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(54) **MONITORING SYSTEM FOR FOREIGN SUBSTANCE REMOVAL DEVICE, FOREIGN SUBSTANCE REMOVAL SYSTEM, AND MONITORING METHOD FOR FOREIGN SUBSTANCE REMOVAL DEVICE**

(57) A monitoring system includes a pressure detection means for detecting a pressure inside a retainer, and a failure sign determination means for determining whether there is a sign of failure of a foreign substance removal device based on the detected pressure inside the retainer. The pressure detection means is disposed

in the foreign substance removal device including a generator that generates compressed air, the retainer that retains the generated compressed air therein, and a jetting device that jets the retained compressed air to blow off a foreign substance existing in a diverging portion of a railway track.

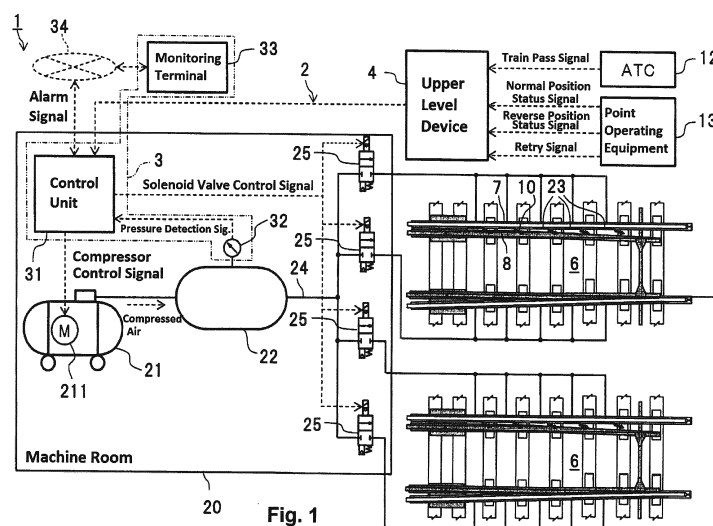


Fig. 1

Description

TECHNICAL FIELD

[0001] The present invention relates to a monitoring system for a foreign substance removal device, a foreign substance removal system, and a monitoring method for a foreign substance removal device.

BACKGROUND

[0002] A foreign substance removal device that blows off foreign substances such as snow and ice held between a stock rail and a tongue rail by jetting compressed air has been developed in order to avoid a failure of switching at a portion of railway track branching off, which may be a cause of delays in railway operation. For example, International Publication WO2015/049879A1 discloses a foreign substance removal system including a control center that can change the operation mode of the foreign substance removal device based on the operation status of a train.

[0003] However, when some failure occurs in the foreign substance removal device, the device is unable to properly remove foreign substances existing in a diverging portion of the railway track and the foreign substances hamper the switching at the diverging portion of the track, which consequently causes a delay in the railway operation. For this reason, it is desired to detect a failure of the foreign substance removal device as early as possible and address the failure.

[0004] However, it has been the case that a failure of the conventional foreign substance removal device is not detected until a switching failure at the diverging portion of the track is actually detected.

SUMMARY

[0005] The invention has been made in view of the above, and it is an object of the invention to provide a monitoring system for a foreign substance removing device capable of promptly detecting a failure of the foreign substance removal device, a foreign substance removal system, and a method of monitoring the foreign substance removal device thereof.

[0006] Provided according to one aspect of the invention is a monitoring system that includes a pressure detection means for detecting a pressure inside a retainer, and a failure sign determination means for determining whether there is a sign of failure of a foreign substance removal device based on the detected pressure inside the retainer. The pressure detection means is disposed in the foreign substance removal device including a generator that generates compressed air, the retainer that retains the generated compressed air therein, and a jetting device that jets the retained compressed air to blow off a foreign substance existing in a diverging portion exist a railway track.

[0007] In the monitoring system, the failure sign determination means may determine whether there is the sign of failure based on a comparison between a pressure inside the retainer that is detected after the jetting of the compressed air and a first upper limit and a first lower limit of the after-jet pressure that are set depending on a pressure inside the retainer detected before the jetting of the compressed air.

[0008] In the monitoring system, a failure sign determination means for determining whether there is a failure of the foreign substance removal device based on the detected pressure inside the retainer may be provided. The failure determination means may determine whether there is the failure based on a comparison between a pressure inside the retainer that is detected after the jetting of the compressed air and a second upper limit and a second lower limit of the after-jet pressure that are set depending on a pressure inside the retainer detected before the jetting of the compressed air.

[0009] In the monitoring system, the failure sign determination means may determine whether there is the sign of failure based on a difference between a before-jet pressure inside the retainer that is detected before the jetting of the compressed air and an after-jet pressure inside the retainer that is detected after the jetting of the compressed air.

[0010] In the monitoring system, the failure sign determination means may determine whether there is the sign of failure based on a pressure inside the retainer that is detected after the jetting of the compressed air.

[0011] In the monitoring system, the failure sign determination means may determine whether there is the sign of failure based on an amount of change in the detected pressure inside the retainer in a predetermined period of time.

[0012] In the monitoring system, the failure sign determination means may not perform the determination whether there is the sign of failure when the foreign substance removal device is in a predetermined state at the time when the amount of change is obtained.

[0013] In the monitoring system, the predetermined state includes at least one selected from the group consisting of that the jetting is being performed, that an ambient temperature of the generator is dropped, and that it is in a predetermined period after operation of the generator.

[0014] The monitoring system may be provided with an alarm output means for outputting an alarm when it is determined that there is the sign of failure.

[0015] The monitoring system may be provided with a check means for checking whether there is a failure of the foreign substance removal device based on an amount of change in the pressure inside the retainer after the jetting of the compressed air.

[0016] According to another aspect of the invention, provided is a foreign substance removal system that includes a foreign substance removal device and a monitoring system. The foreign substance removal device in-

cludes a generator that generates compressed air, a re-
tainer that retains the generated compressed air therein,
and a jetting device that jets the retained compressed air
to blow off a foreign substance existing in a diverging
portion of a railway track. The monitoring system includes
a pressure detection means for detecting a pressure in-
side the retainer, and a failure sign determination means
for determining whether there is a sign of failure of the
foreign substance removal device based on the detected
pressure inside the retainer. The pressure detection
means is disposed in the foreign substance removal de-
vice.

[0017] According to another aspect of the invention is
a method of monitoring a foreign substance removal de-
vice. The method includes a step of detecting a pressure
inside a retainer in a foreign substance removal device
including a generator that generates compressed air, the
retainer that retains the generated compressed air there-
in, and a jetting device that jets the retained compressed
air to blow off a foreign substance existing in a diverging
portion of a railway track; and, a step of determining
whether there is a sign of failure of the foreign substance
removal device based on the detected pressure inside
the retainer.

[0018] According to the aspects of the invention, it is
possible to detect a failure of the foreign substance re-
moval device at an early stage.

BRIEF DESCRIPTION OF THE DRAWINGS

[0019]

Fig. 1 illustrates a foreign substance removal system
according to one embodiment of the invention.

Fig. 2 is a flow chart for showing an example of op-
eration of the foreign substance removal system ac-
cording to the embodiment.

Fig. 3 is a diagram for explaining failure sign deter-
mination performed by the foreign substance remov-
al device in the example of the operation of the fore-
ign substance removal system according to the em-
bodiment.

Fig. 4 is a flow chart for showing an example of op-
eration of the foreign substance removal system in
a first modification example of the embodiment.

Fig. 5 is a time chart for showing the example of the
operation of the foreign substance removal system
in the first modification example of the embodiment.

Fig. 6 is a flow chart for showing an example of op-
eration of the foreign substance removal system in
a second modification example of the embodiment.

Fig. 7 illustrates the foreign substance removal sys-
tem in a third example of the embodiment.

Fig. 8 is a flow chart for showing an example of op-
eration of the foreign substance removal system in
a fourth modification example of the embodiment.

Fig. 9 illustrates the foreign substance removal sys-
tem in a fifth example of the embodiment.

Fig. 10 is a flow chart for showing an example of
operation of the foreign substance removal system
in a fifth modification example of the embodiment.

Fig. 11 is a flow chart for showing an example of
operation of the foreign substance removal system
in a sixth modification example of the embodiment.

Fig. 12 illustrates the foreign substance removal sys-
tem in a seventh example of the embodiment.

Fig. 13 is a flow chart for showing an example of
operation of the foreign substance removal system
in a seventh modification example of the embodi-
ment.

Fig. 14 illustrates the foreign substance removal sys-
tem in an eighth example of the embodiment.

Fig. 15 is a flow chart for showing an example of
operation of the foreign substance removal system
in the eighth modification example of the embodi-
ment.

DESCRIPTION OF THE EMBODIMENTS

[0020] With reference to the appended drawings, the
following describes in detail a monitoring system for a
foreign substance removal device, a foreign substance
removal system, and a monitoring method for a foreign
substance removal device. Embodiments described be-
low are each one example of an embodiment of the in-
vention, and the invention is not intended to be construed
as being limited thereto. Furthermore, in the drawings
referred to in this embodiment, the same parts or parts
having similar functions are denoted by the same or like
reference characters, and duplicate descriptions thereof
are omitted. Furthermore, for the sake of convenience of
description, a dimensional ratio of the drawings is possi-
bly different from an actual dimensional ratio, and some
elements of a configuration are possibly omitted from the
drawings.

[0021] Fig. 1 illustrates a foreign substance removal
system 1 according to one embodiment of the invention.
As shown in Fig. 1, the foreign substance removal system
1 includes a foreign substance removal device 2 and a
monitoring system 3.

Foreign Matter Removal Device 2

[0022] The foreign substance removal device 2 is dis-
posed at a diverging portion of a railway track, and re-
moves foreign substances such as ice and snow existing
between stock rails 7 and tongue rails 8 that constitute
a point 6 of a railroad switch by jetting compressed air
10. The railway track is, for example, a track of a bullet
train line called Shinkansen. The track of Shinkansen
may be either a Japanese Shinkansen standard (that is,
a full standard) track or a mini Shinkansen track which
is a track of the existing conventional line whose gauge
is changed to adapt to Shinkansen and a train can be
operated directly therefrom. Alternatively, the railway
track may be a track dedicated to the conventional line.

Moreover, the railway track may be any railway track in the world including Japan (for example, a track of a high-speed railway line or a track of a conventional line).

[0023] Referring to Fig. 1, the foreign substance removal device 2 includes a compressor 21 which is an example of a generator, a tank 22 which is an example of a retainer, and a nozzle 23 which is an example of a jetting device. The compressor 21 generates compressed air, which is an example of compressed gas. The tank 22 stores therein the compressed air generated by the compressor 21. The nozzle 23 jets the compressed air stored in the tank 22 to remove foreign substances disposed in the diverging portion of the track.

[0024] As shown in Fig. 1, the foreign substance removal device 2 includes a pipe 24 connecting the compressor 21, the tank 22 and the nozzle 23, and a solenoid valve 25 provided on the pipe 24 between the tank 22 and the nozzle 23. The foreign substance removal device 2 further includes a control unit 31 that controls the compressor 21 and the solenoid valve 25. The control unit 31 also serves as failure sign determination means and alarm output means of the monitoring system 3 which will be described later. Further, as shown in Fig. 1, the compressor 21, the tank 22, the solenoid valve 25, the control unit 31 and a part of the pipe 24 are installed inside a machine room 20.

[0025] More specifically, the compressor 21 has a compressor motor 211 therein as shown in Fig. 1. A compressor control signal for commanding rotation of the compressor motor 211 is supplied from the control unit 31 to the compressor 21. The compressor motor 211 is rotated when the compressor control signal is supplied. Alternatively, the compressor motor 211 may rotate based on a pressure detection signal from a pressure sensor 32 which will be described later. When the compressor motor 211 rotates, compressed air is generated in the compressor 21. The compressor 21 may be configured to generate compressed air by converting the rotation of the compressor motor 211 into a reciprocating motion of a piston in a cylinder. However, the invention is not limited to this configuration but may be any configuration. The compressed air generated in the compressor 21 flows into the tank 22 through the pipe 24 and is retained in the tank 22.

[0026] Further, a solenoid valve control signal for commanding the opening of the solenoid valve 25 is supplied to the solenoid valve 25 from the control unit 31. The solenoid valve 25 opens when the solenoid valve control signal is supplied. With the solenoid valve 25 open, the compressed air in the tank 22 moves through the pipe 24 to the nozzle 23. The compressed air that has reached the nozzle 23 is jetted from the nozzle 23 toward a space between the stock rail 7 and the tongue rail 8. By jetting the compressed air, foreign substances existing between the stock rail 7 and the tongue rail 8 can be removed.

[0027] In the example of Fig. 1, two or more nozzles 23 are provided on inner side walls of the stock rails in each of the two tracks running in parallel. The nozzles

23 are arranged at intervals in the longitudinal direction of the track. Four solenoid valves 25 are provided, which is the same number as the total number of the stock rails 7 in the two tracks. Further, the nozzles 23 provided on the same stock rail 7 are configured to communicate with the common solenoid valve 25 through the pipe 24.

[0028] In the example of Fig. 1, the control unit 31 receives, from an upper-level device 4, a jet signal for instructing jetting of the compressed air. The upper-level device 4 may be, for example, an information device or an information terminal installed at a station. In response to reception of the jet signal, the control unit 31 outputs, to the compressor motor 211, the compressor control signal for commanding the compressor motor 211 to rotate. The control unit 31 also outputs, to the solenoid valve 25, the solenoid valve control signal for commanding the solenoid valve 25 to be opened.

[0029] In the example of Fig. 1, the jet signal includes four types of signals: a train pass signal, a normal position status signal, a reverse position status signal, and a retry signal.

[0030] The train pass signal is a signal output by an automatic train control (ATC) 12 to the upper-level device 4 when a train passes on the track. When a train passes, the train shakes at the point 6 so that foreign substances such as ice and snow adhering to the wheels, the floor and the like of the train may fall into a space between the stock rail 7 and the tongue rail 8. The control unit 31 performs a control in which the compressed air is jetted using the train pass signal as a trigger, thereby with such a simple method, it is possible to quickly remove foreign substances fallen between the stock rail 7 and the tongue rail 8 when the train is passing there.

[0031] The normal position status signal is a signal output by a point operating equipment 13 that switches the point 6 to the higher-level device 4 when the point 6 is switched from a reverse position to a normal position by the point operating equipment 13. Note that the normal position is the state of the point 6 where a train enters in the normal direction, that is, a main line. Whereas the reverse position is the state of the point 6 where the train enters a direction other than the normal direction, that is, a secondary main line. The normal position status signal may be, for example, a signal output by a sensor that detects a current supplied to a motor from which the point operating equipment 13 is powered.

[0032] The reverse position status signal is a signal output by the point operating equipment 13 to the higher-level device 4 when the point 6 is switched from the normal position to the reverse position by the point operating equipment 13.

[0033] The retry signal is output by the point operating equipment 13 to the higher-level device 4 when switching failure of the point 6 occurs and the point operating equipment 13 tries to switch the point 6 again, more specifically, when reversing of the point 6 is started for retry of the switching.

[0034] In addition to the four types of jet signals de-

scribed above, the control unit 31 may receive a jetting command signal from a monitoring terminal 33 by remote control, which will be described later, and perform a control to jet the compressed air in response to reception of the jetting command signal. Further, when the control unit 31 has performed a control of jetting the compressed air, the control unit 31 may transmit, to the monitoring terminal 33, an in-jet signal indicating that the compressed air is being jetted.

Monitoring System 3

[0035] The monitoring system 3 is a system capable of monitoring the operation status of the foreign substance removal device 2 and determining whether there is a sign of failure of the foreign substance removal device 2. As shown in Fig. 1, the monitoring system 3 includes a pressure sensor 32 which is an example of a pressure detection means, the control unit 31 which is an example of a failure sign determination means, and the monitoring terminal 33.

[0036] The pressure sensor 32 is disposed in the tank 22 of the foreign substance removal device 2. The pressure sensor 32 detects a pressure inside the tank 22 (hereinafter, also referred to as a tank pressure), and outputs a pressure detection signal indicating the detected tank pressure to the control unit 31.

[0037] The control unit 31 is, for example, a control device such as a programmable logic controller (PLC). The control unit 31 determines whether there is a sign of failure of the foreign substance removal device 2 based on the pressure detection signal supplied from the pressure sensor 32, in other words, based on the detected tank pressure.

[0038] Specifically, the control unit 31 detects a tank pressure before jetting of the compressed air (hereinafter also referred to as a "before-jet tank pressure") and a tank pressure after the jetting of the compressed air (hereinafter also referred to as a "after-jet tank pressure"). Then, the control unit 31 determines whether there is a sign of failure of the foreign substance removal device 2 (hereinafter, also referred to as a failure sign determination) based on comparison between the detected after-jet tank pressure and a predetermined upper limit and lower limit of the after-jet tank pressure that are set in advance depending on the detected before-jet tank pressure. Such a configuration can be made, for example, to perform the failure sign determination based on the comparison between the detected after-jet tank pressure and the predetermined after-jet tank pressure threshold (the upper limit and the lower limit). Further details of the failure sign determination will be described later in an operation example.

[0039] When it is determined in the failure sign determination that there is a sign of failure, the control unit 31 outputs an alarm indicating that the foreign substance removal device 2 may fail in the near future. The alarm may be, for example, at least one selected from the group

consisting of an image signal, a lighting signal of an alarm light, and an audio signal.

[0040] The monitoring terminal 33 is communicably coupled with the control unit 31 over a network 34. The specific configuration of the network 34 is not particularly limited, and may be, for example, a fourth generation mobile communication system (4G). By receiving the alarm output by the control unit 31 over the network 34, the monitoring terminal 33 is able to know a sign of failure of the foreign substance removal device 2 at a remote place (for example, an office of the railway company). The monitoring terminal 33 may be disposed not only at a remote place but also at a location (for example, a station) closer to the foreign substance removal device 2 than the remote place. The monitoring terminal 33 disposed at a short distance from the foreign substance removal device 2 may be communicably coupled to the control unit 31 by wire (for example, an optical cable or the like) or wirelessly.

[0041] The control unit 31 may control jetting of the compressed air based on the tank pressure. For example, the control unit 31 may perform a control to open the solenoid valve 25 when the tank pressure is equal to or higher than a threshold value sufficient for jetting of the compressed air. The compressor motor 211 may also be decelerated or stopped when the tank pressure is too high.

[0042] Further, the control unit 31 may output an alarm to the monitoring terminal 33 when none of the train pass signal, the normal position state signal, and the reverse position state signal has been supplied from the upper-level device 4 in a predetermined period (for example, within 24 hours). By performing this alarm output, it is possible to detect an abnormality in the ATC 12, the point operating equipment 13, or the upper-level device 4 can be detected.

[0043] Further, in order to forcibly stop or return the foreign substance removal device 2 in an emergency, the control unit 31 may turn off or turn on the power of the control unit 31 in accordance with a command from the monitoring terminal 33 or a tablet device not shown.

Operation Example

[0044] Next, an operation example of the foreign substance removal device 1 will now be described. Fig. 2 is a flow chart for showing an example of the operation of the foreign substance removal system 1 in the embodiment. A procedure shown in the flow chart may be repeatedly carried out as required.

[0045] As shown in Fig. 2, the pressure sensor 32 and the control unit 31 firstly detect the tank pressure before and after jetting of the compressed air, that is, the before-jet tank pressure and the after-jet tank pressure (step S1). For example, the control unit 31 compares the time when the pressure detection signal supplied by the pressure sensor 32 in a predetermined cycle is input to the control unit 31 with the time when the control of jetting

the compressed air is performed, and a pressure detection signal immediately before the jetting of the compressed air may be detected as the before-jet tank pressure and a pressure detection signal immediately after the jetting of the compressed air may be detected as the after-jet tank pressure.

[0046] Fig. 3 is a diagram for explaining the failure sign determination performed by the foreign substance removal device 2 in the operation example of the foreign substance removal system 1 in the embodiment. Fig. 3 shows an example of the upper limit and the lower limit of the after-injection tank pressure set in the control unit 31 in advance. As shown in Fig. 3, the upper limit and the lower limit of the after-jet tank pressure (the vertical axis) vary depending on the before-jet tank pressure (the horizontal axis). In the example of Fig. 3, the upper limit and the lower limit of the after-jet tank pressure are respectively expressed by a linear function of the before-jet tank pressure.

[0047] A region where the after-jet tank pressure is higher than the upper limit is an insufficient jet amount region that indicates that the jetted amount of the compressed air is insufficient. A region where the after-jet tank pressure is lower than the lower limit is an excessive jet amount region that indicates that the jetted amount of the compressed air is excessive. A region where the after-jet tank pressure is equal to or more than the lower limit and equal to or less than the upper limit is an appropriate jet amount region that indicates that the jetted amount of the compressed air is appropriate. However, since the before-jet tank pressure has the lower limit and the upper limit, the appropriate jet amount region is defined as equal to or more than the lower limit of the after-jet tank pressure and equal to or less than the upper limit of the after-jet tank pressure within the range from equal to or above the lower limit of the before-jet tank pressure to equal to or below the upper limit of the before-jet tank pressure.

[0048] After detecting the tank pressure before and after jetting, the control unit 31 compares the detected after-jet tank pressure with the upper limit and the lower limit of the after-jet tank pressure shown in Fig. 3 that are determined in advance depending on the detected before-jet tank pressure. Then, the control unit 31 performs the failure sign determination based on whether the after-jet tank pressure is larger than the upper limit (step S2). With this failure sign determination based on the above-described criteria for determination, it is possible to detect abnormal jetting caused by an operation failure of the solenoid valve 25 or the control unit 31 that controls the solenoid valve 25 as a sign of failure of the foreign substance removal device 2.

[0049] The upper limit and the lower limit of the after-jet tank pressure may be common between the two points 6 shown in the example of Fig. 1, or may be set separately for each of the two points 6. When the upper limit and the lower limit is individually set for each point 6, at least one of the slope or the intercept of the linear function

(see Fig. 3) representing the upper limit and the lower limit may be different for each point 6. Alternatively, the upper limit and the lower limit may be values represented by a function other than the linear function. By setting the upper and lower limits individually for each of the points 6 associated with the foreign object removal device 2 as the upper and lower limits of the after-jet tank pressure used for the failure sign determination, it is possible to improve the determination accuracy of the failure sign determination. As described above, the configuration in which the threshold for the failure sign determination is individually set for each of the points 6 that are associated with the foreign substance removal device 2 may be adopted also in each of the modifications described later.

[0050] If the after-jet tank pressure is higher than the upper limit (step S2: Yes), the control unit 31 determines that there is a sign of failure of the foreign substance removal device 2, and outputs, to the monitoring terminal 33, an jet amount shortage alarm reporting that the jet amount is insufficient as the determination result (step S3).

[0051] Whereas when the after-jet tank pressure is equal to or lower than the upper limit (step S2: No), the control unit 31 performs a failure sign determination based on whether the after-jet tank pressure is lower than the lower limit (step S4).

[0052] When the after-jet tank pressure is lower than the lower limit (step S4: Yes), the control unit 31 determines that there is a sign of failure of the foreign substance removal device 2, and outputs, to the monitoring terminal 33, an excessive jet amount alarm reporting that the jet amount is excessive as the determination result (step S5).

[0053] Whereas when the after-jet tank pressure is equal to or higher than the lower limit (step S4: No), the control unit 31 determines that there is no sign of failure of the foreign substance removal device 2, does not perform the alarm output to the monitoring terminal 33, and ends the process. In this case, the control unit 31 may output, to the monitoring terminal 33, information notifying that the foreign substance removal device 2 is normally operating.

[0054] In addition to serving as the failure sign determination means, the control unit 31 may also serve as a failure determination means, and may determine whether there is a failure of the foreign substance removal device 2 based on the detected tank pressure. For example, the control unit 31 may determine whether there is a failure of the foreign substance removal device 2 (hereinafter also referred to as a failure determination) based on a result of comparison between the after-jet tank pressure and an upper limit (that is, a second upper limit) and a lower limit (that is, a second lower limit) of the after-jet tank pressure different from those of Fig. 3 that are set depending on the before-jet tank pressure. In other words, the control unit 31 may use a different threshold of the pressure between the failure sign determination and the failure determination.

[0055] More specifically, the control unit 31 may determine that the foreign substance removal device 2 is at fault when the after-jet tank pressure is higher than the second upper limit that is larger than the upper limit shown in Fig. 3 (that is, the first upper limit) or the after-jet tank pressure is lower than the second lower limit that is lower than the lower limit (that is, the first lower limit) shown in Fig. 3. The second upper limit may be expressed as a linear function having the same slope and a large intercept in the vertical axis when compared to the linear function of the upper limit (that is, the first upper limit) shown in Fig. 3. Further, the second lower limit may be expressed as a linear function having the same slope and a smaller intercept in the vertical axis compared to the linear function of the lower limit (that is, the first lower limit) shown in Fig. 3.

[0056] More specifically, after the control unit 31 performs the detection of the before and after jet tank pressures in Fig. 2 (step S1), the control unit 31 may perform the failure determination based on whether the after-jet tank pressure is higher than the second upper limit. Then, when it is determined that there is a failure (in other words, the pressure is higher than the second upper limit) in the failure determination based on whether the pressure is higher than the second upper limit, the control unit 31 may perform alarm output in the same manner as the failure sign determination (step S3 in Fig. 2).

[0057] Whereas when it is determined that there is no failure (in other words, the pressure is lower than or equal to the second upper limit) in the failure determination based on whether the pressure is higher than the second upper limit, the control unit 31 may perform the failure determination based on whether the after-jet tank pressure is lower than the second lower limit. Then, when it is determined that there is a failure (that is, the pressure is lower than the second lower limit) in the failure determination based on whether the pressure is lower than the second lower limit, the control unit 31 may perform alarm output in the same manner as the failure sign determination (step S5 in Fig. 2).

[0058] Whereas when it is determined that there is no failure (in other words, the pressure is higher than or equal to the second upper limit) in the failure determination based on whether the pressure is lower than the second upper limit, the control unit 31 may perform the failure sign determination based on whether the after-jet tank pressure is higher than the upper limit (that is, the first upper limit) (step S2 in Fig. 2).

[0059] The control unit 31 may output the alarm in the failure determination in a way different from the output of the alarm in the failure sign determination. For example, the control unit 31 may output the alarm in the failure determination in a way with higher urgency than the alarm in the failure sign determination (for example, a prominent display color, a message content prompting emergency response, a loud sound, etc.).

[0060] In the embodiment, it is not a case where a failure of the foreign substance removal device 2 is detected

when a switching failure at the diverging portion of the track is actually detected. It is possible to detect an abnormal jet resulting from malfunction of the solenoid valve 25 or the control unit 31 as a sign of failure of the foreign substance removal device 2. Thus, the solenoid valve 25 and the control unit 31 can be repaired or replaced before a failure of the foreign substance removal device 2 actually occurs and it is possible to early detect the failure of the foreign substance removal device 2 (in other words, detect in advance). Since a failure can be detected at an early stage, the foreign substance removal device 2 can be repaired or its parts replaced in a planned manner as compared with the case where the foreign substance removal device 2 is repaired or parts replaced after the failure actually occurred. It is also possible to prevent the occurrence of the failure.

[0061] The after-jet tank pressure is considered to be approximately proportional to a pressure which is obtained by subtracting the pressure lost by the jetting of the compressed air from the before-jet tank pressure. When it is assumed that the pressure lost by each single jet is almost constant, established is the correlation that a normal level of the post-jet tank pressure is higher as the before-jet tank pressure is higher. Based on this correlation, the failure sign determination is performed in the embodiment using the upper limit and the lower limit shown in Fig. 3 that are linearly correlated with the before-jet tank pressure. As a result, it is possible to perform a more accurate failure sign determination based on the before-jet tank pressure, so it is possible to more reliably detect a failure of the foreign substance removal device 2 at an early stage.

[0062] Further, when the failure determination is performed in addition to the failure sign determination, it is possible to detect an actual failure of the foreign substance removal device 2. In this case, although the switching failure at the track diverging portion may not occur immediately after the failure of the foreign substance removal device 2, it is possible to urgently dealt with the device failure in order to prevent the switching failure stemmed from the device failure.

First Modification Example

[0063] Next, a first modification example in which the foreign substance removal device 2 is self-checked will be described. With reference to Figs. 1 to 3, the example in which the control unit 31 serves as the failure sign determination means and the alarm output means has been described. In the first modification example, the control unit 31 also serves as a check means.

[0064] Specifically, the control unit 31 executes a control of the compressed air jetting in accordance with a command of self-check transmitted by the monitoring terminal 33 over the network 34, and checks (that is, self-check) whether there is a failure of the foreign substance removal device 2 based on a rising after-jet tank pressure. The control unit 31 outputs the check result to the

monitoring terminal 33.

[0065] An operation example of the foreign substance removal system 1 in the first modification example will be now described with reference to Figs. 4 and 5. Fig. 4 is a flow chart for showing the operation example of the foreign substance removal system 1 in the first modification example of the embodiment. The process shown in the flow chart of Fig. 4 may be repeatedly carried out as required. At the initial state in Fig. 4, it is assumed that the plurality of (four in Fig. 1) solenoid valves 25 of the foreign substance removal device 2 are all closed. Fig. 5 is a time chart for showing the example of the operation of the foreign substance removal system 1 in the first modification example of the embodiment.

[0066] As shown in Fig. 4, the control unit 31 firstly determines whether the command for a self-check is supplied from the monitoring terminal 33 (step S11).

[0067] When the command for a self-check is supplied (step S11: Yes), the control unit 31 sets the first ($i = 1$) solenoid valve 25 among the total of "n" solenoid valves 25 as a target to instruct opening (step S12). In the example of Fig. 5, the total number "n" of the solenoid valves 25 is four so as to correspond the number of four solenoid valves 25 of the foreign substance removal device 2 of Fig. 1. The control unit 31 outputs a solenoid valve control signal for commanding opening of the first solenoid valve 25 to let the compressed air be jetted for a predetermined period of time through the first solenoid valve 25 as shown in Fig. 5 (step S13).

[0068] After jetting of the compressed air through the first solenoid valve 25 for the predetermined period of time, the control unit 31 closes the first solenoid valve 25 and then waits for the next step with a predetermined interval set in advance as shown in Fig. 5 (step S14). As shown in Fig. 5, a fresh compressed air generated by the compressor 21 flows into the tank 22 with all the solenoid valves 25 closed during the predetermined time interval and the tank pressure is raised thereby. The interval may be, for example, 10 seconds.

[0069] After waiting for the interval, the control unit 31 determines whether jets through all the solenoid valves 25 are completed, in other words, whether "i" is equal to the total number "n" of the solenoid valves (step S15).

[0070] When it is determined that the jetting of all the solenoid valves 25 is completed (step S15: Yes), the control unit 31 measures a rise in the tank pressure within a predetermined period of time from the completion of the interval to a preset self-check completion time, based on the pressure detection signal supplied from the pressure sensor 32 as shown in Fig. 5 (step S16). The period of time in which the tank pressure rise is measured may be 20 second, for example.

[0071] Whereas when the jetting of all the solenoid valves 25 is not completed yet (step S15: No), the control unit 31 sets the next solenoid valve 25 as the one to instruct opening. In other words, "i" is incremented (step S17). Accordingly the process proceeds to jetting through the next solenoid valve 25 for the predetermined time

period (step S13).

[0072] After measuring the rise in the tank pressure, the control unit 31 determines whether the measured tank pressure rise is larger than a threshold value (step S18).

[0073] When the tank pressure rise is larger than the threshold value (step S18: Yes), it may be determined that the compressed air is normally generated by the compressor 21 and no air leak has occurred. In this case, the control unit 31 outputs, to the monitoring terminal 33, a normal result indicating that the compressor 21 is normally operating (step S19). Whereas when the tank pressure rise is equal to or less than the threshold value (step S18: No), the control unit 31 outputs, to the monitoring terminal 33, an abnormal result indicating that the compressor 21 is abnormal (step S20).

[0074] In the first modification example, the failure sign determination of the foreign substance removal device 2 may be performed before or after the self-check.

[0075] In the first modification example, since the result of the self-check can be remotely monitored by the monitoring terminal 33, it is possible to detect a failure of the foreign substance removal device 2 without sending an engineer to the site.

Second Modification Example

[0076] Next, a second modification example in which the failure sign determination is performed during a period of the self-check will be described. Fig. 6 is a flow chart for showing an operation example of the foreign substance removal system 1 in the second modification example of the embodiment. The process shown in the flow chart of Fig. 6 may be repeatedly carried out as required. In the first modification example, the timing when the failure sign determination is performed is independent of the timing when the self-check is performed. Whereas in the second modification example, the failure sign determination is performed during the self-check period.

[0077] Specifically, as shown in Fig. 6, the pressure sensor 32 and the control unit 31 detect the after-jet tank pressure (step S102) after jetting for a predetermined time (step S13) is performed for the self-check. Thereafter, in the same manner as Fig. 2, the failure sign determination (step S2, step S4) is performed by comparing the after-jet tank pressure with the upper limit or the lower limit, and the alarm output is performed according to the determination result (step S3, step S5).

[0078] The control unit 31 may perform a failure sign determination based on a comparison between a preset pressure difference threshold and a difference between the before-jet tank pressure and the after-jet tank pressure, instead of the failure sign determination based on the comparison between the after-jet tank pressure and the upper limit value or the lower limit value (step S2, step S4). For example, the control unit 31 may calculate a pressure difference between the before-jet tank pres-

sure and the after-jet tank pressure before and after each jetting performed by the first to n-th solenoid valves 25 respectively, and may compare the obtained pressure difference with the threshold value of the pressure difference. When the calculated pressure difference is larger than the threshold value, the control unit 31 may determine that there is a sign of failure of the foreign substance removal device 2, and may output an alarm to the monitoring terminal 33 as the determination result. Further, the pressure difference threshold may include an upper limit threshold and a lower limit threshold. In this case, when the calculated pressure difference is larger than the upper-limit threshold value, the control unit 31 may output the excessive jet amount alarm (see step S5 in Fig. 6). When the calculated pressure difference is smaller than the lower-limit threshold value, the control unit 31 may output the jet amount shortage alarm (see step S3 in Fig. 6).

[0079] Also in the second modification example, in addition to the failure sign determination, the control unit 31 may perform the above-described failure determination based on whether the after-jet tank pressure is higher than the second upper limit or lower than the second lower limit.

[0080] In the second modification example, since jetting performed at the time of the self-check can be utilized for the failure sign determination, it is possible to perform the failure sign determination efficiently. Further, with the failure sign determination, it is possible to detect a failure sign that cannot be detected through the self-check.

Third Modification Example

[0081] Next, a third modified example in which a video of the diverging portion of the track is obtained will be described. Fig. 7 illustrates the foreign substance removal system 1 in the third modification example.

[0082] As shown in Fig. 7, the foreign substance removal system 1 of the third modified example includes a web camera 35 installed at the track diverging portion. The web camera 35 transmits, to the monitoring terminal 33a, a diverging portion video signal obtained by photographing the track diverging portion.

[0083] In the third modification example, it is possible to issue the self-check command after confirming that there is no worker at the track diverging portion based on the video of the track diverging portion. Thereby, it is possible to prevent a disruption of work caused by jetting during the work at the track diverging portion.

[0084] The web camera 35 may be activated or stopped in accordance with a command from the monitoring terminal 33. In this case, since the web camera 35 may be activated when necessary before the self-check, it is possible to reduce the power consumption by the web camera 35.

Fourth Modification Example

[0085] Next, a fourth modification example in which the failure sign determination is performed based on the amount of change in the tank pressure in a predetermined period of time. Fig. 8 is a flow chart for showing an operation example of the foreign substance removal system 1 in the fourth modification example of the embodiment. The process shown in the flow chart of Fig. 8 may be repeatedly carried out as required.

[0086] In the fourth modification example, the control unit 31 performs the failure sign determination based on the amount of change in the tank pressure in a predetermined period of time.

[0087] Specifically, as shown in Fig. 8, the pressure sensor 32 first starts detection of the tank pressure (step S21).

[0088] After starting the detection of the tank pressure, the control unit 31 determines whether a predetermined time has elapsed from the start of the detection of the tank pressure (step S22). The predetermined time may be, for example, one minute.

[0089] When the predetermined time has elapsed (step S22: Yes), the pressure sensor 32 ends the detection of the tank pressure (step S23).

[0090] Whereas when the predetermined amount of time has not elapsed yet (step S22: No), the control unit 31 repeats the determination as to whether the predetermined time has elapsed (step S22).

[0091] After detecting the tank pressure, the control unit 31 calculates the amount of pressure drop in the predetermined time (step S24).

[0092] After calculating the amount of pressure drop, the control unit 31 performs a failure sign determination based on whether the amount of pressure drop is larger than a threshold value (step S25). With this failure sign determination based on such judgment criteria, it is possible to detect air leak under the tank pressure around the working pressure as a sign of failure of the foreign substance removal device 2.

[0093] When the amount of pressure drop is larger than the threshold value (Yes at step S25), the control unit 31 determines that there is a sign of failure of the foreign substance removal device 2 and outputs an alarm to the monitoring terminal 33 as a determination result (step S26).

[0094] Whereas the amount of pressure drop is equal to or smaller than the threshold value (step S25: No), the control unit 31 determines that there is no sign of failure of the foreign substance removal device 2 and ends the process without performing the alarm output to the monitoring terminal 33.

[0095] In the fourth modification example, it is possible to detect a sign of failure based on the amount of change in the tank pressure, that is, the amount of pressure drop, before a failure such as inability to jet the compressed air due to lack of tank pressure caused by air leakage actually occurs.

[0096] Also in the fourth modification example, the control unit 31 may perform the failure determination in addition to the failure sign determination. In this case, the determination criterion of the failure determination may be, for example, that the tank pressure becomes less than a predetermined pressure (for example, 0.3 MPa).

Fifth Modification Example

[0097] A description is given of a fifth modification example in which the failure sign determination is performed based on both the tank pressure and the temperature in the machine room. The example in which the failure sign determination is performed based on the tank pressure has been described. Whereas in the fifth modification, the failure sign determination is performed based on both the tank pressure and the temperature in the machine room 20 (hereinafter also referred to as the machine room temperature).

[0098] Fig. 9 illustrates the foreign substance removal system 1 in the fifth modification example of the embodiment. As shown in Fig. 9, the foreign substance removal system 1 of the fifth modification example further includes a temperature sensor 37 disposed in the machine room 20 in addition to the elements shown in Fig. 1.

[0099] The temperature sensor 37 detects the temperature in the machine room, and outputs a temperature detection signal indicating the detected temperature in the machine room to the control unit 31.

[0100] The control unit 31 performs the failure sign determination based on the amount of change in the tank pressure and the machine room temperature in a predetermined period of time. Specifically, the control unit 31 does not determine that there is a sign of failure of the foreign substance removal device 2 when a decrease in the machine room temperature (that is, the ambient temperature of the compressor 21) is equal to or larger than a threshold which is an example of a predetermined state at the time when the amount of change in the tank pressure is obtained. In addition, the control unit 31 may not determine that there is a sign of failure of the foreign substance removal device 2 if the timing at which the amount of change in the tank pressure is obtained is within a certain time after the jetting or the operation (start) of the compressor 21.

[0101] An operation example of the foreign substance removal system 1 of the fifth modified example configured as described above will be described with reference to Fig. 10. Fig. 10 is a flow chart for showing an operation example of the foreign substance removal system 1 in the fifth modification example of the embodiment. The process shown in the flow chart of Fig. 10 may be repeatedly carried out as required.

[0102] As shown in Fig. 10, the pressure sensor 32 and the temperature sensor 37 first starts detection of the tank pressure and the machine room temperature (step S31).

[0103] After the detection of the tank pressure and the

machine room temperature is started, the control unit 31 determines whether a predetermined time has elapsed from the start of the detection of the tank pressure and the machine room temperature (step S32).

[0104] When the predetermined time has elapsed (step S32: Yes), the pressure sensor 32 and the temperature sensor 37 end the detection of the tank pressure and the machine room temperature respectively (step S33).

[0105] Whereas when the predetermined time has not elapsed yet (step S32: No), the control unit 31 repeats the determination as to whether the predetermined amount of time has elapsed (step S32).

[0106] After the detection of the tank pressure and the machine room temperature is ended, the control unit 31 calculates the amount of pressure drop and the amount of temperature drop in the predetermined period of time (step S34).

[0107] After calculating the amount of pressure drop and the amount of temperature drop, the control unit 31 performs a failure sign determination based on whether the amount of pressure drop is larger than a threshold value (step S35).

[0108] When the amount of pressure drop is larger than the threshold value (Yes at step S35), the control unit 31 performs a failure sign determination subsequent to step S35 based on whether the amount of pressure drop is smaller than the threshold value (step S36).

[0109] Whereas when the amount of pressure drop is equal to or smaller than the threshold value (step S35: No), the control unit 31 determines that there is no sign of failure of the foreign substance removal device 2, and ends the process without performing the alarm output to the monitoring terminal 33.

[0110] When the amount of temperature drop is smaller than the threshold value (step S36: Yes), the control unit 31 determines that there is a sign of failure of the foreign substance removal device 2 and outputs an alarm to the monitoring terminal 33 as a determination result (step S37).

[0111] Whereas when the amount of temperature drop is equal to or more than the threshold value (step S36: No), the control unit 31 ends the process without performing the alarm output to the monitoring terminal 33 even if the amount of pressure drop is larger than the threshold value.

[0112] When the machine room temperature drops sharply, the tank pressure also drops in accordance with the drop in the machine room temperature. The drop in the tank pressure due to the drop in the machine room temperature is a phenomenon based on Boyle-Charles's law and is not a phenomenon caused by air leakage. In the fifth modification example, since the tank pressure drop caused by air leak is not considered as a sign of failure, it is possible to avoid an erroneous determination.

[0113] Also in the fifth modification example, the control unit 31 may perform the failure determination in addition to the failure sign determination. In this case, the

determination criterion of the failure determination may be, for example, that the tank pressure becomes less than a predetermined pressure (for example, 0.3 MPa).

Sixth Modification Example

[0114] A description is given of a sixth modification example in which the failure sign determination is performed based on the temperature in the machine room. Fig. 11 is a flow chart for showing an operation example of the foreign substance removal system 1 in the sixth modification example of the embodiment. The process shown in the flow chart of Fig. 11 may be repeatedly carried out as required. The flowchart of Fig. 11 can be implemented by the foreign substance removal system 1 of the fifth modification example.

[0115] As shown in Fig. 11, the temperature sensor 37 first detects the temperature in the machine room (step S41).

[0116] After detecting the machine room temperature, the control unit 31 performs a failure sign determination based on whether the detected machine room temperature is higher than a threshold value (step S42). With this failure sign determination based on such determination criterion, as a failure sign of the foreign substance removal device 2, it may detect an operation failure of an exhaust fan (not shown) installed in the machine room 20 or it may detect that the frequency of operation of the compressor 21 is too high.

[0117] The failure sign determination based on the machine room temperature (step S42) may be performed at the same timing as the failure sign determination based on the tank pressure (Fig. 2, steps S2, S4 in Fig. 6, step S25 in Fig. 8, or steps S35, S36 in Fig. 10). Alternatively, it may be performed at a different timing.

[0118] When the machine room temperature is higher than the threshold (step S42: Yes), the control unit 31 determines that there is a sign of failure of the foreign substance removal device 2 and outputs an alarm to the monitoring terminal 33 as a determination result (step S43). The threshold value of the machine room temperature may be, for example, 50°C.

[0119] Whereas the machine room temperature is equal to or lower than the threshold (step S42: No), the control unit 31 determines that there is no sign of failure of the foreign substance removal device 2 and ends the process without performing the alarm output to the monitoring terminal 33.

[0120] The foreign substance removal device 2 is required to operate normally without failure not only in winter where snow removal at the point 6 is performed but also in summer where foreign substances other than ice and snow are removed in a high temperature environment. In the sixth modification example, by detecting a sign of failure of the foreign substance removal device 2 caused by high temperature, it is possible to prevent occurrence of failure of the foreign substance removal device 2 at the time of high temperature such as summer

season.

[0121] Also in the sixth modification example, the control unit 31 may perform the failure determination in addition to the failure sign determination. In this case, the determination criterion of the failure determination may be, for example, that the temperature in the machine room is higher than the threshold value of the failure determination that is larger than the threshold value of the failure sign determination (step S42 of Fig. 11). The threshold value of the failure determination may be 60°C., for example.

Seventh Modification Example

[0122] A description is given of a seventh modification example in which the failure sign determination is performed based on a current value of the compressor motor 211. Fig. 12 illustrates the foreign substance removal system 1 in the seventh modification example of the embodiment.

[0123] As shown in Fig. 12, the foreign substance removal system 1 of the seventh modification example further be equipped with a current sensor 38 disposed in the compressor 21 in addition to the elements shown in Fig. 9. The current sensor 38 detects a current value (hereinafter also referred to as a compressor motor current value) of the current supplied to the compressor motor 211 by a power supply (not shown), and outputs, to the control unit 31, a current detection signal indicating the detected value of the compressor motor current. The control unit 31 performs a failure sign determination based on whether the compressor motor current value is larger than a threshold value, and then performs alarm output in accordance with the determination result.

[0124] An operation example of the foreign substance removal system 1 in the seventh modification example will be now described with reference to Fig. 13. Fig. 13 is a flow chart for showing an operation example of the foreign substance removal system 1 in the seventh modification example of the embodiment. The process shown in the flow chart of Fig. 13 may be repeatedly carried out as required.

[0125] As shown in Fig. 13, the current sensor 38 first detects a current value of the compressor motor (step S51).

[0126] After the current value of the compressor motor is detected, the control unit 31 performs a failure sign determination based on whether the current value of the compressor motor is larger than a threshold value (step S52). The threshold value of the compressor motor current value is, for example, a current value of the compressor motor during its normal operation. With this failure sign determination based on such determination criterion, it is possible to detect an abnormality in the value of the compressor motor current as the sign of failure of the foreign substance removal device 2.

[0127] The failure sign determination based on the current value of the compressor motor (step S52) may be

performed at the same timing as the failure sign determination based on the tank pressure (Fig. 2, steps S2, S4 in Fig. 6, step S25 in Fig. 8, or steps S35, S36 in Fig. 10), and the failure sign determination based on the machine room temperature (step S42 in Fig. 11). Alternatively, it may be performed at a different timing.

[0128] When the current value of the compressor motor is larger than the threshold (step S52: Yes), the control unit 31 determines that there is a sign of failure of the foreign substance removal device 2 and outputs an alarm to the monitoring terminal 33 as a determination result (step S53).

[0129] Whereas when the current value of the compressor motor is equal to or smaller than the threshold (step S52: No), the control unit 31 determines that there is no sign of failure of the foreign substance removal device 2 and ends the process without performing the alarm output to the monitoring terminal 33.

[0130] When a thermal relay is provided in the foreign substance removal device 2 as a protector for the compressor 21, the thermal relay shuts off an electromagnetic contactor of the thermal relay when overcurrent of the compressor motor 211 is detected and stops the compressor motor 211. When the compressor motor 211 is stopped via the thermal relay, the foreign substance removal device 2 is unable to operate until an engineer goes to the site and completes the work on return of the compressor motor 211. In the seventh modification example, it is possible to detect that the current value of the compressor motor exceeds the threshold value of the failure sign determination that is lower than the overcurrent before it reaches the level of the overcurrent of the compressor motor. In this way, when the foreign substance removal device 2 is provided with a thermal relay, it is possible to prevent failure and non-operation of the compressor motor 211 caused by an excessive current.

[0131] Also in the seventh modification example, the control unit 31 may perform the failure determination based on the excessive current of the compressor motor in addition to the failure sign determination.

Eighth Modification Example

[0132] A description will be given of an eighth modification example in which a failure monitoring function of the pressure sensor 32 is provided. Fig. 14 illustrates the foreign substance removal system 1 in the eighth modification example of the embodiment.

[0133] As shown in Fig. 14, the foreign substance removal system 1 of the eighth modification example is further equipped with an auxiliary pressure sensor 39 in addition to the elements shown in Fig. 12. In the same manner as the pressure sensor 32 (hereinafter, also referred to as a main pressure sensor), the auxiliary pressure sensor 39 detects a pressure inside the tank 22, and outputs a pressure detection signal indicating the detected tank pressure to the control unit 31.

[0134] The control unit 31 determines a failure of the

main pressure sensor 32 based on comparison between the tank pressure detected by the main pressure sensor 32 and the tank pressure detected by the auxiliary pressure sensor 39. The controller 31 outputs an alarm to the monitoring terminal 33 when detecting a failure of the main pressure sensor 32.

[0135] An operation example of the foreign substance removal system 1 in the eighth modification example will be now described with reference to Fig. 15. Fig. 15 is a flow chart for showing an operation example of the foreign substance removal system 1 in the eighth modification example of the embodiment. The process shown in the flow chart of Fig. 15 may be repeatedly carried out as required.

[0136] As shown in Fig. 15, the main pressure sensor 32 detects a tank pressure (step S61). At this time, the auxiliary pressure sensor 39 also detects a tank pressure (step S62).

[0137] After detection of the tank pressure by the main pressure sensor 32 and the auxiliary pressure sensor 39 respectively, the control unit 31 calculates a pressure difference between the tank pressure detected by the main pressure sensor 32 and the tank pressure detected by the auxiliary pressure sensor 39 (Step S63).

[0138] After calculating the pressure difference, the control unit 31 determines whether the calculated pressure difference is larger than a predetermined threshold for the pressure difference (step S64).

[0139] When the calculated pressure difference is larger than the threshold, the control unit 31 determines that the main pressure sensor 32 is at fault, and outputs an alarm to the monitoring terminal 33 (step S65).

[0140] Whereas when the calculated pressure difference is equal to or less than the threshold, the control unit 31 determines that the main pressure sensor 32 is not at fault and ends the process without performing the alarm output to the monitoring terminal 33.

[0141] In addition to the case where the failure of the main pressure sensor 32 is detected based on the pressure difference, the control unit 31 may also output an alarm, for example, when disconnection of the pressure sensors 32 and 39 is detected. Further, when a failure of the main pressure sensor 32 is detected, the control unit 31 may use the tank pressure detected by the auxiliary pressure sensor 39 instead of the main pressure sensor 32 for the failure sign determination, the operational control of the foreign substance removal device 2, and the like.

[0142] As described above, the tank pressure can be used for various processes such as opening and closing of the solenoid valve 25, rotation of the compressor motor 211, and the failure sign determination of the foreign substance removal device 2. For this reason, failure of the main pressure sensor 32 that detects the tank pressure has a significant impact on the operation of the foreign substance removal system 1. In the eighth modification example, it is possible to reliably detect a failure of the main pressure sensor 32 by the comparison between the

tank pressure detected by the auxiliary pressure sensor 39 and the tank pressure detected by the main pressure sensor 32. Therefore, the main pressure sensor 32 at fault can be immediately repaired or replaced and thereby the foreign substance removal system 1 can be operated properly.

[0143] The embodiment and each modification example described above may be adequately combined with each other. In addition to the above-described modification examples, various modifications can be applied to the invention. For example, the monitoring terminal 33 may show, on the display as temporal information, the tank pressure, the temperature in the machine room, and the current value of the compressor motor acquired from the control unit 31 over the network. In addition, the number of rails corresponding to a single foreign substance removal device 2 may be one, or three or more. The control unit 31 may perform the failure sign determination in the same manner as the failure sign determinations described above. Such an embodiment will be described by replacing the term "failure sign determination" with the term "failure determination", and replacing the term "failure sign" with the term "failure" in the above-described embodiment. In this case, even if there is no actual failure of the foreign substance removal device 2, it is determined that there is a failure when a sign of failure is detected. Therefore the failure can be detected in advance and it is possible to handle with the failure in a planned manner.

[0144] Aspects of the present invention are not limited to the foregoing embodiment and embrace various modifications conceivable by those skilled in the art. Effects of the present invention are also not limited to the above-mentioned contents. That is, various additions, changes, and partial deletions are possible in a range of not departing from the conceptual ideas and spirit of the present invention derived from contents defined in the claims and equivalents thereof.

Claims

1. A monitoring system for foreign substance removal device, comprising:

a pressure detection means for detecting a pressure inside a retainer, the pressure detection means being disposed in a foreign substance removal device including a generator that generates compressed air, the retainer that retains the generated compressed air therein, and a jetting device that jets the retained compressed air to blow off a foreign substance existing in a diverging portion of a railway track; and a failure sign determination means for determining whether there is a sign of failure of the foreign substance removal device based on the detected pressure inside the retainer.

2. The monitoring system of claim 1, wherein the failure sign determination means determines whether there is the sign of failure based on a comparison between a pressure inside the retainer that is detected after the jetting of the compressed air and a first upper limit and a first lower limit of the after-jet pressure that are set depending on a pressure inside the retainer detected before the jetting of the compressed air.

3. The monitoring system of claim 2, further comprising:

a failure sign determination means for determining whether there is a failure of the foreign substance removal device based on the detected pressure inside the retainer, wherein the failure determination means determines whether there is the failure based on a comparison between a pressure inside the retainer that is detected after the jetting of the compressed air and a second upper limit and a second lower limit of the after-jet pressure that are set depending on a pressure inside the retainer detected before the jetting of the compressed air.

4. The monitoring system of claim 1, wherein the failure sign determination means determines whether there is the sign of failure based on a difference between a before-jet pressure inside the retainer that is detected before the jetting of the compressed air and an after-jet pressure inside the retainer that is detected after the jetting of the compressed air.

5. The monitoring system of claim 1, wherein the failure sign determination means determines whether there is the sign of failure based on a pressure inside the retainer that is detected after the jetting of the compressed air.

6. The monitoring system of claim 1, wherein the failure sign determination means determines whether there is the sign of failure based on an amount of change in the detected pressure inside the retainer in a predetermined period of time.

7. The monitoring system of claim 6, wherein the failure sign determination means does not perform the determination whether there is the sign of failure when the foreign substance removal device is in a predetermined state at the time when the amount of change is obtained.

8. The monitoring system of claim 7, wherein the predetermined state includes at least one selected from the group consisting of that the jetting is being performed, that an ambient temperature of the generator is dropped, and that it is in a predetermined period

after operation of the generator.

9. The monitoring system of any one of claims 1 to 8,
further comprising:
an alarm output means for outputting an alarm when it is determined that there is the sign of failure. 5

10. The monitoring system of any one of claims 1 to 9,
further comprising:
a check means for checking whether there is a failure of the foreign substance removal device based on an amount of change in the pressure inside the retainer after the jetting of the compressed air. 10

11. A foreign substance removal system, comprising: 15

a foreign substance removal device including a generator that generates compressed air, a retainer that retains the generated compressed air therein, and a jetting device that jets the retained compressed air to blow off a foreign substance existing in a diverging portion of a railway track; and 20
a monitoring system including a pressure detection means for detecting a pressure inside the retainer, and a failure sign determination means for determining whether there is a sign of failure of the foreign substance removal device based on the detected pressure inside the retainer, the pressure detection means being disposed in the foreign substance removal device. 25 30

12. A method of monitoring a foreign substance removal device, comprising: 35

detecting a pressure inside a retainer in a foreign substance removal device including a generator that generates compressed air, the retainer that retains the generated compressed air therein, and a jetting device that jets the retained compressed air to blow off a foreign substance existing in a diverging portion of a railway track; and 40
determining whether there is a sign of failure of the foreign substance removal device based on the detected pressure inside the retainer. 45

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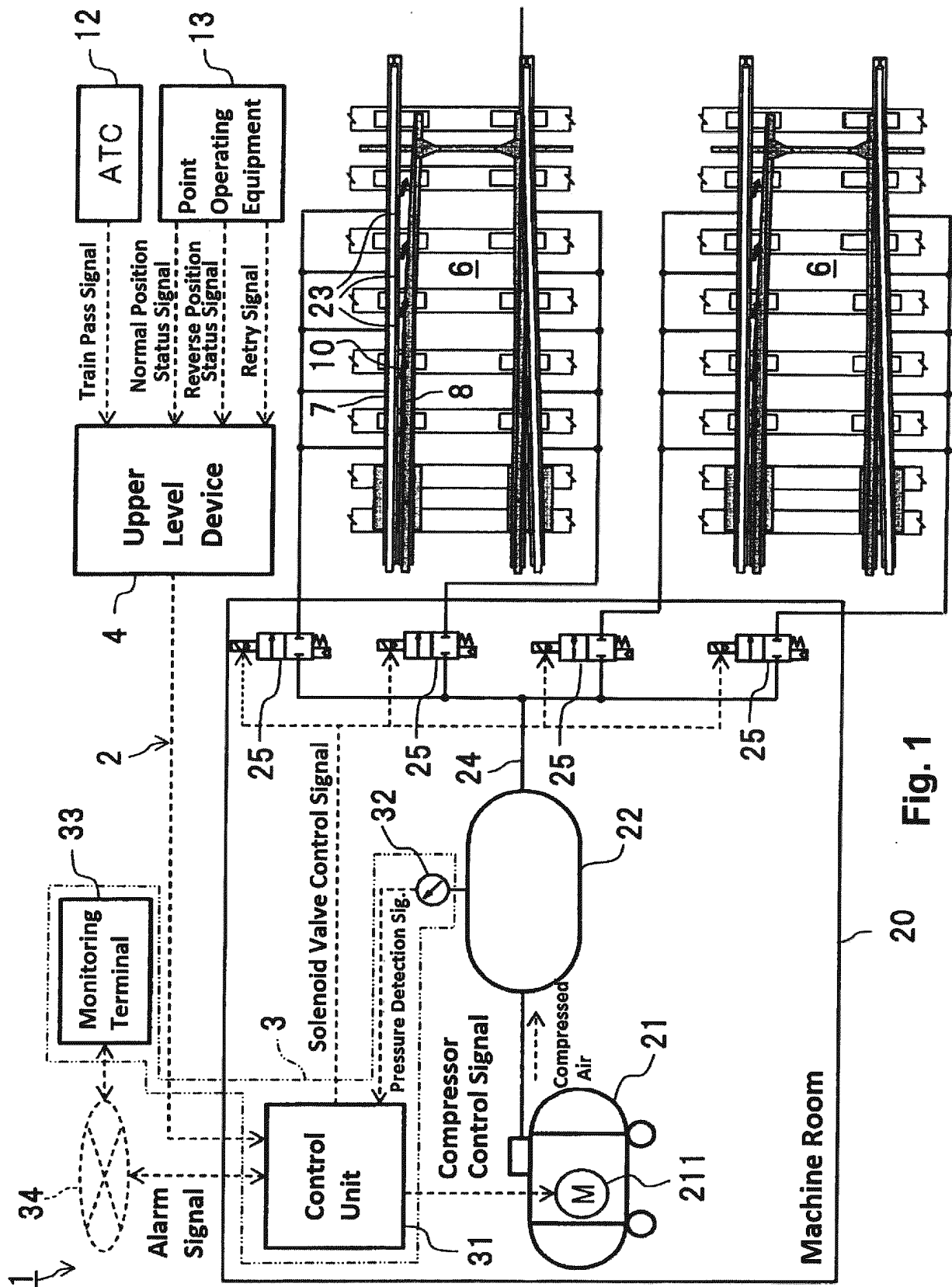


Fig. 1

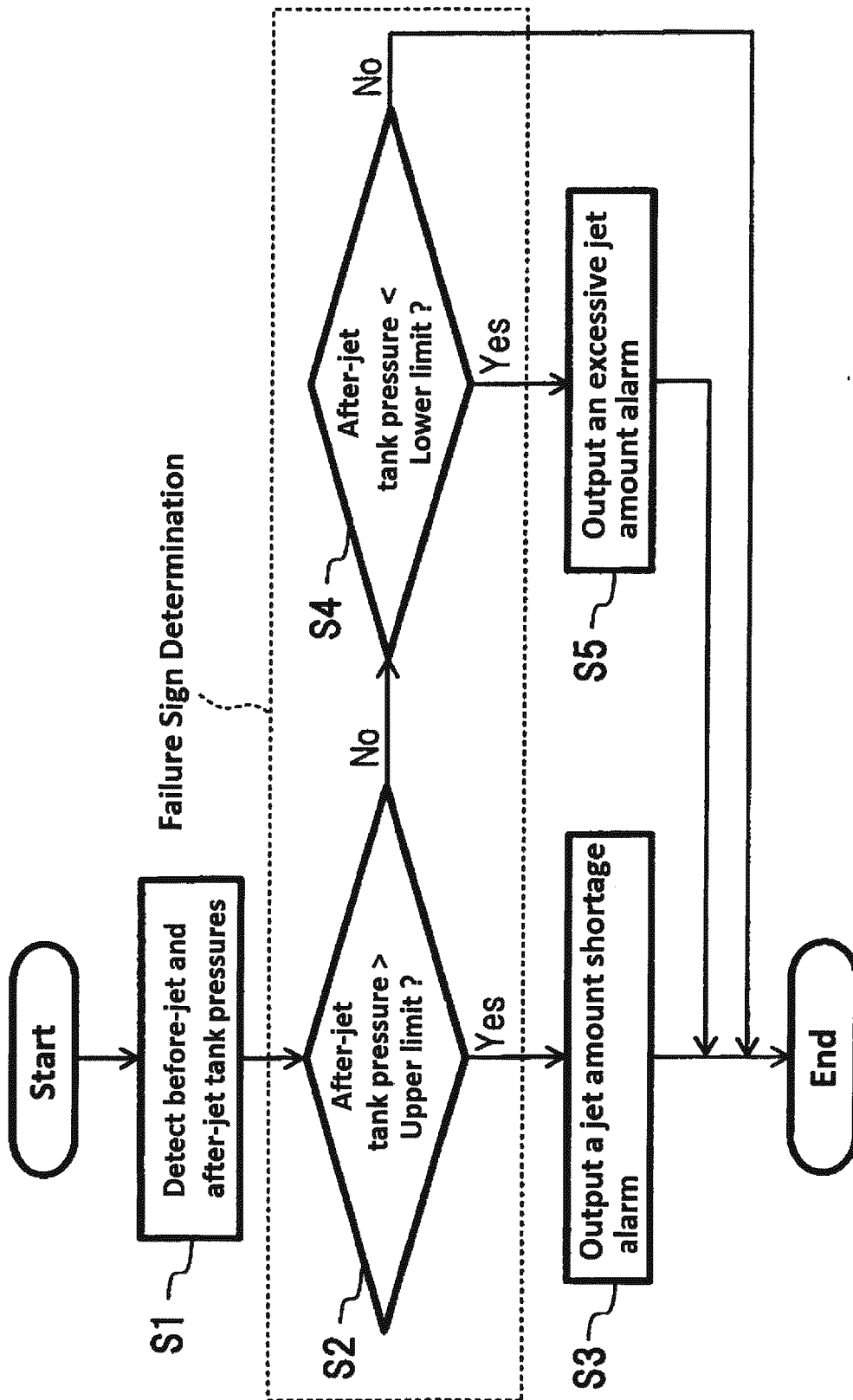
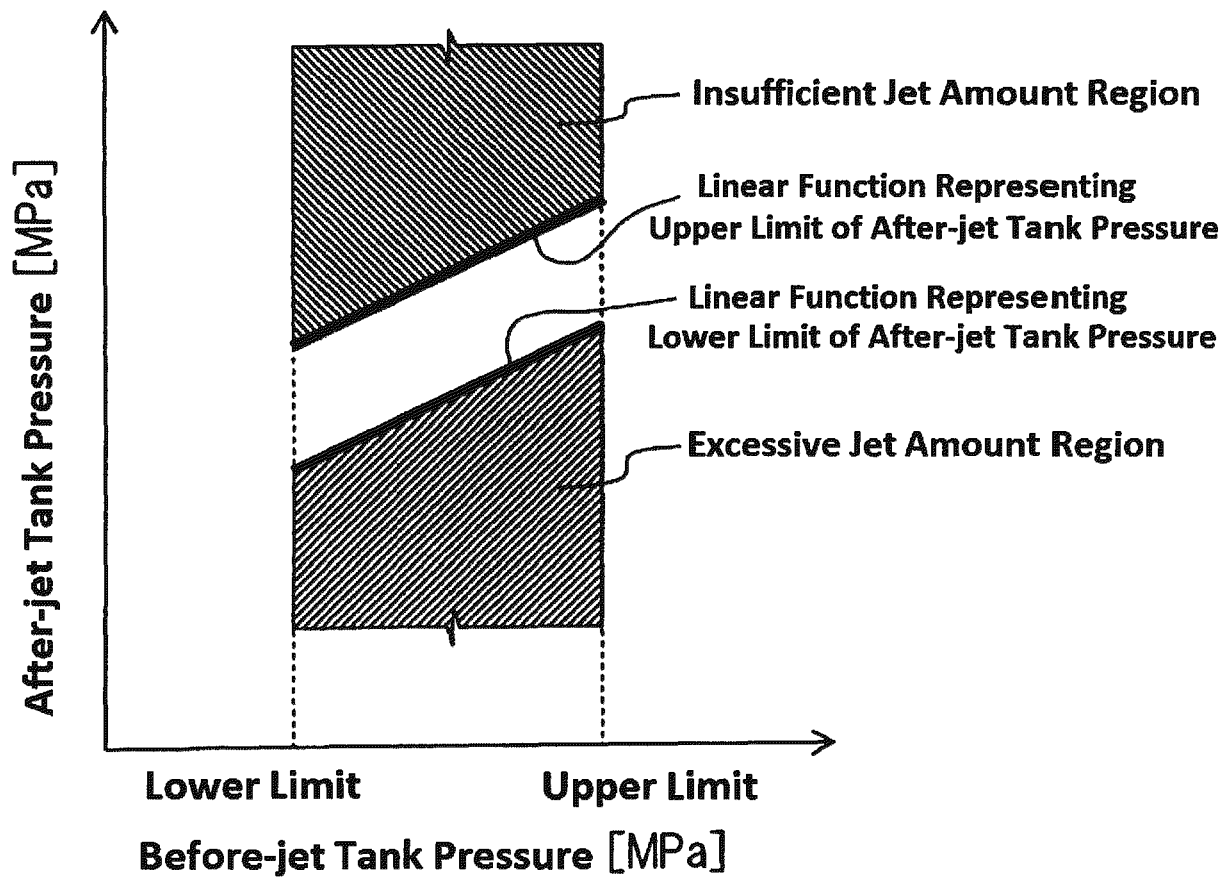


Fig. 2

**Fig. 3**

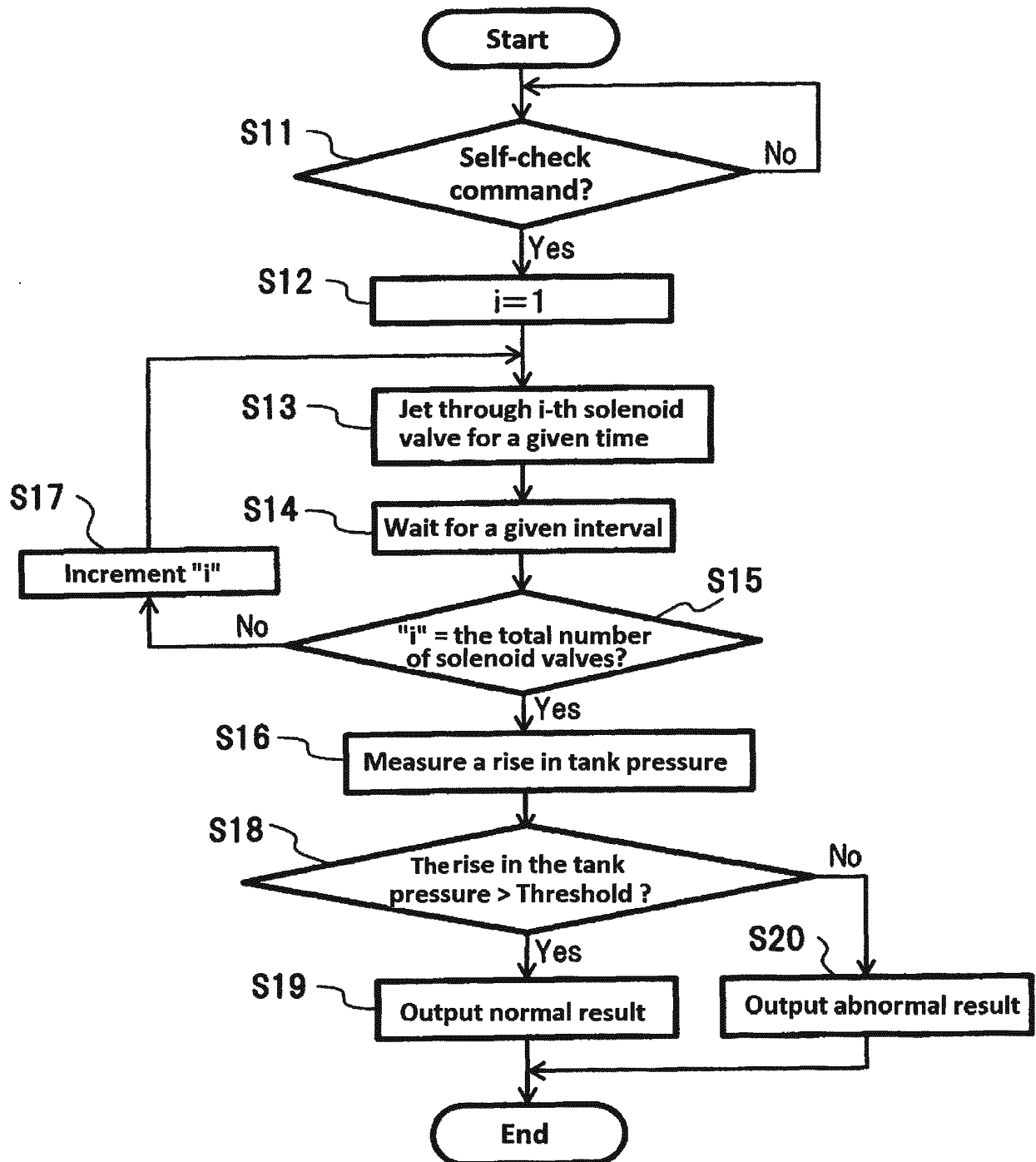


Fig. 4

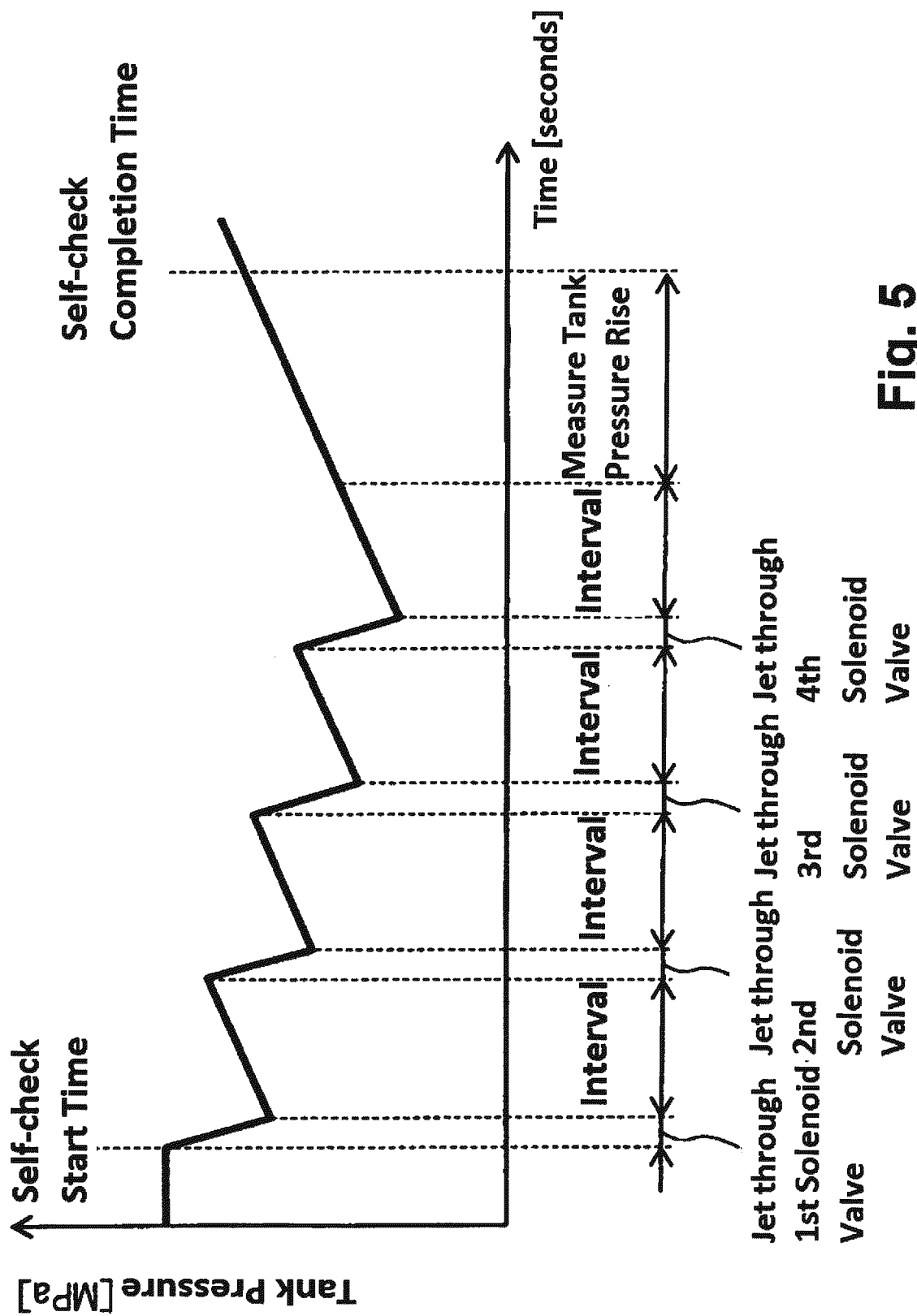


Fig. 5

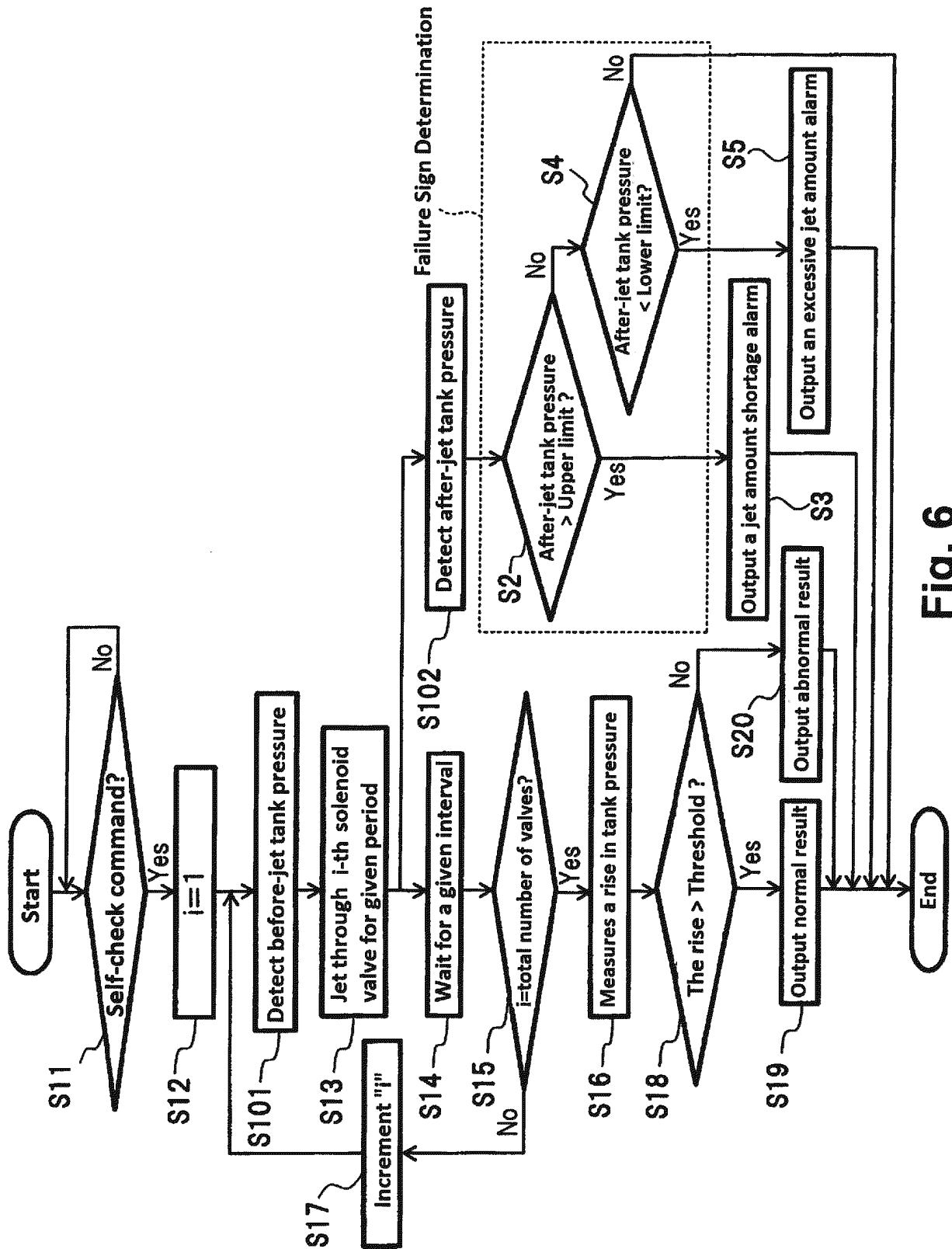


Fig. 6

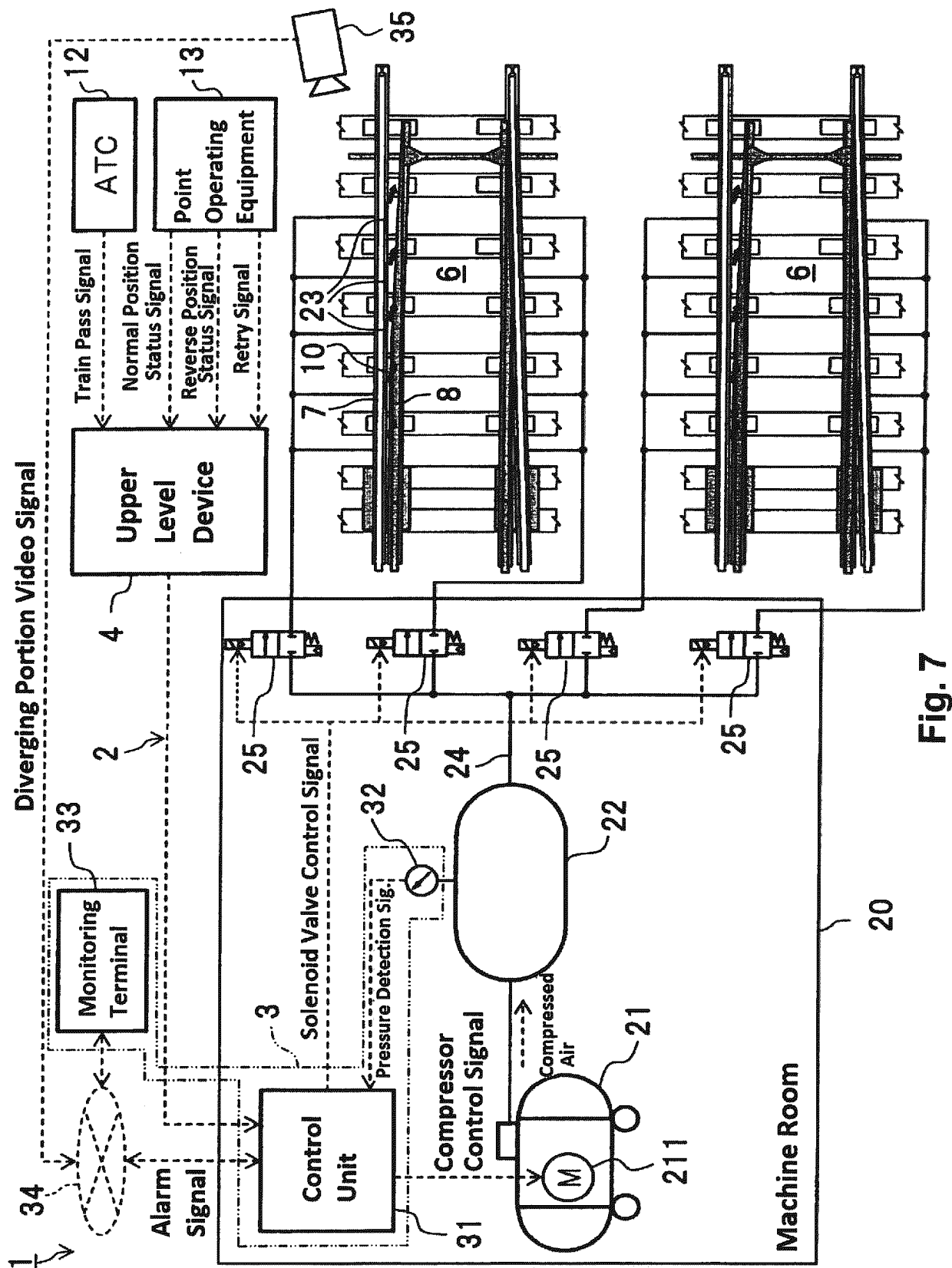


Fig. 7

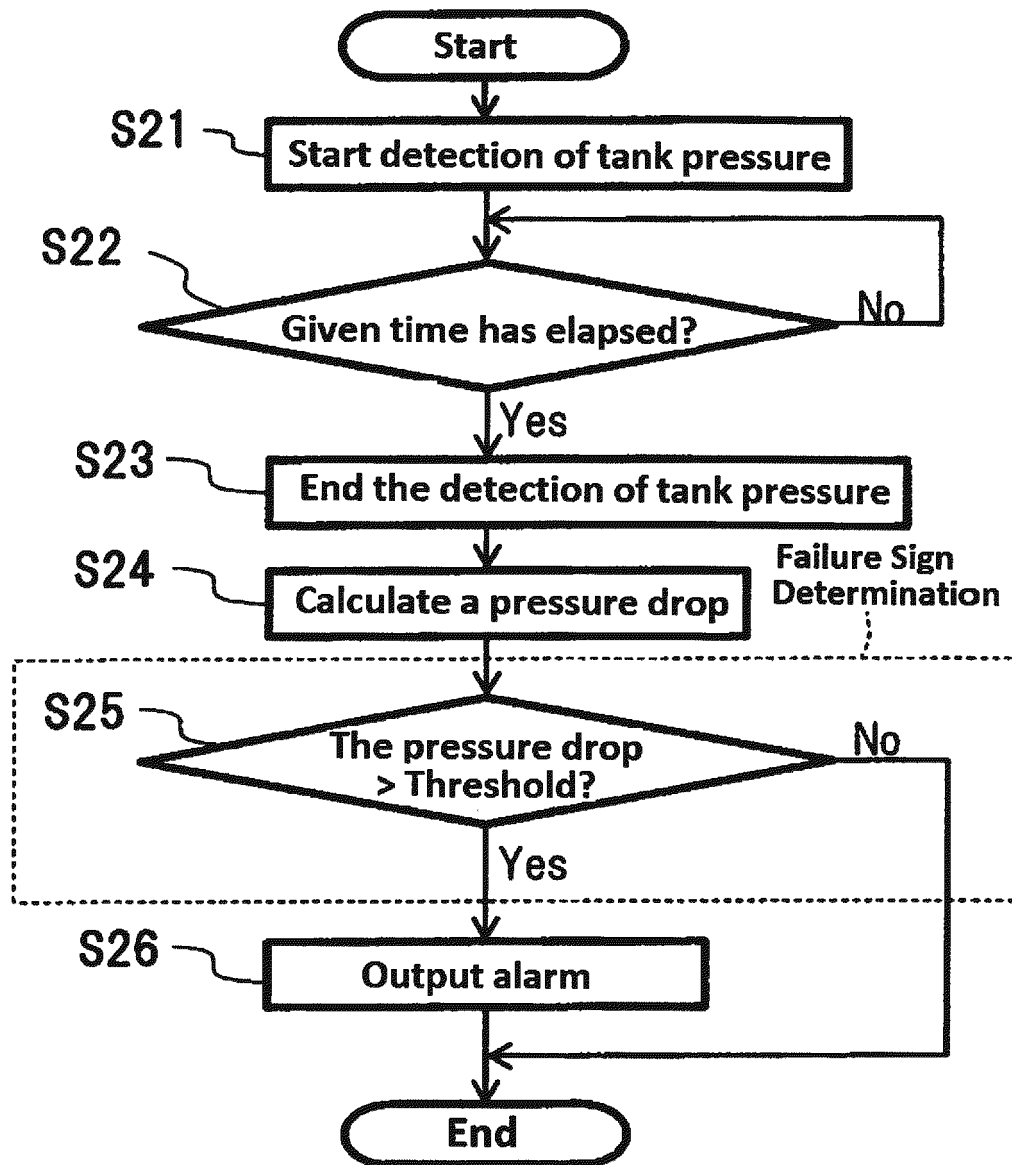


Fig. 8

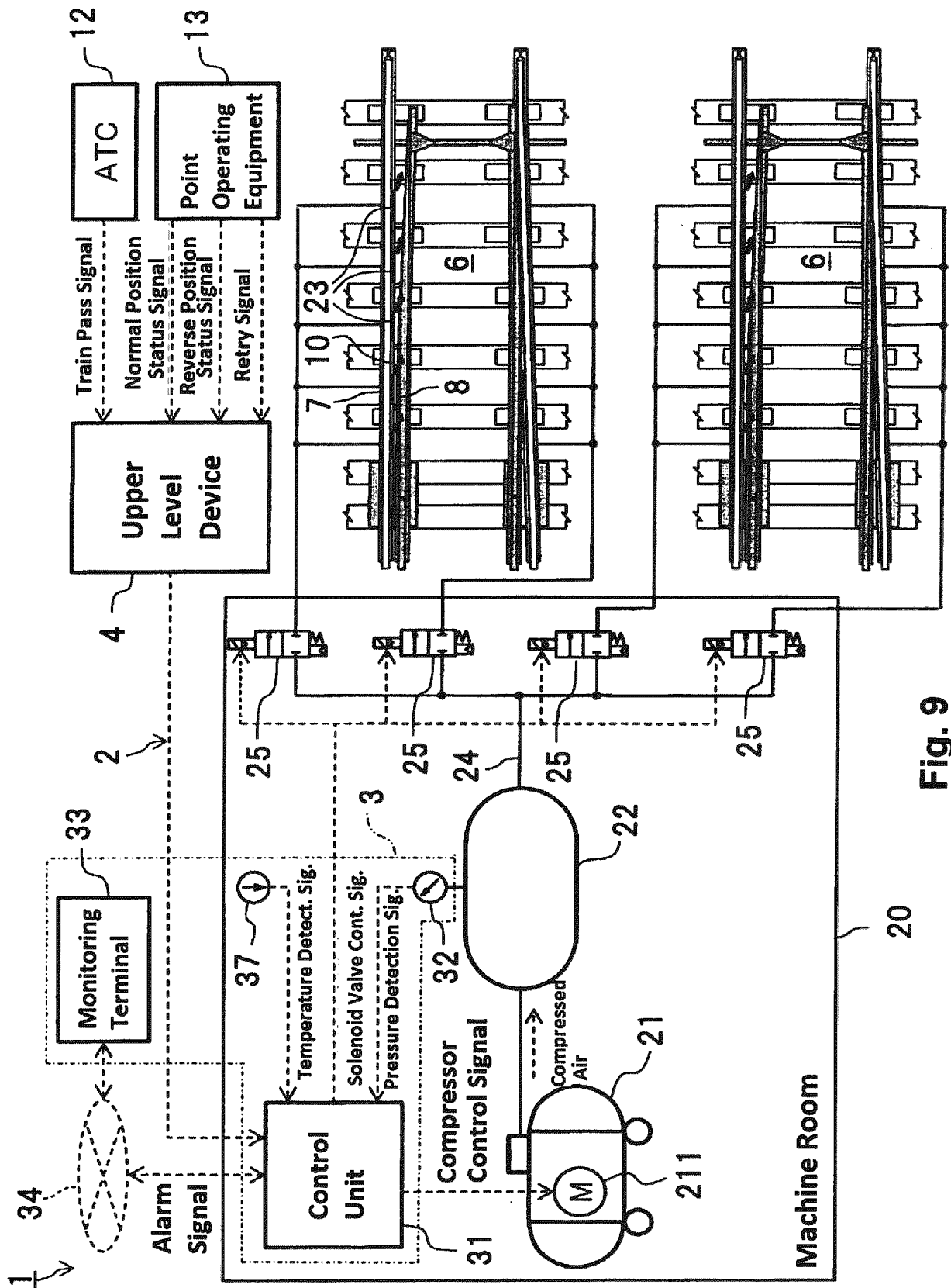


Fig. 9

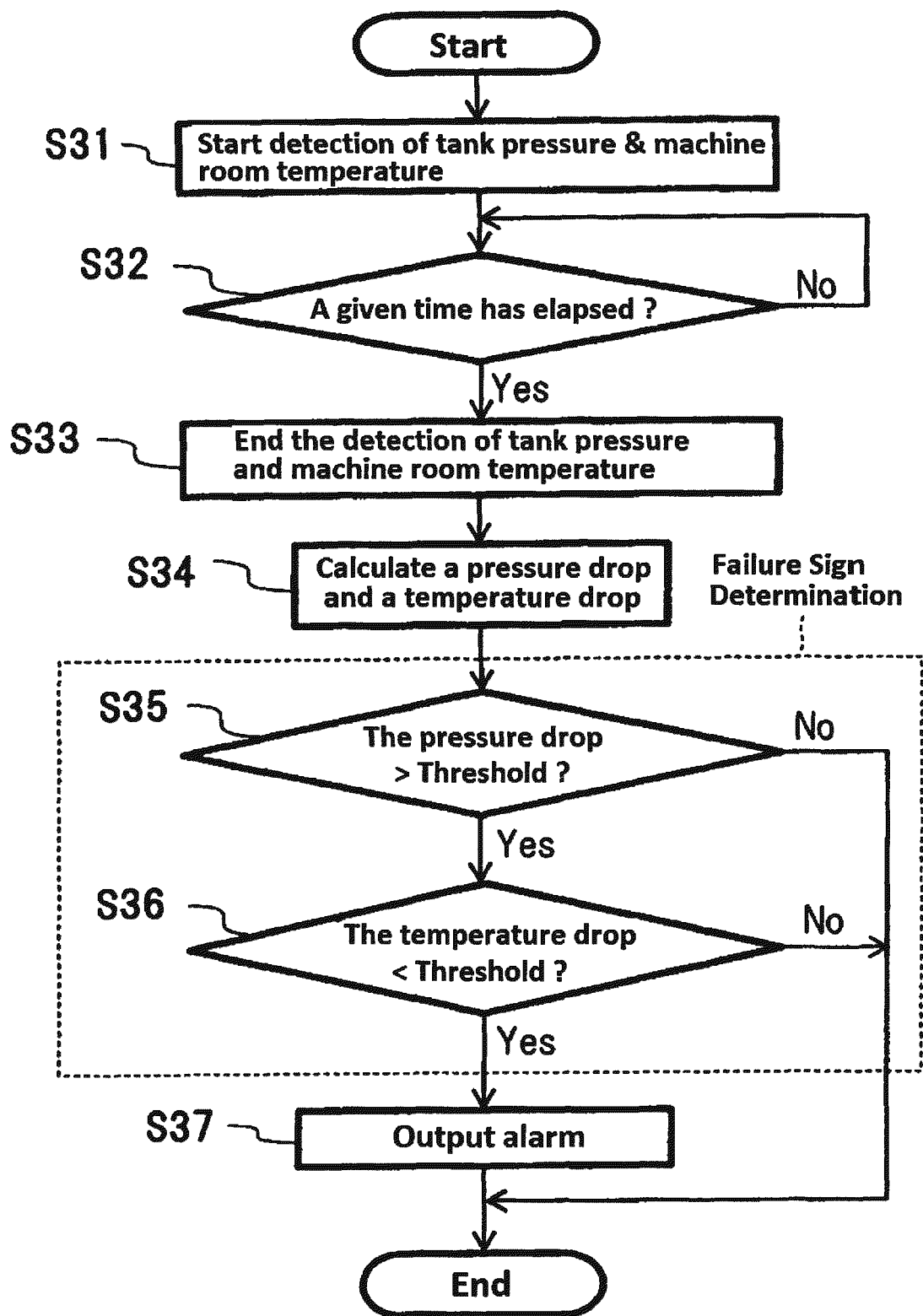
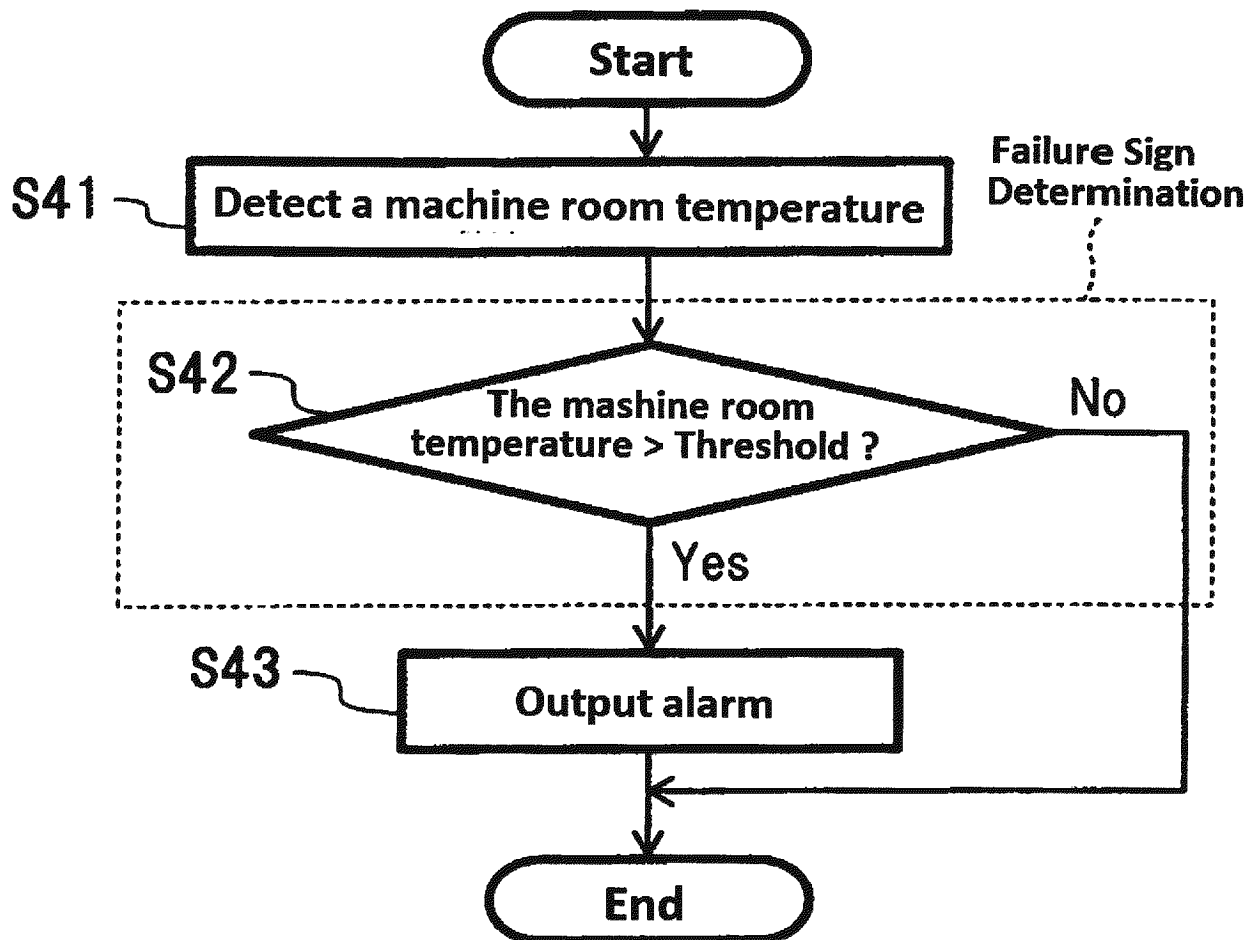


Fig. 10

**Fig. 11**

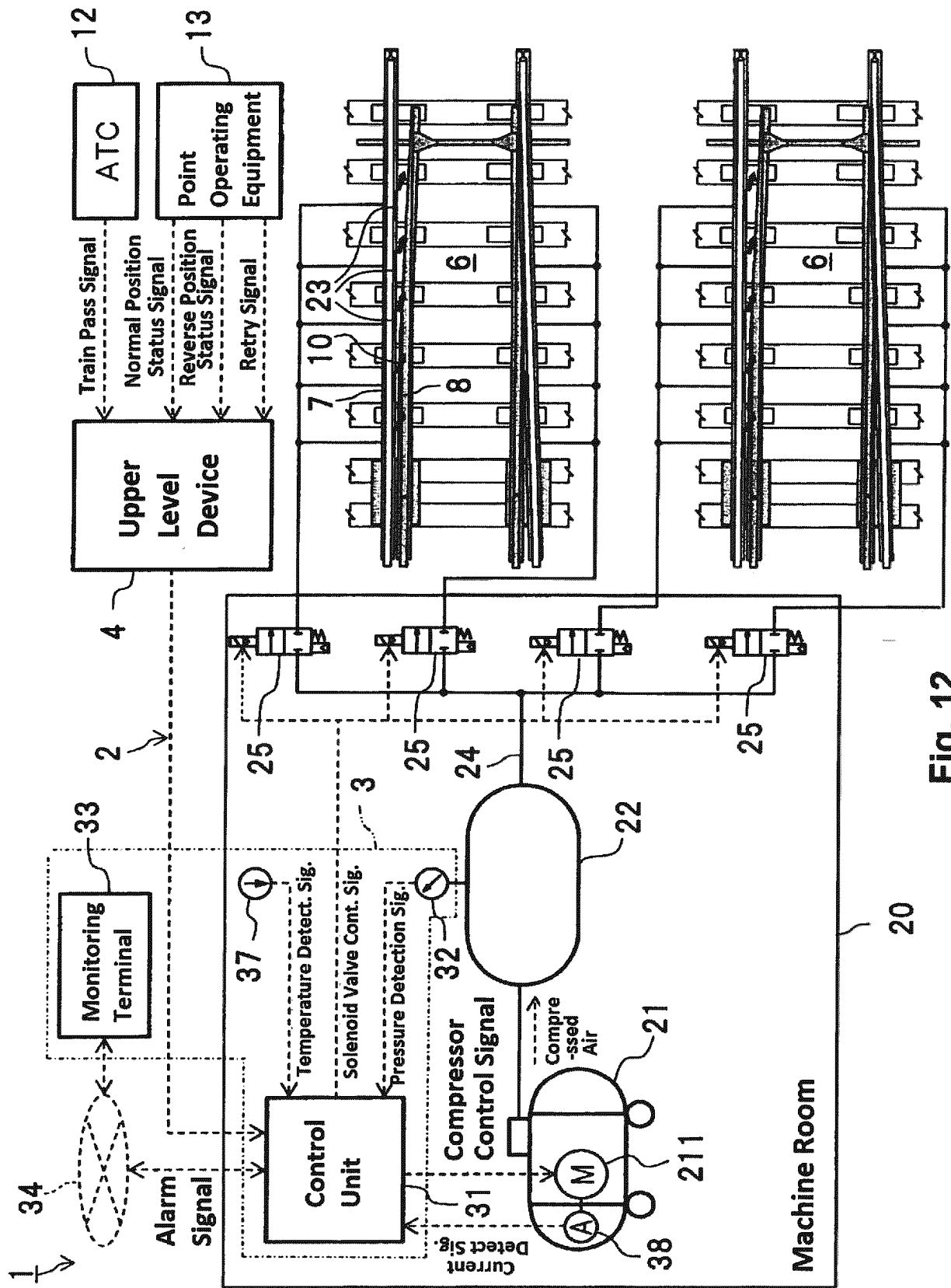
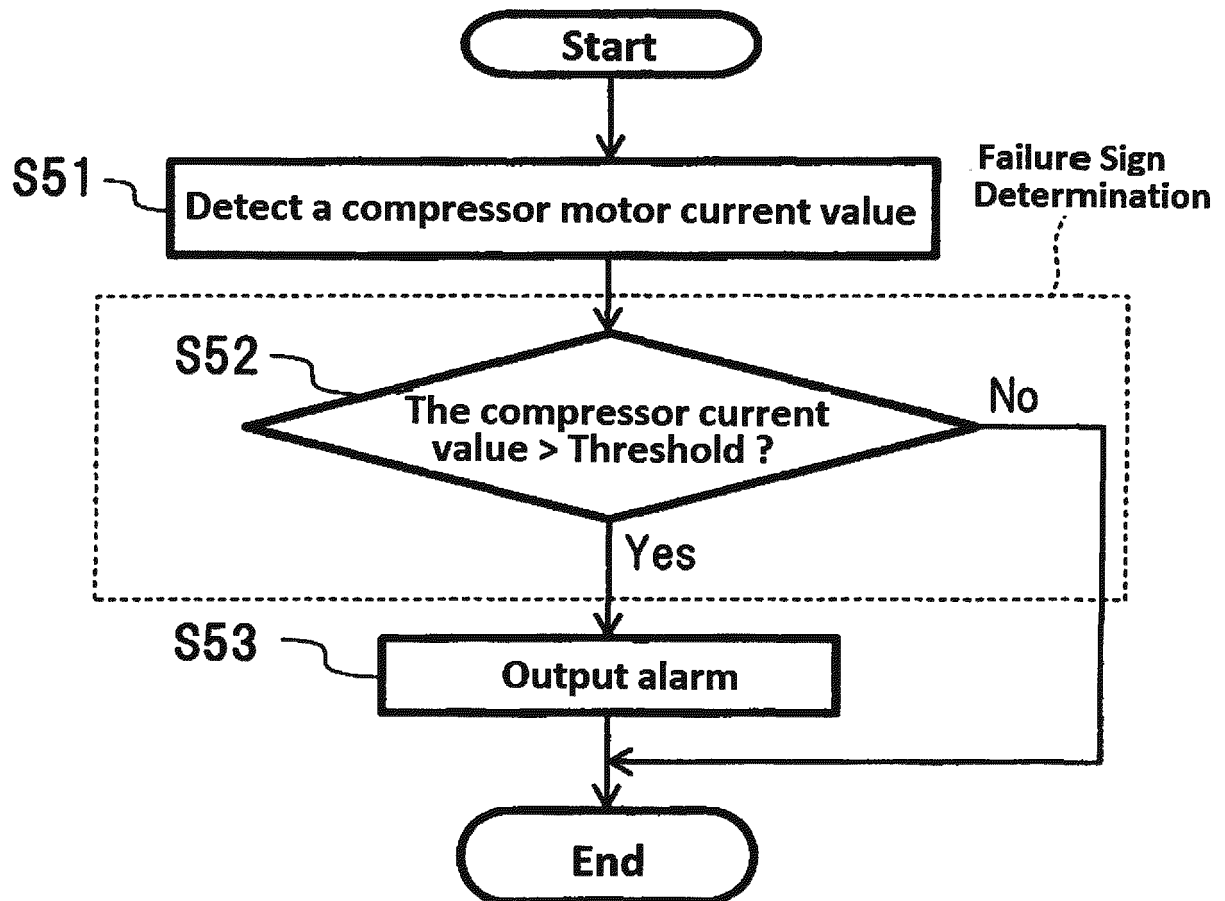


Fig. 12

**Fig. 13**

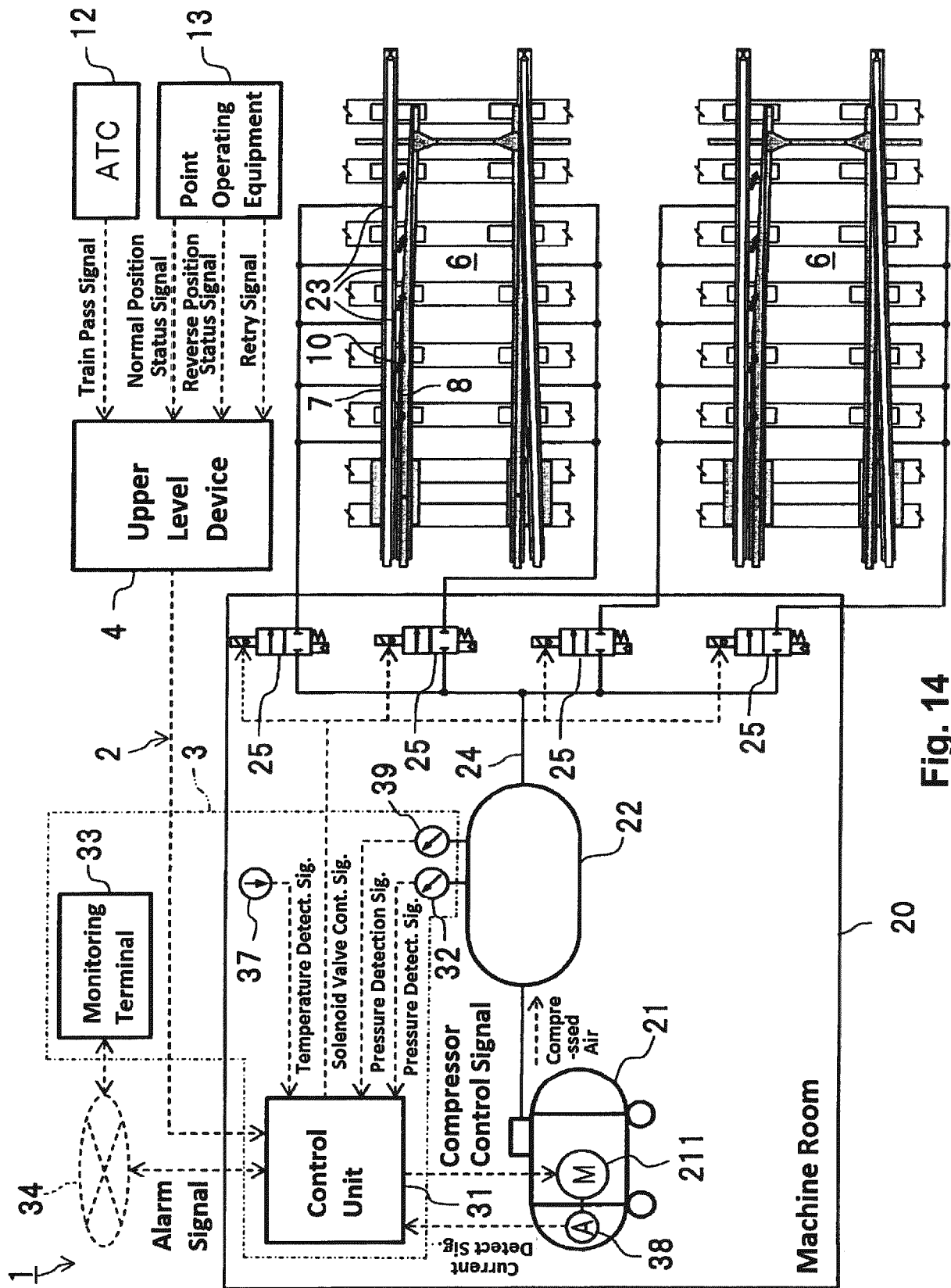


Fig. 14

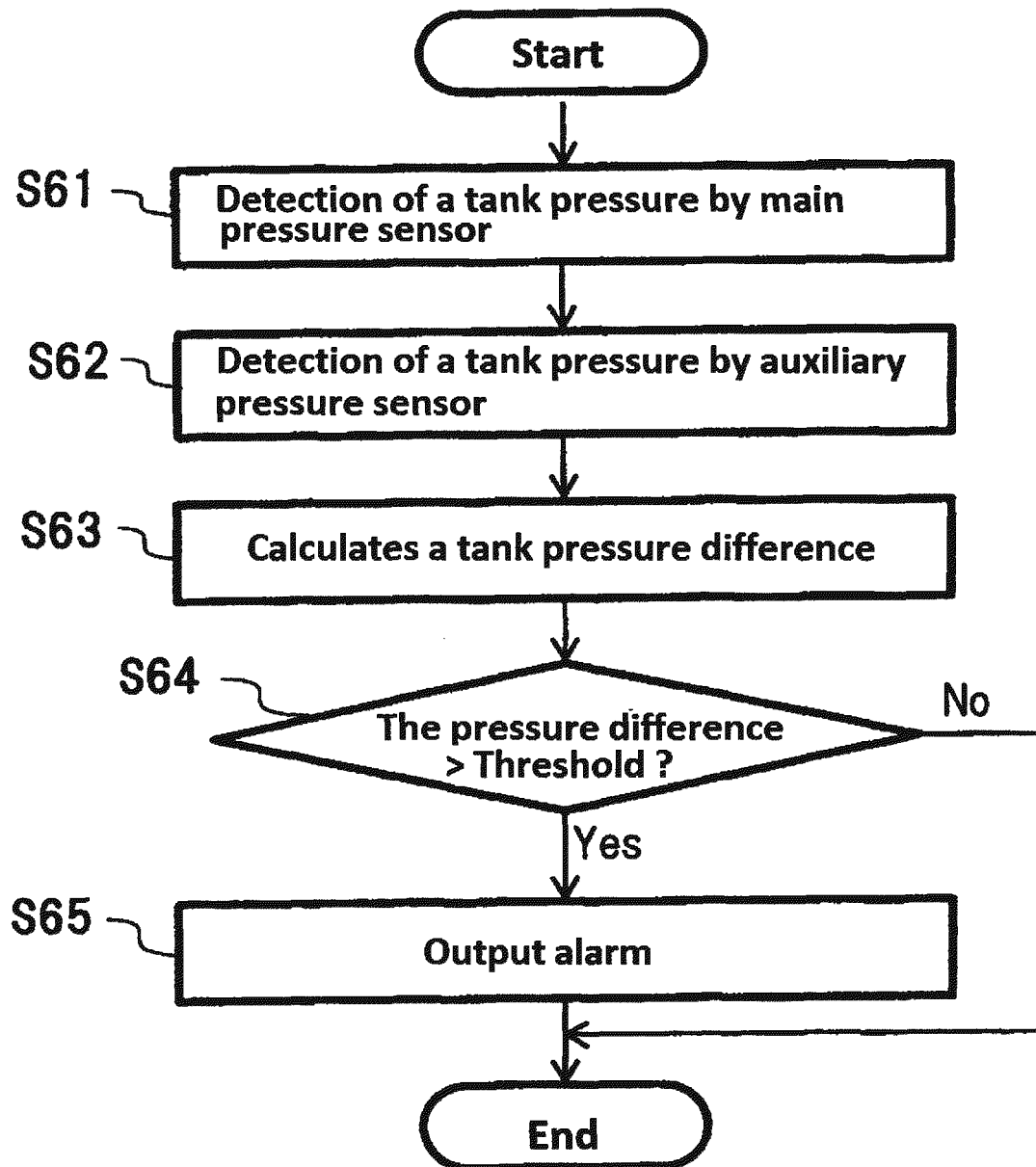


Fig. 15

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2017/047080

A. CLASSIFICATION OF SUBJECT MATTER

Int.Cl. E01H1/08 (2006.01) i, E01B19/00 (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)

Int.Cl. E01H1/08, E01B19/00

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 1971-2018

Registered utility model specifications of Japan 1996-2018

Published registered utility model applications of Japan 1994-2018

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 2013-024015 A (EAST JAPAN RAILWAY CO., et al.) 04 February 2013, paragraphs [0033]-[0041], fig. 1-4 & US 2014/0298613 A1, paragraphs [0075]-[0084], fig. 1-4 & WO 2013/014937 A1 & EP 2740844 A1	1-12
A	JP 2004-133553 A (TOSHIBA CORP.) 30 April 2004, paragraphs [0018]-[0058], fig. 1-21 (Family: none)	1-12
A	JP 5-087421 A (SANYO ELECTRIC CO., LTD.) 06 April 1993, paragraphs [0006]-[0013], fig. 1-2 (Family: none)	1-12



Further documents are listed in the continuation of Box C.



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"&"

document member of the same patent family

Date of the actual completion of the international search
20 March 2018 (20.03.2018)Date of mailing of the international search report
03 April 2018 (03.04.2018)Name and mailing address of the ISA/
Japan Patent Office
3-4-3, Kasumigaseki, Chiyoda-ku,
Tokyo 100-8915, Japan

Authorized officer

Telephone No.

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

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- WO 2015049879 A1 [0002]