Office de la Propriété Intellectuelle du Canada
Un organisme d'Industrie Canada

Canadian Intellectual Property Office
An agency of Industry Canada

CA 2354876 C 2007/03/13

(11)(21) **2 354 876**

(12) **BREVET CANADIEN**
CANADIAN PATENT

(13) **C**

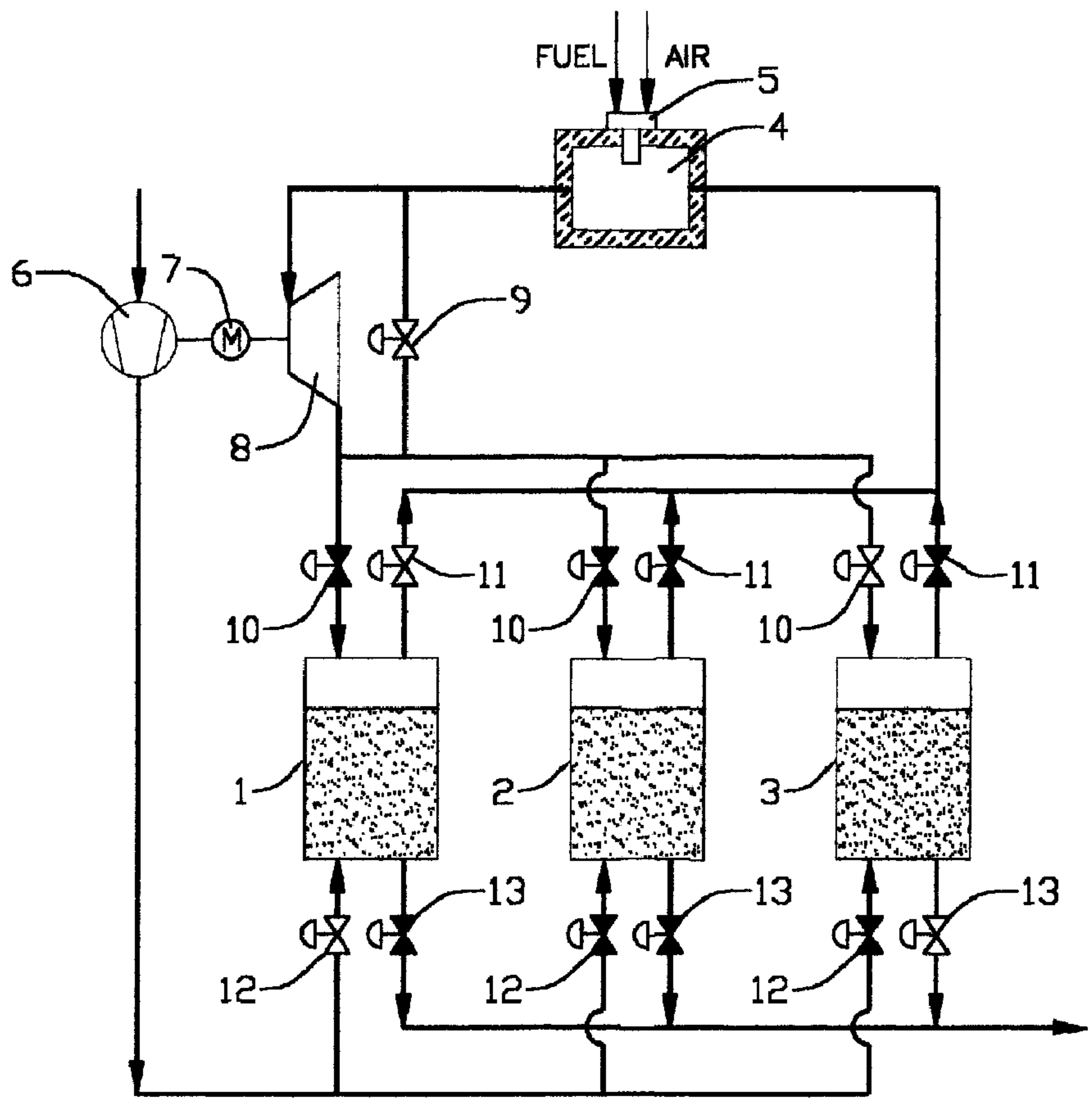
(22) Date de dépôt/Filing Date: 2001/07/27
(41) Mise à la disp. pub./Open to Public Insp.: 2003/01/27
(45) Date de délivrance/Issue Date: 2007/03/13

(51) Cl.Int./Int.Cl. *F23G 7/06* (2006.01), *F23J 15/00* (2006.01)

(72) Inventeurs/Inventors:
PONOMAREV, VLADIMIR, CA;
PONOMARYOVA, IRYNA, CA

(73) Propriétaires/Owners:
PONOMAREV, VLADIMIR, CA;
PONOMARYOVA, IRYNA, CA

(54) Titre : DISPOSITIF D'OXYDATION THERMIQUE A RECUPERATION DE CHALEUR
(54) Title: REGENERATIVE THERMAL OXIDIZER



(57) Abrégé/Abstract:
The invention provides an improved regenerative thermal oxidizer (RTO) comprising two or three regenerators (heat exchangers) and combustion chamber. A centrifugal gas motor, being connected to combustion chamber, generates mechanical energy due to

(57) Abrégé(suite)/Abstract(continued):

expansion of hot gas. A fan compresses relatively cold process gas to overcome pressure losses in RTO and develop additional pressure to be used by a centrifugal gas motor. The mechanical energy generated by a centrifugal gas motor exceeds additional power consumption by a fan due to higher volume flow of hot gas. It results in significant net savings in power consumption, and, in some cases, in generation of additional power.

ABSTRACT OF THE DISCLOSURE

The invention provides an improved regenerative thermal oxidizer (RTO) comprising two or three regenerators (heat exchangers) and combustion chamber. A centrifugal gas motor, being connected to combustion chamber, generates mechanical energy due to expansion of hot gas. A fan compresses relatively cold process gas to overcome pressure losses in RTO and develop additional pressure to be used by a centrifugal gas motor. The mechanical energy generated by a centrifugal gas motor exceeds additional power consumption by a fan due to higher volume flow of hot gas. It results in significant net savings in power consumption, and, in some cases, in generation of additional power.

REGENERATIVE THERMAL OXIDIZER

TECHNICAL FIELD OF THE INVENTION

The present invention relates generally to regenerative thermal oxidizers. More specifically, the present invention relates to regenerative thermal oxidizers with high gas flow rates (for cement plants, refineries, power plants, etc.).

BACKGROUND OF THE INVENTION AND PRIOR ART

Regenerative thermal oxidizers (RTOs) are used in a number of industries to reduce the quantity of combustible contaminants in process effluent gases. In a RTO, the process effluent gases are oxidized in a combustion chamber. A heat recovery section of RTO is filled with loose or structured ceramic packing. A mass of heat-resistant ceramic packing in heat exchanger stores heat from the hot gases exiting the combustion chamber while another preheated heat exchanger releases heat into the relatively cold gases entering the combustion chamber. In the heat exchanger, up to 95% of the heat is transferred from the gases to the ceramic packing. The flow of gases is then reversed to preheat another heat exchanger (regenerator). Typical cycle time range is from 30 to 120 seconds.

In a RTO having three or more heat exchangers, one heat exchanger sequentially serves as a standby heat exchanger. A RTO having two heat exchangers does not have any standby heat exchangers. A RTO having three heat exchangers, various types of valves (butterfly, wafer, etc) are employed. In the case of two heat exchangers RTO the most frequently used valves are poppet valves.

Typical RTOs are shown, for example, in the following patents granted in Canada:

2,161,860 Wilhelm
2,211,924 Gribbons
2,251,768 Blazejewski

The prior art does not address the issue of high power consumption. However, the fan for RTO having high gas flow rates (above 10,000 scfm) requires hundreds of kilowatts of electricity. Therefore it would be desirable to address the high electrical energy demand.

SUMMARY OF THE INVENTION

The present invention provides a RTO having a plurality of heat exchangers. Each heat exchanger comprises a process gas inlet, a process gas outlet, a clean gas inlet, and a clean gas outlet. Each heat exchanger is filled with ceramic packing. The valve means are provided to direct a process gas and clean gas through heat exchangers. Depending on process requirements, various types of valve means can be used (poppet valves, butterfly valves, dampers, etc). Heating means produce sufficient heat input to cover the thermal losses and maintain high temperature range of process gas sufficient for oxidizing of combustible components. As an example of said heating means, a combustion chamber with a burner can be used. A combustion chamber is connected by valves or dampers to gas flow path between process gas outlets and clean gas inlets of heat exchangers. A combustion chamber is usually constructed from steel with internal refractory lining. A burner is connected to external air and fuel sources. A centrifugal fan compresses a process gas to overcome pressure losses in a RTO. During start up, a bypass valve of centrifugal gas motor (CGM) is open and CGM is not operating. After start up of a RTO, a process gas is compressed by a fan to a higher pressure. It results in additional power consumption by a fan. A bypass valve of centrifugal gas motor (CGM) is closed and excessive gas pressure is used by CGM to generate mechanical energy by expansion of the gas. The mechanical energy generated by a CGM exceeds said additional power consumption by a fan due to higher volume flow of preheated gas. It results in significant net savings in RTO power consumption, and, in some cases, in generation of additional power.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a diagrammatic view of a RTO according to one embodiment of the present invention, having three heat exchangers, a CGM being connected to outlet of combustion chamber, and a fan being connected to inlet of a RTO.

FIG. 2 is a diagrammatic view of a RTO having three heat exchangers, a CGM being connected to inlet of combustion chamber, and a fan being connected to inlet of a RTO.

FIG. 3 is a diagrammatic view of a RTO having three heat exchangers, a CGM being connected to outlet of combustion chamber, and a fan being connected to outlet of a RTO.

FIG. 4 is a diagrammatic view of a RTO having three heat exchangers, a CGM being connected to inlet of combustion chamber, and a fan being connected to outlet of a RTO.

FIG. 5 is a diagrammatic view of a RTO having three heat exchangers, a CGM being connected to outlet of combustion chamber, a fan being connected to inlet of a RTO, and a purging line being connected to the fan inlet.

FIG. 6 is a diagrammatic view of a RTO having three heat exchangers, a CGM being connected to inlet of combustion chamber, a fan being connected to inlet of a RTO, and a purging line being connected to the fan inlet.

FIG. 7 is a diagrammatic view of a RTO having three heat exchangers, a CGM being connected to outlet of combustion chamber, a fan being connected to outlet of a RTO, and a purging line having additional fan and being connected to the process gas inlets of heat exchangers.

FIG. 8 is a diagrammatic view of a RTO having three heat exchangers, a CGM being connected to inlet of combustion chamber, a fan being connected to outlet of a RTO, and a purging line having additional fan and being connected to the process gas inlets of heat exchangers.

FIG. 9 is a diagrammatic view of a RTO having two heat exchangers, a CGM being connected to outlet of combustion chamber, and a fan being connected to inlet of a RTO.

FIG. 10 is a diagrammatic view of a RTO having two heat exchangers, a CGM being connected to inlet of combustion chamber, and a fan being connected to inlet of a RTO.

FIG. 11 is a diagrammatic view of a RTO having two heat exchangers, a CGM being connected to outlet of combustion chamber, and a fan being connected to outlet of a RTO.

FIG. 12 is a diagrammatic view of a RTO having two heat exchangers, a CGM being connected to inlet of combustion chamber, and a fan being connected to outlet of a RTO.

FIG. 13 is a diagrammatic view of a RTO having three heat exchangers, a CGM being connected to outlet of combustion chamber, a fan being connected to inlet of a RTO, and additional air heater being connected to outlet of CGM.

FIG. 14 is a diagrammatic view of a RTO having two heat exchangers, a CGM being connected to outlet of combustion chamber, a fan being connected to inlet of a RTO, and additional air heater being connected to outlet of CGM.

FIG. 15 is a diagrammatic view of a RTO having three heat exchangers, a CGM being connected to outlet of combustion chamber, a fan being connected to inlet of a RTO, and additional air heater being connected to inlet of CGM.

FIG. 16 is a diagrammatic view of a RTO having two heat exchangers, a CGM being connected to outlet of combustion chamber, a fan being connected to inlet of a RTO, and additional air heater being connected to inlet of CGM.

FIG. 17 is a diagrammatic view of a RTO having three heat exchangers, a CGM being connected to inlet of combustion chamber, and an electrical generator being mechanically connected to a CGM.

FIG. 18 is a diagrammatic view of a RTO having three heat exchangers, a CGM being connected to outlet of combustion chamber, a fan being connected to inlet of a RTO and a gaseous fuel inlet being connected to process gas inlets of heat exchangers.

DETAILED DESCRIPTION OF THE INVENTION

Referring to FIG. 1 of the drawings, a RTO is shown having heat exchangers 1, 2, and 3, having process gas inlets 12 with associated valve means, process gas outlets 11, clean gas inlets 10, and clean gas outlets 13. The heat exchangers are filled with ceramic elements. As heating means, a combustion chamber 4 with internal refractory lining and burner 5 is provided. An outlet of combustion chamber is connected to the inlet of centrifugal gas motor (CGM) 8. Clean gas inlets 10 of heat exchangers 1, 2, and 3 are connected to CGM 8 outlet. A consumer of mechanical energy comprises a fan 6 being in flow communication with process gas inlets 12 of heat exchangers 1, 2, and 3. Electrical motor 7 rotates a fan 6 during start up or in the modes of operation when mechanical energy generated by CGM 8 is not sufficient to rotate a fan 6. A fan 6 can be placed anywhere upstream of RTO, including upstream of a source of process gas.

A process gas containing combustible components (products of incomplete combustion or other contaminants) enters preheated heat exchanger 1 through process gas inlet 12 and associated valve. The preheated process gas passes directly from process gas outlet 11 of heat exchanger 1 to a combustion chamber 4 where it is subjected to temperatures and times delays sufficient for oxidizing of combustible contaminants. Additional heat is provided by a burner 5 to maintain sufficient temperature range of 1500°F to 1900°F if required. The oxidizing temperature depends on contaminant type, required destruction efficiency, and available residence time. A hot clean gas having higher temperature and higher volume flow than initial volume flow of relatively cold process gas enters a CGM 8 and expands. After expansion, a clean gas enters heat exchanger 3 through clean gas inlet 10, preheating a heat exchanger for the next heating cycle. A clean gas leaves heat exchanger 3 through clean gas outlet 13 at a temperature higher than initial temperature of process gas. A power generated by CGM 8 is used by consumer of mechanical energy, a fan 6, to compensate additional power consumption by a fan 6 due to additional compression of a process gas in a fan, equal to pressure drop across a CGM 8, and to compensate at least a part of power consumption required to overcome a pressure drop across heat exchangers. If a power generated by CGM 8 exceeds power consumption of a fan 6, excessive power can be converted to electricity in another consumer of mechanical energy, a motor-generator 7, or it can be used to develop additional head in a fan 6 in order to reduce the load of other process fans installed upstream and/or downstream of RTO.

Later the flow of gases is redirected to preheat a heat exchanger 2 and to use a heat stored in a heat exchanger 3, etc. Typical cycle range is from 30 to 120 seconds.

As can be seen from Fig. 2, a CGM 8 can be placed upstream of combustion chamber 4 to reduce temperature of gas entering CGM 8. It results in insignificantly reduced power generation by CGM 8. A fan 6 can be provided downstream of a RTO seen in Fig. 3 and Fig. 4. In this case a RTO is always under negative pressure. It guarantees zero leaks of a process gas to the environment.

A RTO seen in Fig. 5 and Fig. 6 differs from RTO seen in Fig. 1 and Fig. 2 by having additional valve means 14 provided to remove a process gas left in heat exchangers when a gas flow changes its direction. The valve means 14 connect process gas inlet 12 of one of heat exchangers 1, 2, or 3, which is not being heated or cooled at this moment, to a fan 6 inlet and further to process gas inlet 12 of one of heat exchangers 1, 2, or 3, which is being cooled by a process gas at this moment.

A RTO seen in Fig. 7 and Fig. 8 differs from RTO seen in Fig. 3 and Fig. 4 by having additional valve means 14 and additional fan 15 provided to remove a process gas left in heat exchangers when a gas flow changes its direction. The valve means 14 connect process gas inlet 12 of one of heat exchangers 1, 2, or 3, which is not being heated or cooled at this moment, to the inlet of additional fan 15 and further to a process gas inlet 12 of one of heat exchangers 1, 2, or 3, which is being cooled by a process gas at this moment (heat exchanger 1). It results in removal of process gas with contaminants from the idle heat exchanger (heat exchanger 2, Fig. 5, Fig. 6, Fig. 7, and Fig. 8) and returning the contaminated gas for further processing by heating it in heat exchanger 1 and combustion chamber 4. A fan 15, Fig. 7 and Fig. 8, is provided to overcome a pressure difference between clean gas inlets 10 and process gas inlets 12 of heat exchangers 1, 2, and 3, and develop sufficient gas flow rate to purge a contaminated gas from idle heat exchanger.

The RTOs seen in Fig. 9, Fig. 10, Fig. 11 and Fig. 12, are similar to RTO seen in Fig. 1, Fig. 2, Fig. 3 and Fig. 4 respectively, with exception of total number of heat exchangers provided.

An air heater 16 and additional fan 17, Fig. 13, Fig. 14, Fig. 15, and Fig. 16, are provided to preheat the air required for combustion of fuel in a burner 5. Comparing with RTOs seen in Fig. 1, Fig. 2, Fig. 3 and Fig. 3, preheating the air in air heater 16 reduces a fuel consumption by the burner 5 having the given heat output, or increases a heat output if fuel consumption remains the same.

As seen in Fig. 17, a RTO is provided with electrical generator 18 as a consumer of mechanical energy. It is effective if a fan cannot be used as a consumer of mechanical energy. The electricity generated by an electrical generator 18 can be used by other consumers of electrical energy such as process equipment, which produces a process gas to be cleaned in RTO.

Referring to Fig. 18, a RTO is shown having gaseous fuel inlet 19 connected to a process gas flow path upstream of process gas inlets 12 of heat exchangers 1, 2, and 3. Being mixed with a process gas, a gaseous fuel passes through heat exchangers, fully using recovery heat and eventually increasing the temperature above autoignition temperature and being oxidized by excessive oxygen containing in process gas. The heat release results in higher thermal efficiency of RTO due to greatly reduced burner heat output required to maintain sufficient temperature in combustion chamber.

The efficiency of RTO having process gas flow of 60,000 acfm, temperature in combustion chamber of 1800°F, nominal pressure drop across RTO of 20' w.c. (when CGM is not in service), clean gas pressure at RTO outlet of 0' w.c., and mechanical efficiency of a fan and a CGM of 80%, is illustrated by following data:

No.	RTO mode of operation	Gas pressure at process gas inlet, inch w.c.	Fan power consumption, hp	CGM mechanical output, hp	Total RTO electrical power consumption, hp
1	Valve 9 open, CGM is not operating	20	892	0	892
2	Valve 9 closed, CGM in service	36	1513	1070	441
3	Valve 9 closed, CGM in service	48	2018	1847	172
4	Valve 9 closed, CGM in service	56	2360	2360	≈0

A RTO will have zero electrical power consumption and generate excessive mechanical energy if gas pressure at process gas inlet exceeds 56” w.c.

The efficiency of RTO having process gas flow of 30,000 acfm, temperature in combustion chamber of 1800°F, nominal pressure drop across RTO of 10’ w.c. (when

CGM is not in service), clean gas pressure at RTO outlet of 0' w.c., and mechanical efficiency of a fan and a CGM of 80%, is illustrated by following data:

No.	RTO mode of operation	Gas pressure at process gas inlet, inch w.c.	Fan power consumption, hp	CGM mechanical output, hp	Total RTO electrical power consumption, hp
1	Valve 9 open, CGM is not operating	10	223	0	223
2	Valve 9 closed, CGM in service	18	378	268	110
3	Valve 9 closed, CGM in service	24	505	462	43
4	Valve 9 closed, CGM in service	28	590	590	≈0

A RTO will have zero electrical power consumption and generate excessive mechanical energy if gas pressure at process gas inlet exceeds 28" w.c.

THE EMBODIMENT OF THE INVENTION IN WHICH AN EXCLUSIVE PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:

1. A regenerative thermal oxidizer, comprising:

a plurality of heat exchangers, each heat exchanger containing heat exchange media and having a process gas inlet, a process gas outlet, a clean gas inlet, and a clean gas outlet;

heating means for producing or maintaining a temperature range of process gas sufficient for oxidizing of combustible components in said process gas;

a centrifugal gas motor being in flow communication with said heat exchangers;

a consumer of mechanical energy being connected to said centrifugal gas motor; and

valve means being in flow communication with said heat exchangers for alternately directing a process gas through said heat exchangers.

2. A regenerative thermal oxidizer of claim 1, wherein said heating means comprises a combustion chamber.

3. A regenerative thermal oxidizer of claim 2, wherein said heat exchanger process gas outlets are in flow communication with said combustion chamber inlet; whereas an outlet of said combustion chamber is in flow communication with said centrifugal gas motor inlet; said centrifugal gas motor outlet is in flow communication with said heat exchanger clean gas inlets.

4. A regenerative thermal oxidizer of claim 2, wherein said heat exchanger process gas outlets are in flow communication with said centrifugal gas motor inlet; whereas an outlet of said centrifugal gas motor outlet is in flow communication with said combustion chamber inlet; said combustion chamber outlet is in flow communication with said heat exchanger clean gas inlets.

5. A regenerative thermal oxidizer of claim 3, wherein said consumer of mechanical energy comprises a fan being in flow communication with said process gas inlet of each heat exchanger.

6. A regenerative thermal oxidizer of claim 4, wherein said consumer of mechanical energy comprises a fan being in flow communication with said process gas inlet of each heat exchanger.

7. A regenerative thermal oxidizer of claim 3, wherein said consumer of mechanical energy comprises a fan being in flow communication with said clean gas outlet of each heat exchanger.

8. A regenerative thermal oxidizer of claim 4, wherein said consumer of mechanical energy comprises a fan being in flow communication with said clean gas outlet of each heat exchanger.

9. A regenerative thermal oxidizer of claim 1, wherein said consumer of mechanical energy comprises an electrical generator.

10. A regenerative thermal oxidizer of claim 5, further comprising additional valve means, wherein said heat exchanger process gas inlets are in flow communication with said fan inlet through said additional valve means.

11. A regenerative thermal oxidizer of claim 6, further comprising additional valve means, wherein said heat exchanger process gas inlets are in flow communication with said fan inlet through said additional valve means.

12. A regenerative thermal oxidizer of claim 7 further comprising additional valve means and additional fan having inlet and outlet, said heat exchanger process gas inlets being in flow communication with said fan inlet through said additional valve means, said fan outlet being in flow communication with said heat exchanger process gas inlets through said additional valve means.

13. A regenerative thermal oxidizer of claim 8 further comprising additional valve means and additional fan having inlet and outlet, said heat exchanger process gas inlets being in flow communication with said fan inlet through said additional valve means, said fan outlet being in flow communication with said heat exchanger process gas inlets through said additional valve means.

14. A regenerative thermal oxidizer of claim 5 further comprising additional heat exchanger having gas inlet, gas outlet, air inlet and air outlet, and additional fan having inlet and outlet, wherein said heating means in said combustion chamber comprises a burner having fuel inlet and air inlet, said additional heat exchanger gas inlet being in flow communication with said centrifugal gas motor outlet, said additional heat exchanger gas outlet being in flow communication with said heat exchangers clean gas inlets, said additional heat exchanger air inlet being in flow communication with said additional fan outlet, said additional heat exchanger air outlet being in flow communication with said burner air inlet.

15. A regenerative thermal oxidizer of claim 6 further comprising additional heat exchanger having gas inlet, gas outlet, air inlet and air outlet, and additional fan having inlet and outlet, wherein said heating means in said combustion chamber comprises a burner having fuel inlet and air inlet, said additional heat exchanger gas outlet being in flow communication with said centrifugal gas motor inlet, said additional heat exchanger gas inlet being in flow communication with said combustion chamber outlet, said additional heat exchanger air inlet being in flow communication with said additional fan outlet, said additional heat exchanger air outlet being in flow communication with said burner air inlet.

16. A regenerative thermal oxidizer of claim 1, further comprising additional gaseous fuel inlet being in flow communication with said process gas inlets of said heat exchangers.

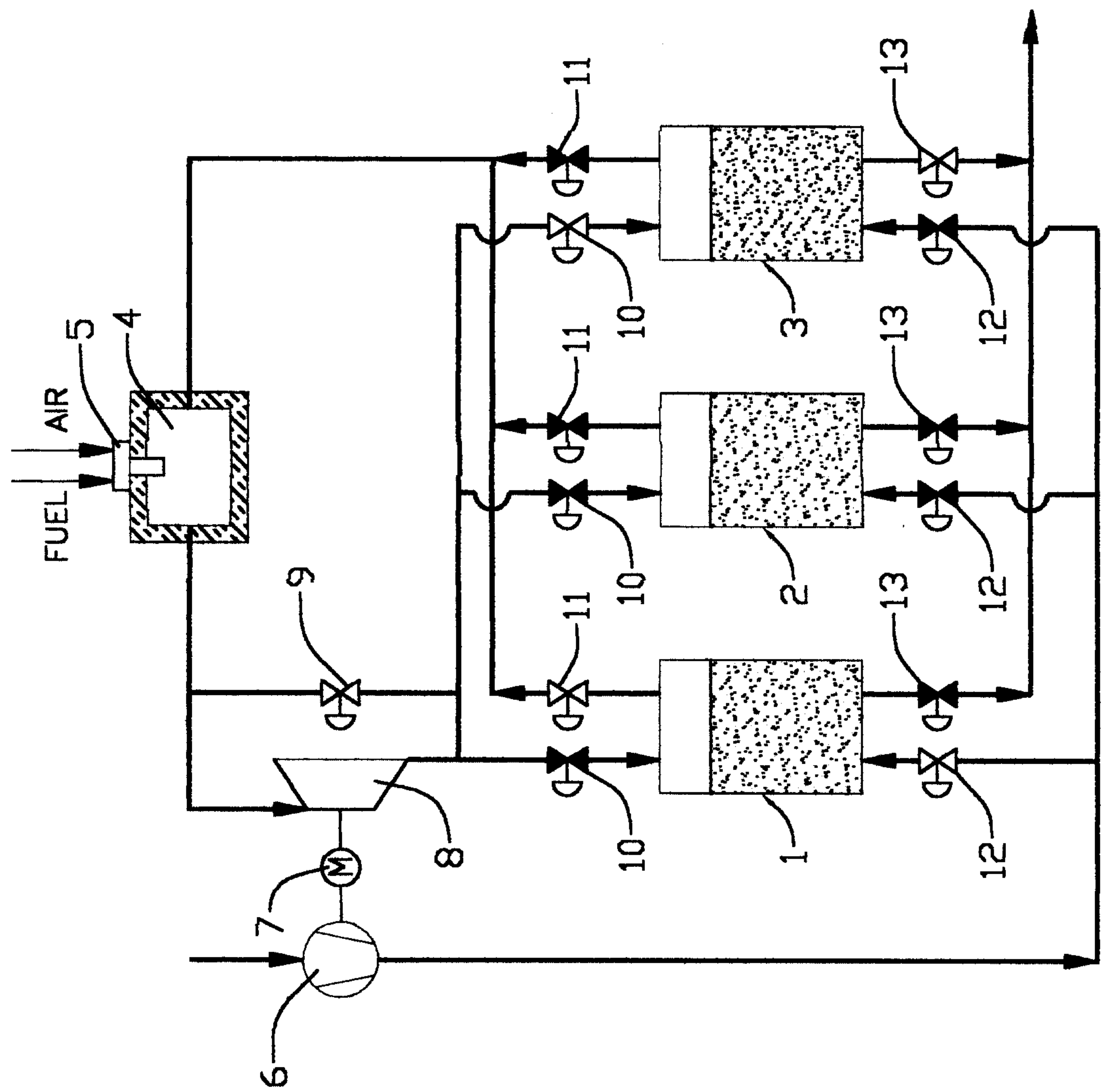


Fig. 1

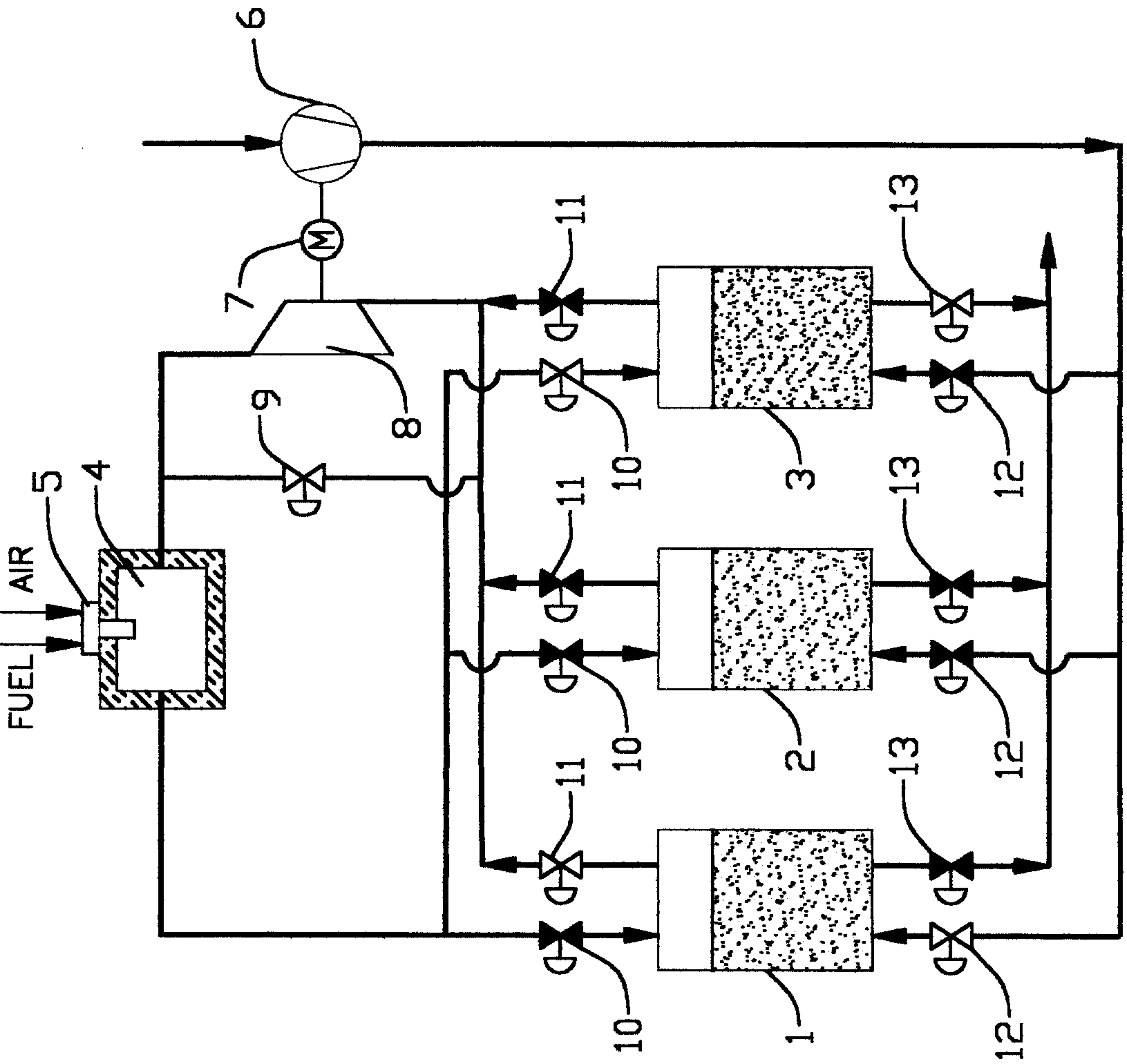


Fig. 2

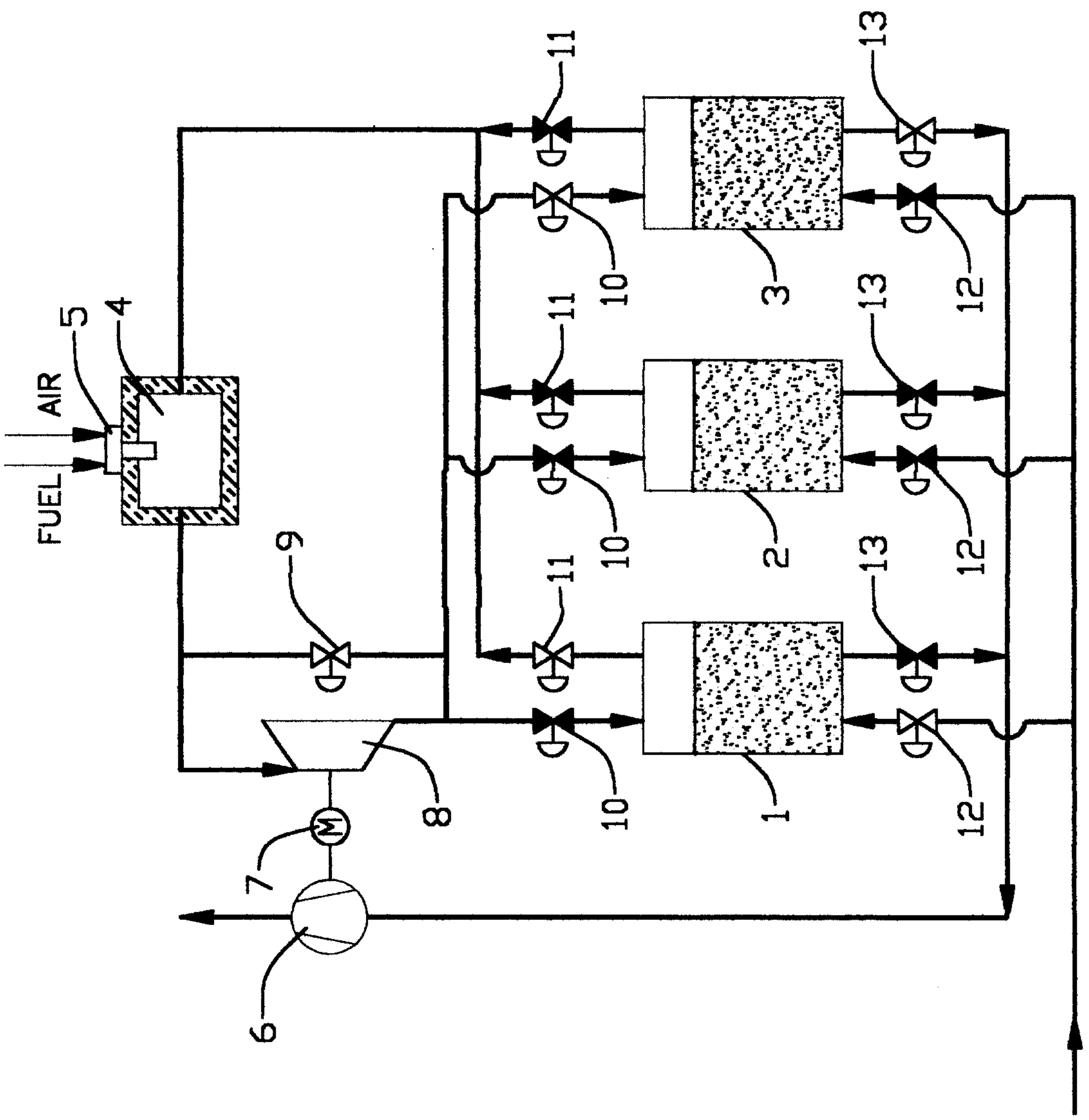


Fig. 3

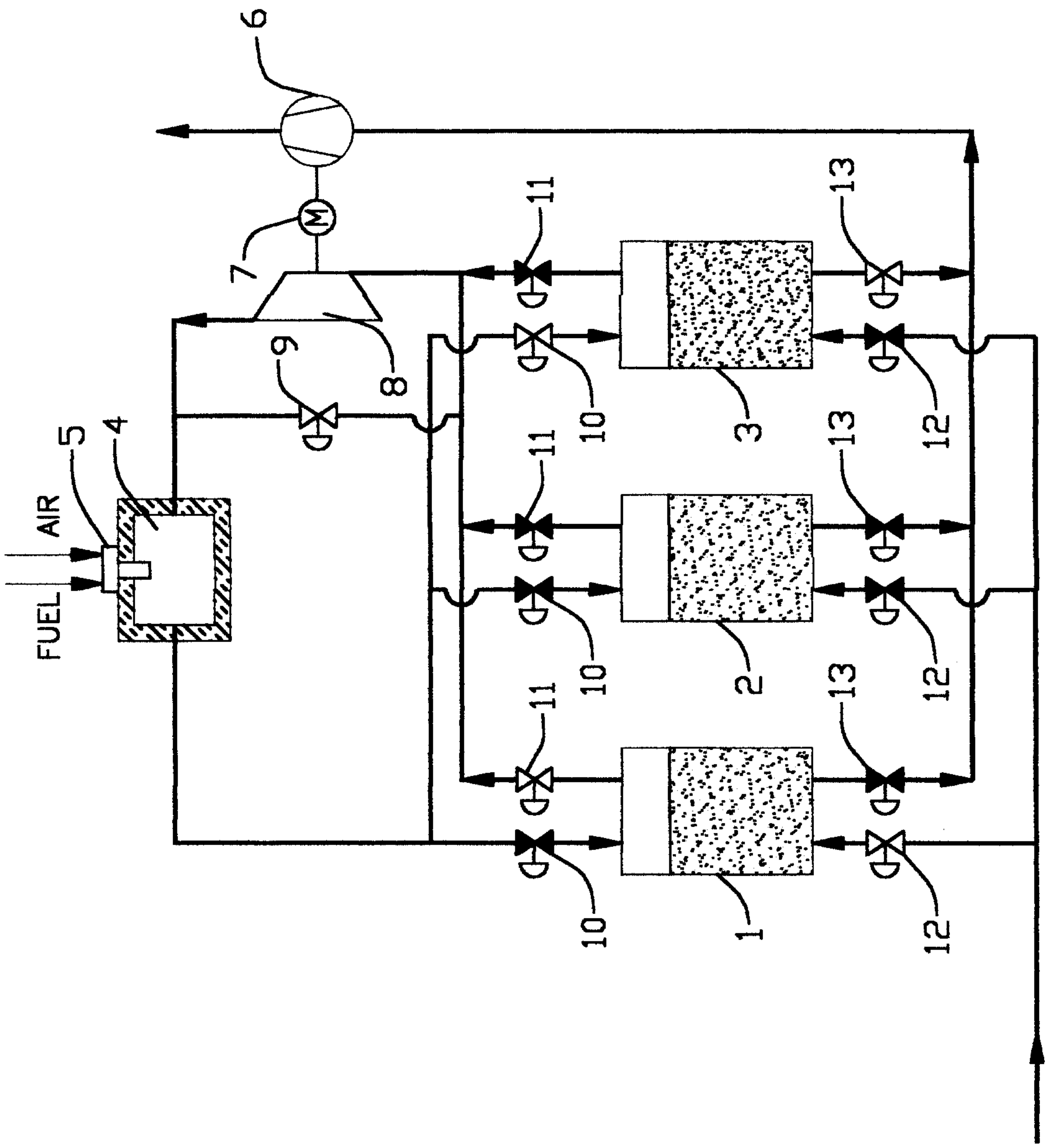


Fig. 4

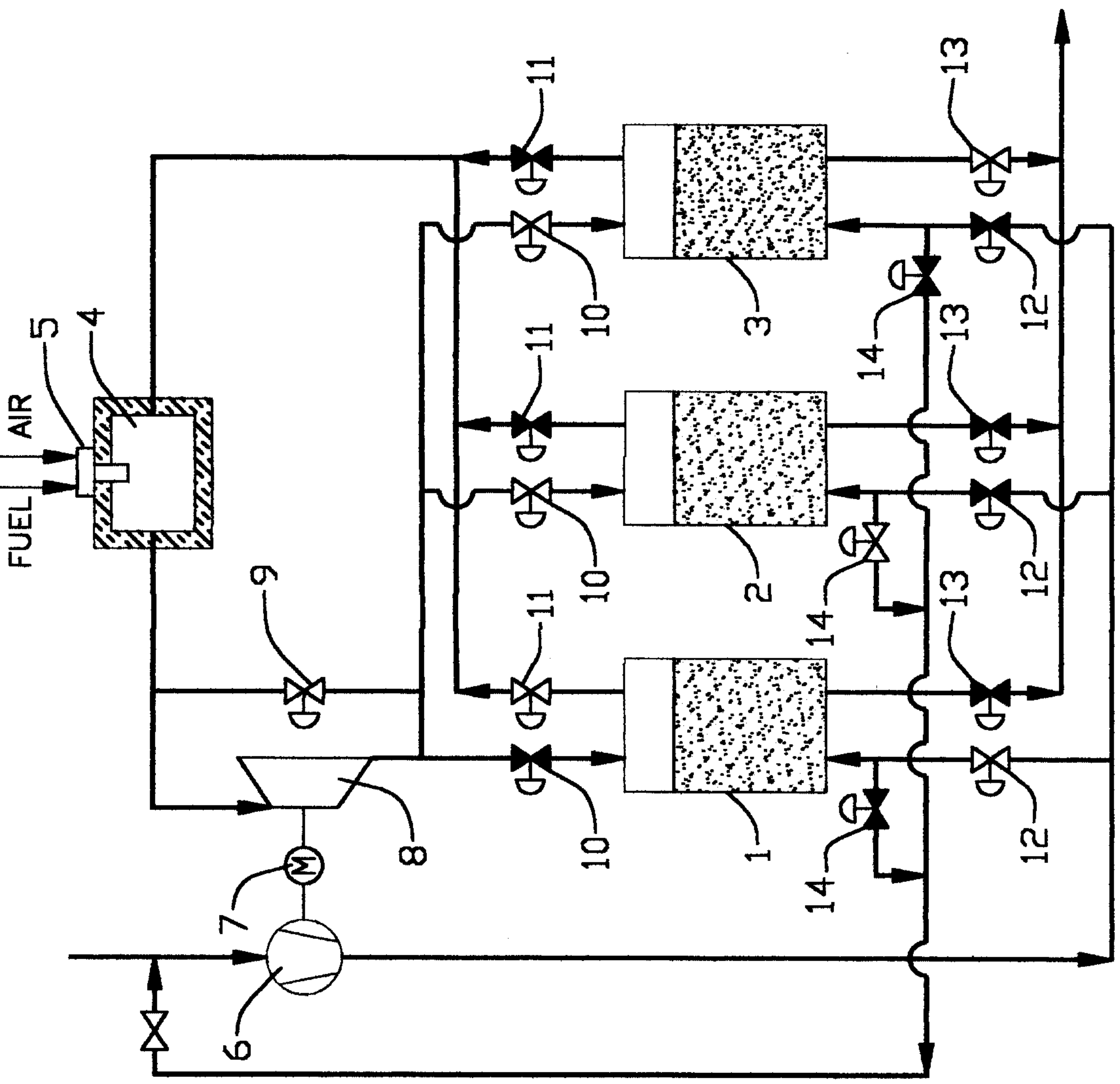


Fig. 5

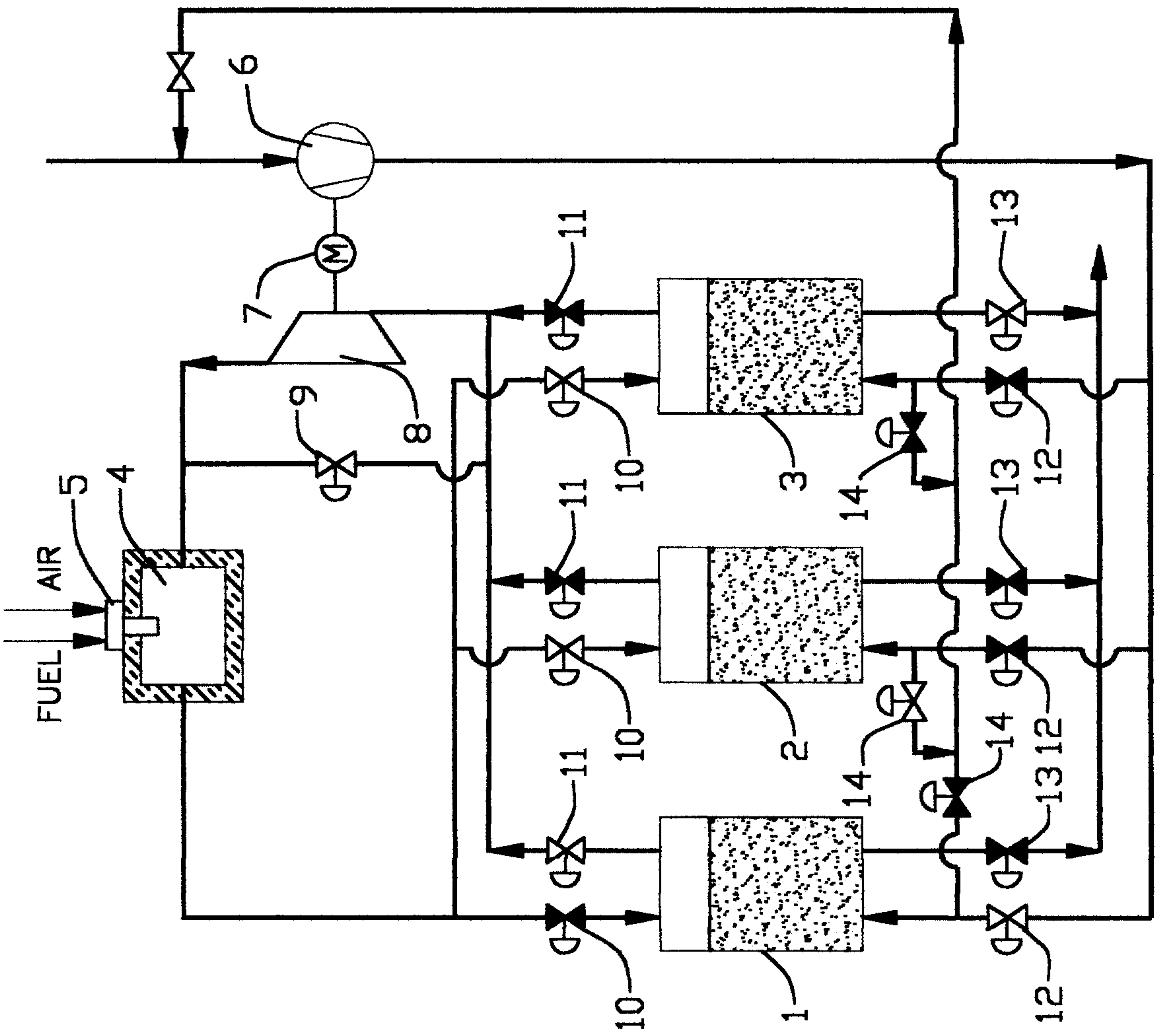


Fig. 6

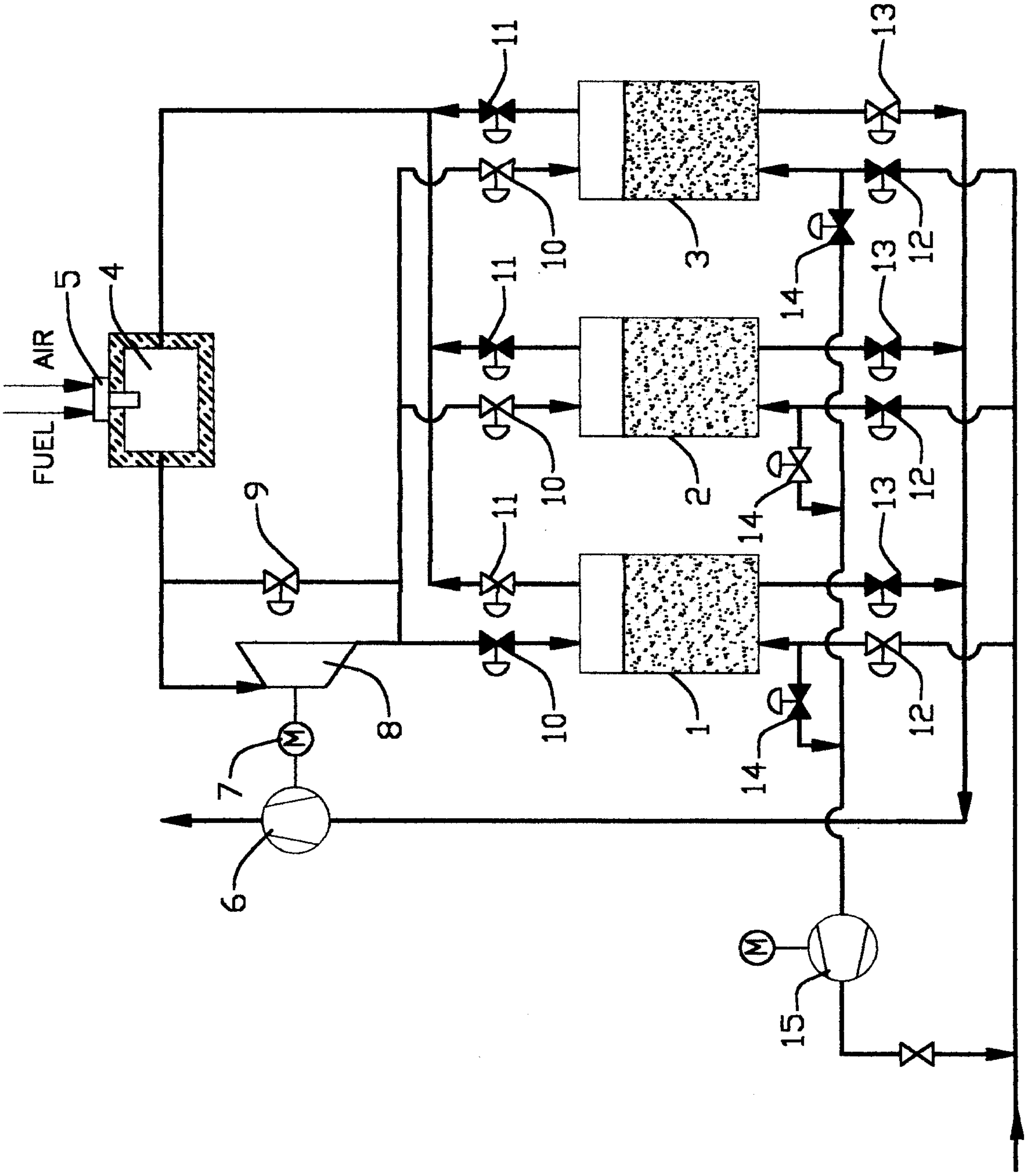


Fig. 7

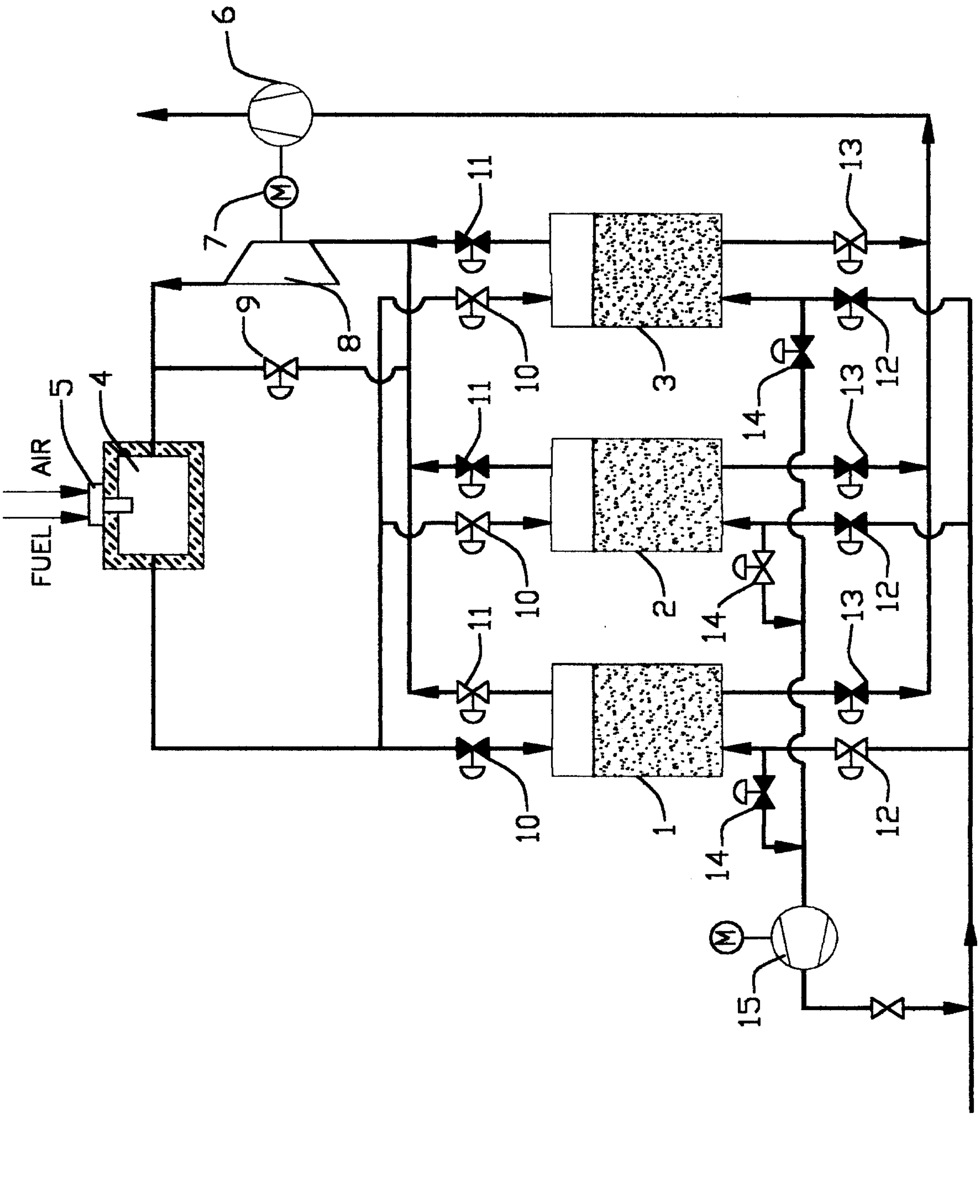


Fig. 8

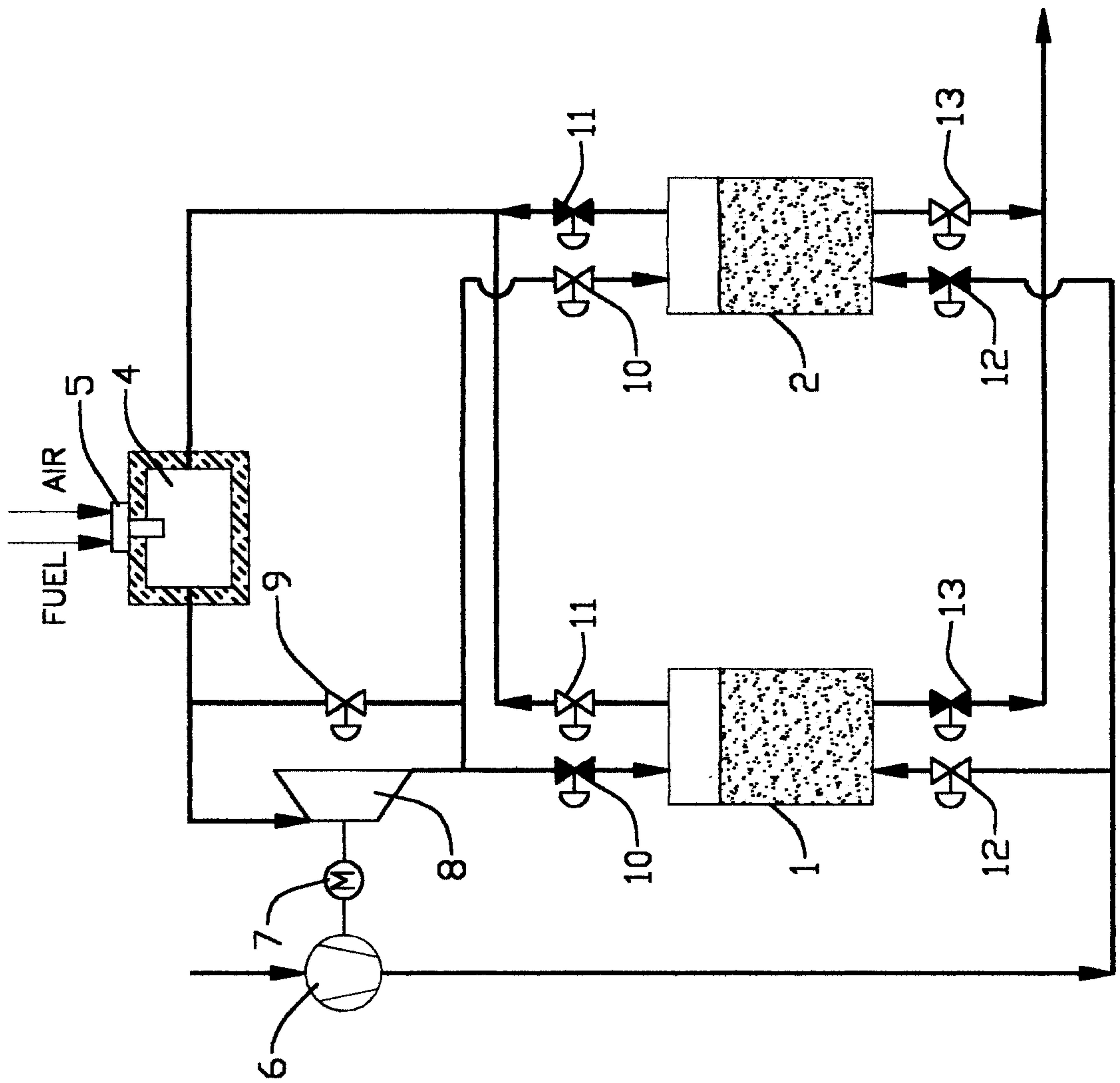


Fig. 9

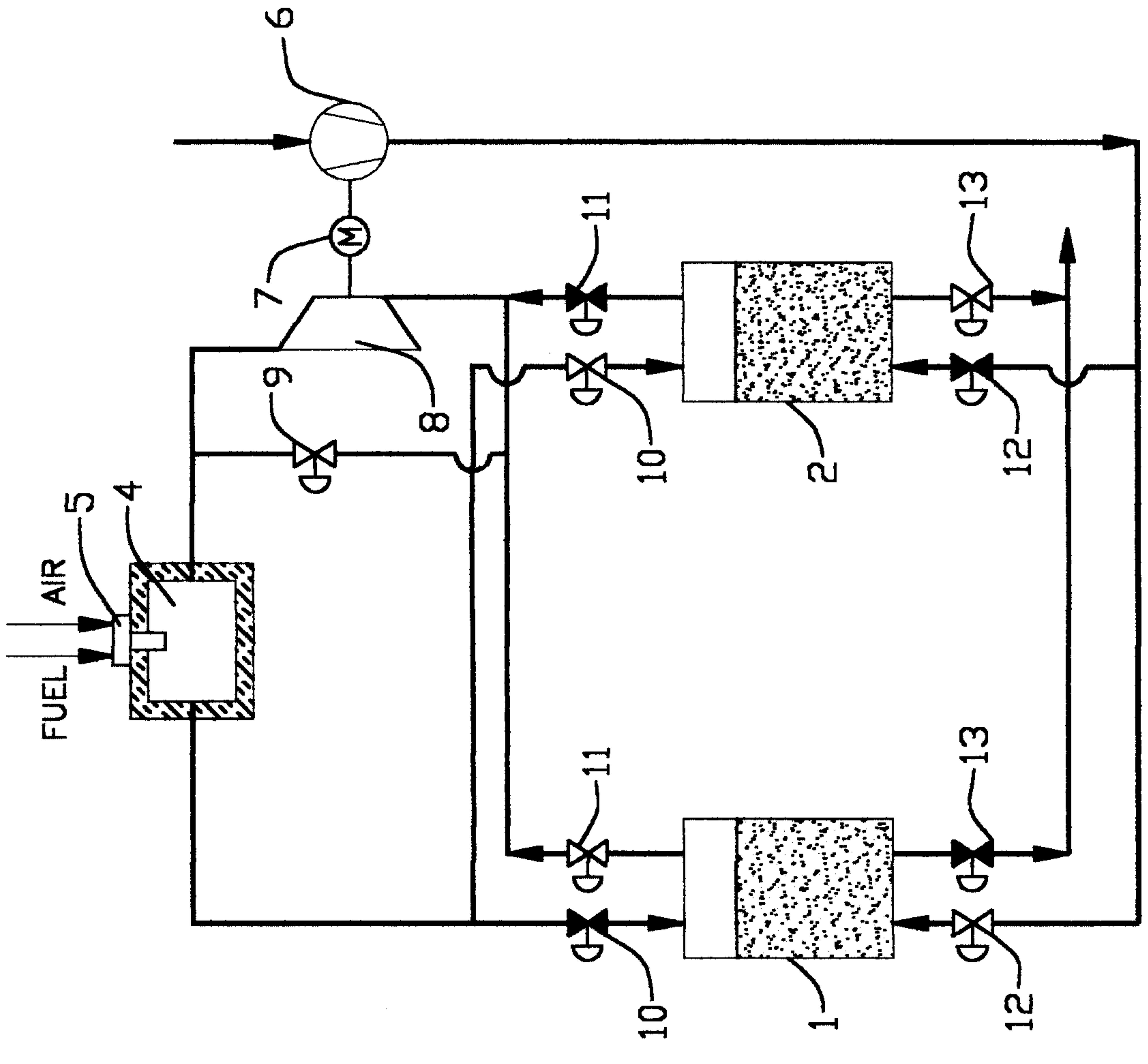


Fig. 10

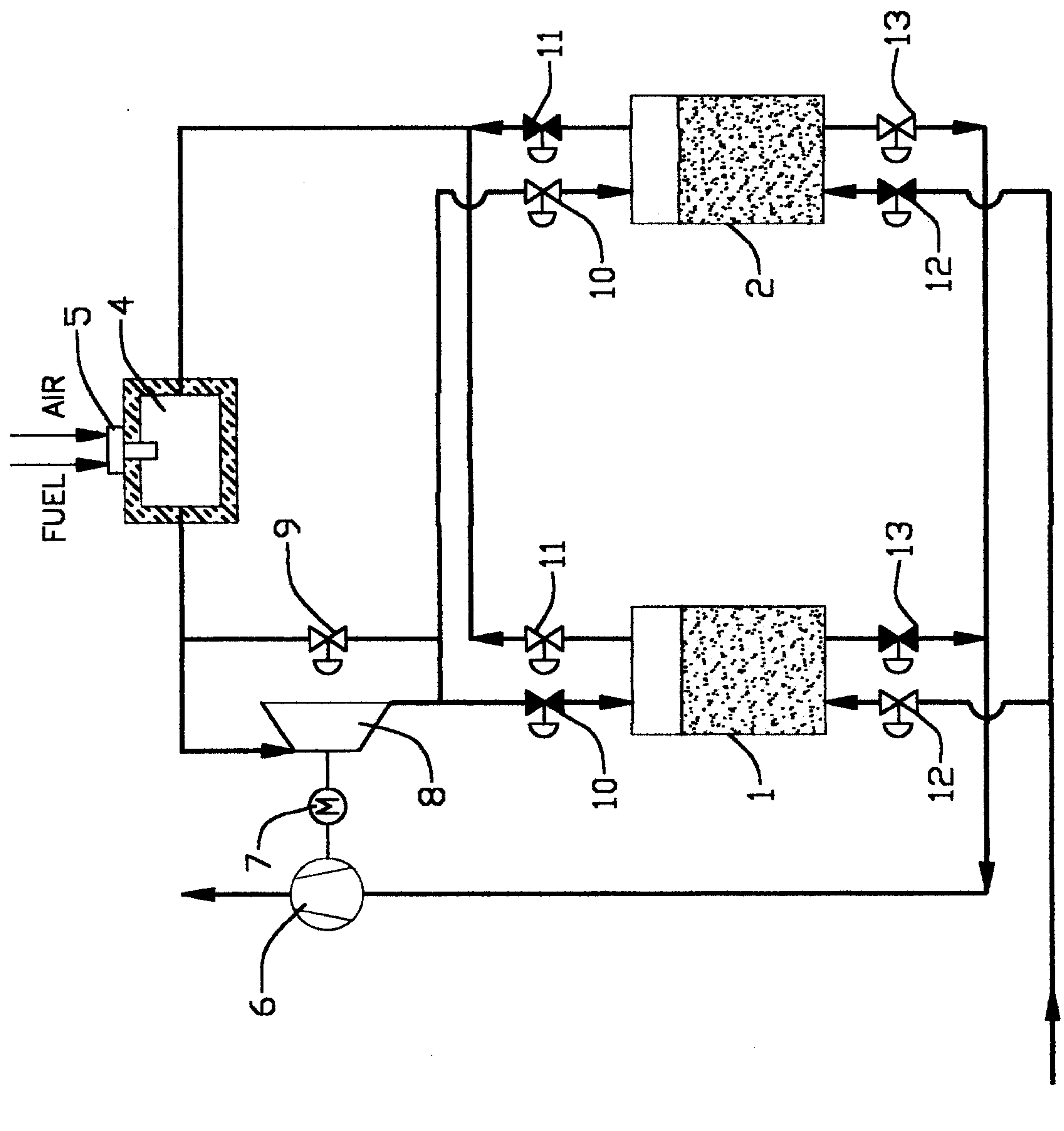


Fig. 11

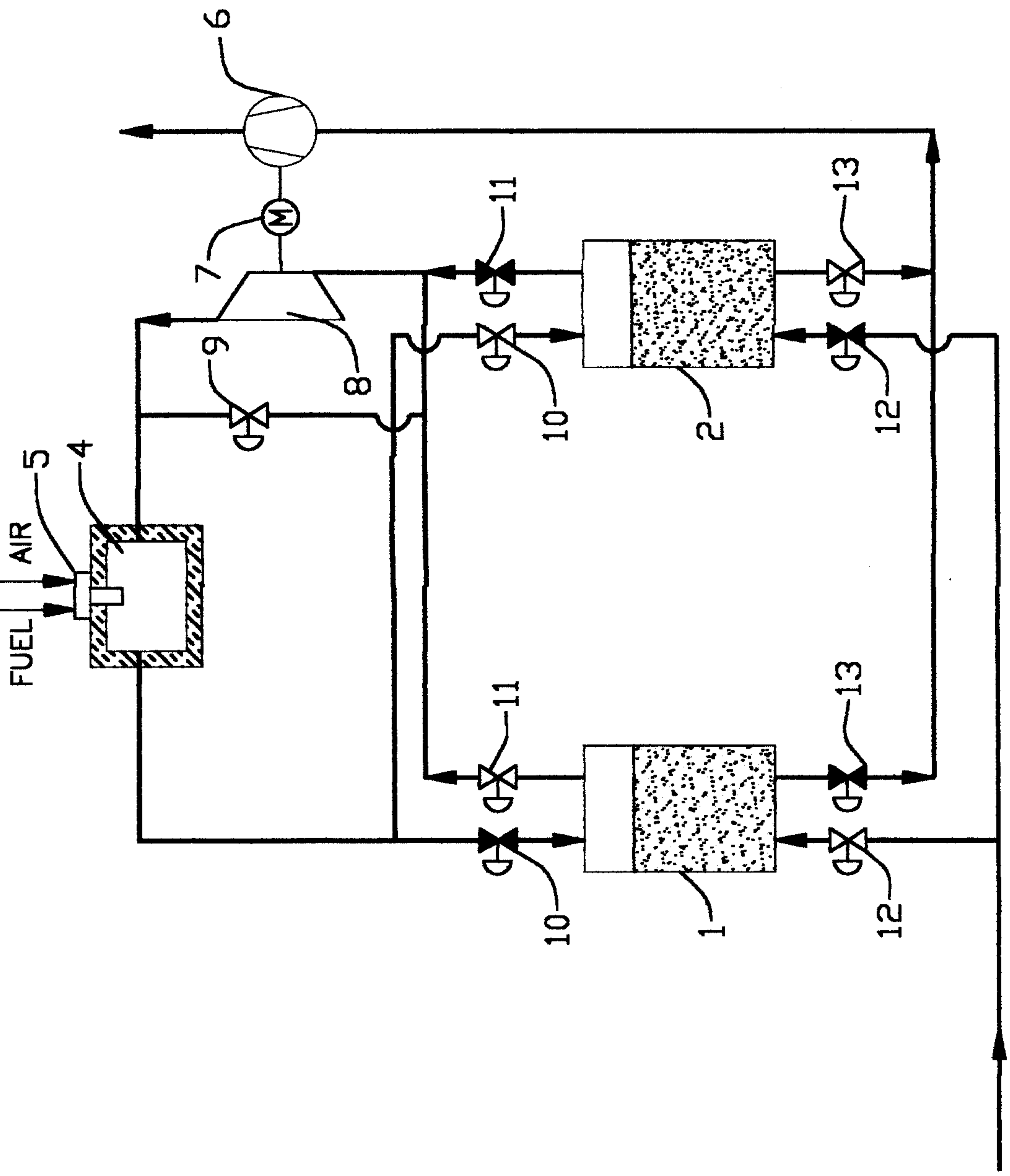


Fig. 12

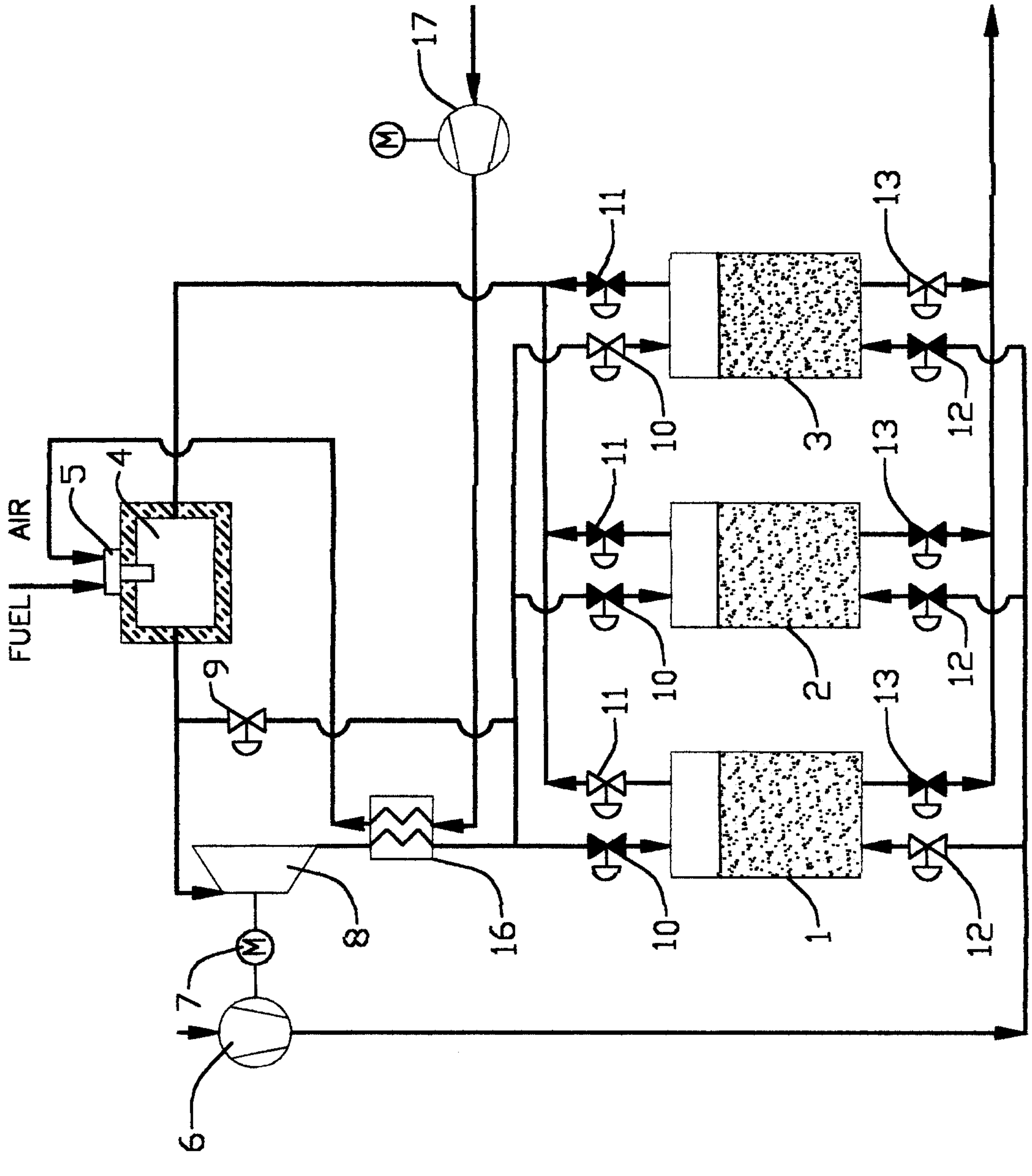


Fig. 13

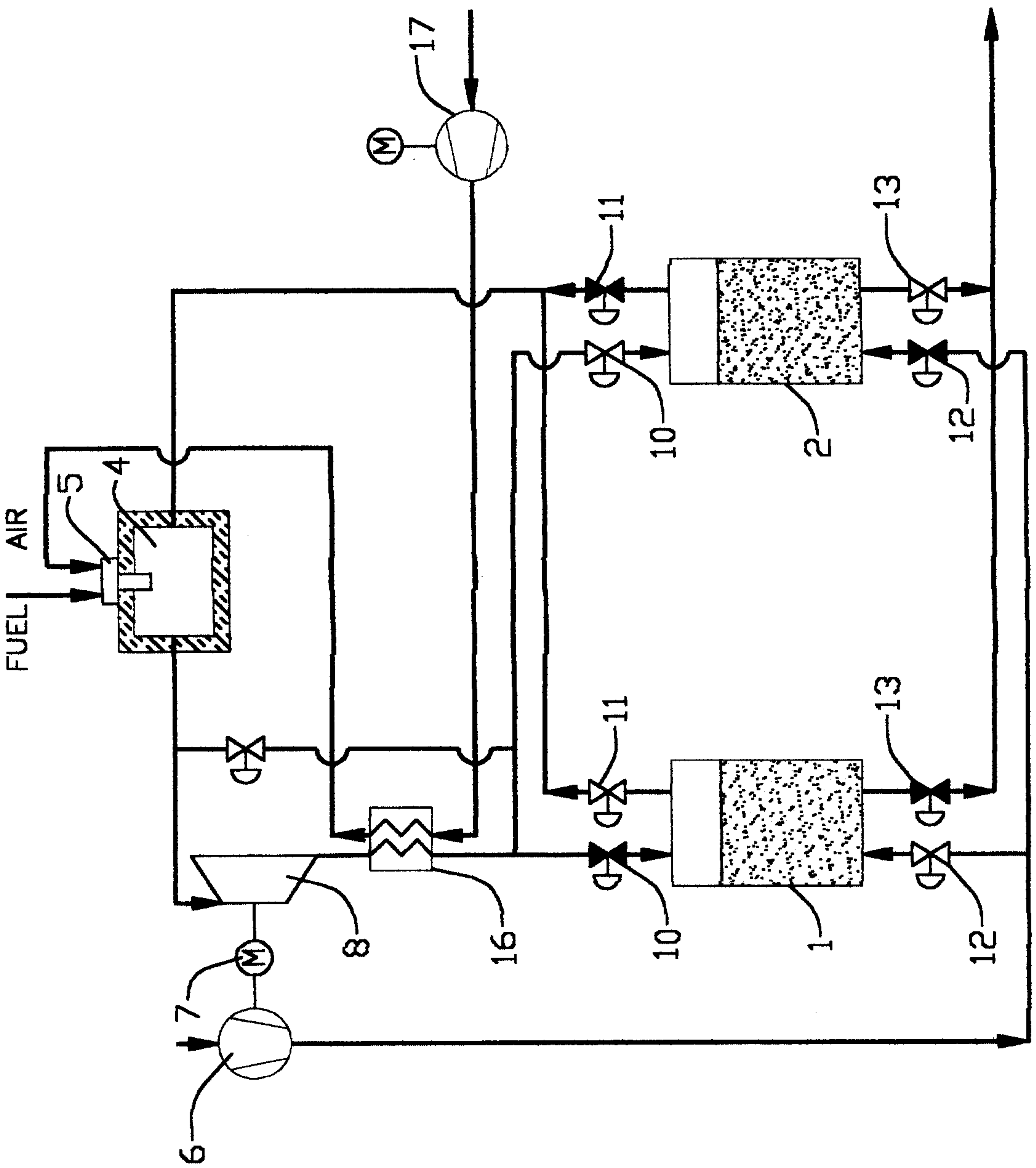


Fig. 14

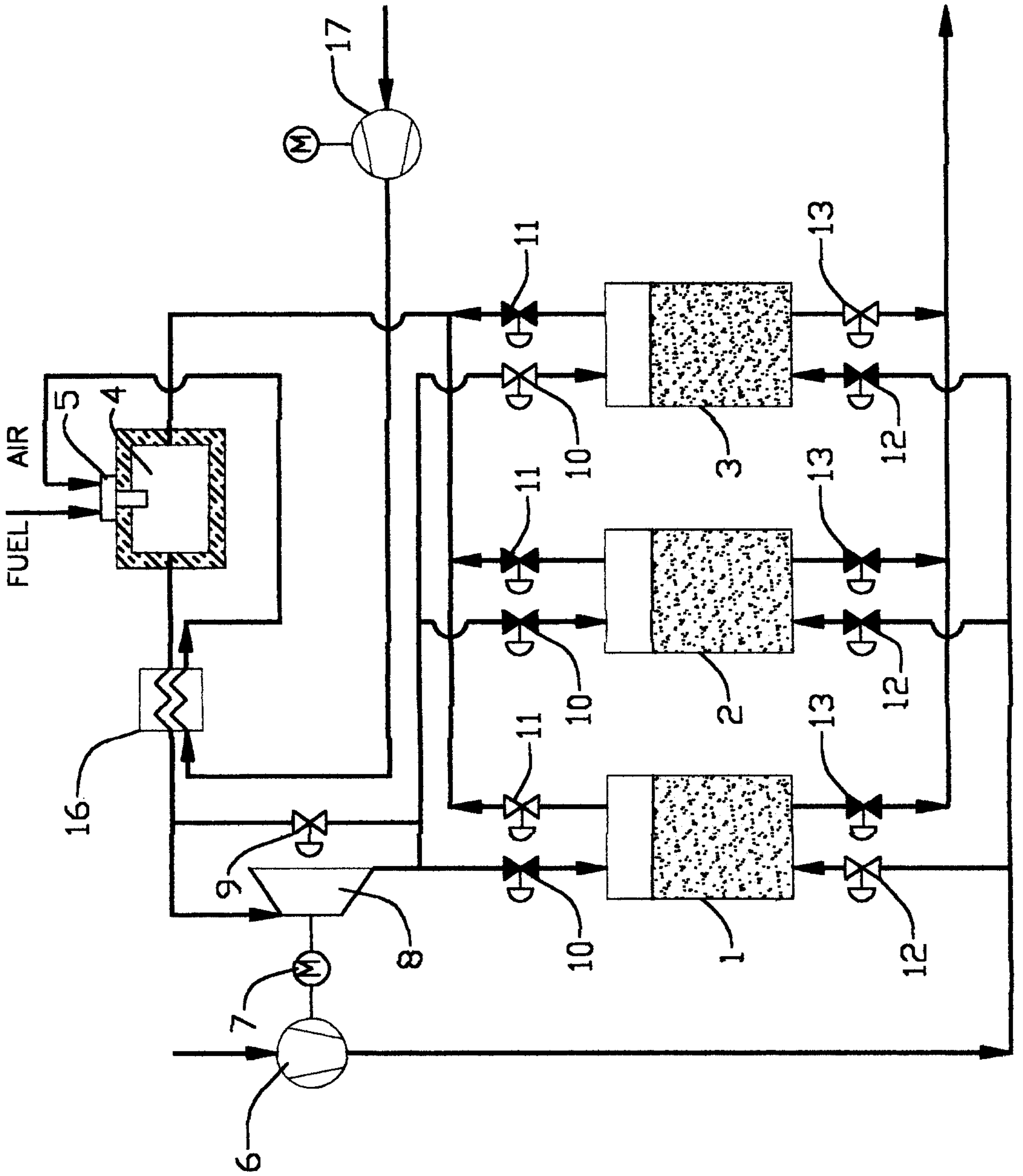


Fig. 15

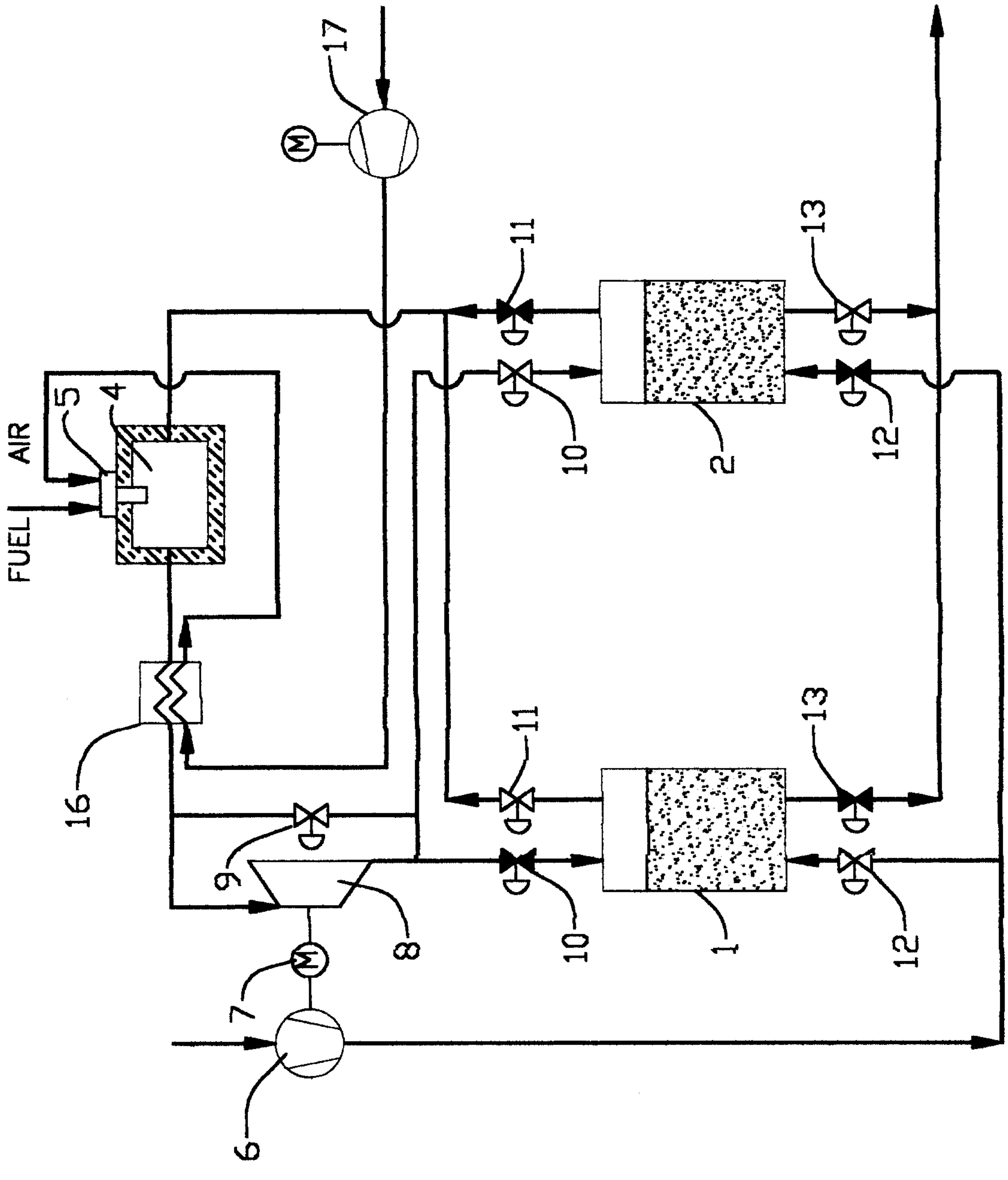


Fig. 16

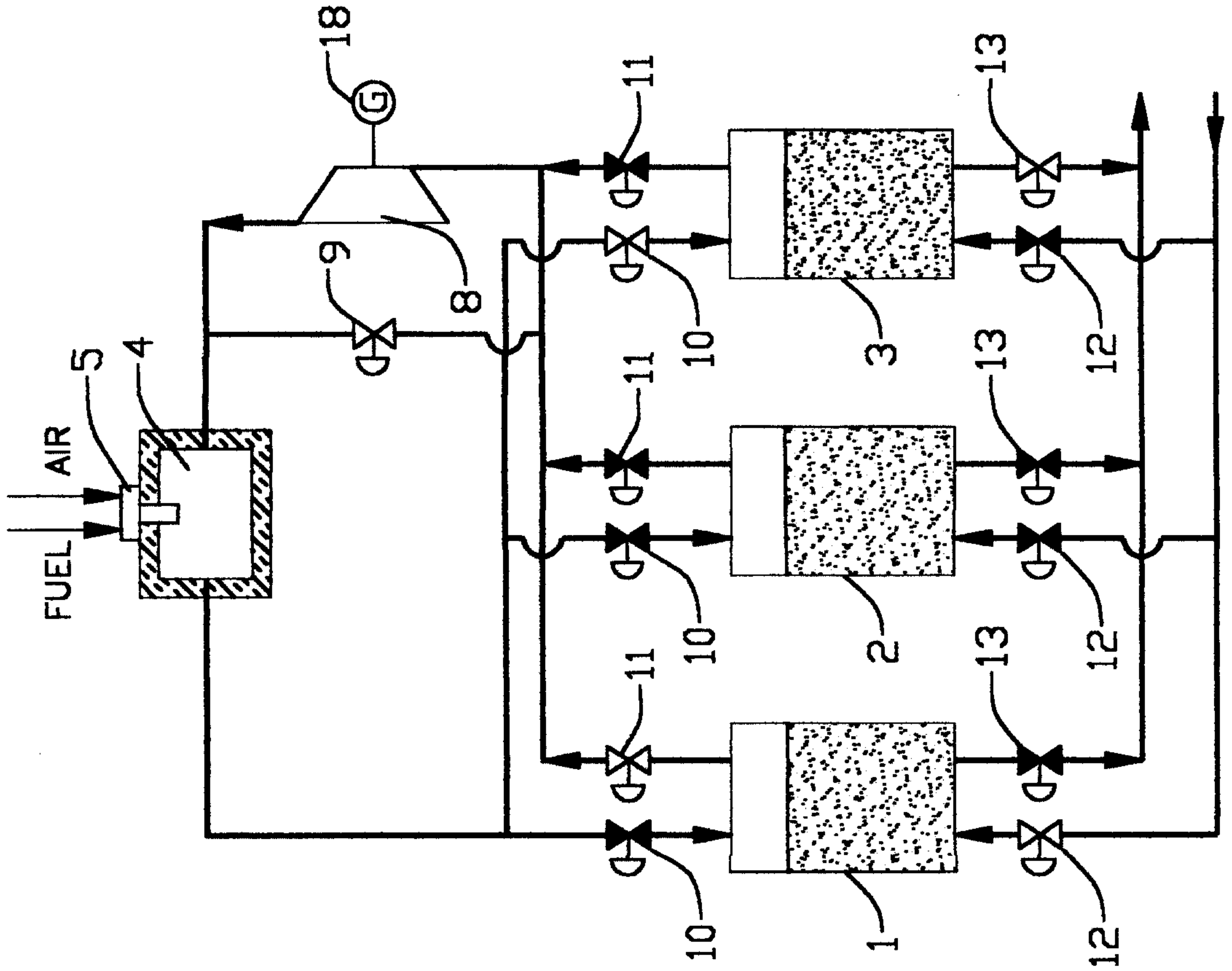


Fig. 17

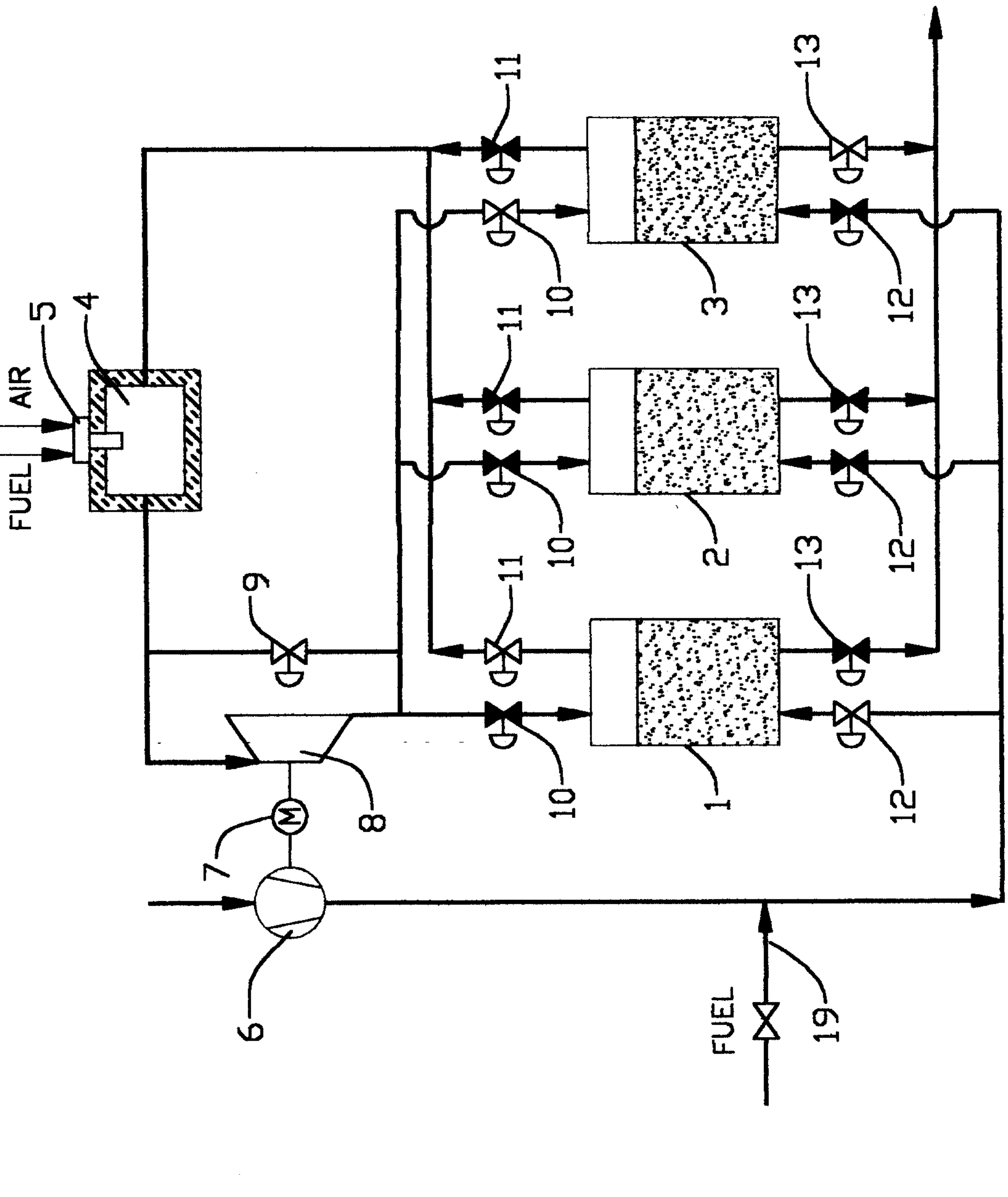
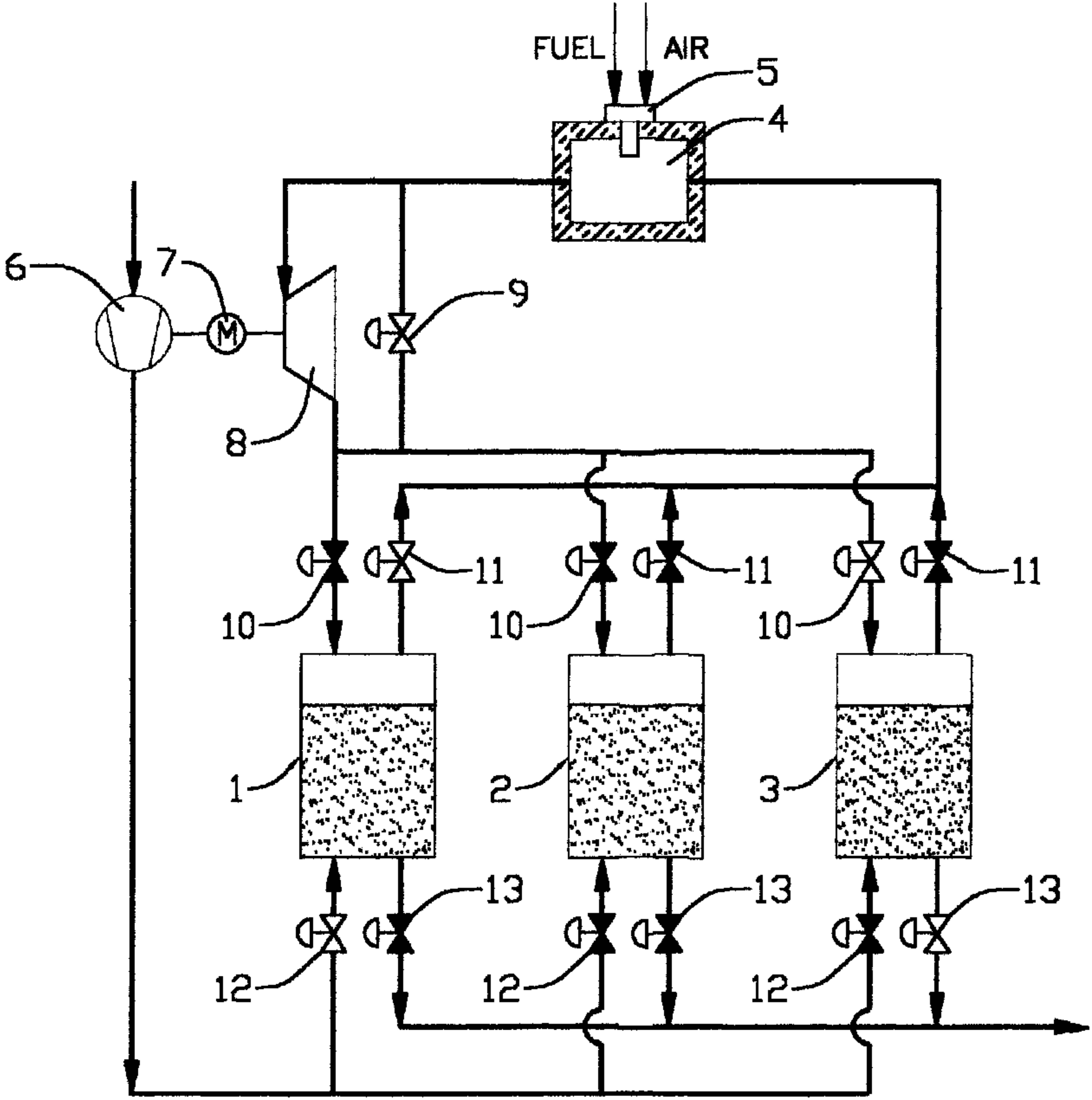


Fig. 18



FUEL
AIR
5
4
6
7
M
9
8
11
11
11
10
10
10
1
2
3
13
13
13
12
12
12