US 20140027089A1

(19) United States
(12) Patent Application Publication
(10) Pub. No.: US 2014/0027089 A1
(43) Pub. Date: Jan. 30, 2014
Hisada

(54) COOLING SYSTEM AND VEHICLE WITH THE SAME

(75) Inventor: **Shuhei Hisada**, Nagoya-shi (JP)

(73) Assignee: **TOYOTA JIDOSHA KABUSHIKI KAISHA**, Toyota-shi, Aichi-ken (JP)

(21) Appl. No.: **14/004,046**

(22) PCT Filed: **Apr. 20, 2011**

(86) PCT No.: **PCT/JP2011/059721**

§ 371 (c)(1), (2), (4) Date: **Sep. 9, 2013**

Publication Classification

(51) **Int. Cl.**
F28F 27/00 (2006.01)

(52) **U.S. Cl.**
CPC *F28F 27/00* (2013.01)
USPC **165/11.1**

(57) **ABSTRACT**

A cooling system for cooling a heat source includes a flow channel through which liquid medium cooling the heat source is circulated, and a pump provided on the flow channel for circulating the liquid medium. The flow channel includes a plurality of branches arranged between an upstream side and a downstream side of the heat source in parallel to a distribution direction of the liquid medium. The cooling system further includes a control device for detecting an abnormality occurred in the cooling system by detecting an imbalance among flow rates of the liquid medium flowing through the plurality of branches, respectively.

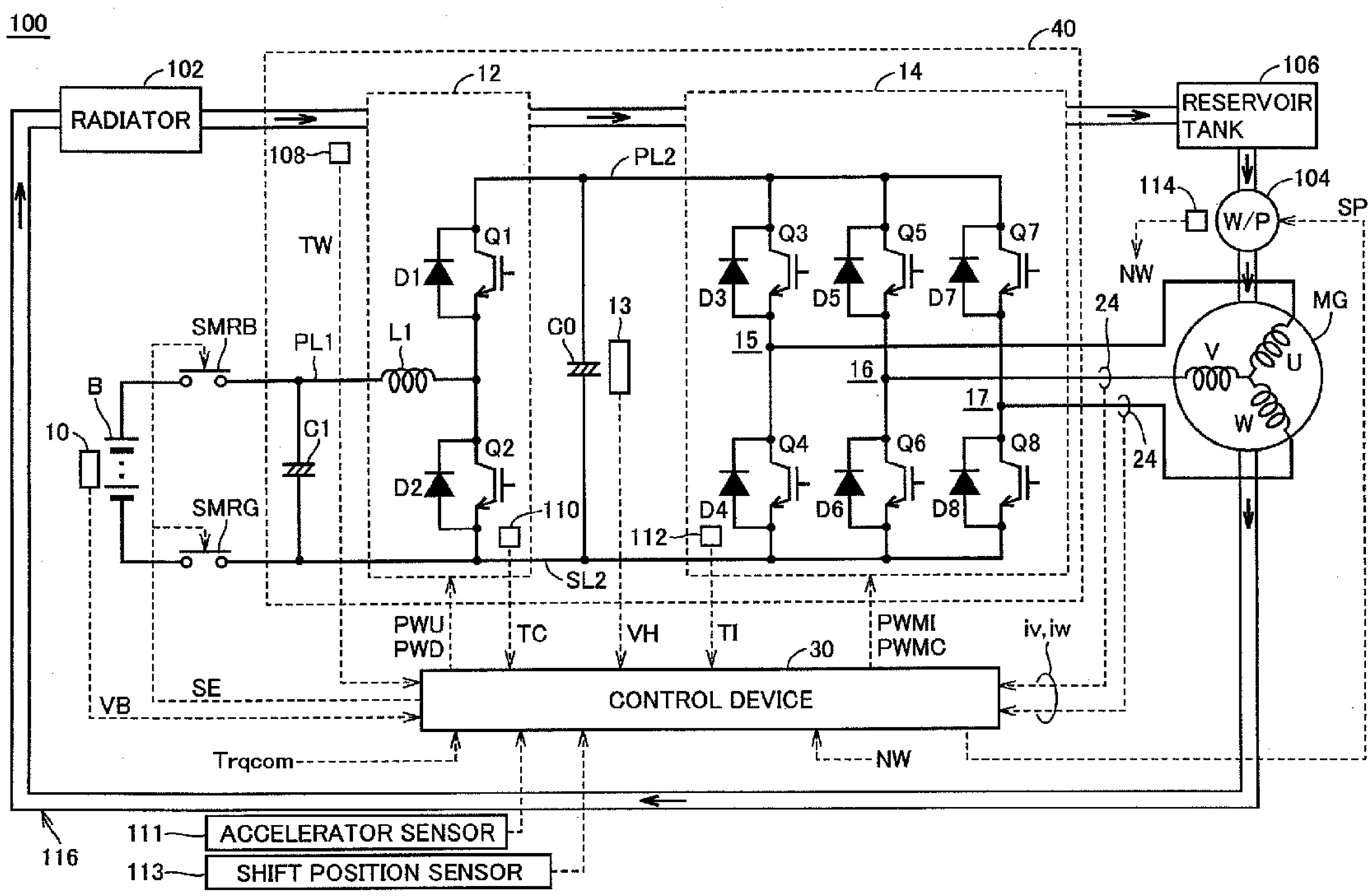


FIG.1

100

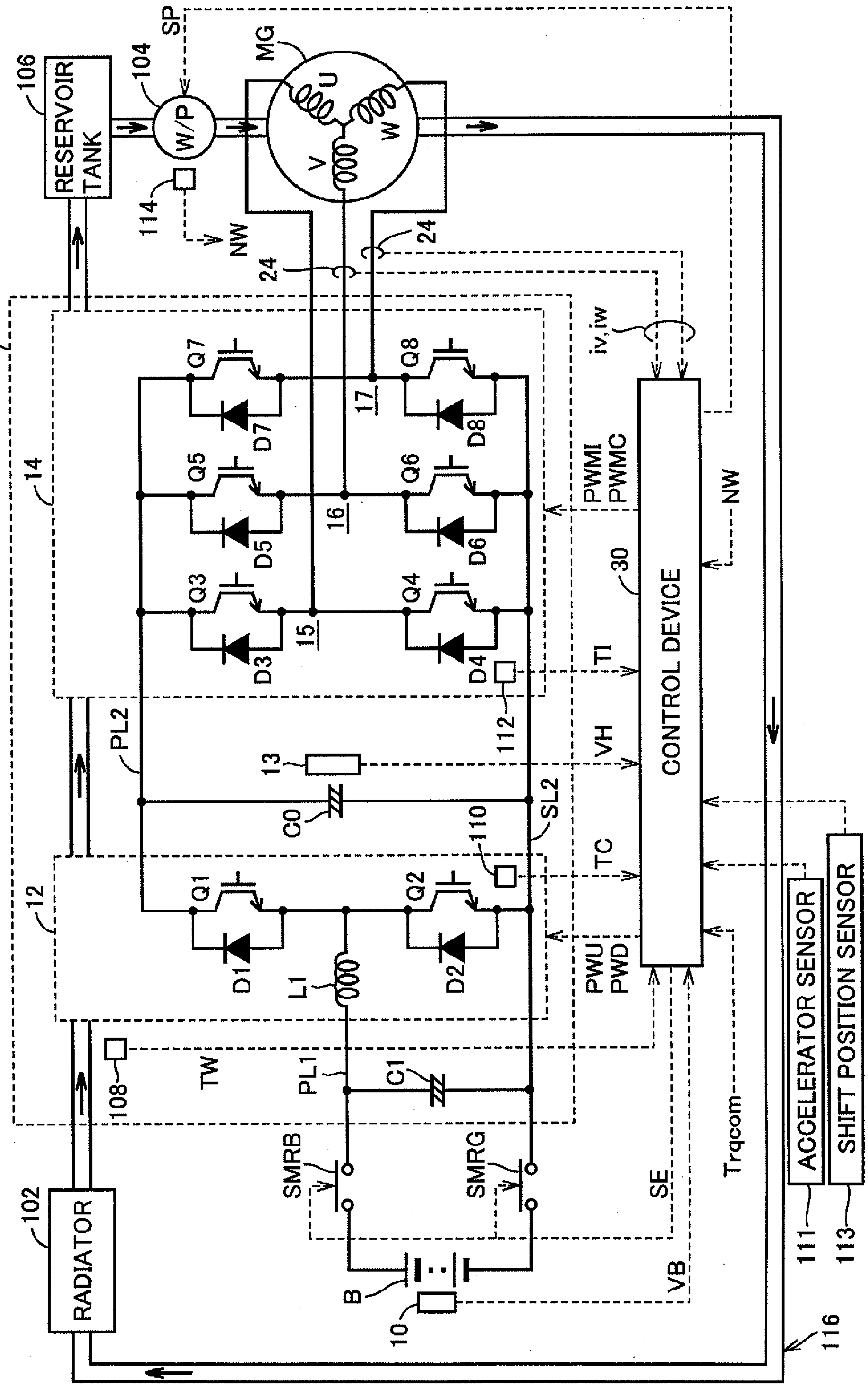

RADIATOR
102
RESERVOIR TANK
106
W/P
104
SP
MG
U
V
W
114
NW
24
24
40
iv,iw
14
Q7
D7
Q8
D8
17
Q5
D5
Q6
D6
16
Q3
D3
Q4
D4
15
PWMI
PWMC
NW
30
CONTROL DEVICE
TI
112
VH
13
PL2
C0
SL2
110
TC
12
Q1
D1
Q2
D2
L1
PWU
PWD
108
TW
PL1
C1
SMRB
SMRG
SE
Trqcom
B
10
VB
ACCELERATOR SENSOR
SHIFT POSITION SENSOR
111
113
116

FIG.2

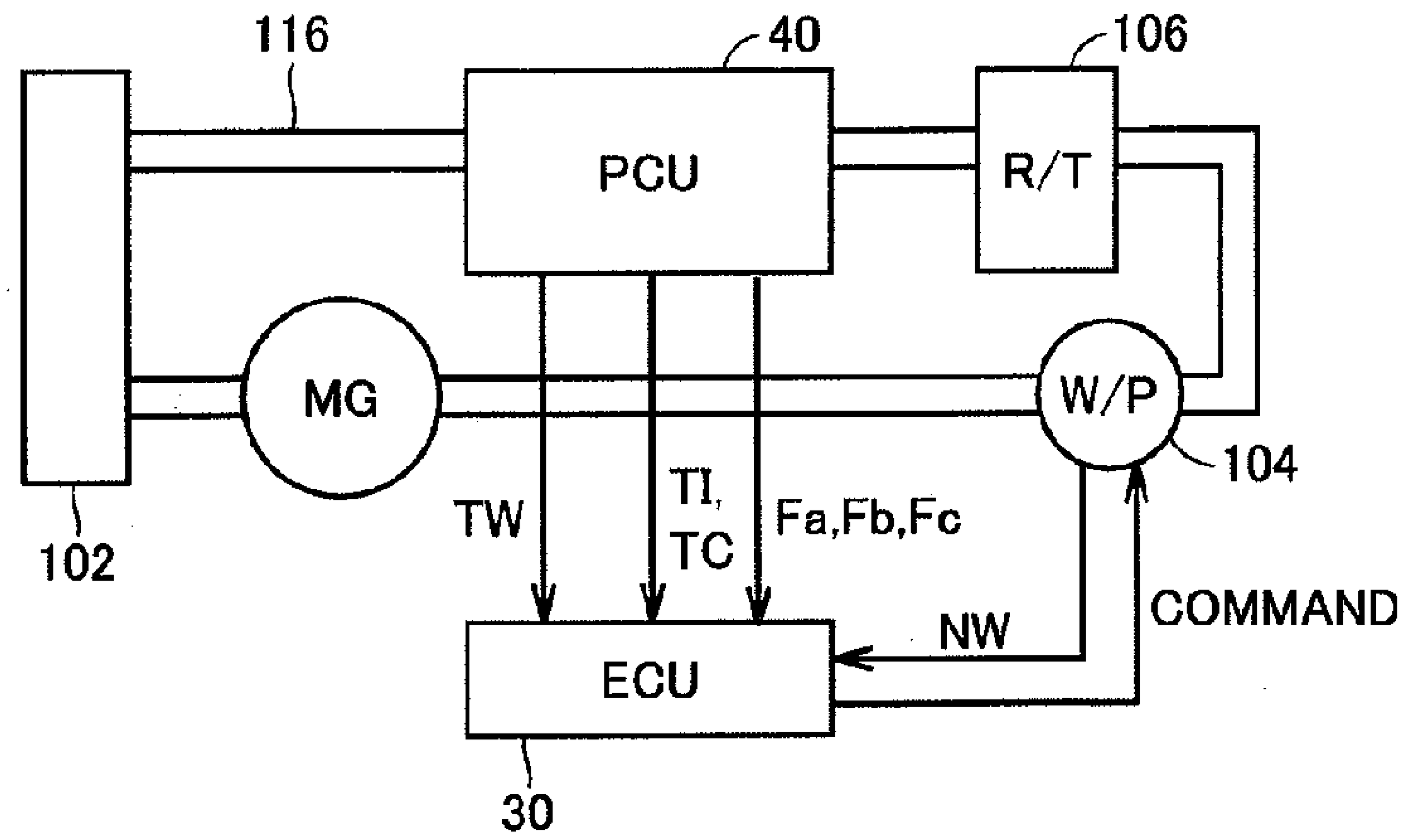

116
40
106
PCU
R/T
MG
W/P
104
102
TW
TI,
TC
Fa,Fb,Fc
NW
COMMAND
ECU
30

FIG.3

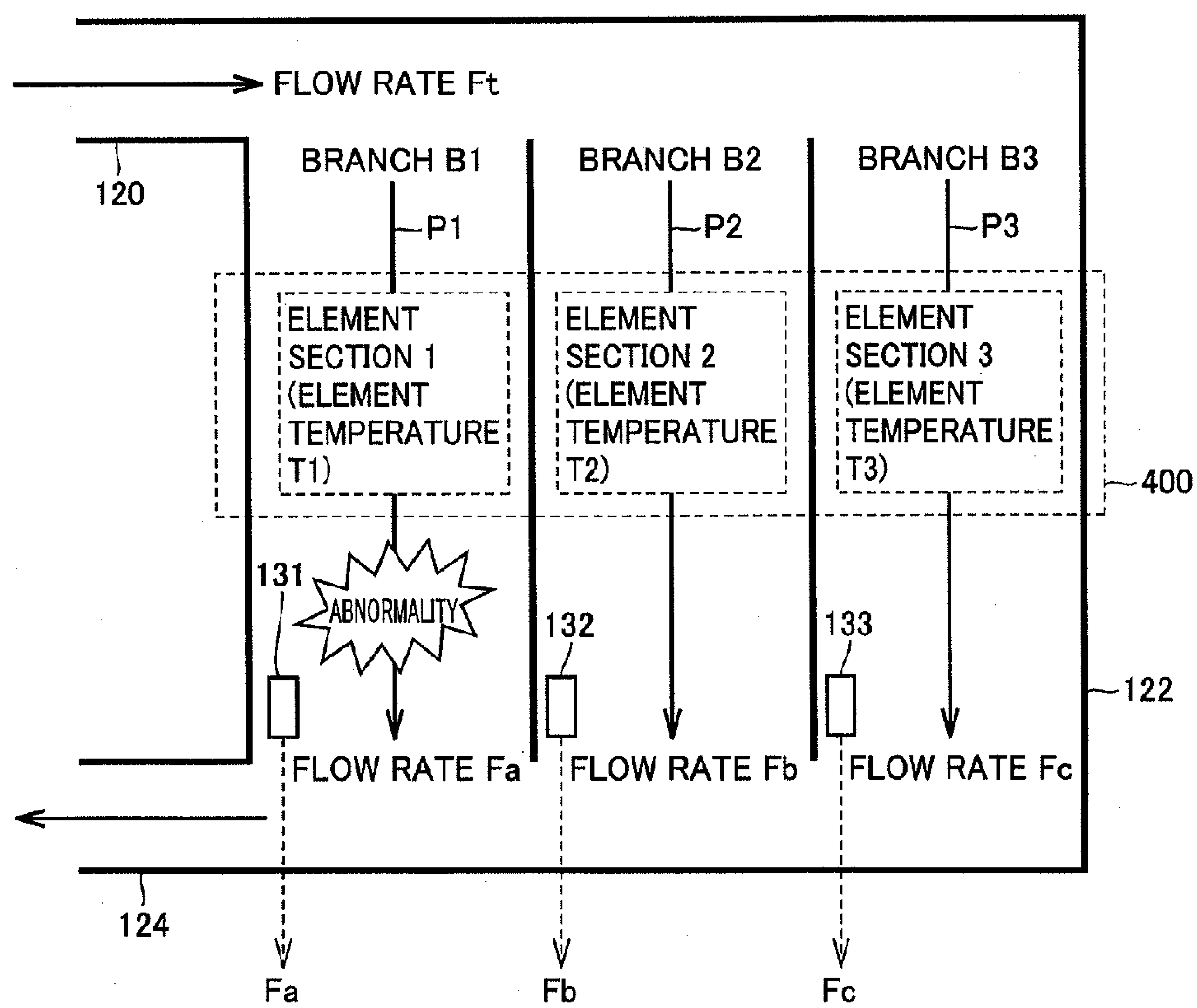

FLOW RATE Ft
120
BRANCH B1
BRANCH B2
BRANCH B3
P1
P2
P3
ELEMENT SECTION 1 (ELEMENT TEMPERATURE T1)
ELEMENT SECTION 2 (ELEMENT TEMPERATURE T2)
ELEMENT SECTION 3 (ELEMENT TEMPERATURE T3)
400
131
ABNORMALITY
132
133
122
FLOW RATE Fa
FLOW RATE Fb
FLOW RATE Fc
124
Fa
Fb
Fc

FIG.4

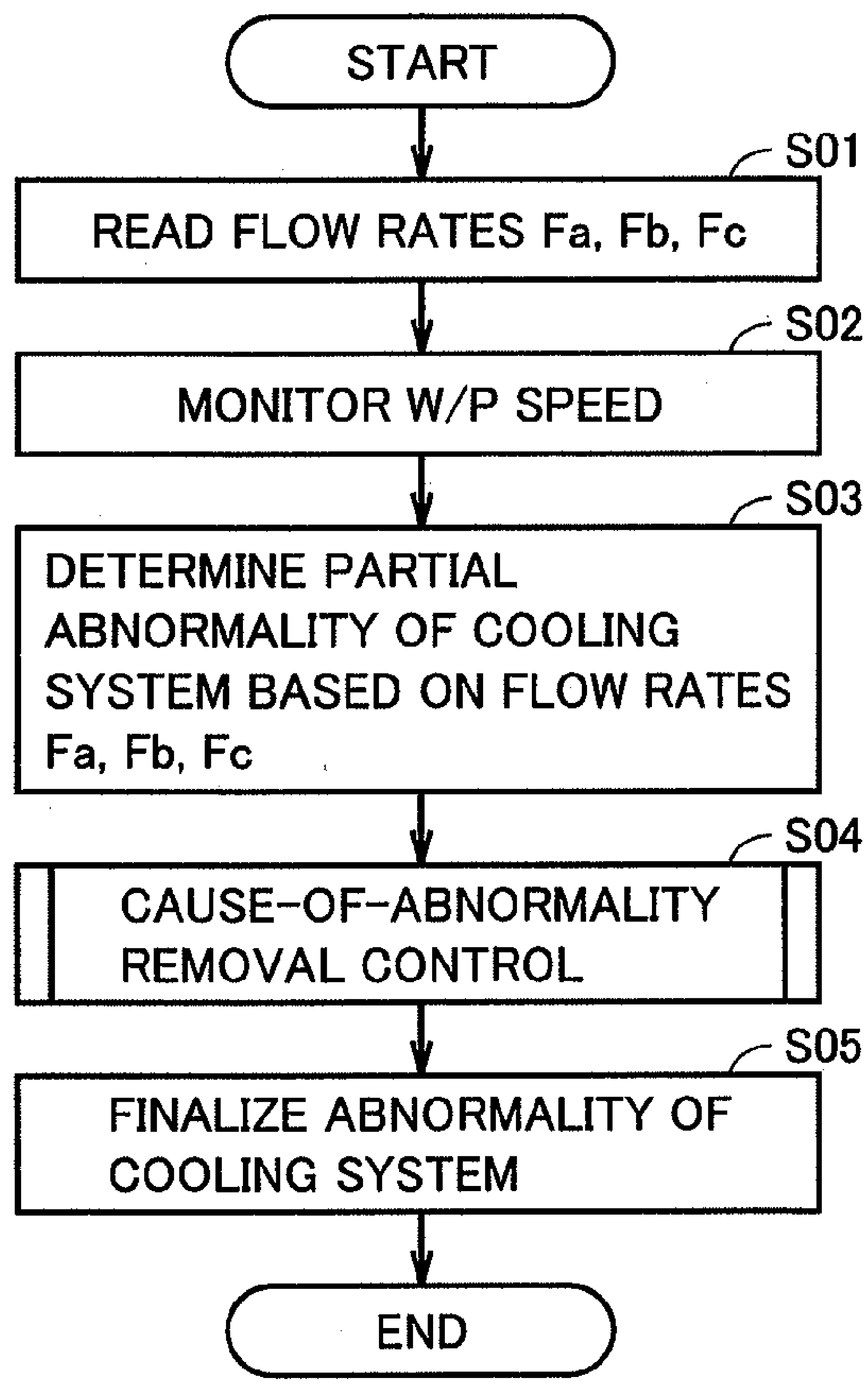

START
S01
READ FLOW RATES Fa, Fb, Fc
S02
MONITOR W/P SPEED
S03
DETERMINE PARTIAL ABNORMALITY OF COOLING SYSTEM BASED ON FLOW RATES Fa, Fb, Fc
S04
CAUSE-OF-ABNORMALITY REMOVAL CONTROL
S05
FINALIZE ABNORMALITY OF COOLING SYSTEM
END

FIG. 5

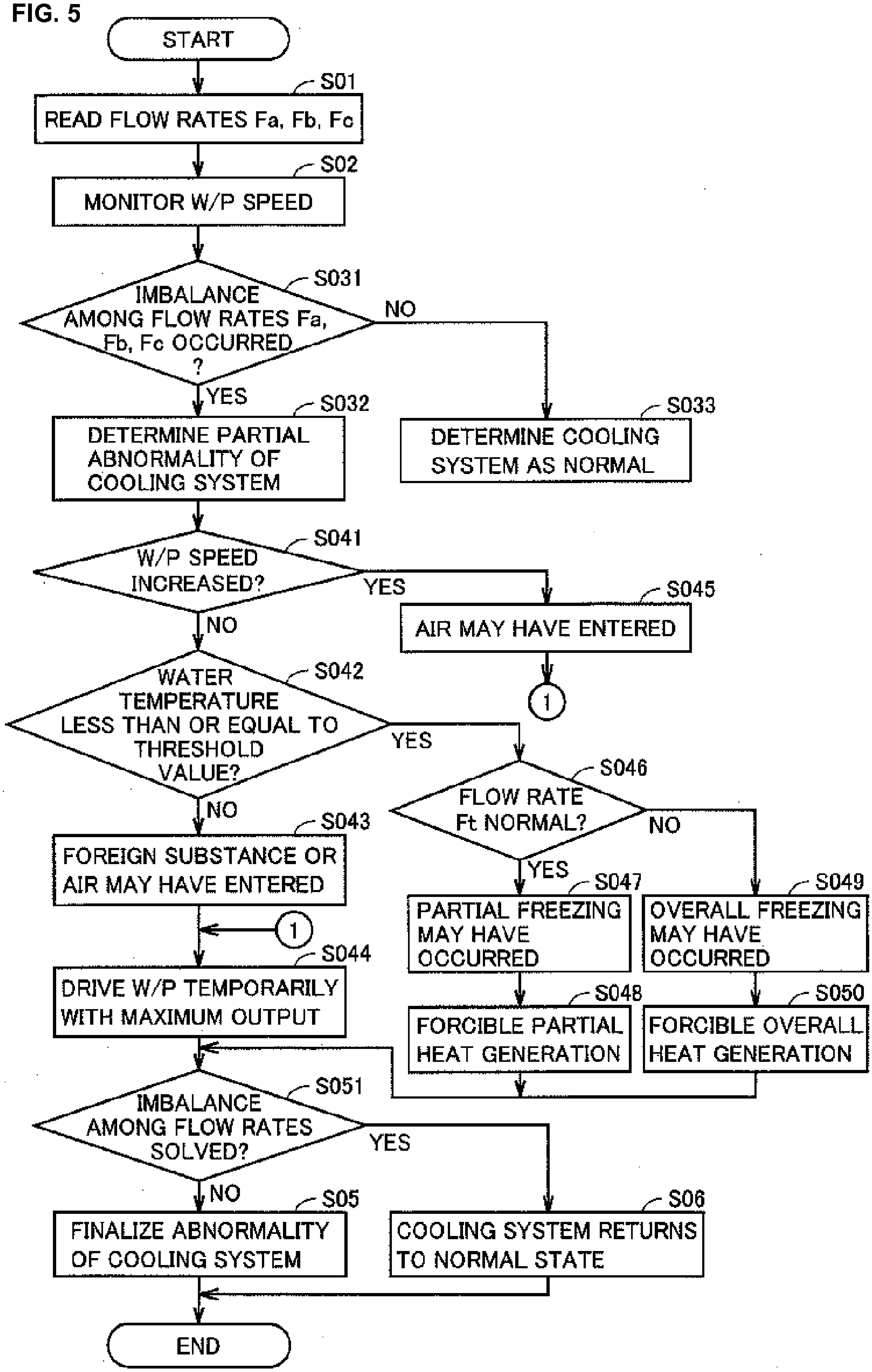

START
S01
READ FLOW RATES Fa, Fb, Fc
S02
MONITOR W/P SPEED
S031
IMBALANCE AMONG FLOW RATES Fa, Fb, Fc OCCURRED ?
NO
YES
S032
DETERMINE PARTIAL ABNORMALITY OF COOLING SYSTEM
S033
DETERMINE COOLING SYSTEM AS NORMAL
S041
W/P SPEED INCREASED?
YES
S045
AIR MAY HAVE ENTERED
1
NO
S042
WATER TEMPERATURE LESS THAN OR EQUAL TO THRESHOLD VALUE?
YES
S046
FLOW RATE Ft NORMAL?
NO
NO
S043
FOREIGN SUBSTANCE OR AIR MAY HAVE ENTERED
YES
S047
PARTIAL FREEZING MAY HAVE OCCURRED
S049
OVERALL FREEZING MAY HAVE OCCURRED
1
S044
DRIVE W/P TEMPORARILY WITH MAXIMUM OUTPUT
S048
FORCIBLE PARTIAL HEAT GENERATION
S050
FORCIBLE OVERALL HEAT GENERATION
S051
IMBALANCE AMONG FLOW RATES SOLVED?
YES
NO
S05
FINALIZE ABNORMALITY OF COOLING SYSTEM
S06
COOLING SYSTEM RETURNS TO NORMAL STATE
END

FIG.6

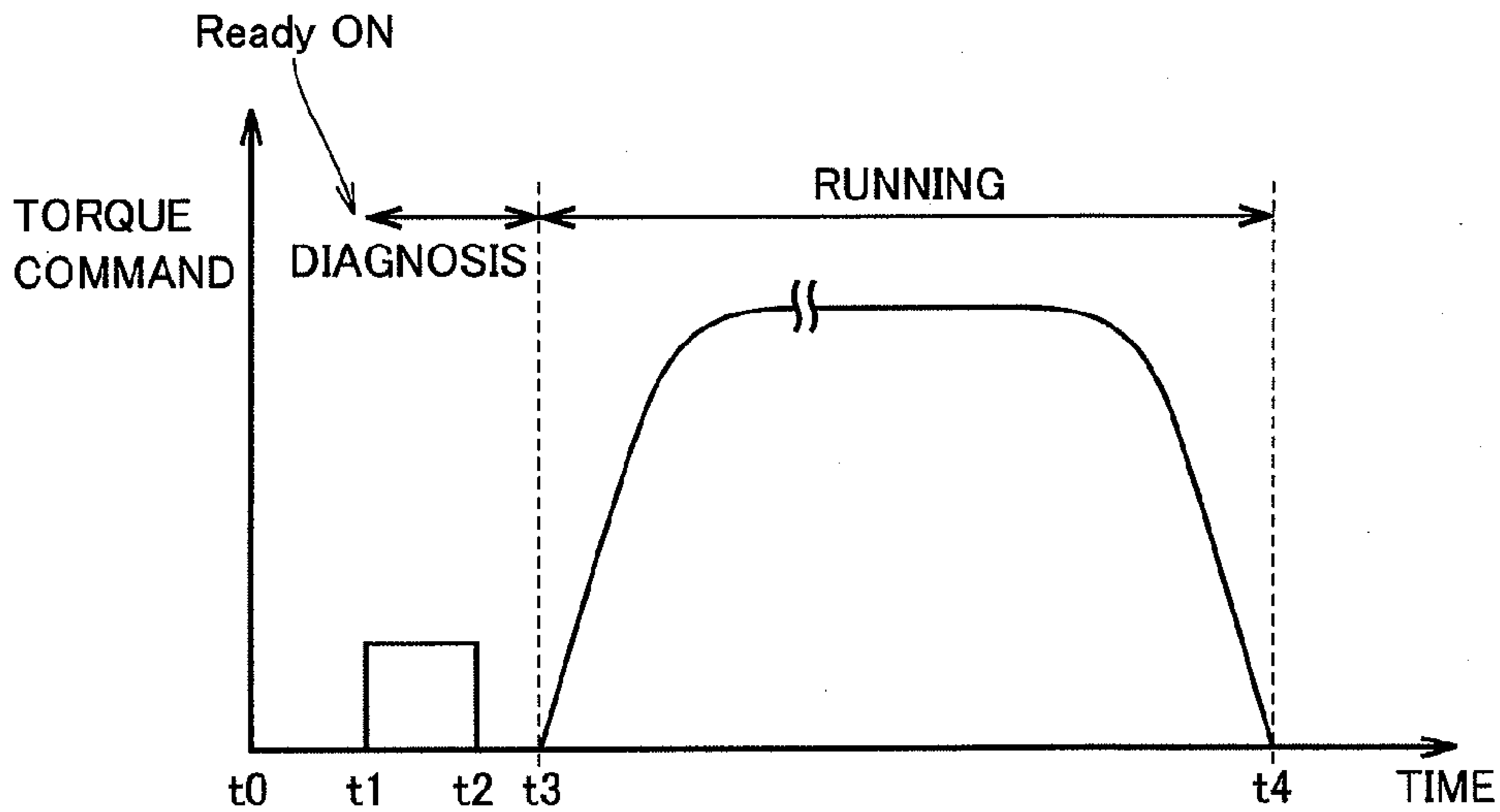

Ready ON
TORQUE COMMAND
DIAGNOSIS
RUNNING
t0
t1
t2
t3
t4
TIME

FIG.7

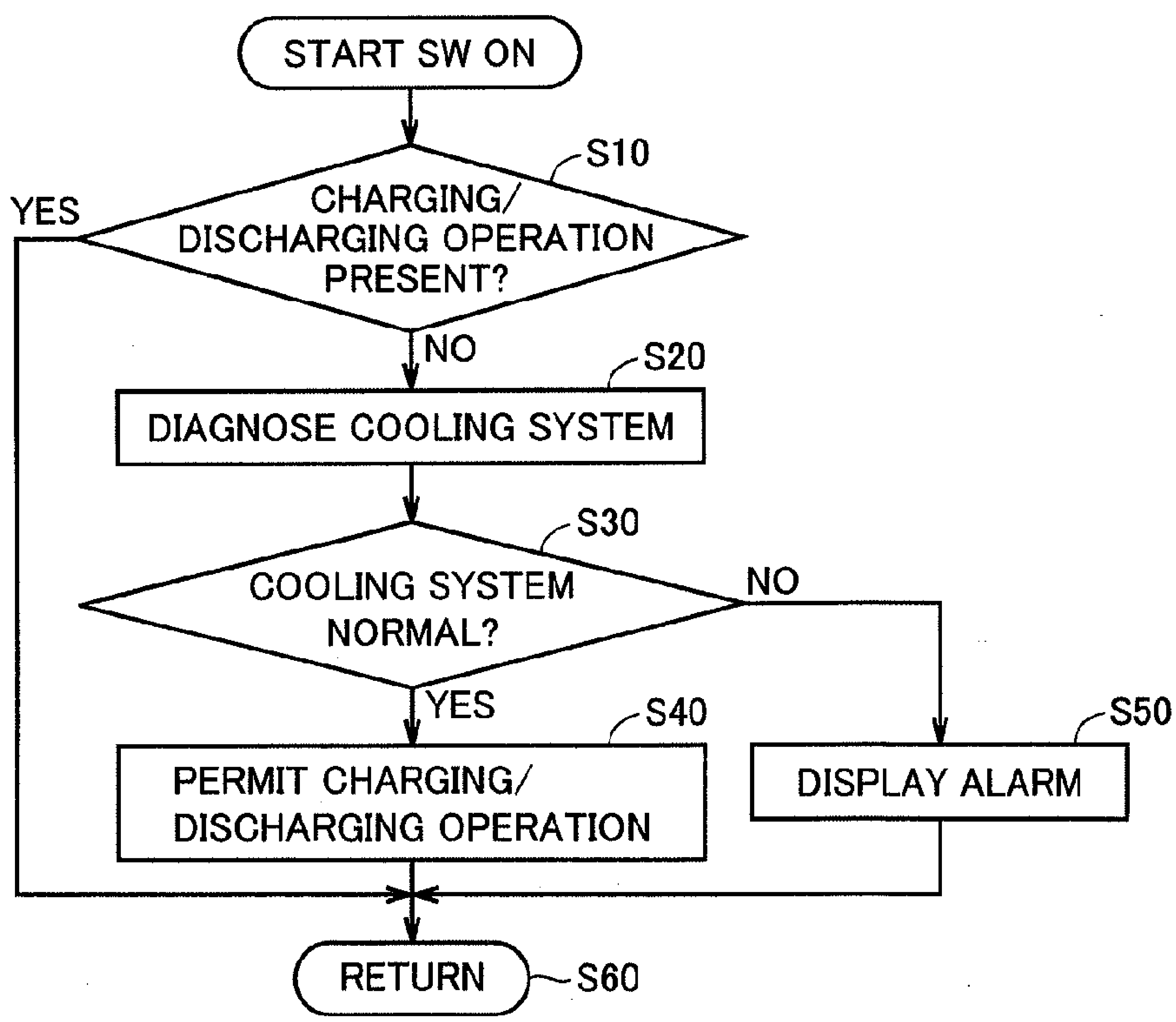

START SW ON
S10
CHARGING/ DISCHARGING OPERATION PRESENT?
YES
NO
S20
DIAGNOSE COOLING SYSTEM
S30
COOLING SYSTEM NORMAL?
NO
YES
S40
PERMIT CHARGING/ DISCHARGING OPERATION
S50
DISPLAY ALARM
RETURN
S60

FIG.8

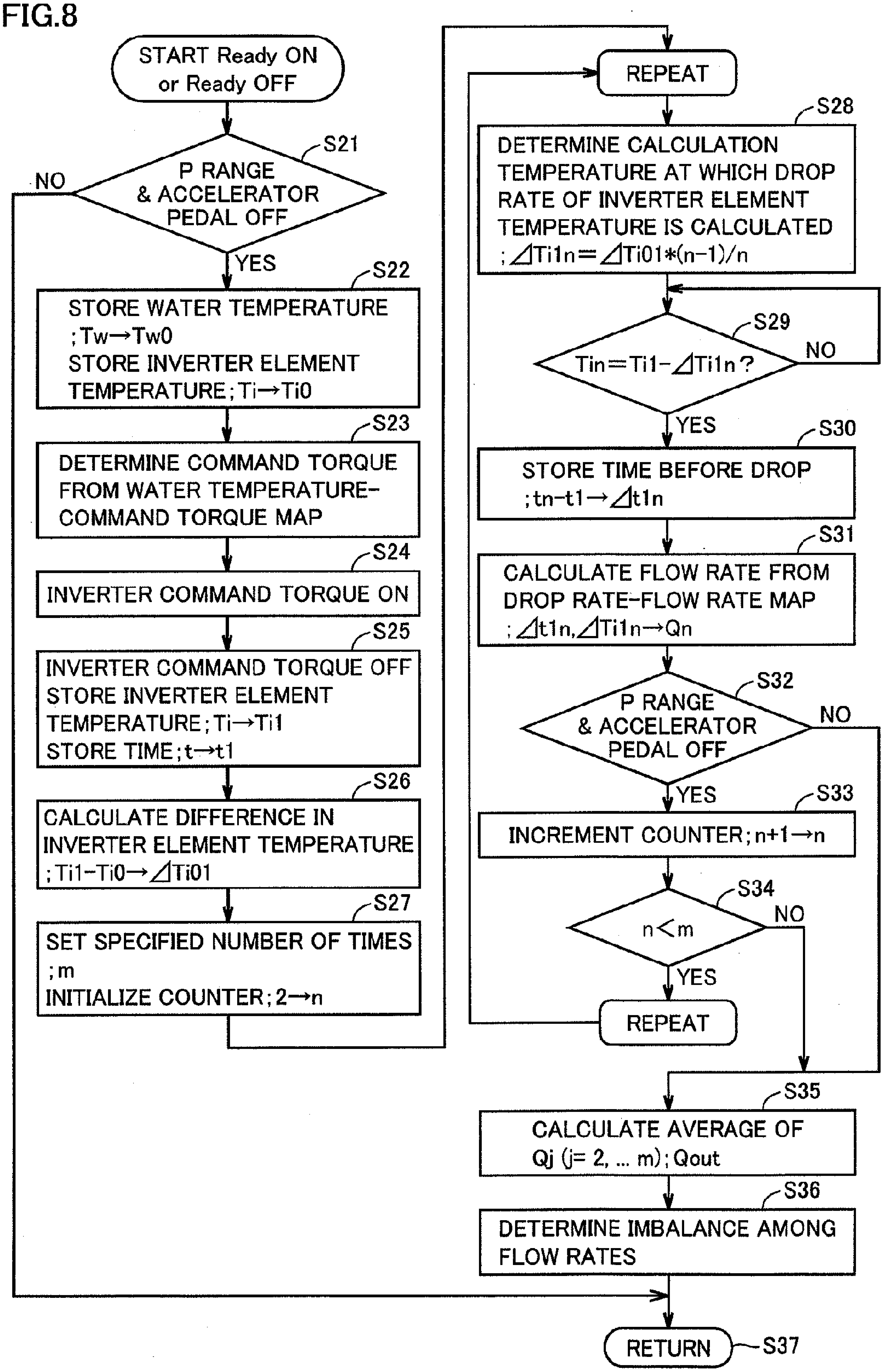

START Ready ON or Ready OFF
S21
P RANGE & ACCELERATOR PEDAL OFF
NO
YES
S22
STORE WATER TEMPERATURE ;Tw→Tw0 STORE INVERTER ELEMENT TEMPERATURE;Ti→Ti0
S23
DETERMINE COMMAND TORQUE FROM WATER TEMPERATURE-COMMAND TORQUE MAP
S24
INVERTER COMMAND TORQUE ON
S25
INVERTER COMMAND TORQUE OFF STORE INVERTER ELEMENT TEMPERATURE;Ti→Ti1 STORE TIME;t→t1
S26
CALCULATE DIFFERENCE IN INVERTER ELEMENT TEMPERATURE ;Ti1-Ti0→⊿Ti01
S27
SET SPECIFIED NUMBER OF TIMES ;m INITIALIZE COUNTER;2→n
REPEAT
S28
DETERMINE CALCULATION TEMPERATURE AT WHICH DROP RATE OF INVERTER ELEMENT TEMPERATURE IS CALCULATED ;⊿Ti1n=⊿Ti01*(n-1)/n
S29
Tin=Ti1-⊿Ti1n?
NO
YES
S30
STORE TIME BEFORE DROP ;tn-t1→⊿t1n
S31
CALCULATE FLOW RATE FROM DROP RATE-FLOW RATE MAP ;⊿t1n,⊿Ti1n→Qn
S32
P RANGE & ACCELERATOR PEDAL OFF
NO
YES
S33
INCREMENT COUNTER;n+1→n
S34
n<m
NO
YES
REPEAT
S35
CALCULATE AVERAGE OF Qj (j= 2, ... m);Qout
S36
DETERMINE IMBALANCE AMONG FLOW RATES
RETURN
S37

FIG.9

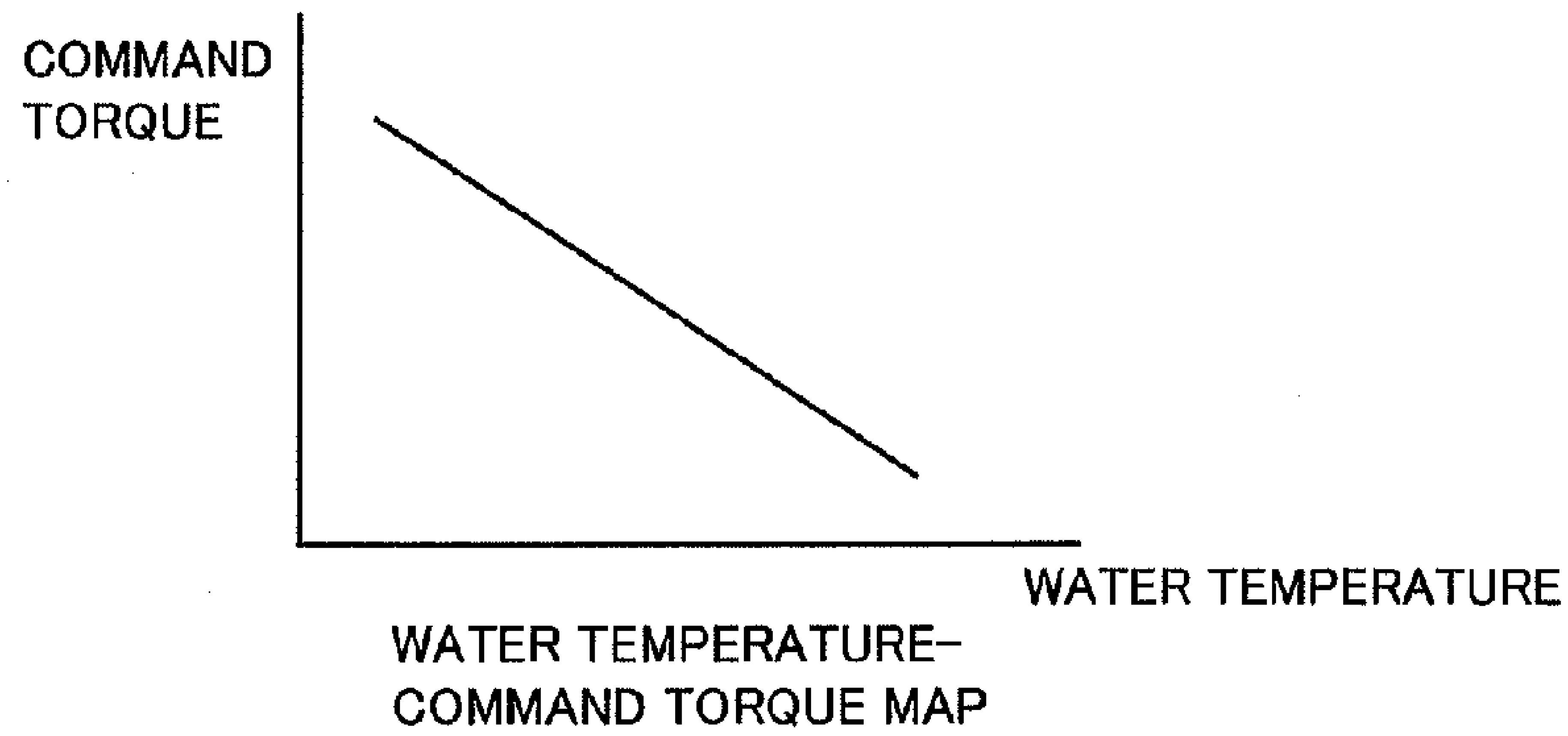

COMMAND
TORQUE
WATER TEMPERATURE
WATER TEMPERATURE–
COMMAND TORQUE MAP

FIG.10

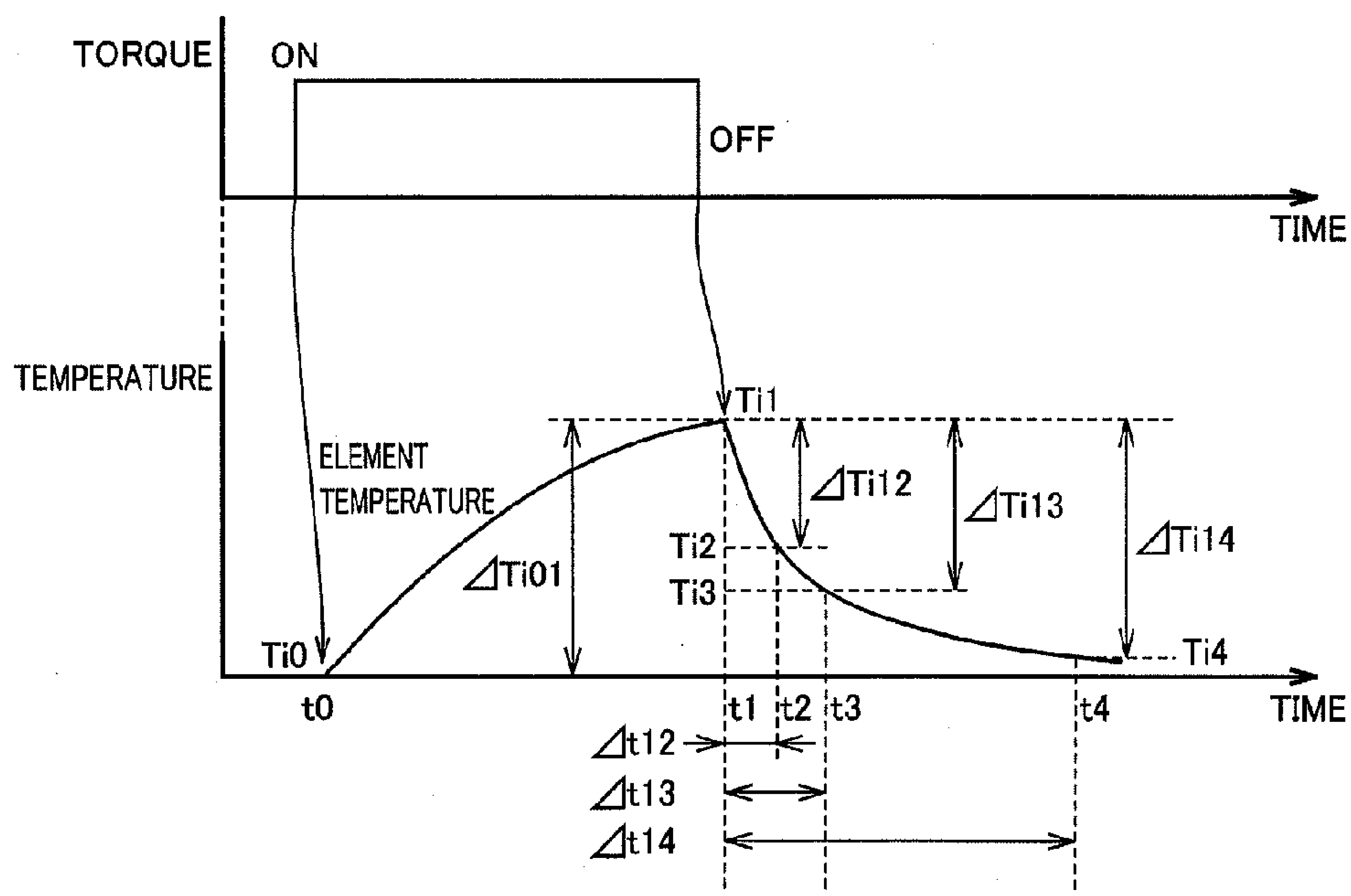
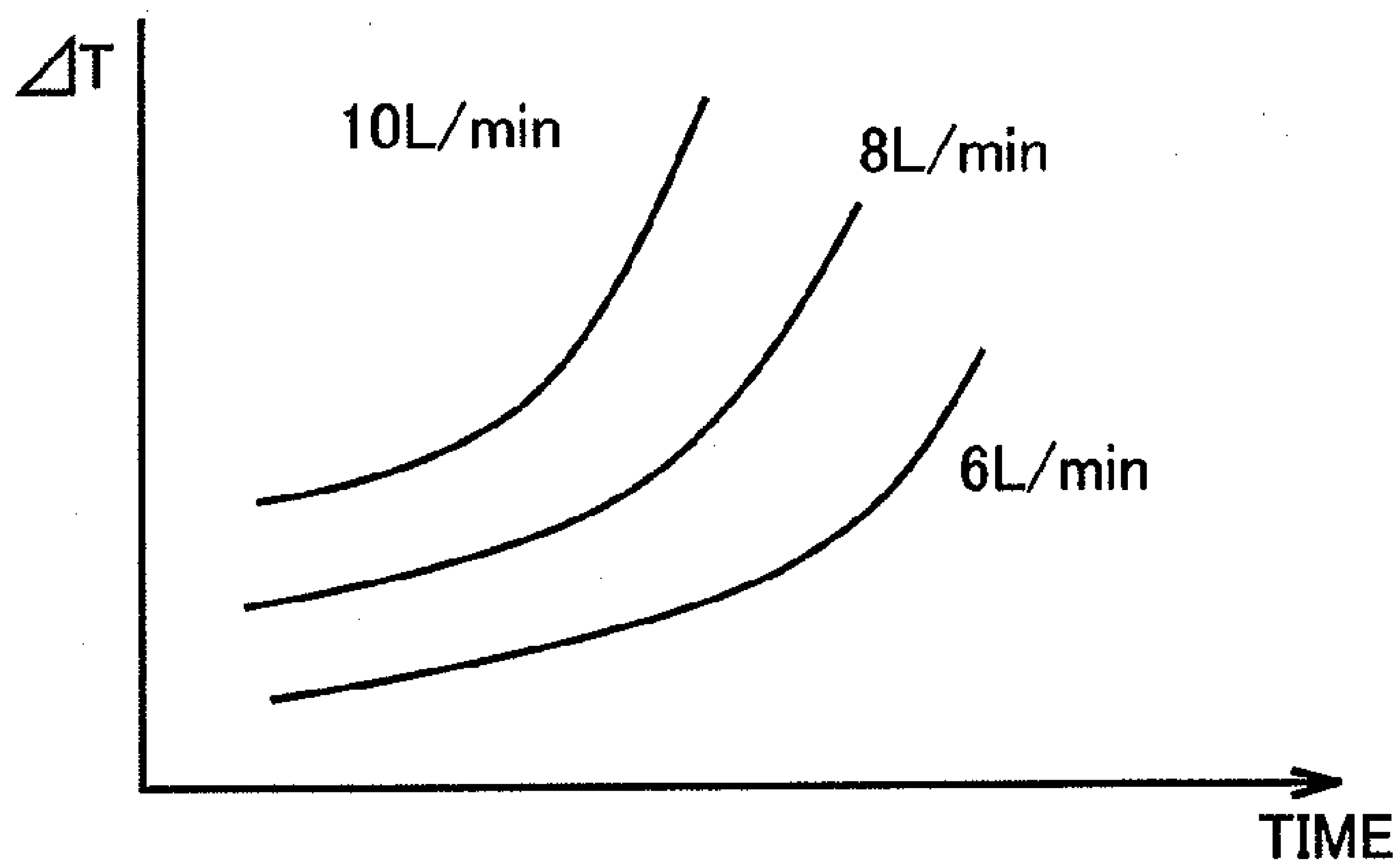

TORQUE
ON
OFF
TIME
TEMPERATURE
ELEMENT
TEMPERATURE
Ti1
⊿Ti01
⊿Ti12
⊿Ti13
⊿Ti14
Ti2
Ti3
Ti0
Ti4
t0
t1
t2
t3
t4
TIME
⊿t12
⊿t13
⊿t14

FIG.11



DROP RATE-FLOW RATE MAP

COOLING SYSTEM AND VEHICLE WITH THE SAME

TECHNICAL FIELD

[0001] The present invention relates to a cooling system and a vehicle with the same, and more particularly relates to a technique for diagnosing a partial abnormality of the cooling system.

BACKGROUND ART

[0002] In order to prevent a motor and a driving device, such as an inverter, driving the motor from overheating, an electric powered vehicle with the motor used as a drive source is equipped with a cooling system for cooling the motor and the driving device.

[0003] Japanese Patent Laying-Open No. 2008-256313 (PTD 1) discloses a cooling system equipped with a circulation channel for cooling water, a pump circulating the cooling water through the circulation channel and a radiator cooling the cooling water.

[0004] A control device of the cooling system described in PTD 1 includes, as a technique for determining the presence/absence of occurrence of abnormality of the cooling system, an abnormality determination unit determining the type of abnormality occurring in the cooling system based on the temperature of cooling water acquired from a temperature sensor provided for the circulation channel for cooling water and the speed of the water pump. When the cooling water has a temperature more than or equal to a threshold value set previously, this abnormality determination unit determines the type of abnormality, such as an abnormality of the radiator, clogging of the circulation channel and a malfunction of the water pump, based on the speed of the water pump.

Citation List

Patent Document

PTD 1: Japanese Patent Laying-Open No. 2008-256313

PTD 2: Japanese Patent Laying-Open No. 2005-20881

PTD 3: Japanese Patent Laying-Open No. 2004-332988

SUMMARY OF INVENTION

Technical Problem

[0005] With the technique for determining the presence/absence of occurrence of abnormality in a cooling system based on the temperature of cooling water and the speed of a water pump as described in PTD 1, the type of abnormality occurred in the cooling system can be determined. However, it is difficult to determine the cause of the abnormality. Therefore, with the technique described in PTD 1, fail-safe processing, such as restricting motor's output torque or stopping the water pump can be performed depending on the type of abnormality, however, processing for removing the cause of the abnormality cannot be performed.

[0006] The present invention was therefore made to solve such a problem, and has an object to provide a cooling system capable of identifying the cause of an abnormality occurred in the cooling system and removing the cause of the abnormality, as well as a vehicle equipped with such cooling system.

Solution to Problem

[0007] According to an aspect of the present invention, a cooling system for cooling a heat source includes a flow channel through which liquid medium cooling the heat source is circulated, and a pump provided on the flow channel for circulating the liquid medium. The flow channel includes a plurality of branches arranged between an upstream side and a downstream side of the heat source in parallel to a distribution direction of the liquid medium. The cooling system further includes a control device for detecting an abnormality occurred in the cooling system by detecting an imbalance among flow rates of the liquid medium flowing through the plurality of branches, respectively.

[0008] Preferably, the control device diagnoses a cause of occurrence of the abnormality at least based on the speed of the pump when the imbalance among the flow rates of the liquid medium is detected.

[0009] Preferably, the cooling system further includes a speed sensor for detecting the speed of the pump. In the case where the imbalance among the flow rates of the liquid medium is detected, the control device diagnoses that air has entered the flow channel when a first condition that a detection value of the speed sensor obtained when the pump is driven is higher than a control target value is met.

[0010] Preferably, the cooling system further includes a temperature sensor for detecting the temperature of the liquid medium. In the case where the first condition is not met, the control device determines whether or not a second condition that a detection value of the temperature sensor is lower than a predetermined threshold value is met, and when the second condition is met, the control device diagnoses that the flow channel is frozen.

[0011] Preferably, in the case where the second condition is met, the control device determines whether or not a flow rate of the flow channel falls within a control range, and when a third condition that the flow rate of the flow channel falls within the control range is met, the control device diagnoses that any of the plurality of branches is frozen.

[0012] Preferably, in the case where the first condition is not met, the control device diagnoses that a foreign substance has entered any of the plurality of branches when the second condition is not met.

[0013] Preferably, in the case where it is diagnosed that one of air and a foreign substance has entered any of the plurality of branches, the control device temporarily increases the speed of the pump.

[0014] Preferably, in the case where it is diagnosed that any of the plurality of branches is frozen, the control device temporarily increases the amount of heat generation of a heat source corresponding to a branch diagnosed as frozen.

[0015] Preferably, the heat source is a driving device having a motor and an inverter driving the motor. The cooling system further includes an element temperature sensor detecting the temperature of a power control element in the inverter. Under a situation where a condition that another driving instruction is not issued to the inverter is satisfied, the control device temporarily causes the power control element in the inverter to generate heat and then reduces heat generation of the power control element to presume the flow rates of the plurality of branches depending on the degree of drop of a detection value of the element temperature sensor, and detects an imbalance among the flow rates of the liquid medium based on presumed values of the flow rates of the plurality of branches.

[0016] Preferably, the plurality of branches are configured to have an equal flow rate.

[0017] According to another aspect of the present invention, a vehicle includes a driving device using a motor as a drive source, and a cooling system for cooling the driving device. The cooling system includes a flow channel through which liquid medium cooling the driving device is circulated, and a pump provided on the flow channel for circulating the liquid medium. The flow channel includes a plurality of branches arranged between an upstream side and a downstream side of the heat source in parallel to a distribution direction of the liquid medium and configured to have an equal flow rate. The vehicle further includes a control device for detecting an abnormality occurred in the cooling system by detecting an imbalance among flow rates of the liquid medium flowing through the plurality of branches, respectively.

Advantageous Effects of Invention

[0018] According to the present invention, when an abnormality occurred in the cooling system is detected, the cause of the abnormality can be identified, and the cause of the abnormality can be removed. Thereby, even if an abnormality occurs in the cooling system, abnormality determination can be prevented from being immediately finalized. As a result, a restriction on the output of the driving device or unnecessary exchange of water pumps can be avoided.

BRIEF DESCRIPTION OF DRAWINGS

[0019] FIG. **1** is a schematic configuration diagram of a vehicle equipped with a cooling system according to an embodiment of the present invention.

[0020] FIG. **2** is a diagram showing the configuration of the cooling system taken out from the configuration of the vehicle of FIG. **1**.

[0021] FIG. **3** is a conceptual view illustrating the configuration of flow channel passing through PCU.

[0022] FIG. **4** is a flowchart schematically showing a processing structure of a control device.

[0023] FIG. **5** is a flowchart for achieving cause-of-abnormality removal control shown in step S**04** of FIG. **4**.

[0024] FIG. **6** is a waveform diagram for illustrating diagnostic timing of a cooling system according to the present exemplary modification.

[0025] FIG. **7** is a flowchart for illustrating control of diagnostic timing of the cooling system shown in FIG. **6**.

[0026] FIG. **8** is a flowchart for illustrating flow-rate detection processing used in diagnosing the cooling system in step S**20** of FIG. **7**.

[0027] FIG. **9** is a diagram showing an example of water temperature-command torque map referred to in step S**23** of FIG. **8**.

[0028] FIG. **10** is a diagram for illustrating measurements of temperature drop rate.

[0029] FIG. **11** is a diagram showing an example of drop rate-flow rate map.

DESCRIPTION OF EMBODIMENTS

[0030] Hereinafter, embodiments of the present invention will be described in detail with reference to the drawings. It is noted that, in the drawings, the same or corresponding portions have the same reference characters allotted, and repeated description thereof will not be provided.

[0031] Vehicular Configuration

[0032] FIG. **1** is a schematic configuration diagram of a vehicle **100** equipped with a cooling system according to an embodiment of the present invention. It is noted that, although vehicle **100** is shown as an electric vehicle by way of example, the present invention is applicable not only to an electric vehicle but also to any hybrid vehicle with an internal combustion engine used in combination or any fuel-cell vehicle that is equipped with a cooling system.

[0033] Referring to FIG. **1**, vehicle **100** includes a battery B as a power storage device, a voltage sensor **10**, a power control unit (PCU) **40**, a motor-generator MG, and a control device **30**. PCU **40** includes a voltage converter **12**, smoothing capacitors C**0** and C**1**, a voltage sensor **13**, and an inverter **14**. It is noted that PCU **40** may include inverter **14** alone, without being provided with voltage converter **12**. Vehicle **100** further includes a positive bus PL**2** for supplying electric power to inverter **14** driving motor-generator MG.

[0034] Smoothing capacitor C**1** is connected across positive bus PL**1** and a negative bus SL**2**. Voltage converter **12** boosts a voltage across the terminals of smoothing capacitor C**1**. Smoothing capacitor C**0** smoothes the voltage boosted by voltage converter **12**. Voltage sensor **13** detects a voltage VH across the terminals of smoothing capacitor C**0**, and outputs the voltage to control device **30**.

[0035] Vehicle **100** further includes a system main relay SMRB connected across a positive electrode of battery B and positive bus PL**1** and a system main relay SMRG connected across a negative electrode of battery B (negative bus SL**1**) and a node N**2**.

[0036] The conducting/non-conducting state of system main relays SMRB and SMRG is controlled in response to a control signal SE supplied from control device **30**. Voltage sensor **10** detects a voltage VB across the terminals of battery B. Although not shown, in order to monitor the state of charge of battery B, a current sensor for detecting a current IB flowing through battery B is provided together with voltage sensor **10**.

[0037] Battery B can be implemented by, for example, a secondary battery such as a lead acid battery, a nickel-metal hydride battery or a lithium ion battery, or a large-capacitance capacitor such as an electric double layer capacitor, or the like. Negative bus SL**2** extends to the inverter **14** side passing through voltage converter **12**.

[0038] Voltage converter **12** is a voltage converter provided across battery B and positive bus PL**2** and performing voltage conversion. Voltage converter **12** includes a reactor L**1** having one end connected to positive bus PL**1**, IGBT elements Q**1** and Q**2** connected in series across positive bus PL**2** and negative bus SL**2**, and diodes D**1** and D**2** connected to IGBT elements Q**1** and Q**2**, respectively.

[0039] Reactor L**1** has its other end connected to the emitter of IGBT element Q**1** and the collector of IGBT element Q**2**. Diode D**1** has its cathode connected to the collector of IGBT element Q**1**, and diode D**1** has its anode connected to the emitter of IGBT element Q**1**. Diode D**2** has its cathode connected to the collector of IGBT element Q**2**, and diode D**2** has its anode connected to the emitter of IGBT element Q**2**.

[0040] Inverter **14** is connected to positive bus PL**2** and negative bus SL**2**. Inverter **14** converts a DC voltage output from voltage converter **12** into a three-phase AC voltage for output to motor-generator MG that drives a wheel **2**. Also, inverter **14** returns electric power generated in motor-generator MG to voltage converter **12** following regenerative braking. At this time, voltage converter **12** is controlled by control device **30** to operate as a step-down circuit.

[0041] Inverter **14** includes a U-phase arm **15**, a V-phase arm **16** and a W-phase arm **17**. U-phase arm **15**, V-phase arm **16** and W-phase arm **17** are connected in parallel across positive bus PL**2** and negative bus SL**2**.

[0042] U-phase arm **15** includes IGBT elements Q**3** and Q**4** connected in series across positive bus PL**2** and negative bus SL**2** and diodes D**3** and D**4** connected in parallel to IGBT elements Q**3** and Q**4**, respectively. Diode D**3** has its cathode connected to the collector of IGBT element Q**3**, and diode D**3** has its anode connected to the emitter of

[0043] IGBT element Q**3**. Diode D**4** has its cathode connected to the collector of IGBT element Q**4**, and diode D**4** has its anode connected to the emitter of IGBT element Q**4**.

[0044] V-phase arm **16** includes IGBT elements Q**5** and Q**6** connected in series across positive bus PL**2** and negative bus SL**2** and diodes D**5** and D**6** connected in parallel to IGBT elements Q**5** and Q**6**, respectively. Diode D**5** has its cathode connected to the collector of IGBT element Q**5**, and diode D**5** has its anode connected to the emitter of IGBT element Q**5**. Diode D**6** has its cathode connected to the collector of IGBT element Q**6**, and diode D**6** has its anode connected to the emitter of IGBT element Q**6**.

[0045] W-phase arm **17** includes IGBT elements Q**7** and Q**8** connected in series across positive bus PL**2** and negative bus SL**2** and diodes D**7** and D**8** connected in parallel to

[0046] IGBT elements Q**7** and Q**8**, respectively. Diode D**7** has its cathode connected to the collector of IGBT element Q**7**, and diode D**7** has its anode connected to the emitter of IGBT element Q**7**. Diode D**8** has its cathode connected to the collector of IGBT element Q**8**, and diode D**8** has its anode connected to the emitter of IGBT element Q**8**.

[0047] Motor-generator MG is a three-phase permanent magnet synchronous motor, and three stator coils of U, V and W phases have their one ends connected in common to a neutral point. The U-phase coil has its other end connected to a line drawn from a connection node between IGBT elements Q**3** and Q**4**. The V-phase coil has its other end connected to a line drawn from a connection node between IGBT elements Q**5** and Q**6**. The W-phase coil has its other end connected to a line drawn from a connection node between IGBT elements Q**7** and Q**8**.

[0048] A current sensor **24** detects a current flowing in motor-generator MG as a motor current MCRT, and outputs motor current MCRT to control device **30**. Control device **30** receives an accelerator pedal position from an accelerator sensor **111**, and receives a set position of a shift lever from a shift position sensor **113**. Furthermore, control device **30** receives a rotation speed (motor speed) Nm of motor-generator MG, respective values of current IB and voltages VB, VH, motor current MCRT, and an activation signal IGON. Control device **30** then controls voltage converter **12** and inverter **14** based on these pieces of information.

[0049] More specifically, control device **30** outputs, to voltage converter **12**, a control signal PWU giving a boost instruction, a control signal PWD giving a step-down instruction and a shutdown signal instructing prohibition of movement.

[0050] Control device **30** also outputs, to inverter **14**, a control signal PWMI giving a driving instruction of converting a DC voltage output from voltage converter **12** into an

[0051] AC voltage for driving motor-generator MG and a control signal PWMC giving a regeneration instruction of converting an AC voltage generated by motor-generator MG into a DC voltage for return to the voltage-converter **12** side.

[0052] Configuration of Cooling System

[0053] In the configuration shown in FIG. **1**, vehicle **100** further includes a radiator **102**, a reservoir tank **106** and a water pump **104**, as a cooling system for cooling PCU **40** and motor-generator MG. FIG. **2** shows the configuration of the cooling system taken out from the configuration of vehicle **100** of FIG. **1**.

[0054] Radiator **102**, PCU **40**, reservoir tank **106**, water pump **104**, and motor-generator MG are circularly connected in series by a flow channel **116**.

[0055] Water pump **104** is a pump for circulating cooling water such as an antifreeze solution. Water pump **104** pumps up cooling water from reservoir tank **106**, and circulates cooling water toward motor-generator MG. A speed sensor **114** detects a rotation speed (hereinafter denoted as W/P speed) NW of water pump **104**, and outputs detected W/P speed NW to control device **30**.

[0056] Radiator **102** receives cooling water having cooled voltage converter **12** and inverter **14** within PCU **40** from flow channel **116**, and cools the received cooling water using a radiator fan not shown.

[0057] A temperature sensor **108** detecting the temperature of cooling water is provided in proximity to a cooling water inlet of PCU **40**. A cooling water temperature TW is transmitted from temperature sensor **108** to control device **30**. Moreover, a temperature sensor **110** detecting a temperature TC of voltage converter **12** and a temperature sensor **112** detecting a temperature TI of inverter **14** are provided within PCU **40**. Temperature sensors **110** and **112** are implemented by temperature detecting elements, for example, built in an intelligent power module.

[0058] Control device **30** generates a signal SP for driving water pump **104** based on temperature TC from temperature sensor **110** and temperature TI from temperature sensor **112**, and outputs generated signal SP to water pump **104**.

[0059] In the configuration shown in FIG. **2**, flow channel **116** in a zone from the upstream side to the downstream side of PCU **40** is branched into a plurality of branches. FIG. **3** is a conceptual view illustrating the configuration of flow channel **116** passing through PCU **40**. Referring to FIG. **3**, provided within PCU **40** is a power element substrate **400** on which power control elements (IGBT elements etc.) of voltage converter **12** and inverter **14** are mounted. A flow channel **122** for cooling power element substrate **400** is provided on the rear surface of this power element substrate **400**. Flow channel **122** communicates with a cooling water inlet **120** and a cooling water outlet **124**.

[0060] In FIG. **3**, the plurality of power control elements mounted on power element substrate **400** are divided into three element sections (element sections **1** to **3**). Flow channel **122** is branched into three branches B**1** to B**3** to pass through these three element sections, respectively. These three branches B**1** to B**3** are arranged between cooling water inlet **120** and cooling water outlet **124** in parallel to the distribution direction of cooling water, and are configured such that their flow rates are equal to one another. Therefore, cooling water introduced through cooling water inlet **120** is trisected, and then flows through branches B**1** to B**3** in the direction indicated by arrows P**1** to P**3**, respectively. At this time, the cooling water flowing through each branch and each element section exchange heat with each other, so that the power control elements included in the element sections are cooled.

[0061] Flow sensors **131** to **133** for detecting the flow rate of cooling water are provided for branches B**1** to B**3**, respectively. From flow sensor **131**, a flow rate Fa of cooling water in branch B**1** is transmitted to control device **30**. From flow sensor **132**, a flow rate Fb of cooling water in branch B**2** is transmitted to control device **30**. From flow sensor **133**, a flow rate Fc of cooling water in branch B**3** is transmitted to control device **30**.

[0062] Control device **30** diagnoses a partial abnormality of the cooling system based on flow rates Fa, Fb and Fc input from flow sensors **131** to **133**, respectively. The partial abnormality of the cooling system as used in the present embodiment refers to the occurrence of an abnormality in any of the plurality of branches. FIG. **3** shows the case where a foreign substance has entered branch B**1** as an example of partial abnormality. In this case, the flow rate of cooling water flowing through branch B**1** decreases, so that an imbalance in flow rate among branches B**1** to B**3** occurs. When such an imbalance in flow rate occurs, a difference in cooling capacity occurs among element sections **1** to **3**, which may cause a problem in that the element temperature partly becomes higher. In the case of FIG. **3**, an element temperature T**1** of element section **1** may become higher than an element temperature T**2** of element section **2** and an element temperature T**3** of element section **3**. It is therefore necessary to quickly detect a partial abnormality of the cooling system and to solve an imbalance in flow rate due to the partial abnormality.

[0063] In the cooling system according to the present embodiment, control device **30** detects whether an imbalance among flow rates Fa, Fb and Fc has occurred based on detection values (flow rates Fa, Fb and Fc) of flow sensors **131** to **133** in accordance with FIGS. **4** and **5** which will be described below. When an imbalance among flow rates has occurred, control device **30** determines it as a partial abnormality of the cooling system.

[0064] Then, when the partial abnormality of the cooling system is determined, control device **30** diagnoses the cause of the partial abnormality based on the condition of the cooling system when the partial abnormality has occurred. When the cause of the partial abnormality is diagnosed, control device **30** further executes control for removing the diagnosed cause to thereby solve the partial abnormality.

[0065] FIG. 4 is a flowchart schematically showing a processing structure of control device **30**. It is noted that the processing of this flowchart is executed at regular time intervals or every time predetermined conditions are met.

[0066] Referring to FIG. **4**, control device **30** in step S**01** reads flow rates Fa, Fb and Fc of branches B**1** to B3 detected by flow sensors **131** to **133** (FIG. **3**), respectively. Next, control device **30** in step S**02** monitors rotation speed (W/P speed) NW of water pump **104** detected by speed sensor **114** (FIG. **1**). Control device **30** in step S**03** determines whether a partial abnormality of the cooling system has occurred based on flow rates Fa, Fb and Fc. More specifically, control device **30** determines whether or not an imbalance among flow rates Fa, Fb and Fc has occurred. For example, control device **30** calculates the ratio of each of flow rates Fa, Fb and Fc relative to the total value of flow rates Fa, Fb and Fc (equivalent to a flow rate Ft of flow channel **116**). Control device **30** then compares the calculated ratios to thereby determine whether or not an imbalance among the flow rates has occurred.

[0067] When the calculated ratios differ among flow rates Fa, Fb and Fc, that is, when the ratio of each flow rate deviates from one third, control device **30** determines that a partial abnormality of the cooling system has occurred. At this time, control device **30** determines that an abnormality has occurred in a branch having a smaller ratio of flow rate than the other branches.

[0068] When it is determined in step S**03** that a partial abnormality of the cooling system has occurred, control device **30** in step S**04** diagnoses the cause of the partial abnormality based on the condition of the cooling system when the partial abnormality has occurred. Then, control device **30** executes control for removing the diagnosed cause (hereinafter referred to as "cause-of-abnormality removal control"). When the partial abnormality is not solved by execution of the cause-of-abnormality removal control, control device **30** in step S**05** finalizes the abnormality of the cooling system.

[0069] When the abnormality of the cooling system is finalized, control device **30** causes a warning to be displayed on a display device, a warning lamp or the like.

[0070] FIG. **5** is a flowchart for achieving the cause-of-abnormality removal control shown in step S**04** of FIG. **4**. It is noted that the processing in steps S**01** and S**02** of FIG. **5** is the same as the processing in steps S**01** and S**02** of FIG. **4**. The processing in steps S**031**, S**032** and S**033** of FIG. **5** corresponds to the processing in step S**03** of FIG. **4**.

[0071] Referring to FIG. **5**, control device **30** in step S**01** reads flow rates Fa, Fb and Fc of branches B**1** to B3 detected by flow sensors **131** to **133** (FIG. **3**), respectively, and in step S**02** monitors rotation speed (W/P speed) NW of water pump **104**. Control device **30** in step S**031** determines whether or not an imbalance among flow rates Fa, Fb and Fc has occurred based on the result of comparison among the ratios of respective flow rates Fa, Fb and Fc relative to flow rate Ft of flow channel **116**. When an imbalance among flow rates Fa, Fb and Fc has not occurred (when determined NO in step S**031**), control device **30** in step S**033** determines the cooling system as being normal.

[0072] On the other hand, when an imbalance among flow rates Fa, Fb and Fc has occurred (when determined YES in step S**031**), control device **30** in step S**032** determines that a partial abnormality of the cooling system has occurred. Control device **30** determines that the partial abnormality has occurred in a branch of plurality of branches B**1** to B**3** that has a smaller ratio of flow rate relative to flow rate Ft. When it is determined in step S**032** that a partial abnormality of the cooling system has occurred, control device **30** performs processing in steps S**041** to S**050**, thereby diagnosing the cause of the partial abnormality and executing the cause-of-abnormality removal control for the cooling system.

[0073] More specifically, first, control device **30** in step S**041** determines whether or not W/P speed NW has increased based on monitored W/P speed NW. When W/P speed NW has increased (when determined YES in step S**041**), control device **30** in step S**045** diagnoses that air may have entered the branch determined as being abnormal. Air entering a branch means that a mass of air exists in that branch.

[0074] When air has entered the flow channel, the load imposed on water pump **104** becomes smaller than in the case where air has not entered. The real speed of water pump **104** thus becomes higher than a control speed specified by signal SP. When the state that W/P speed NW is higher than the control speed is continued for a predetermined time or longer, control device **30** diagnoses that air may have entered the branch.

[0075] When it is diagnosed in step S**045** that air may have entered the branch, control device **30** in step S**044** temporarily increases the output of water pump **104**. For example, control device **30** drives water pump **104** at the maximum speed for a certain time period. When the discharge flow rate of water pump **104** increases by the increase in the speed of water pump **104**, air existing in the branch is forced to flow into reservoir tank **106** together with cooling water. In reservoir tank **106**, air is isolated from the cooling water, and is discharged to the atmosphere. Air existing in the branch can thereby be removed.

[0076] In contrast, when W/P speed NW has not increased in step S**041** (when determined NO in step S**041**), control device **30** in step S**042** determines whether or not cooling water temperature TW detected by temperature sensor **108** is less than or equal to a predetermined threshold value. The predetermined threshold value is set at a temperature at which the cooling water in the flow channel becomes frozen, for example. It is noted that a determination may be made based on a detection value of a temperature sensor for detecting the outside air temperature, instead of cooling water temperature TW detected by temperature sensor **108**.

[0077] When cooling water temperature TW is less than or equal to the predetermined threshold value (when determined YES in step S**042**), control device **30** then in step S**046** determines whether or not flow rate Ft of cooling water flowing through flow channel **116** is normal. Control device **30** calculates, as flow rate Ft, the total value of flow rates Fa, Fb and Fc detected by flow sensors **131** to **133**, respectively. When flow rate Ft falls within a flow rate control range in accordance with the control speed of water pump **104**, control device **30** determines flow rate Ft as being normal.

[0078] When flow rate Ft is determined in step S**046** as being normal (when determined YES in step S**046**), control device **30** in step S**047** diagnoses that branches B**1** to B**3** shown in FIG. **3** may be partly frozen because the cooling water temperature is low. Control device **30** presumes that a branch of plurality of branches B**1** to B**3** that has a smaller ratio of flow rate relative to the total flow rate than the other branches is frozen. Then, control device **30** in step S**048** forces an element section corresponding to that branch presumed to be frozen to generate heat. More specifically, control device **30** outputs a control signal for bringing about the conducting state for a short time, to a power control element included in the element section corresponding to that branch. It is noted that, since this control signal is intended to cause a power control element to generate heat, it is not to produce torque for driving the vehicle like control signals PWMI and PMWC. By the self-heating of the power control element for a short time, the branch can be defreezed.

[0079] In contrast, when flow rate Ft is determined in step S**046** as not being normal (when determined NO in step S**046**), control device **30** in step S**049** diagnoses that flow channel **116** including plurality of branches B**1** to B**3** may be frozen. In this case, control device **30** in step S**050** forces all element sections **1** to **3** to generate heat. More specifically, control device **30** outputs a control signal for bringing about the conducting state for a short time to power control elements included in element sections **1** to **3**. By the self-heating of all the power control elements mounted on power element substrate **400** for a short time, the flow channel can be defreezed.

[0080] Returning to step S**042**, when cooling water temperature TW is not less than or equal to the predetermined threshold value (when determined NO in step S**042**), control device **30** diagnoses that a foreign substance or air may have entered part of plurality of branches B**1** to B**3**. Control device **30** presumes that a foreign substance or air has entered a branch of plurality of branches B**1** to B**3** that has a smaller ratio of flow rate relative to the total flow rate. It is noted that entrance of air into a branch in step S**043** means that a mass of air exists in that branch similarly to step S**045**. However, step S**043** is different in that a case is presumed in which the flow area of that branch is smaller because of the presence of numerous masses of air of smaller size in the branch than in step S**045**.

[0081] When it is diagnosed in step S**041** that a foreign substance or air may have entered the branch, control device **30** in step S**044** temporarily increases the output of water pump **104**. By increasing the discharge flow rate of water pump **104** as described above, the foreign substance or air existing in the branch can be removed.

[0082] As described above, when the cause of the partial abnormality of the cooling system is diagnosed based on the speed of water pump **104** and the cooling water temperature, the cause-of-abnormality removal control is executed in an optimum control mode for removing the diagnosed cause. Then, control device **30** in step S**051** determines whether or not the imbalance among flow rates Fa, Fb and Fc has been solved. When the imbalance among the flow rates has not been solved (when determined NO in step S**051**), control device **30** in step S**05** finalizes the abnormality of the cooling system.

[0083] On the other hand, when the imbalance among the flow rates has been solved by the above-described cause-of-abnormality removal control (when determined YES in step S**051**), control device **30** in step S**06** determines that the partial abnormality of the cooling system has been solved and the cooling system has been returned to the normal state.

[0084] As described above, the cooling system according to the present embodiment can detect the partial abnormality of the cooling system by determining whether or not an imbalance in flow rate of cooling water has occurred among the plurality of branches connected in parallel to the distribution direction of cooling water.

[0085] Here, as described above, when an imbalance in flow rate of cooling water has occurred among the plurality of branches, a problem may arise in that the element temperature becomes partly higher. Therefore, it can be configured such that an abnormality of the cooling system is determined based on detection values of temperature sensor **110** detecting temperature TC of voltage converter **12** and temperature sensor **112** detecting temperature TI of inverter **14** (see FIG. **1**). However, with the configuration in which an abnormality of the cooling system is determined based on the detection values of the temperature sensors, it cannot be identified if the temperature rise of power control elements results from: an increase in amount of heat generation of the power control element caused by a flow of overcurrent; a reduction in flow rate caused by entrance of air or a foreign substance into the flow channel; or a malfunction of water pump **104**. Therefore, in order to suppress the temperature rise of the power control elements, the load factor of motor-generator MG may be restricted, or water pump **104** may be replaced incorrectly although it is operable normally.

[0086] In this respect, the cooling system according to the present embodiment can detect a partial abnormality of the flow channel by determining whether or not an imbalance in flow rate among the plurality of branches has occurred. It is therefore possible to avoid such a problem that the load factor of motor-generator MG is restricted or unnecessary replacement of water pump **104** is performed.

[0087] Moreover, since the cause of the partial abnormality can be identified based on the speed of water pump **104** and cooling water temperature TW when the partial abnormality is detected, the partial abnormality can be solved by executing control for removing that cause.

[0088] Exemplary Modification

[0089] Although the cooling system according to the present embodiment is configured such that flow rates Fa, Fb and Fc in plurality of branches B**1** to B**3** are detected by the flow sensors provided for the branches, respectively, it may be configured such that flow rates Fa, Fb and Fc are presumed. As the method of presuming the flow rates, in the cooling system shown in FIG. **2**, for example, control device **30** can cause the power control elements in inverter **14** to temporarily generate heat for flow rate presumption under the situation where the condition that another driving instruction is not issued to PCU **40** is satisfied, and can presume the flow rates based on the degree by which the power control elements are cooled thereafter. This allows the flow rates to be detected accurately without providing a flow sensor for each branch.

[0090] Diagnostic processing for the cooling system according to an exemplary modification of the embodiment of the present invention will be described below with reference to the drawings.

[0091] FIG. **6** is a waveform diagram for illustrating diagnostic timing of the cooling system according to the present exemplary modification.

[0092] Referring to FIGS. **1** and **6**, when a starting instruction is given by a driver with a start button of the vehicle or the like, the vehicle completes self-check of ECU, for example, to assume a ReadyON state. Thereafter, in the state where the vehicle is set at a parking range and is stopped from time t**1** to t**2**, control device **30** outputs a torque command to inverter **14** for a short time. This torque command is smaller than a torque command during running at and after time t**3**. Therefore, when the vehicle is set at the parking range and the accelerator pedal is not depressed, torque that causes the vehicle to start to move is not produced.

[0093] It is noted that since this torque command for a short time is to cause the power control elements of the inverter to generate heat, it may not produce torque. For example, it may control inverter **14** to flow only a d-axis current of the inverter and not to flow a q-axis current so as not to produce torque.

[0094] When a diagnosis of the operating condition of water pump **104** is completed by time t**3** and it is confirmed that the operating condition is normal, a torque command is issued in response to an instruction of acceleration/deceleration from the accelerator pedal or the like as shown at time t**3** to t**4**, so that a transition is made to the state where the vehicle can run. It is noted that the point of time t**3** may be defined as the ReadyON state.

[0095] FIG. **7** is a flowchart for illustrating control of diagnostic timing of the cooling system shown in FIG. **6**. When a start switch that activates the vehicular system is set at the ON state, the processing of this flowchart is invoked from a main routine and executed.

[0096] Referring to FIGS. **6** and **7**, the presence/absence of a charging/discharging operation from battery B using inverter **14** is determined in step S**10**. In the absence of a charging/discharging operation, the processing advances to step S**20**, where a diagnosis of the cooling system is performed. An environment with less noise suitable for diagnosing cooling system **104** is thereby ensured. In the presence of a charging/discharging operation in step S**10**, for example, in the case where the accelerator pedal is depressed immediately, control is returned to the main routine in step S**60** for waiting for a next opportunity without diagnosing the cooling system.

[0097] It is noted that, in order to give priority to a diagnosis of the cooling system, it may be configured such that the shift position after the start switch may be prohibited from moving from the parking position or input of the accelerator pedal is not accepted until a diagnosis of the cooling system is completed.

[0098] In step S**20**, the power control elements of inverter **14** are caused to generate heat for a short time, and flow rate Ft of flow channel **116** and flow rates Fa, Fb and Fc of branches B**1** to B**3** are detected based on the degree by which the power control elements are cooled thereafter. It can be diagnosed whether an imbalance among the flow rates has occurred based on detected flow rates Fa, Fc and Fc.

[0099] It is determined in step S**30** whether or not the cooling system is normal. The processing in step S**30** is executed in accordance with the flowcharts of FIGS. **4** and **5**. When the cooling system is determined as being normal, the processing advances to step S**40**, where the charging/discharging operation from battery B using inverter **14** is permitted. The vehicle is thereby allowed to run. It is noted that the detected amount of cooling water may be fed back for use in pump control. On the other hand, when the cooling system is determined in step S**30** as not being normal, that is, when an abnormality of the cooling system is finalized, an alarm display is made on the display device, the warning lamp or the like.

[0100] When the processing in step S**40** or S**50** terminates, the control is transferred to the main routine in step S**60**.

[0101] FIG. **8** is a flowchart for illustrating flow-rate detection processing for use in diagnosing the cooling system in step S**20** of FIG. **7**. The processing of this flowchart is invoked from the processing of the flowchart of FIG. **7** which is the main routine, and executed. Moreover, the processing of this flowchart is executed in parallel for flow channel **116** and branches B**1** to B**3**.

[0102] Referring to FIG. **8**, the processing of this flowchart is started based on an operation instructing the vehicular system activation or the vehicular system termination. First, control device **30** in step S**21** determines whether or not the condition that the shift range is set at the P (parking) range and the accelerator pedal is not being operated (OFF state) is met. While this condition is not met, the processing advances to step S**37**, and the control is transferred to the main routine. It is noted that, since some hybrid vehicles apply electric power to the inverter of the motor for starting the engine when the amount of power stored in a battery has been lowered, the condition that the amount of power stored in the battery has not been lowered may be added.

[0103] When the condition in step S**21** is met, the processing advances to step S**22**, where water temperature Tw at that time is stored as a value Tw**0**, and an inverter element temperature Ti is stored as a value Ti**0**.

[0104] Then, in step S**23**, a command torque is determined from a water temperature-command torque map.

[0105] FIG. **9** is a diagram showing an example of the water temperature-command torque map referred to in step S**23** of

FIG. 8. In the example of map shown in FIG. 9, the command torque is set to decrease as the water temperature rises.

[0106] Referring again to FIG. 8, in step S24 following step S23, control device 30 gives a command torque determined based on the water temperature to inverter 14 (torque ON). In step S25, the command torque is returned to zero (torque OFF). From the foregoing, the power control elements in the inverter generate heat for a short time as shown at time t1 to time t2 in FIG. 3.

[0107] In step S25, control device 30 returns the command torque to zero, and simultaneously stores the temperature of the power control elements in the inverter at that time as a peak temperature Ti1 and stores the time at that time as t1.

[0108] FIG. 10 is a diagram for illustrating measurements of temperature drop rate. Referring to FIGS. 8 and 10, the temperature of the power control elements in the inverter starts to rise at time t0 in response to having set the torque command to the inverter at the ON state. The element temperature keeps rising until the torque command to the inverter is set at the OFF state. At time t1 corresponding to having set the torque command to the inverter at the OFF state, the element temperature takes peak value Ti1. This peak value Ti1 and time t1 at that time are recorded on an internal memory of control device 30 or the like during the processing in step S25.

[0109] Then, in step S26, a difference value ΔTi01 between peak temperature Ti1 and current inverter element temperature Ti0 is calculated based on an expression (1) below.

$$\Delta Ti01 = Ti1 - Ti0 \tag{1}$$

[0110] Then, in step S27, a specified number of times m is set, and further, a counter is initialized. The counter value n is set at "2".

[0111] The processing from step S28 to step S34 is repeatedly performed based on counter value n.

[0112] First, control device 30 in step S28 determines a calculation temperature at which the temperature drop rate of the power control elements of the inverter is calculated. Representing the difference in calculation temperature at which the temperature drop rate of the power control elements of the inverter corresponding to counter value n is calculated by ΔTi1n, an expression (2) below holds.

$$\Delta Ti1n = \Delta Ti01 * (n-1)/n \tag{2}$$

[0113] For example, when n=2, ΔTi12=ΔTi01*½ holds, so that a first measurement shall be performed when the temperature difference is reduced to half. When n=3, a measurement shall be performed when the temperature difference is reduced to one third.

[0114] Then, it is determined in step S29 whether or not the current temperature has dropped to temperature Tin expressed by an expression (3) below.

$$Tin = Ti1 - \Delta Ti1n \tag{3}$$

[0115] In step S29, when temperature differences ATi12, ATi13 and ATi14 calculated in step S28 drop from peak value Ti1, times t2, t3 and t4 are measured, respectively. Times t2 and t3 can be, for example, times at which the temperature differences become ½ and ⅓ of ATi01, respectively. Although not shown in the flowchart of FIG. 8, a time at which the temperature becomes slightly higher than initial temperature TiO (e.g., +2° C.) like time t4 of FIG. 10 can also be a point of measurement.

[0116] Based on a measured time to and stored time t1, time difference Δt1n from time t1 is calculated in step S30. As shown in FIG. 10, time differences Δt12, Δt13 and Δt14 corresponding to temperature differences ATi12, ATi13 and ATi14, respectively, are calculated. The calculated values are recorded on the internal memory of control device 30, for example.

[0117] Next, in step S31, the flow rate is calculated from temperature difference ΔTin, time difference Δtin and the drop rate-flow rate map.

[0118] FIG. 11 is a diagram showing an example of drop rate-flow rate map. Since the drop rate-flow rate map of FIG. 11 differs among vehicular cooling systems, values experimentally calculated beforehand are used. It is noted that the vehicle itself may acquire data when the water pump is normal immediately after the shipment from the factory and/or an inspection, and this data may be set as a reference value. A calculated flow rate Qn is stored in step S31.

[0119] Then, it is determined in step S32 again whether or not the condition in step S21 is continued. This condition is that the shift range is set at the P (parking) range and the accelerator pedal is not being operated (OFF state)

[0120] When this condition is no longer met, the processing advances to step S35, where the flow rate is calculated based on results of measurements having been obtained so far. On the other hand, when this condition is still met, the processing advances to step S33, where acquisition of measured data is performed for further improving the accuracy of detected flow rate.

[0121] In step S33, counter value n of the counter set in step S27 is incremented by 1. Then, it is determined in step S24 whether or not the counter value is smaller than measured number of times m set in step S27. When n<m holds, the processing of and after step S28 is repeated again, and acquisition of a data pair of time difference Atln and temperature difference ΔTin is continued.

[0122] When n is equal to m in step S34 and measurements by specified number of measurement times m are completed, the processing advances to step S35.

[0123] In step S35, an average value Qout of flow rates Qj (j=2, . . . m) for the measured number of times is calculated. Then, it is determined in step S36 whether or not the cooling system is normal by execution of the processing in the flowcharts of FIGS. 4 and 5 based on the flow rates detected for flow channel 116 and branches B1 to B3, respectively. In step S37 following step S36, the control is transferred to the flowchart of FIG. 7 which is the main routine.

[0124] According to the present exemplary modification, a correct flow rate of coolant medium can be detected, which enables an abnormality of the cooling system to be determined correctly. More specifically, by detecting the drop rate of the inverter element temperature, the amount of cooling water is known from the map showing the relationship between "the drop rate and the flow rate", without adding a new flow sensor.

[0125] Moreover, by performing a pump diagnosis before the start or after the end of running, or in the case of a hybrid vehicle, at the time of engine stop and vehicle stop, a disturbance that would cause the inverter element temperature to rise is removed, which enables correct flow rate detection.

[0126] Furthermore, by changing the magnitude of inverter command torque based on the cooling water temperature, the inverter elements can be warmed as a heat source while avoiding damage to the inverter elements.

[0127] In addition, by measuring the drop rate several times, the flow rate of cooling water can be calculated accurately from the map showing the relationship between "the drop rate and the flow rate." In this case, even when running is started or the engine is started (some hybrid vehicles use the inverter of the motor for starting the engine) before measurements are made by the specified number of times, the amount of cooling water can be calculated from the drop rate having been measured so far.

[0128] It is noted that although the present embodiment has illustrated the electric vehicle as an example of a vehicle equipped with the cooling system, application of the present invention is not limited to such an example. That is, the present invention is also applicable to any hybrid vehicle with an internal combustion engine used in combination or any fuel-cell vehicle that is equipped with the cooling system.

[0129] It should be understood that the embodiments disclosed herein are illustrative and non-restrictive in every respect. The scope of the present invention is defined by the claims not by the description above, and is intended to include any modification within the meaning and scope equivalent to the terms of the claims.

INDUSTRIAL APPLICABILITY

[0130] The present invention is applicable to a vehicle equipped with a cooling system.

REFERENCE SIGNS LIST

[0131] **10** voltage sensor; **12** voltage converter; **13** voltage sensor; **14** inverter; **15** U-phase arm; **16** V-phase arm; **17** W-phase arm; **24** current sensor; **30** control device; **100** vehicle; **102** radiator; **104** water pump; **106** reservoir tank; **108**, **110**, **112** temperature sensor; **111** accelerator sensor; **113** shift position sensor; **114** speed sensor; **116**, **122** flow channel; **120** cooling water inlet; **124** cooling water outlet; **131** to **133** flow sensor; **400** power element substrate; B battery; B**1** to B**3** branch; C**0**, C**1** smoothing capacitor; D**1** to D**8** diode; L**1** reactor; MG motor-generator; Q**1** to Q**8** IGBT element; SMRB, SMRG system main relay.

1. A cooling system for cooling a heat source, comprising:
- a flow channel through which liquid medium cooling said heat source is circulated; and
- a pump provided on said flow channel for circulating said liquid medium,
- said flow channel including a plurality of branches arranged between an upstream side and a downstream side of said heat source in parallel to a distribution direction of said liquid medium,
- said cooling system further comprising a control device for detecting an abnormality occurred in any of said plurality of branches by detecting an imbalance among flow rates of said liquid medium flowing through said plurality of branches, respectively, and for diagnosing a cause of occurrence of said abnormality based on the state of said cooling system when the imbalance among the flow rates of said liquid medium is detected.

2. The cooling system according to claim **1**, wherein said control device diagnoses a cause of occurrence of said abnormality at least based on the speed of said pump when the imbalance among the flow rates of said liquid medium is detected.

3. The cooling system according to claim **2**, further comprising a speed sensor for detecting the speed of said pump, wherein
- in the case where the imbalance among the flow rates of said liquid medium is detected, said control device diagnoses that air has entered said flow channel when a first condition that a detection value of said speed sensor obtained when said pump is driven is higher than a control target value is met.

4. The cooling system according to claim **3**, further comprising a temperature sensor for detecting the temperature of said liquid medium, wherein
- in the case where said first condition is not met, said control device determines whether or not a second condition that a detection value of said temperature sensor is lower than a predetermined threshold value is met, and when said second condition is met, said control device diagnoses that said flow channel is frozen.

5. The cooling system according to claim **4**, wherein in the case where said second condition is met, said control device determines whether or not a flow rate of said flow channel falls within a control range, and when a third condition that the flow rate of said flow channel falls within said control range is met, said control device diagnoses that any of said plurality of branches is frozen.

6. The cooling system according to claim **3**, wherein in the case where said first condition is not met, said control device diagnoses that a foreign substance has entered any of said plurality of branches when said second condition is not met.

7. The cooling system according to claim **3**, wherein in the case where it is diagnosed that one of air and a foreign substance has entered any of said plurality of branches, said control device temporarily increases the speed of said pump.

8. The cooling system according to claim **5**, wherein in the case where it is diagnosed that any of said plurality of branches is frozen, said control device temporarily increases the amount of heat generation of a heat source corresponding to a branch diagnosed as frozen.

9. The cooling system according to claim **1**, wherein
- said heat source is a driving device having a motor and an inverter driving said motor,
- said cooling system further comprising an element temperature sensor detecting the temperature of a power control element in said inverter, wherein
- under a situation where a condition that another driving instruction is not issued to said inverter is satisfied, said control device temporarily causes the power control element in said inverter to generate heat and then reduces heat generation of said power control element to presume the flow rates of said plurality of branches depending on the degree of drop of a detection value of said element temperature sensor, and detects an imbalance among the flow rates of said liquid medium based on presumed values of the flow rates of said plurality of branches.

10. The cooling system according to claim **1**, wherein said plurality of branches are configured to have an equal flow rate.

11. A vehicle comprising:
- a driving device using a motor (MG) as a drive source; and
- a cooling system for cooling said driving device,
- said cooling system including
  - a flow channel through which liquid medium cooling said driving device is circulated, and
  - a pump provided on said flow channel for circulating said liquid medium,

said flow channel including a plurality of branches arranged between an upstream side and a downstream side of said heat source in parallel to a distribution direction of said liquid medium and configured to have an equal flow channel area,

said vehicle further comprising a control device for detecting an abnormality occurred in system any of said plurality of branches by detecting an imbalance among flow rates of said liquid medium flowing through said plurality of branches, respectively, and for diagnosing a cause of occurrence of said abnormality based on the state of said cooling system when the imbalance among the flow rates of said liquid medium is detected.

* * * * *