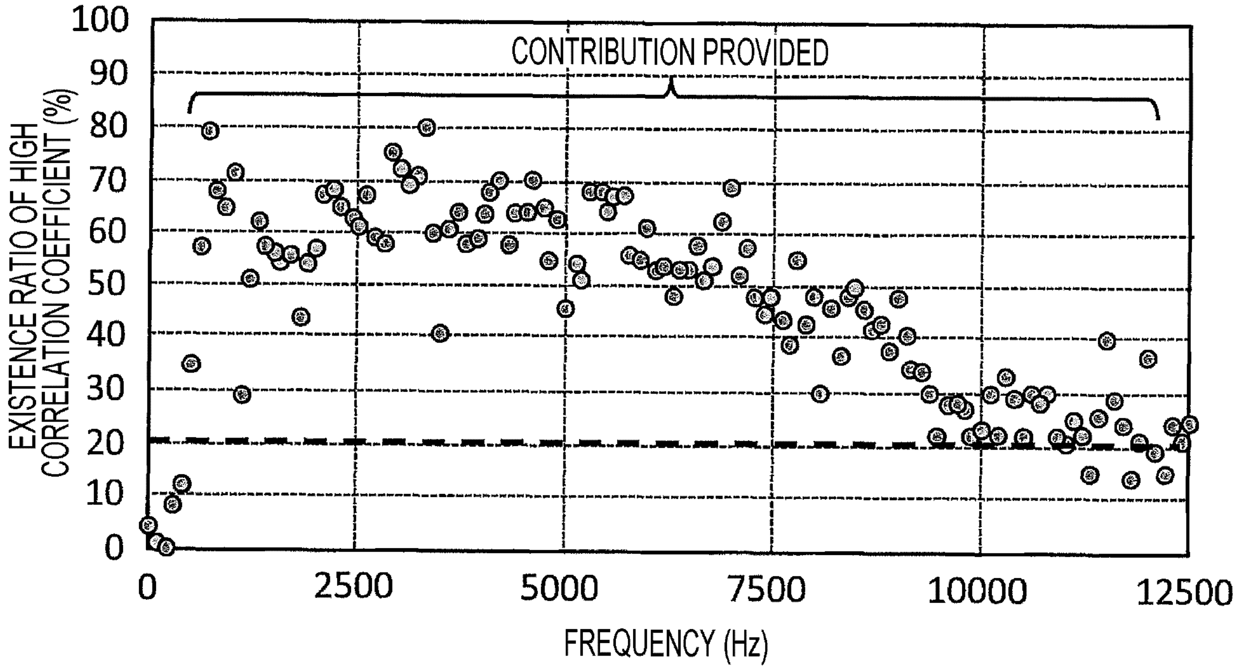

CONTRIBUTION PROVIDED
EXISTENCE RATIO OF HIGH CORRELATION COEFFICIENT (%)
100
90
80
70
60
50
40
30
20
10
0
0
2500
5000
7500
10000
12500
FREQUENCY (Hz)

FIG. 9

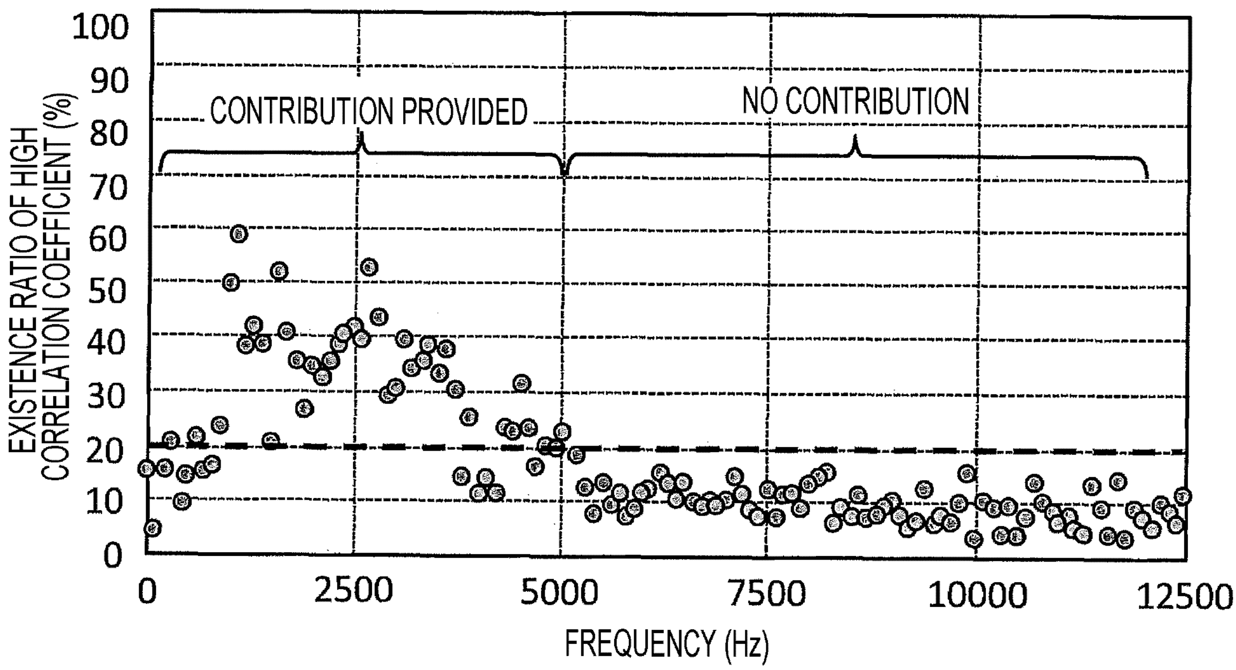

CONTRIBUTION PROVIDED
NO CONTRIBUTION
EXISTENCE RATIO OF HIGH CORRELATION COEFFICIENT (%)
100
90
80
70
60
50
40
30
20
10
0
0
2500
5000
7500
10000
12500
FREQUENCY (Hz)

FIG. 10

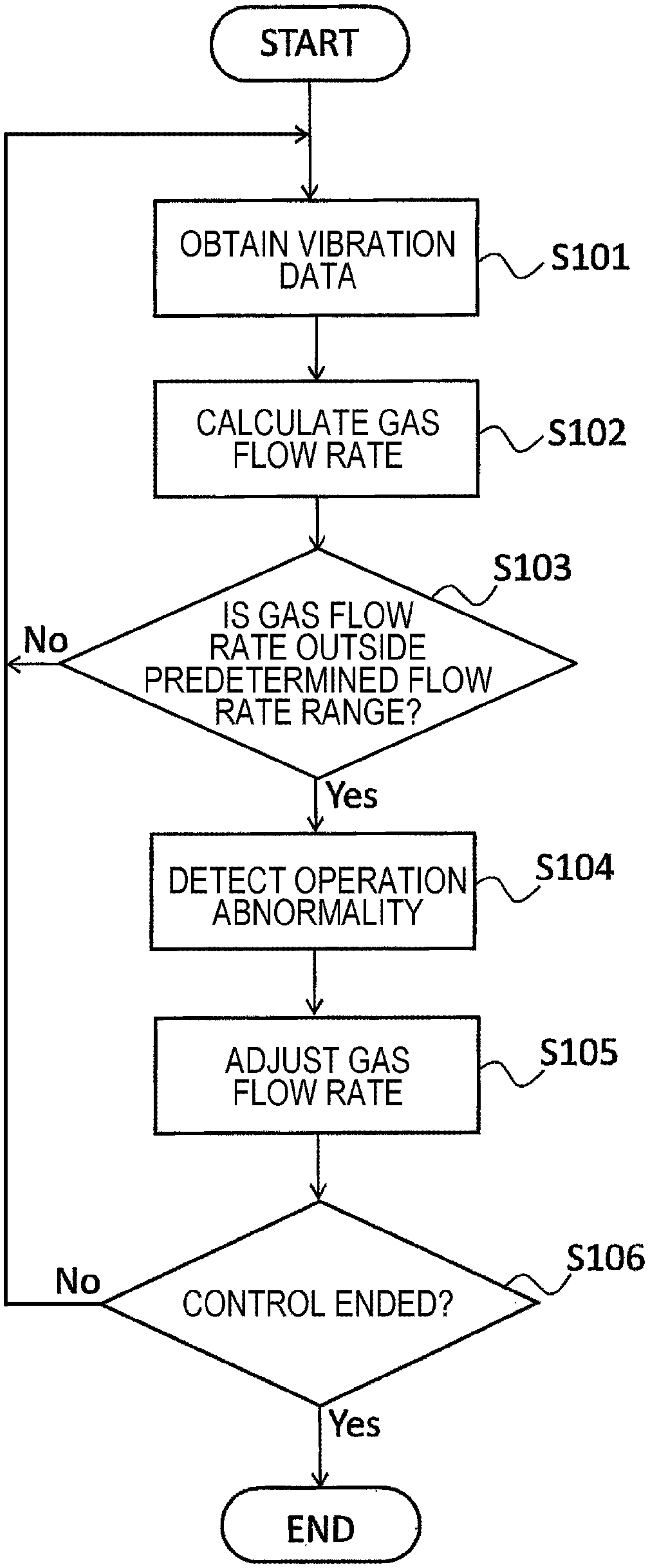

START
OBTAIN VIBRATION DATA
S101
CALCULATE GAS FLOW RATE
S102
S103
IS GAS FLOW RATE OUTSIDE PREDETERMINED FLOW RATE RANGE?
No
Yes
DETECT OPERATION ABNORMALITY
S104
ADJUST GAS FLOW RATE
S105
S106
No
CONTROL ENDED?
Yes
END

FIG. 11

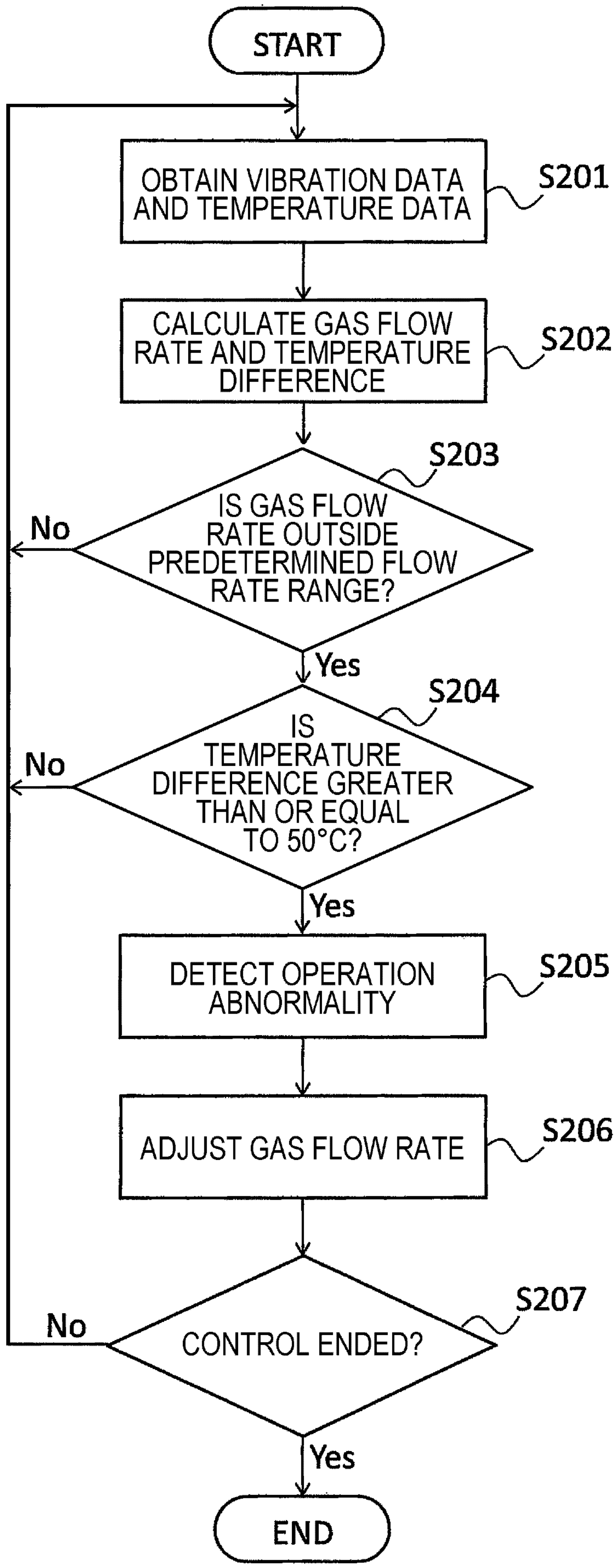
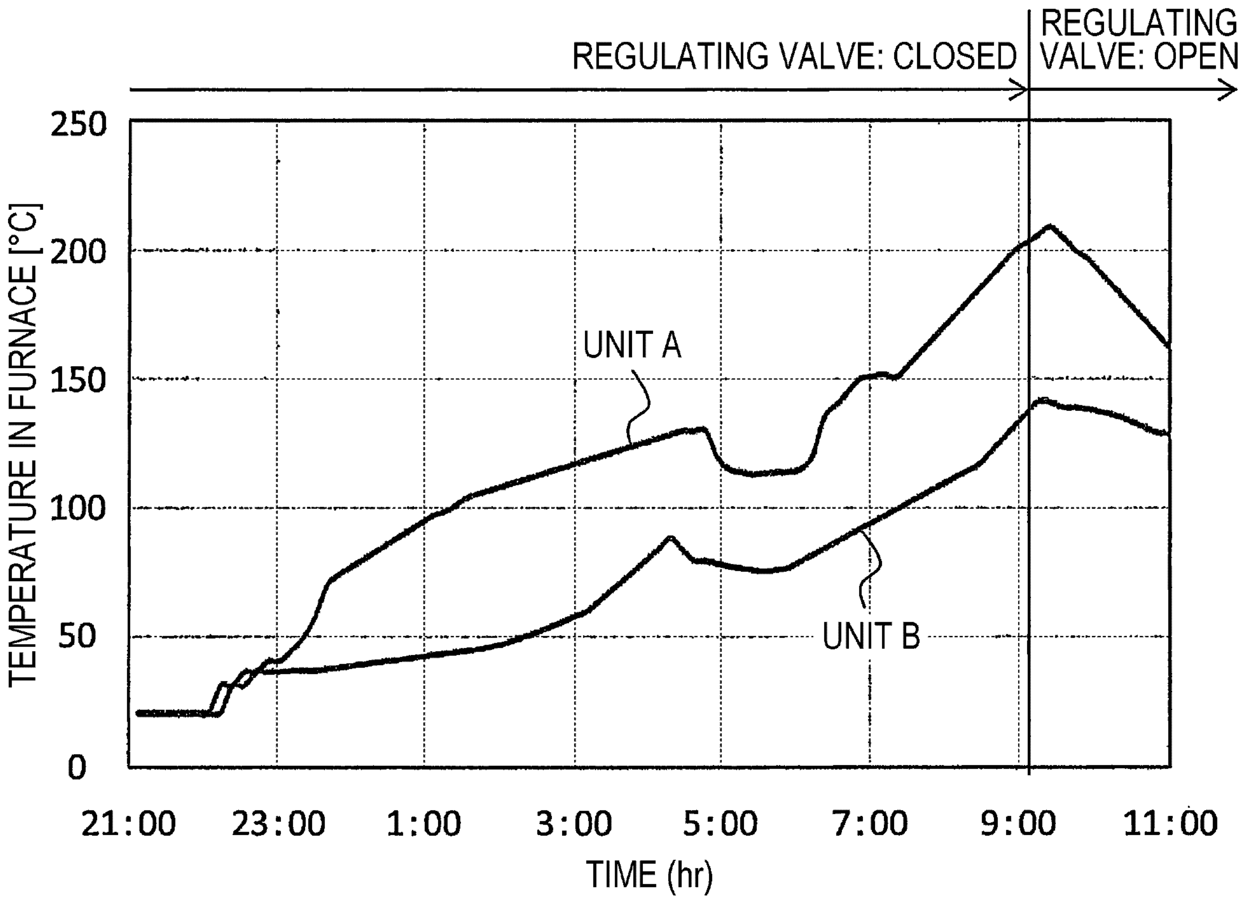

START
OBTAIN VIBRATION DATA AND TEMPERATURE DATA
S201
CALCULATE GAS FLOW RATE AND TEMPERATURE DIFFERENCE
S202
S203
IS GAS FLOW RATE OUTSIDE PREDETERMINED FLOW RATE RANGE?
No
Yes
S204
IS TEMPERATURE DIFFERENCE GREATER THAN OR EQUAL TO 50°C?
No
Yes
DETECT OPERATION ABNORMALITY
S205
ADJUST GAS FLOW RATE
S206
S207
No
CONTROL ENDED?
Yes
END

FIG. 12


REGULATING VALVE: CLOSED
REGULATING VALVE: OPEN
TEMPERATURE IN FURNACE [°C]
250
200
150
100
50
0
UNIT A
UNIT B
21:00
23:00
1:00
3:00
5:00
7:00
9:00
11:00
TIME (hr)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2023/023272

A. CLASSIFICATION OF SUBJECT MATTER

C10B 53/08(2006.01)i; ***C10B 41/00***(2006.01)i; ***C10B 47/20***(2006.01)i
FI: C10B53/08; C10B47/20; C10B41/00

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)

C10B53/08; C10B41/00; C10B47/20

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

Published examined utility model applications of Japan 1922-1996
Published unexamined utility model applications of Japan 1971-2023
Registered utility model specifications of Japan 1996-2023
Published registered utility model applications of Japan 1994-2023

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.
A	JP 2017-160283 A (JFE STEEL CORP.) 14 September 2017 (2017-09-14)	1-16
A	JP 2016-151011 A (JFE STEEL CORP.) 22 August 2016 (2016-08-22)	1-16
A	JP 2013-142090 A (NIPPON STEEL & SUMIKIN ENGINEERING CO., LTD.) 22 July 2013 (2013-07-22)	1-16
A	JP 2019-109194 A (HITACHI INDUSTRIAL EQUIPMENT SYSTEMS CO., LTD.) 04 July 2019 (2019-07-04)	2-4, 11-13

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

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
26 July 2023	**08 August 2023**

Name and mailing address of the ISA/JP	Authorized officer
Japan Patent Office (ISA/JP) **3-4-3 Kasumigaseki, Chiyoda-ku, Tokyo 100-8915** **Japan**	Telephone No.

Form PCT/ISA/210 (second sheet) (January 2015)

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2023/023272

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
JP 2017-160283 A	14 September 2017	(Family: none)	
JP 2016-151011 A	22 August 2016	(Family: none)	
JP 2013-142090 A	22 July 2013	(Family: none)	
JP 2019-109194 A	04 July 2019	(Family: none)	

Form PCT/ISA/210 (patent family annex) (January 2015)

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- JP 6274126 B **[0007]**
- JP 5087868 B **[0007]**