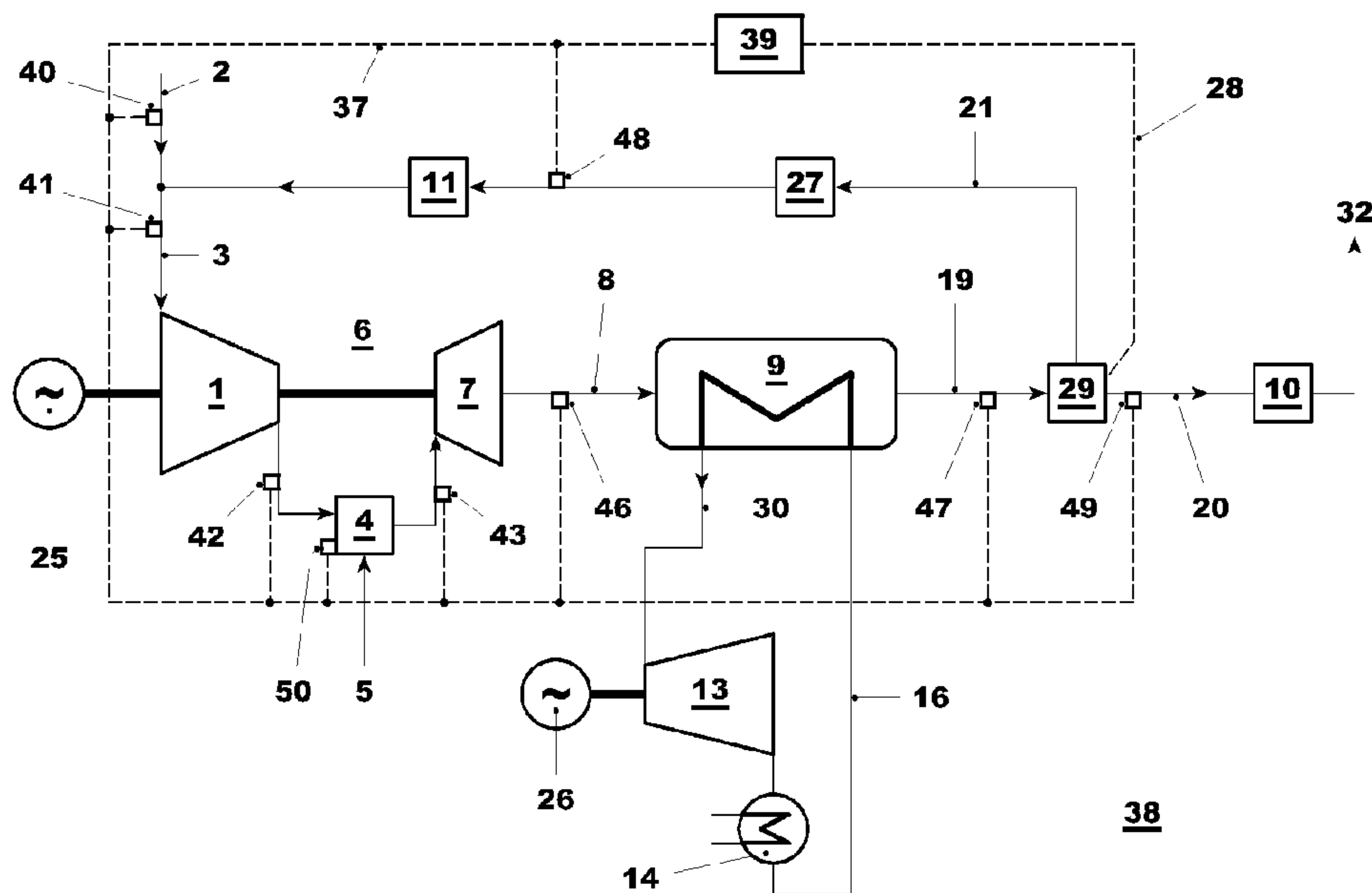




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(54) **Titre : REGULATION DE LA COMPOSITION DU GAZ DANS UNE CENTRALE ELECTRIQUE A TURBINE A GAZ AVEC  
 RECIRCULATION D'EFFLUENTS GAZEUX**  
 (54) **Title: CONTROL OF THE GAS COMPOSITION IN A GAS TURBINE POWER PLANT WITH FLUE GAS RECIRCULATION**



(57) **Abrégé/Abstract:**

The invention relates to a method for operating a gas turbine power plant (38) with exhaust gas recirculation. In the method a setpoint concentration of one component ( $C_c$ ) of the inlet gas (3) and/or of the hot working gas and/or of the exhaust gas of the gas turbine (8, 19, 20, 21, 24) is determined in a first step, in accordance with the operating conditions of the gas turbine (6), from a combination of a setpoint value of a control loop, a feedforward control signal and a correction value. In a second step, the position of a control element (11, 29) is adjusted in accordance with the setpoint/actual deviation in the concentration of the component. The invention furthermore relates to a gas turbine power plant for carrying out the method.

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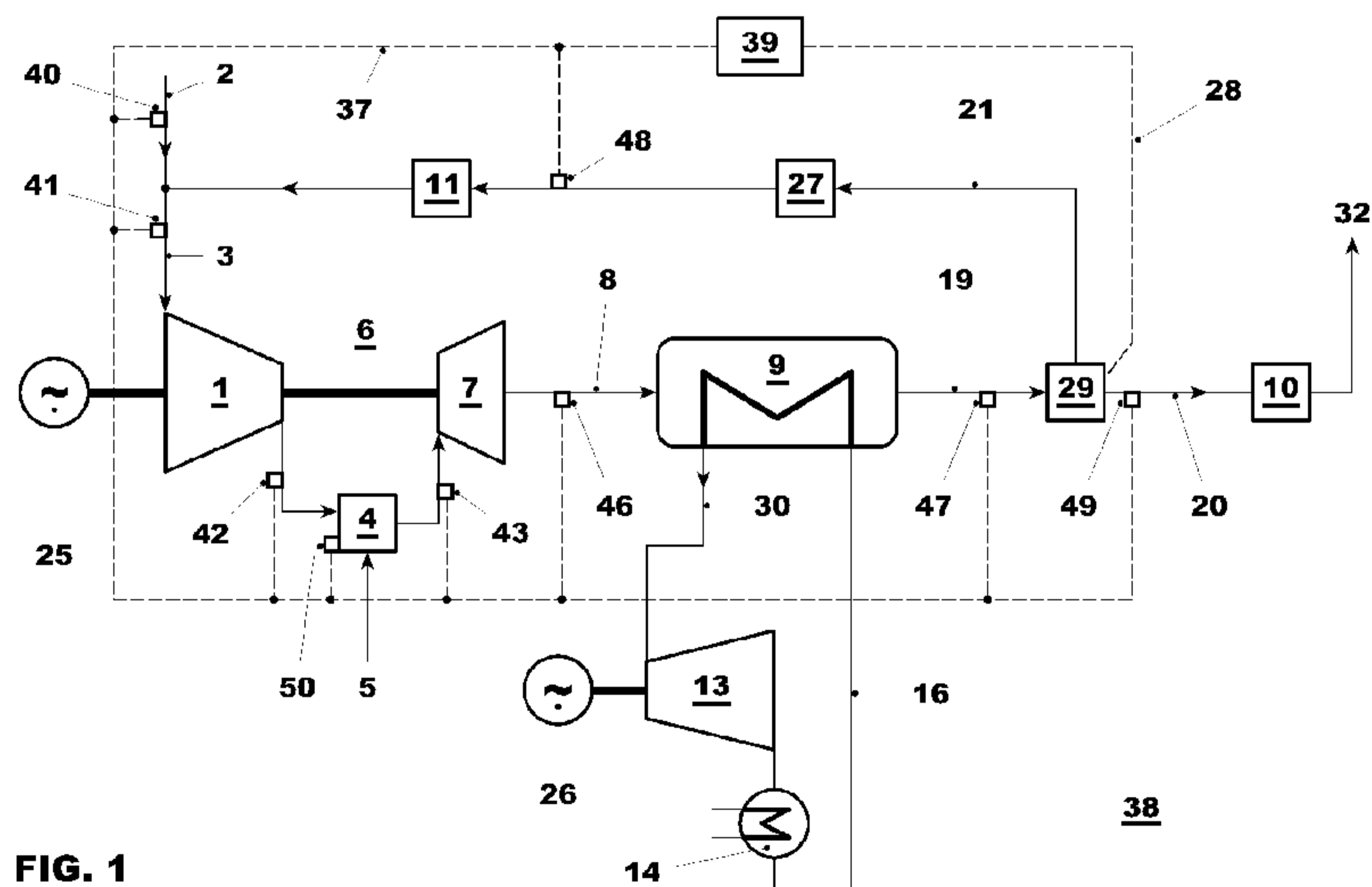


FIG. 1

(57) Abstract: The invention relates to a method for operating a gas turbine power plant (38) with exhaust gas recirculation. In the method a setpoint concentration of one component ( $C_c$ ) of the inlet gas (3) and/or of the hot working gas and/or of the exhaust gas of the gas turbine (8, 19, 20, 21, 24) is determined in a first step, in accordance with the operating conditions of the gas turbine (6), from a combination of a setpoint value of a control loop, a feedforward control signal and a correction value. In a second step, the position of a control element (11, 29) is adjusted in accordance with the setpoint/actual deviation in the concentration of the component. The invention furthermore relates to a gas turbine power plant for carrying out the method.

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## TITLE

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CONTROL OF THE GAS COMPOSITION IN A GAS TURBINE POWER PLANT WITH FLUE GAS RECIRCULATION

## TECHNICAL FIELD

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The present invention relates to a method for operating a gas turbine power plant with exhaust gas recirculation and to a gas turbine power plant for carrying out the method.

## PRIOR ART

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Recirculation of exhaust gases is a technology which can fundamentally be employed for a very wide range of applications in gas turbines. Thus, for example, exhaust gas recirculation is proposed for reducing NO<sub>x</sub> emissions (nitrogen oxide emissions) or for reducing the exhaust gas flow that has to be discharged. In the recirculation of exhaust gases of a gas turbine, a significant proportion of the exhaust gas is diverted from the overall exhaust gas flow and, typically after cooling and cleaning, is fed to the inlet mass flow of the gas turbine or the compressor, the recirculated exhaust gas flow being mixed with fresh air, and this mixture then being fed to the compressor.

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By means of exhaust gas recirculation, it is advantageously possible to increase the carbon dioxide concentration in the exhaust gases and hence reduce the power losses and efficiency losses of power plants that have carbon dioxide removal.

35

Exhaust gas recirculation has also been proposed with the aim of reducing the oxygen concentration in the intake gases of gas turbines in order thereby to reduce NO<sub>x</sub>

emissions.

A method for controlling an exhaust gas recirculation flow of a turbomachine, which is recirculated to the inlet of the turbomachine via an exhaust gas recirculation system, is described in US 7536252 B1, for example. In this method, the concentration of one component of an exhaust gas flow is adjusted by changing the exhaust gas recirculation ratio. Here, the exhaust gas recirculation ratio is defined as the ratio of the recirculated exhaust gas flow to the inlet flow of the turbomachine.

Because of the large volume of exhaust gas lines, waste heat boilers, recirculation lines and fittings in the exhaust gas system, a simple feedback control system is slow and inaccurate.

15

## DESCRIPTION OF THE INVENTION

It is an object of the present disclosure to indicate a method for reliable operation of a gas turbine power plant with exhaust gas recirculation in which the content of at least one component of the operating medium is controlled. The disclosure furthermore relates to a gas turbine power plant which is suitable for carrying out the method.

A gas turbine power plant with exhaust gas recirculation comprises a gas turbine, a heat recovery steam generator and an exhaust gas divider, which divides the exhaust gases of the gas turbine power plant into a first exhaust gas flow for recirculation into the intake flow of the gas turbine and into a second exhaust gas flow for release to the environment, and an exhaust gas re-cooler. The gas turbine itself comprises a compressor, typically with adjustable compressor guide vanes, one or more combustion chamber(s) and one or more turbine(s). The exhaust gas divider is designed as a control element for controlling the first exhaust gas flow, or a control element is provided in a recirculation line through which the recirculated exhaust gases are fed to the compressor of the gas turbine. The control element for controlling the recirculation flow can be a flap or a valve, for example. However, it can also be an adjustable blower, for example.

According to one embodiment of the method for operating a gas turbine power plant with exhaust gas recirculation, a setpoint concentration of one component of the inlet gas

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and/or of the exhaust gas of the gas turbine is determined in a first step in accordance with the operating conditions of the gas turbine. In a second step, the position of the control element is adjusted in accordance with the setpoint/actual deviation in the concentration of the component. Here, the setpoint concentration of the one component is determined from the setpoint value of a closed control loop for a relevant operating variable of the combustion process in the combustion chamber of the gas turbine, a feedforward control value of the setpoint concentration and a correction value of the setpoint concentration.

In one particular embodiment, there is provided a method for operating a gas turbine power plant with exhaust gas recirculation, which comprises a gas turbine, a controller, a heat recovery steam generator and an exhaust gas divider, which divides the exhaust gases of the gas turbine power plant into a first partial exhaust gas flow for recirculation into an intake flow of the gas turbine and into a second partial exhaust gas flow for release to the environment, and a control element for controlling the first exhaust gas flow, and an exhaust gas re-cooler, wherein a setpoint concentration of one component of the inlet gas and/or of the exhaust gas of the gas turbine is determined in a first step in accordance with the operating conditions of the gas turbine, the position of the control element is adjusted in a second step in accordance with the setpoint/actual deviation in the concentration of the component, wherein the setpoint concentration of the one component is determined from the setpoint value of the concentration of one gas component from a control loop for an operating variable relevant to combustion in the gas turbine, a feedforward control value of the setpoint concentration of the gas component and a correction value of the setpoint concentration of the gas component.

"Inlet gas" is intended to mean the gas used in the gas turbine process before combustion. In practice, for example, the compressor inlet gas can be used as the inlet gas, and control can be exercised by means of the gas composition thereof. If

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## 3a

no fluid, e.g. water for intercooling and power boosting, is introduced in the compressor, the gas composition in the compressor does not change. If a fluid is fed in, the change in the gas composition can be determined by way of a mass balance. As an alternative to the compressor inlet gas, a concentration of one component of a cooling air flow discharged from the compressor or the compressor outlet flow can be used, for example.

"Outlet gas" is intended to mean the gas used in the gas turbine process after combustion. In practice, for example, the exhaust gas can be used as the outlet gas, and control can be exercised by means of the gas composition thereof. If no fluid, e.g. a leakage flow from a desuperheater or cooling air diverted past the combustion process, is introduced in the turbine, there is no change in the gas composition in the turbine. If a fluid is fed in, a change in the gas composition can be determined by way of a mass balance, if necessary. As an alternative to the exhaust gas, a concentration of one component of the hot gases at the combustion chamber outlet can be used, for example.

The concentration of the one component of the inlet gas and/or of the outlet gas of the gas turbine is controlled in order to keep at least one operating variable relevant to combustion in a target range, e.g. a permissible or optimum range. In one embodiment, the setpoint concentration of the one component of the inlet gas and/or of the outlet gas of the gas turbine is determined in the closed control loop in accordance with the gas turbine load control, the combustion chamber pulsations, the NO<sub>x</sub> emissions, the unburned hydrocarbons (UHC), the measured concentration of the one component in the inlet gas

and/or in the outlet gas of the gas turbine, or the ratio of carbon to hydrogen in the fuel. In this case, the one component is oxygen or carbon dioxide, for example.

5 In addition to direct control by means of a flap, a valve or an adjustable blower in the recirculation lines or ducts, the recirculation flow can also be controlled indirectly. For example, a control element, that is to say, for example, a valve, a flap or a blower, by means of which the pressure at the exhaust gas divider is influenced, can be provided in an exhaust gas line downstream of the exhaust gas divider. The recirculated exhaust gas flow increases with the pressure at the exhaust gas divider and can be controlled  
10 indirectly by means of the latter.

The concentration of the one component of the inlet gas or of the outlet gas of the gas turbine can be controlled by means of a closed control loop. Owing to the large volumes and dead times of the intake lines, of the exhaust gas lines, of the recirculation lines and  
15 of the waste heat boiler, however, this feedback control is slow, relatively inaccurate and requires large safety margins.

The aim of controlling the concentration of one component is typically to make this concentration approximate as accurately as possible to a setpoint value at which the  
20 process runs in a particularly advantageous manner.

In the case of recirculation of exhaust gases for NO<sub>x</sub> reduction, for example, the oxygen concentration in the inlet gases or the residual oxygen concentration of the outlet gases should be controlled as accurately as possible. On the one hand, an excessive oxygen  
25 concentration means that the positive effect of recirculation falls, i.e. the high oxygen concentration allows locally intense combustion and leads to temperature peaks and hence to increasing NO<sub>x</sub> emissions from the gas turbine. On the other hand, there is the risk, in the case of an excessively low oxygen concentration, of incomplete combustion, which leads to high CO emissions (carbon monoxide) and UHC emissions (unburned  
30 hydrocarbons).

In the case of recirculation of exhaust gases in a process with CO<sub>2</sub> removal (carbon dioxide) from the exhaust gases, there is a need, on the one hand, to keep the CO<sub>2</sub>

concentration in the exhaust gases as high as possible in order to allow an effective removal process. On the other hand, the oxygen concentration in the intake gases falls with an increasing CO<sub>2</sub> concentration, and this can lead, in turn, to incomplete combustion.

5

For a good process, it is therefore advantageous to follow the setpoint variable as quickly and accurately as possible. To this end and depending on the operating conditions of the gas turbine and on transient changes in the operating conditions of the gas turbine, a control loop in which a setpoint variable is formed is supplemented by formation of a feedforward control value of the setpoint variable. The feedforward control values are the result of calculations, simulations or tests and have been determined for specific operating conditions or transient changes. In practice, however, the behavior of the system deviates from models or idealized calculations, and therefore the feedforward control typically does not lead directly to optimum results. In order to adapt the feedback control to the actual results in the system and to adapt the behavior thereof, a third value, a correction value of the setpoint variable, is also determined.

20

The setpoint concentration of the component is determined from all three values, i.e. the setpoint concentration of the control loop, the setpoint concentration of the feedforward control and the correction value of the setpoint concentration.

25

Typically, the setpoint concentration is simply the sum of the setpoint concentration of the control loop, the setpoint concentration of the feedforward control and the correction value of the setpoint concentration.

However, the setpoint concentration can also be determined as an average or as weighted averages, for example.

30

In another embodiment of the method, the setpoint value of the control element is determined from a setpoint value of a closed control loop for the control element, a feedforward control value of the setpoint value of the control element and a correction value of the setpoint value of the control element. The setpoint value of the control element can be a flap or valve position, for example. When using an adjustable blower, it

can be the rotational speed or the guide vane position of a blower of this kind.

In another embodiment of the method, the setpoint value of the control element is determined in the closed control loop in accordance with at least one of the following  
5 measured variables: the exhaust gas recirculation ratio, the intake mass flow of the compressor, the fresh air mass flow, the exhaust gas mass flow, the concentration of one component in the inlet gas and/or in the outlet gas of the gas turbine.

In one embodiment of the method, the feedforward control values and/or the correction  
10 values are stored for discrete values in one or more matrices, and interpolation is carried out between these values.

Moreover, a working characteristic for the feedforward control of the setpoint concentration can be predetermined. For adaptation to the actual system and the  
15 operating conditions thereof, this working characteristic can be adapted by a correction value of the setpoint concentration.

Accordingly, a working characteristic for the feedforward control of the setpoint concentration of the control element can be predetermined, and this working characteristic  
20 can be shifted by a correction value of the setpoint value.

In addition to simple shifting, another embodiment specifies that the slope of the working characteristic for the feedforward control of the setpoint concentration and/or of the setpoint value of the control element is adapted by means of a correction value of the  
25 setpoint concentration and/or a correction value of the setpoint value.

In yet another embodiment, the shape of the working characteristic for the feedforward control of the setpoint concentration and/or of the setpoint value of the control element is adapted by means of a correction value of the setpoint concentration and/or a correction  
30 value of the setpoint value.

In one embodiment of the method, which is used for controlling low-NO<sub>x</sub> combustion for

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example, the oxygen concentration of the inlet gas, of the outlet gas of the gas turbine or the oxygen concentration of the inlet gas and the oxygen concentration of the outlet gas of the gas turbine is used as a controlled variable.

In one embodiment of the method, which is used, for example, when operating with subsequent CO<sub>2</sub> removal, the CO<sub>2</sub> concentration of the inlet gas, of the outlet gas of the gas turbine or the CO<sub>2</sub> concentration of the inlet gas and the CO<sub>2</sub> concentration of the outlet gas of the gas turbine are used as a controlled variable.

Since the CO<sub>2</sub> concentration is approximately inversely proportional to the oxygen concentration, these can be used virtually interchangeably or in combination for control purposes.

According to another embodiment of the method, the exhaust gas flow is passed through a waste heat boiler, in which the usable heat thereof is removed.

According to one embodiment of the method, it is furthermore possible for the second exhaust gas flow, for release to the environment, to be fed to a carbon dioxide removal system. In this carbon dioxide removal system, carbon dioxide is separated from the exhaust gases and taken off for further use. Exhaust gas low in carbon dioxide is released to the environment.

In addition to the method, the subject matter of the disclosure includes a gas turbine power plant with exhaust gas recirculation, which comprises a gas turbine having at least one sensor for measuring the concentration of one component of the inlet gas and/or of the outlet gas (and/or of the hot working gas in an embodiment) of the gas turbine, a controller, a heat recovery steam generator and an exhaust gas divider, which divides the exhaust gases of the gas turbine power plant into a first exhaust gas flow for recirculation into an intake flow of the gas turbine and into a second exhaust gas flow for release to the environment, and a control element for controlling the first exhaust gas flow, and an exhaust gas re-cooler. The controller comprises three controller levels for determining a setpoint concentration of one component.

According to one embodiment, the controller levels are as follows:

1. a closed control loop for the setpoint concentration,
  2. a feedforward control for the setpoint concentration, and
  3. a feedback circuit, by means of which the setpoint values of the feedforward control are
- 5 corrected in accordance with the actual operating behavior of the gas turbine power plant.

In one embodiment of the gas turbine power plant, the controller of the gas turbine power plant comprises a block for determining a setpoint concentration and a subsequent block for determining the setpoint position of the control element. Here, the block for

10 determining the setpoint position of the control element is connected to the output signal of the block for determining the setpoint concentration. Furthermore, the gas turbine power plant comprises at least one measurement of an operating parameter of the gas turbine power plant. Moreover, the gas turbine power plant can comprise an online measurement of the fuel composition, and this measurement is connected to the

15 controller.

In another embodiment of the gas turbine power plant, the gas turbine power plant comprises a pulsation measurement in the combustion chamber(s), which is connected to the controller.

20

For good feedforward control, it is advantageous to store as comprehensive a matrix of operating states as possible in the controller, covering the entire operating range and possible transient changes. In particular, the target values for various ambient conditions, i.e. ambient temperatures, ambient pressure, relative atmospheric humidity, various load

25 points, i.e. idling, part load and full load, should be predetermined. The feedforward control is furthermore advantageously dependent on the compressor intake mass flow or on an adjustable inlet vane, on the hot gas temperature, the turbine inlet temperature or an equivalent temperature, on the outlet gas composition, the composition of the recirculated gases and the composition of the combustion gas.

30

For control of transient changes, the dependence on the load gradients, in particular, should be taken into account, i.e. values for a typically slow standard load gradient, for rapid load gradients, for emergency relief with a very high gradient, and for partial and

complete load shedding should be predetermined. Moreover, values for operation in the case of frequency support can be predetermined.

5 Since the controller compares the specified target with the actual behavior of the gas turbine and compensates for the difference by means of the correction values, it is possible to achieve rapid, accurate control with relatively inaccurate measurements, especially of the difficult-to-measure intake and exhaust gas flows.

10 Continuous comparison between the specified target and the actual behavior of the gas turbine furthermore allows compensation of aging effects, e.g. a decrease in the compressor intake flow due to soiling.

15 All the advantages explained can be employed not only in the respectively indicated combinations but also in other combinations or in isolation without exceeding the scope of the invention. For example, instead of recirculation of exhaust gases into the intake flow of the compressor, the plant can have a compressor for fresh air and a compressor for recirculated exhaust gases, and the fresh or recirculated gases can be fed to the process proper only after compression or partial compression.

20 Instead of measurement of the compressor inlet gases, measurement in the compressor or at the compressor outlet can furthermore be employed. The composition of the gas typically remains unchanged in the compressor as long as no substances, e.g. water for intercooling, are introduced into the compressor. If additional fluids are fed to the compressor in addition to the compressor inlet gas, the composition at the outlet can be approximated by means of a mass balance.

25 Various closed-loop controllers, such as two-position controllers, proportional controllers, integral or IP controllers, are known to those skilled in the art for implementing the control loops for the concentration of one component and for implementing the control element.

30

#### BRIEF DESCRIPTION OF THE DRAWINGS

Preferred embodiments of the invention are described below with reference to the drawings, which serve merely for illustration and are not to be interpreted as restrictive.

35 The drawings show, by way of example:

Fig. 1 a schematic representation of a gas turbine power plant with exhaust gas

recirculation;

Fig. 2 a schematic representation of a gas turbine power plant having a gas turbine with sequential combustion and exhaust gas recirculation;

Fig. 3 a schematic representation of a gas turbine power plant having a gas turbine with exhaust gas recirculation and a carbon dioxide removal system;

Fig. 4 an illustrative control loop in schematic form.

10

## DESCRIPTION OF THE PREFERRED EMBODIMENTS

Fig. 1 shows, in schematic form, the essential elements of a gas turbine power plant 38 according to the invention. The gas turbine 6 comprises a compressor 1, and the combustion air compressed therein is fed to a combustion chamber 4 and used there with fuel 5 for combustion. The hot combustion gases are then expanded in a turbine 7. The useful energy produced in the turbine 7 is then converted into electrical energy by means of a first generator 25 arranged on the same shaft, for example.

In order to make optimum use of the energy that still remains in the hot exhaust gases 8 emerging from the turbine 7, said exhaust gases are used in a heat recovery steam generator 9 (HRSG) to produce live steam 30 for a steam turbine 13 or for other systems. The useful energy produced in the steam turbine 13 is converted into electrical energy by means of a second generator 26 arranged on the same shaft, for example. In the example, the steam circuit is represented in simplified and merely schematic form with a condenser 14 and a feed water line 16. Various pressure stages, feed water pumps etc. are not shown since they are not part of the subject matter of the invention.

Downstream of the heat recovery steam generator 9, the exhaust gases from the heat recovery steam generator 9 are divided in an exhaust gas divider 29 into a first partial exhaust gas flow 21 and a second partial exhaust gas flow 20. The first partial exhaust gas flow 21 is recirculated into the intake line of the gas turbine 6 and mixed there with ambient air 2. The second partial exhaust gas flow 20, which is not recirculated, is released to the environment via a flue 32. In order to overcome the pressure losses of the exhaust gas line and as a further means of controlling the division of the exhaust gas flows, an exhaust gas blower 11 or an adjustable exhaust gas blower 11 can optionally be provided.

In operation with recirculation, the recirculated exhaust gas flow 21 is cooled to somewhat above (typically 5° C to 20° C above) ambient temperature in an exhaust gas re-cooler 27, which can be fitted with a condenser. The booster or the exhaust gas blower 11 for the recirculation flow 21 can be arranged downstream of this exhaust gas re-cooler 27. The recirculated exhaust gas flow 21 is mixed with the ambient air 2 before the mixture is fed to the gas turbine 6 as an intake flow via the compressor inlet 3.

In the example shown, the exhaust gas divider 29 is embodied as a control element, which makes it possible to control the recirculation mass flow or recirculation ratio. Data exchange on the setpoint and the actual position of the exhaust gas divider 29 with the controller 39 takes place via the signal line 28. With measurement 40, inlet conditions of the ambient air 2 drawn in, such as the temperature, pressure, humidity, mass flow, air composition and, in particular, the oxygen concentration or the carbon dioxide concentration, can be determined. With the measurement 41, inlet conditions of the inlet gases 3 to the compressor 1, such as the temperature, pressure, humidity, mass flow, gas composition and, in particular, the oxygen concentration or the carbon dioxide concentration, can be determined.

With measurements 42 and 43, inlet and outlet conditions of the combustion chamber 4, such as quantity, gas composition and, in particular, the oxygen concentration or the carbon dioxide concentration, can be determined.

With measurements 46 to 49, the exhaust gas conditions of the gas turbine 6 and the conditions in the various exhaust gas flows of the gas turbine, such as quantity, gas composition and, in particular, the oxygen concentration or the carbon dioxide concentration, can be determined.

Moreover, the combustion chamber pulsations can be determined with measurement 50.

30

The measured values are transmitted to the controller 39 via the signal line 37. For the sake of clarity, none of the other conventional signal lines, sensors and control elements are shown since they do not affect the essence of the invention. Depending on the embodiment of the method, however, they are necessary in order, for example, to verify or indirectly determine the measured values by means of a mass balance or a thermal balance.

35

In a first step, the controller determines the setpoint concentration  $C_c$  for at least one component of the inlet gas 3 or of the exhaust gas flow 8 of the gas turbine in accordance with at least one of the measured values. In a second step, the controller determines a  
5 setpoint value for the position of the exhaust gas divider 29 in accordance with the setpoint concentration  $C_c$ .

Instead of an absolute setpoint position, the controller can also determine a change in the setpoint value for the position of the exhaust gas divider 29 and exercise control by means  
10 of relative changes. Moreover, the actual position can be taken into account in determining the setpoint position.

The example in figure 1 shows a gas turbine 6 with a single combustion chamber 4. The invention can also be employed without restriction to gas turbines with sequential  
15 combustion, of the kind known from EP0718470, for example. In figure 2, an example of a gas turbine power plant 38 with sequential combustion and exhaust gas recirculation is shown schematically. In the case of this gas turbine, the first combustion chamber 4 is followed by a high-pressure turbine 33. In the second combustion chamber 34, more fuel  
20 5 is fed to the outlet gases of the high-pressure turbine 33, which have been partially expanded, thereby producing work, and is burnt. The hot combustion gases of the second combustion chamber 34 are further expanded in the low-pressure turbine 35, thereby producing work. Use of the waste heat and recirculation are accomplished in a manner similar to the illustrative embodiment in figure 1. For controlling and shutting off the  
25 recirculation flow, a control element 36 is provided in addition to the exhaust gas divider 29, which can be of nonadjustable design. This control element 36 is likewise connected to the controller 39 by signal lines 28.

Inlet and outlet conditions of the first combustion chamber 4 can be determined with measurements 42 and 43, and inlet and outlet conditions of the second combustion  
30 chamber 34 can be determined with measurements 44 and 45. In addition to the pulsation measurement for the first combustion chamber 50, a pulsation measurement for the second combustion chamber 51 is shown.

Based on figure 1, figure 3 additionally shows a carbon dioxide removal system 18. The  
35 second partial exhaust gas flow 20, which is not recirculated, is typically cooled further in an exhaust gas re-cooler 23 and fed to the carbon dioxide removal system 18. Exhaust

gases 22 low in carbon dioxide are released from the latter to the environment via a flue 32. In order to overcome the pressure losses of the carbon dioxide removal system 18 and of the exhaust gas line, an exhaust gas blower 10 can be provided. The carbon dioxide 31 removed in the carbon dioxide removal system 18 is typically compressed in a compressor (not shown) and taken off for storage or further treatment. The carbon dioxide removal system 18 is supplied with steam, typically medium- or low-pressure steam diverted from the steam turbine 13 via a steam extraction system 15. The steam is fed back to the steam circuit after releasing energy in the carbon dioxide removal system 18. In the example shown, the steam is condensed and fed to the feed water via the condensate recirculation line 17.

The second partial exhaust gas flow 20 can also be fed directly to the flue 32 as an exhaust gas bypass flow 24 via an exhaust gas bypass, which comprises a bypass flap or valve 12.

In addition to the illustrative embodiment shown in figure 1, the exhaust gas recirculation system of the example shown in figure 3 furthermore comprises a separate control element 36 for controlling the recirculation flow.

Figure 4 shows an illustrative control loop in schematic form. The measured values 40 to 51 of the gas turbine power plant 38 are transmitted to the controller 39. In a first block 39a, the setpoint value of the concentration of one gas component  $C_c$  is determined, taking into account the measured values 40 to 51, from the setpoint value of the concentration of the gas component of a closed control loop  $C_{cl}$ , the feedforward control value of the setpoint concentration of one gas component  $C_{map}$  and the correction value of the setpoint concentration of one gas component  $C_{cor}$ .

In a second block 39b, the setpoint value of the control element  $R_c$  is determined, taking into account the measured values 40 to 51 and the setpoint value of the concentration of one gas component  $C_c$ , from the setpoint value of the control element of a closed control loop  $R_{cl}$ , the feedforward control value of the setpoint value of the control element  $R_{map}$  and the correction value of the setpoint value of the control element  $R_{cor}$ .

## LIST OF REFERENCE SIGNS

5	1	compressor
	2	ambient air
	3	compressor inlet gas
	4	combustion chamber, first combustion chamber
	5	fuel
10	6	gas turbine
	7	turbine
	8	hot exhaust gases of the gas turbine
	9	heat recovery steam generator (HRSG)
	10	exhaust gas blower for the second partial exhaust gas flow (to the carbon dioxide
15		removal system or flue)
	11	exhaust gas blower for the first partial exhaust gas flow (exhaust gas recirculation)
	12	bypass flap or valve
	13	steam turbine
	14	condenser
20	15	steam extraction system for the carbon dioxide removal system
	16	feed water line
	17	condensate recirculation line
	18	carbon dioxide removal system
	19	exhaust gas from the heat recovery steam generator
25	20	second partial exhaust gas flow (exhaust gas line to the carbon dioxide removal
		system)
	21	first partial exhaust gas flow (exhaust gas recirculation)
	22	exhaust gas low in carbon dioxide
	23	exhaust gas re-cooler (for the second partial exhaust gas flow)
30	24	exhaust gas bypass flow to the flue
	25	first generator
	26	second generator
	27	exhaust gas re-cooler (for the first partial exhaust gas flow)
	28	signal line to the control element (29, 36)
35	29	exhaust gas divider
	30	live steam

- 31 carbon dioxide removed
- 32 flue
- 33 high-pressure turbine
- 34 second combustion chamber
- 5 35 low-pressure turbine
- 36 control element
- 37 signal line
- 38 gas turbine power plant
- 39 controller
- 10 40-49 measurement
- 50 pulsation measurement in the first combustion chamber
- 51 pulsation measurement in the second combustion chamber
- $C_c$  setpoint value of the concentration of one gas component
- 15  $C_{cl}$  setpoint of the concentration of one gas component of a control loop
- $C_{map}$  feedforward control value of the setpoint concentration of one gas component
- $C_{cor}$  correction value of the setpoint concentration of one gas component
- $R_c$  setpoint value of the control element
- $R_{cl}$  setpoint value of the control element in a closed control loop
- 20  $R_{map}$  feedforward control value of the control element
- $R_{cor}$  correction value of the control element

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CLAIMS:

1. A method for operating a gas turbine power plant with exhaust gas recirculation, which comprises a gas turbine, a controller, a heat recovery steam generator and an exhaust gas divider, which divides the exhaust gases of the gas turbine power plant into a first partial exhaust gas flow for recirculation into an intake flow of the gas turbine and into a second partial exhaust gas flow for release to the environment, and a control element for controlling the first exhaust gas flow, and an exhaust gas re-cooler, wherein

a setpoint concentration of one component of the inlet gas and/or of the exhaust gas of the gas turbine is determined in a first step in accordance with the operating conditions of the gas turbine, the position of the control element is adjusted in a second step in accordance with the setpoint/actual deviation in the concentration of the component,

wherein the setpoint concentration of the one component is determined from the setpoint value of the concentration of one gas component from a control loop for an operating variable relevant to combustion in the gas turbine, a feedforward control value of the setpoint concentration of the gas component and a correction value of the setpoint concentration of the gas component.

2. The method as claimed in claim 1, wherein the setpoint concentration of the one component of the inlet gas and/or of the exhaust gas of the gas turbine is determined in the closed control loop in accordance with one or more of the following operating variables relevant to combustion in the gas turbine, namely

the combustion chamber pulsations, the NO<sub>x</sub> emissions, the unburned hydrocarbons (UHC), the measured concentration of the one component in the inlet gas and/or in the exhaust gas of the gas turbine and/or the ratio of carbon to hydrogen in the fuel.

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3. The method as claimed in claim 1 or 2, wherein the setpoint value of the control element is determined from a setpoint value of a closed control loop for the control element, a feedforward control value of the setpoint value of the control element for controlling the recirculated first exhaust gas flow and a correction value of  
5 the setpoint value of the control element.
4. The method as claimed in any one of claims 1 to 3, wherein the setpoint value of the control element is determined in the closed control loop in accordance with one or more of  
10 the exhaust gas recirculation ratio, the inlet flow of the compressor, the ambient air flow and the exhaust gas flow.
5. The method as claimed in any one of claims 1 to 4, wherein at least one of the feedforward control values of the setpoint concentration and of the setpoint value of the control element and/or at least one of the correction values of the setpoint concentration and of the setpoint value of the control element is stored for  
15 discrete values in a matrix, and interpolation is carried out between these values.
6. The method as claimed in any one of claims 1 to 5, wherein a working characteristic for the feedforward control of the setpoint concentration and/or of the setpoint value of the control element is predetermined, and this working characteristic is shifted by a correction value of the setpoint concentration and/or by a correction  
20 value of the setpoint value.
7. The method as claimed in claim 6, wherein the slope of the working characteristic for the feedforward control of the setpoint concentration and/or of the setpoint value of the control element is adapted by means of a correction value of the setpoint concentration and/or a correction value of the setpoint value.
- 25 8. The method as claimed in claim 6 or 7, wherein the shape of the working characteristic for the feedforward control of the setpoint concentration and/or

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of the setpoint value of the control element is adapted by means of a correction value of the setpoint concentration and/or a correction value of the setpoint value.

9. The method as claimed in any one of claims 1 to 8, wherein the correction value of the setpoint concentration and/or the correction value of the setpoint value of the control element is formed in accordance with past control deviations.
10. The method as claimed in any one of claims 1 to 9, wherein the CO<sub>2</sub> concentration and/or the oxygen concentration of the inlet gas and/or of the exhaust gas of the gas turbine is used as a controlled variable.
- 10 11. The method as claimed in any one of claims 1 to 10, wherein the exhaust gas flow is passed through a heat recovery steam generator, in which the usable heat thereof is removed.
12. The method as claimed in any one of claims 1 to 11, wherein, before being released to the environment, the second exhaust gas flow is fed to a carbon dioxide removal system, exhaust gases low in carbon dioxide are released to the environment by said carbon dioxide removal system, and carbon dioxide is taken off for further use.
13. A gas turbine power plant with exhaust gas recirculation, which comprises a gas turbine, a controller, a heat recovery steam generator and an exhaust gas divider, which divides the exhaust gases of the gas turbine power plant into a first exhaust gas flow for recirculation into an intake flow of the gas turbine and into a second exhaust gas flow for release to the environment, and a control element for controlling the first exhaust gas flow, and an exhaust gas re-cooler,
- 20 wherein at least one sensor for measuring the concentration of one component of the inlet gas and/or of the hot working gas and/or of the exhaust gas of the gas turbine is provided,
- 25

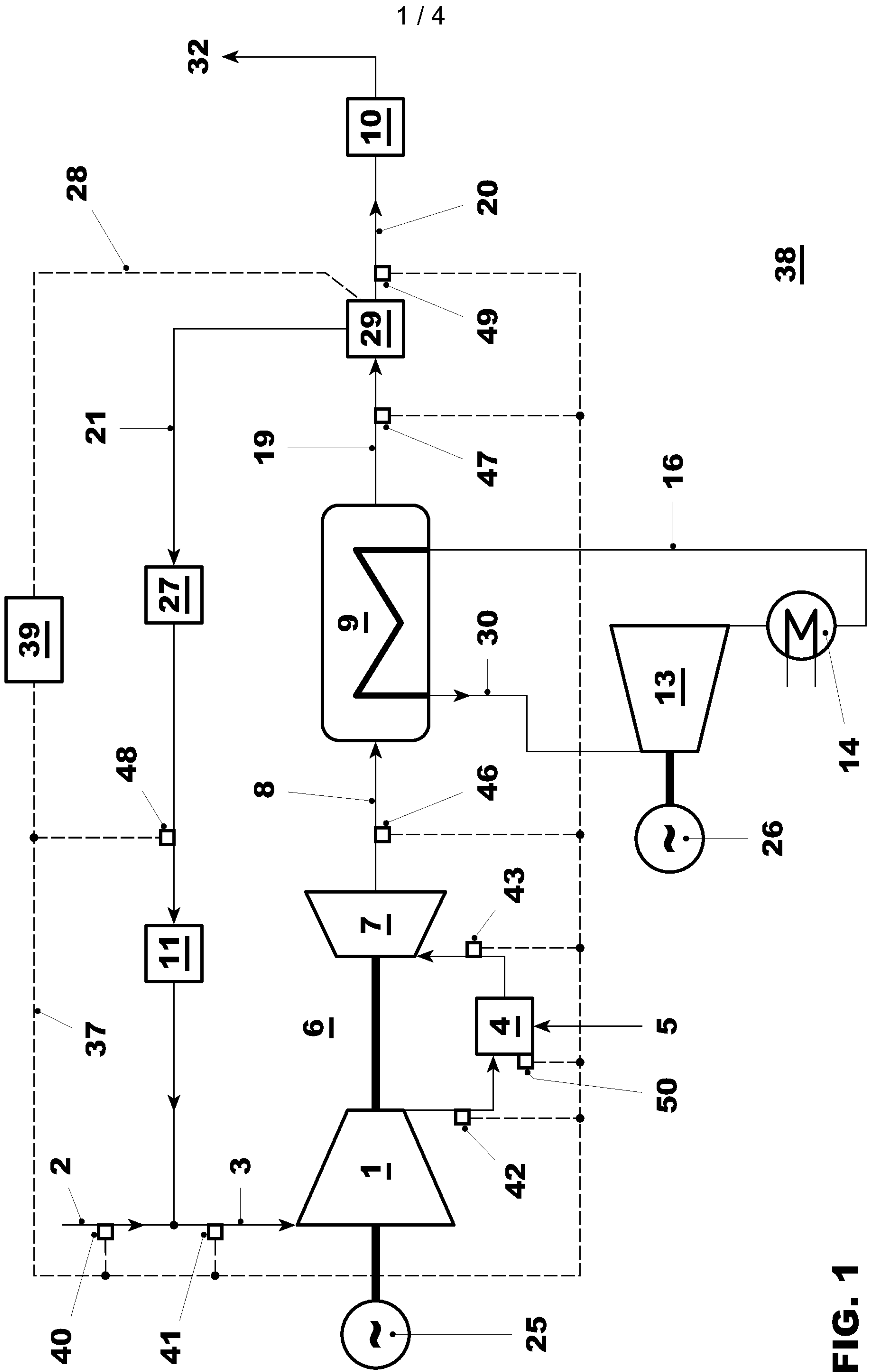
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wherein the controller comprises three controller levels for determining a setpoint concentration of the one component, wherein the first controller level comprises a closed control loop for the setpoint concentration of the one component, the second controller level comprises a feedforward control for the setpoint  
5 concentration of the one component, and the third controller level comprises a feedback circuit, by means of which the setpoint values of the feedforward control are corrected in accordance with the actual operating behavior of the gas turbine power plant.

14. The gas turbine power plant as claimed in claim 13, wherein the  
10 controller comprises a block for determining a setpoint concentration and a subsequent block for determining a setpoint position of the control element, wherein the block for determining the setpoint position of the control element is connected to the output signal of the block for determining the setpoint concentration and comprises at least one measurement of an operating parameter of the gas turbine  
15 power plant and/or an online measurement of the fuel composition, and this measurement is connected to the controller.

15. The gas turbine power plant as claimed in claim 13 or 14, further comprising a pulsation measurement in a combustion chamber, which is connected to the controller.



**FIG. 1**

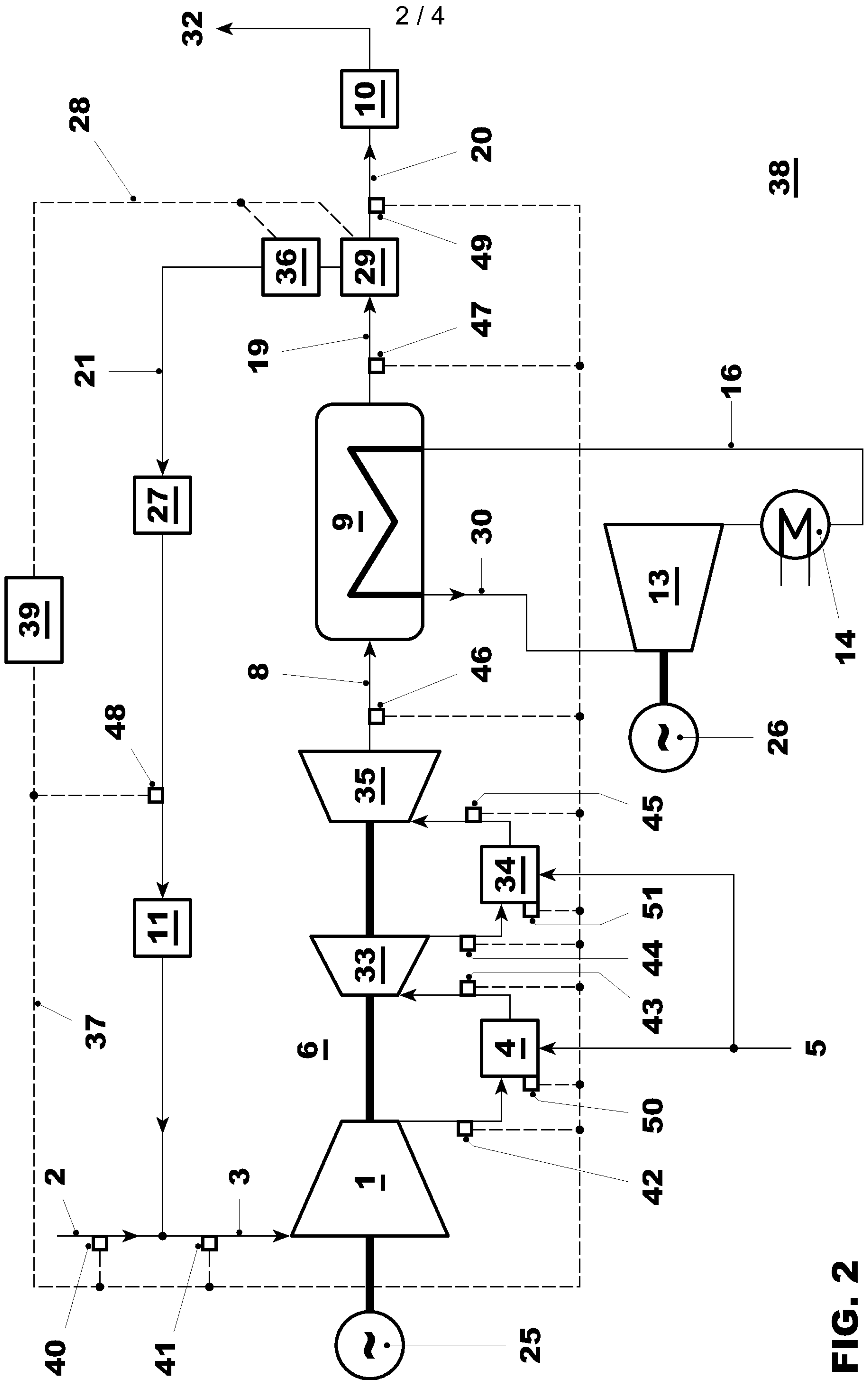


FIG. 2

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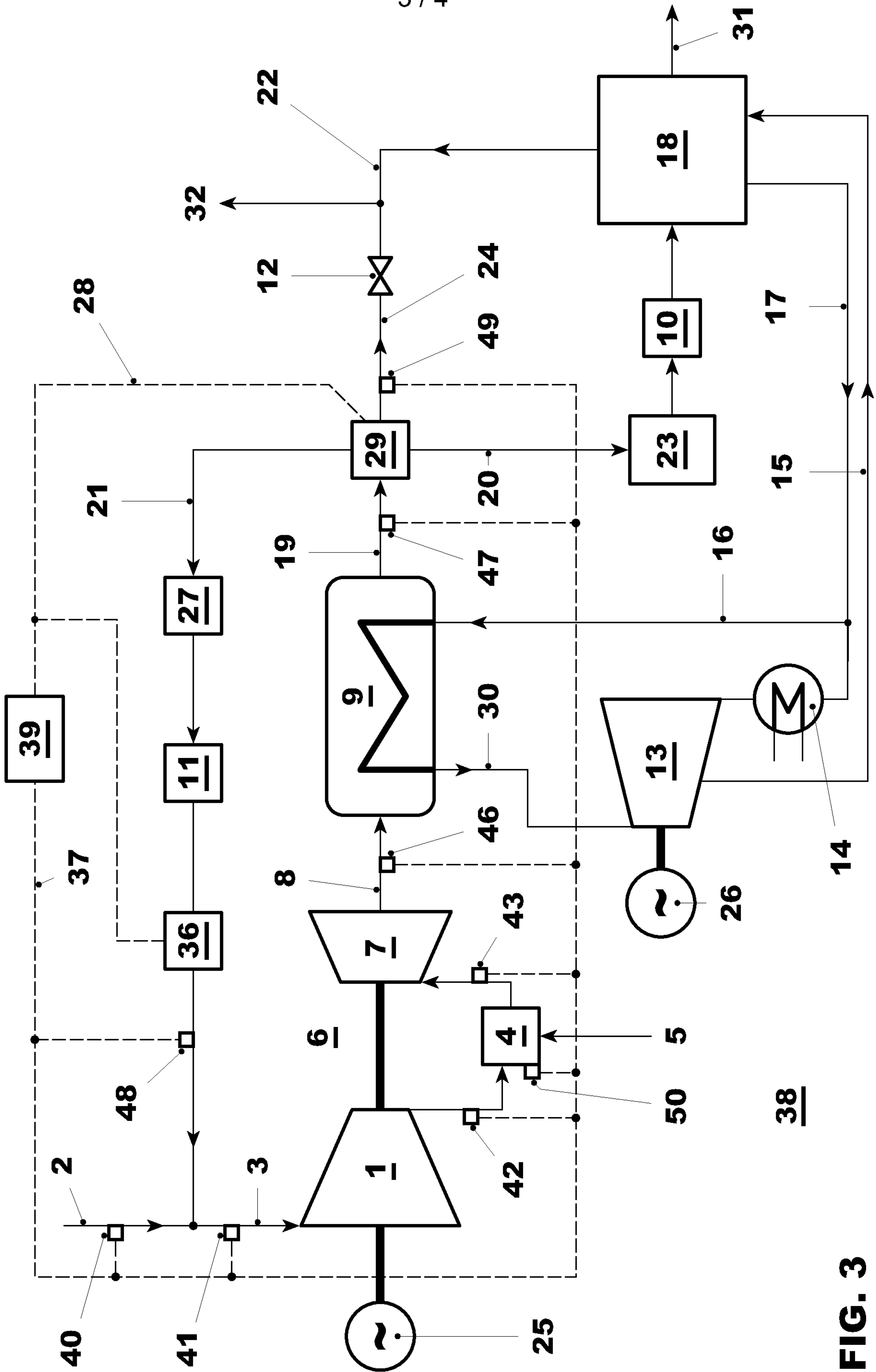


FIG. 3

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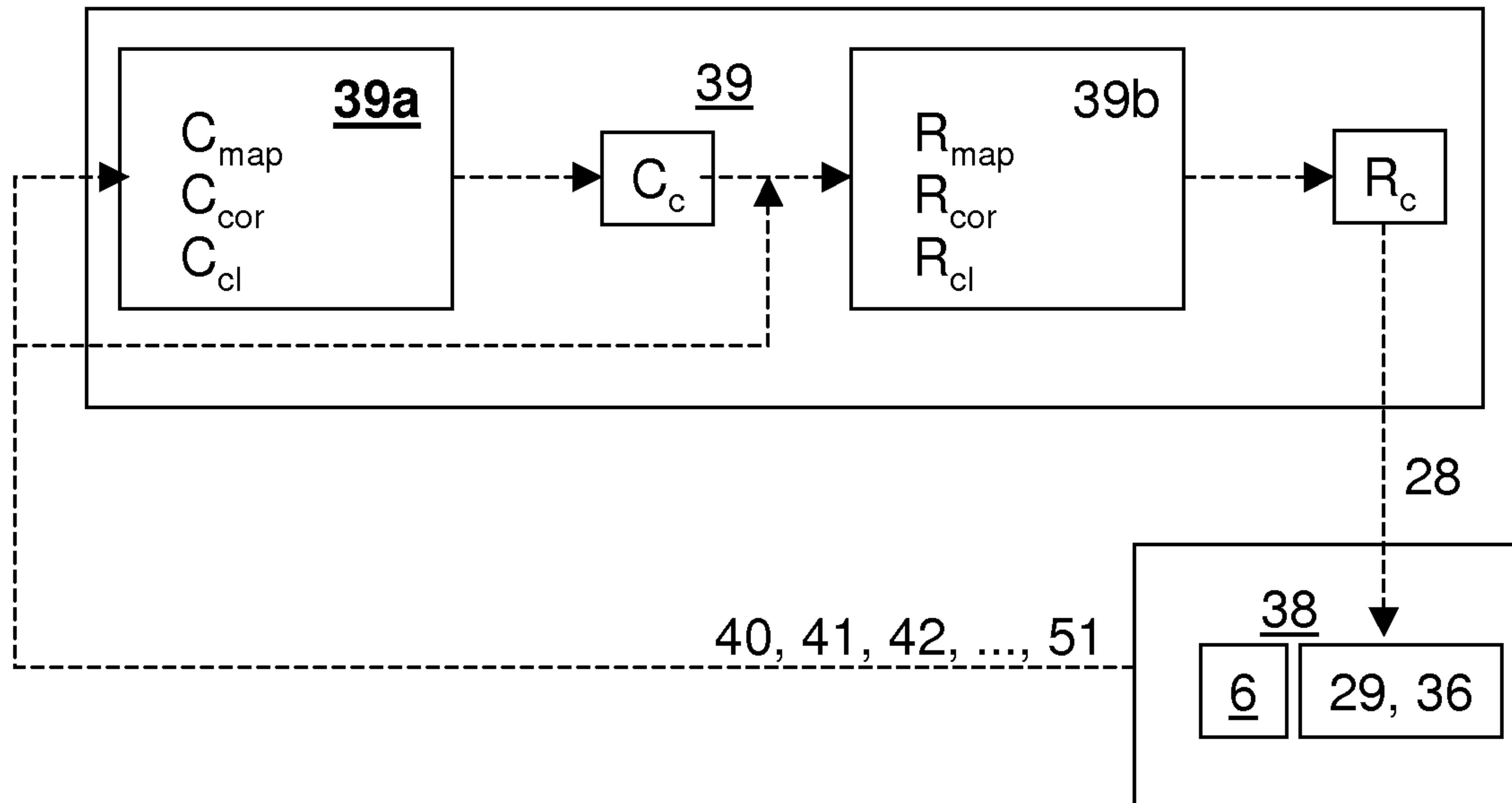


Fig. 4

