



(12) APPLICATION

(11) 20171112

(13) A1

NORWAY

(19) NO

(51) Int Cl.

F02B 19/10 (2006.01)

F02B 37/007 (2006.01)

F02B 43/00 (2006.01)

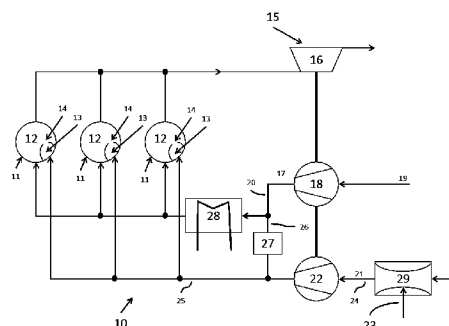
Norwegian Industrial Property Office

(21)	Application nr	20171112	(86)	Int. application day and application nr	
(22)	Application day	2017.07.06	(85)	Entry into national phase	
(24)	Date from which the industrial right has effect	2017.07.06	(30)	Priority	2016.07.08, DE, 10 2016 112 537
(41)	Available to the public	2018.01.09			
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(54) Title **Gas engine and method for operating the same**

(57) Abstract

A gas engine (10), with at least one cylinder (11), wherein the or each cylinder (11) comprises a main combustion chamber (12) for combusting a fuel gas-air mixture and a scavenged precombustion chamber (13) that is coupled to the main combustion chamber (12) via an overflow duct (14), and with at least one exhaust gas turbocharger (15), which comprises a turbine (16) for expansion of exhaust gas leaving the or each cylinder (11) and a compressor (18, 22) for compressing air to be fed to the or each cylinder (11), and with a plurality of air paths for air to be fed to the or each cylinder (11), wherein via a first air path (17) at least air can be compressed with a first compressor (18) and fed to the main combustion chamber (12) of the or each cylinder (11), and wherein via a second air path (21) a fuel gas-air mixture can be compressed with a second compressor (22) and fed to the precombustion chamber (13) of the or each cylinder (11).



Gas engine and method for operating the same

Field of invention

The invention relates to a gas engine and to a method for operating a gas engine.

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Background

Gas engines known from practice, which serve for combusting a gaseous fuel, comprise at least one cylinder, wherein in the cylinder(s) a fuel gas-air mixture is combusted. The cylinders of gas engine known from practice typically comprise a main
10 combustion chamber and a precombustion chamber that is coupled to the main combustion chamber via at least one overflow duct. It is known to feed a fuel gas-air mixture consisting of fuel gas and air to the main combustion chamber, wherein less fuel gas is fed to the precombustion chamber for scavenging. It is usual, furthermore, with gas engines known from practice to feed exhaust gas, which accrues during the
15 combustion of the fuel gas-air mixture in the cylinders of the gas engine, to one or more exhaust gas turbochargers, namely to a turbine of an exhaust gas turbocharger, wherein energy extracted during the expansion of the exhaust gas in the turbine is utilised in order to at least combust air, so-called charge air or combustion air, to be fed to the or each cylinder. With gas engines known from practice, the fuel gas can be
20 admixed to the compressed charge air either before or after the compressor via one or more admixing points.

There is increasingly a need for improving the efficiency of gas engines and reduce exhaust gas emissions.

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Summary

Starting out from this, the present invention is based on the object of creating a new type of gas engine and a method for operating a gas engine. This object is solved through a gas engine according to Claim 1. According to the invention, the gas engine
30 comprises a plurality of air paths for combustion air to be fed to the or each cylinder, wherein via a first air path at least air can be compressed with a first compressor and fed to the main combustion chamber of the or each cylinder, and wherein via a second air path a fuel gas-air mixture can be compressed with a second compressor and fed to the precombustion chamber of the or each cylinder.

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According to the invention, two air paths for combustion air are present, namely the first air path, via which compressed combustion air can be fed to the main combustion

chamber of the or each cylinder, and the second air path, via which a compressed fuel gas-air mixture can be fed to the precombustion chamber of the or each cylinder for scavenging. According to the invention, the scavenging of the precombustion chamber of the or each cylinder accordingly does not take place with pure fuel gas, but rather with a fuel gas-air mixture. Ignition conditions can thereby be improved and thus an optimised combustion of the fuel gas ensured, as a result of which on the one hand an efficiency improvement can be realised and on the other hand exhaust gas emissions reduced.

According to an advantageous further development, the first air path and the second air path are coupled via a non-return valve in such a manner that from the second air path a part of the fuel gas-air mixture compressed in the second compressor can be conducted into the first air path downstream of the first compressor. By way of this, the gas engine can be operated particularly advantageously.

Preferentially, the first compressor of the first air path compresses a fuel gas-air mixture and feeds the same to the main combustion chamber of the or each cylinder. The version, in which the first compressor also compresses a fuel gas-air mixture, is particularly preferred.

According to an advantageous further development, an exhaust gas recirculation interacts with the first air path but not with the second air path, wherein the exhaust gas recirculation branches off exhaust gas upstream of the turbine and downstream of the first compressor feeding it to the first air path and/or downstream of the turbine branches of exhaust gas and feeding it to the first air path upstream of the first compressor. Advantages of both of the air paths take effect in particular when the gas engine utilises an exhaust gas recirculation. The higher the so-called exhaust gas recirculation is the more intensively will the effect of the advantage of the mixture-scavenged precombustion chamber of the respective cylinder be with respect to an efficiency improvement and reduction of exhaust gas emissions. By scavenging the precombustion chambers with a fuel gas-air mixture, a significantly improved homogeneity can be realised in the precombustion chamber, thus an accelerated pressure combustion and a significantly lower soot development during the combustion in particular in gas engines with exhaust gas recirculation. Less deposits of soot form in the precombustion chamber and on an ignition device, which serves for the ignition of the fuel gas-air mixture.

- Preferentially, a further compressor is assigned to the second air path downstream of the second compressor, wherein the further compressor in the second air path is arranged downstream of the second compressor, and wherein a coupling line of the first and second air path comprising the non-return valve branches off from the second air path in the direction of the first air path between the second compressor and the further compressor. Via the further compressor, it can be ensured that the pressure of the fuel gas-air mixture in the second air path always is above the pressure in the precombustion chamber of the respective cylinder, so that the precombustion chamber of the respective cylinder can always be securely scavenged with the fuel gas-air mixture. Utilising the further compressor is advantageous in particular when this pressure cannot always be maintained or adjusted via the second compressor. In this case, the corresponding pressure for the fuel gas-air mixture can then be adjusted in the second air path via a preferentially electromotorically driven further compressor.
- 15 The first compressor and the second compressor are jointly driveable starting out from a common turbine or starting out from separate turbines. In particular, when the first compressor and the second compressor can be driven by a common turbine, the expenditure in terms of devices can be reduced.
- 20 The method for operating a gas engine is defined in Claim 11.

Brief description of the drawing

- Preferred further developments of the invention are obtained from the subclaims and the following description. Exemplary embodiments of the invention are explained in more detail by way of the drawing without being restricted to this. There it shows:

- Fig. 1: a first gas engine according to the invention;
Fig. 2: a second gas engine according to the invention;
Fig. 3: a third gas engine according to the invention; and
30 Fig. 4: a fourth gas engine according to the invention.

Detailed description

- The invention present here relates to a gas engine and to a method for operating such a gas engine.

- 35 Fig. 1 shows highly schematically a diagram of a first gas engine 10 according to the invention, which comprises a plurality of cylinders 11. Each of the cylinders 11

comprises a main combustion chamber 12 and a precombustion chamber 13, wherein the precombustion chamber 13 is coupled to the main combustion chamber 12 of the respective cylinder 11 via an overflow duct 14.

5 In the cylinders 11 of the gas engine 10, namely in the region of the main combustion chambers 12 of the cylinders 11, a mixture of fuel gas and air is combusted, wherein exhaust gas created in the process is conducted via an exhaust gas turbocharger 15, namely a turbine 16 of the exhaust gas turbocharger 15. Energy extracted in the process in the region of the turbine 16 of the exhaust gas turbocharger 15 is utilised
10 for compressing combustion air, which is then fed to the cylinders 11 of the gas engine 10 as compressed combustion air or charge air.

The gas engine 10 according to the invention comprises a plurality of air paths for the combustion air, wherein via a first air path 17 with a first compressor 18 at least air 19
15 is compressed and fed to the main combustion chamber 12 of the respective cylinder 11 as compressed charge air 20, and wherein via a second air path 21 air 19 and fuel gas 23 is compressed in the form of a fuel gas-air mixture 24 in a second compressor 22 and fed to the precombustion chambers 13 of the cylinders 11 as compressed fuel gas-air mixture 25.

20 By scavenging the precombustion chambers 13 of the cylinders 11 of the gas engine 10 with the fuel gas-air mixture 25, better ignition conditions can be provided so that an improved combustion and thus an efficiency improvement materialises. Furthermore, lower exhaust gas emissions can be ensured.

25 The first air path 17 and the second air path 21 are connected or coupled via a coupling line 26 to a non-return valve 27 connected in the coupling line 26 namely in such a manner that starting out from the second air path 21 a part of the fuel gas-air mixture 25 compressed in the second compressor 22 can be conducted into the first
30 air path 17 downstream of the first compressor 18, whereas an overflowing from the first air path 17 into the second air path 21 is excluded.

In the exemplary embodiment of Fig. 1, both compressors 18, 22 of the two air paths 17, 21 can be driven from the common turbine 16.

35 From Fig. 1 it is evident that a charge air cooler 28 is integrated in the first air path 17 downstream of the coupling line 26 and thus downstream of the first compressor 18.

The provision of the fuel gas-air mixture 24 to be compressed in the second compressor 22 of the second air path 21 is effected via a mixing device 29 which mixes fuel gas 23 with combustion gas 19, wherein this mixing device 29 can preferentially be a Venturi nozzle.

Fig. 2 shows a further development of the gas engine 10 of Fig. 2, wherein for avoiding unnecessary repetitions same reference numbers as in the exemplary embodiment of Fig. 1 are used for the exemplary embodiment of Fig. 2 and only such details, by which the exemplary embodiment of Fig. 2 differs from the exemplary embodiment of Fig. 1, are discussed in the following.

Those optional however preferred further developments shown by Fig. 2 can be employed on the gas engine 10 of Fig. 1 either alone or in any combination.

In the case of the gas engine 10 of Fig. 2, the first compressor 18 of the first air path 17 does not serve exclusively for compressing combustion air 19 but for compressing the combustion air 19 and the fuel gas 23, wherein a corresponding fuel gas-air mixture 30 is provided by a mixing device 31, which in turn is preferentially embodied as Venturi nozzle. Then, a compressed fuel gas-air mixture 30' is then present downstream of the first compressor.

Furthermore it is provided with the gas engine 10 of Fig. 2 that the same utilises at least one exhaust gas recirculation, wherein via a first exhaust gas recirculation 32 exhaust gas can be branched off upstream of the turbine 16 and conducted downstream of the first compressor 18 in the direction of the first air path 17 and mixed with the compressed fuel gas-air mixture 30' upstream of the first compressor 18. Alternatively or additionally, exhaust gas can be branched off downstream of the turbine 16 via a second exhaust gas recirculation 33 and mixed with the fuel gas-air mixture 30 upstream of the first compressor 18. In this case, the first compressor 18 then compresses a mixture of exhaust gas, fuel gas and charge air. The exhaust gas recirculation 32 utilises a control device 34 and the exhaust gas recirculation 33 utilises a control device 35 in order to adjust the quantity of the recirculated exhaust gas. The control devices 34, 35 are typically exhaust gas recirculation flaps. Downstream of the control device 35, a heat exchanger 36 is integrated in the exhaust gas recirculation 33 in order to cool the recirculated exhaust gas.

A further distinction of the gas engine 10 of Fig. 2 from the gas engine 10 of Fig. 1 consists in that in the second air path 21 downstream of the second compressor 22 a further compressor 37 is integrated, wherein the coupling line 26, via which the two air paths 17, 21 are coupled, branches off the second air path 21 between the two compressors 22, 37 of the second air path 21 and leads in the direction of the first air path 17. This further compressor 37 can be utilised for the further compression of the fuel-air mixture 25 in order to always ensure a pressure level which ensures a secure scavenging of the precombustion chambers 13 with the fuel gas-air mixture. The pressure of the fuel gas-air mixture in the second air path 21 is always above the precombustion chamber pressure. Preferentially it is provided to this end that the pressure downstream of the second compressor 22 in the second air path 21 is greater than the pressure downstream of the first compressor 18 in the first air path 17. This can be ensured via a suitable configuration of the compressors 18, 22. Alternatively or additionally via the further compressor 37 which is preferentially electromotorically driven.

A further version of the invention is shown by Fig. 3, wherein in Fig. 3 a gas engine 10 is shown, which comprises two exhaust gas turbochargers 15 and thus two turbines 16. Exhaust gas from cylinders 11 of a first cylinder group is conducted via the exhaust gas turbocharger 15 or the turbine 16 of that exhaust gas turbocharger 15 which drives the first compressor 18 of the first air path 17, whereas exhaust gas from cylinders 11 of a second cylinder group of the turbine 16 is fed to that exhaust gas turbocharger 15 which drives the second compressor 19 of the second air path 21. Accordingly, in the exemplary embodiment of Fig. 3, the two compressors 18, 22, in contrast with the exemplary embodiment of Fig. 1, are driven by separate turbines 16. With respect to all remaining details however the exemplary embodiment of Fig. 3 corresponds to the exemplary embodiment of Fig. 1 so that again for avoiding unnecessary repetitions reference to the explanations regarding the exemplary embodiment of Fig. 1 is made.

Fig. 4, which shows a further exemplary embodiment of a gas engine 10 according to the invention, illustrates that the further developments described in connection with Fig. 2 can also be utilised with the gas engine 10 of Fig. 3, the compressors 18, 22 of which are driven by separate turbines 16, i.e. the compression of the fuel gas-air mixture 30 in the first compressor 18 of the first air path 17 and/or the utilisation of the exhaust gas recirculation 32 in the first air path 17 and/or the utilisation of the exhaust gas recirculation 33 in the first air path 17 and/or the utilisation of the further compressors 32 in the second air path 21. With respect to these details, reference is

made to the explanations regarding the exemplary embodiment of Fig. 2 for the exemplary embodiment of Fig. 4.

All exemplary embodiments of Fig. 1 to 4 have in common that the gas engine 10
5 utilises two air paths 17, 21 with separate compressors 18, 22, wherein in the first air path 17 at least combustion air 19 is mixed with exhaust gas if applicable and/or fuel gas is compressed, whereas in the second air path 21 air 19 is always compressed with fuel gas 23 in order to scavenge precombustion chambers 13 of the cylinders 11 with a fuel gas-air mixture.

10 In particular when the gas engine 10 is to be operated as lean engine with a lambda value greater than 1, exclusively air 19 is preferentially compressed in the first air path 17, whereas in the second air path 21 the mixture 24 of air 19 and fuel gas 23 is compressed.

15 In particular when the gas engine 10 is to be preferentially operated as stoichiometric lean engine with a lambda value of approximately 1, the exhaust gas recirculation 32 and/or the exhaust gas recirculation 33 is utilised in the first air path 17 in order to then supply the main combustion chambers 12 of the cylinders 11 with a mixture of
20 combustion air 19 and exhaust gas via the first air path 17.

In particular when the gas engine 10 is to be utilised as stoichiometric gas engine with a lambda value of approximately 1 combined with a three-way catalytic converter, preferentially air 19, fuel gas 23 and exhaust gas is conducted via the first air path 17,
25 preferentially, as shown in Fig. 4, in such a manner that in the first compressor 18 of the first air path 17 the mixture 30 of fuel gas 23 and combustion air 19 is mixed and that exhaust gas is fed to the mixture 30 and/or 30' either via the exhaust gas recirculation 32 downstream of the first compressor 18 and/or via the exhaust gas recirculation 33 upstream of the first compressor 18.

30 With gas engines, the invention allows an increase of the thermodynamic efficiency, an improved combustion in the main combustion chambers of the cylinders, lower exhaust gas emissions, lower soot formation and the reduction of soot deposits in the region of the precombustion chambers and in the region of ignition devices assigned to
35 the precombustion chambers, which serve for remote ignition in the region of the precombustion chambers. Preferentially, gas engines with exhaust gas recirculation

are employed in particular stoichiometric gas engines with exhaust gas recirculation and three-way catalytic converter.

List of reference numbers

	10	Gas engine
	11	Cylinder
5	12	Main combustion chamber
	13	Precombustion chamber
	14	Overflow duct
	15	Exhaust gas turbocharger
	16	Turbine
10	17	First air path
	18	Compressor
	19	Air
	20	Compressed air
	21	Second air path
15	22	Compressor
	23	Fuel gas
	24	Fuel gas-air mixture
	25	compressed fuel gas-air mixture
	26	Coupling line
20	27	Non-return valve
	28	Charge air cooler
	29	Mixing device
	30	Fuel gas-air mixture
	31	Mixing device
25	32	Exhaust gas recirculation
	33	Exhaust gas recirculation
	34	Regulating device
	35	Regulating device
	36	Heat exchanger
30	37	Compressor

PATENT CLAIMS

1. A gas engine (10), with at least one cylinder (11), wherein the or each cylinder (11) comprises a main combustion chamber (12) for combusting a fuel-gas air mixture and a scavenged precombustion chamber (13) which is coupled to the main combustion chamber (12) via an overflow duct (14), and with at least one exhaust gas turbocharger (15), which comprises a turbine (16) for expansion of exhaust gas leaving the or each cylinder (11) and a compressor (18, 22) for compressing air to be fed to the or each cylinder (11), characterized by a plurality of air paths for the air to be fed to the or each cylinder (11), wherein via a first air path (17) air can be compressed with a first compressor (18) and fed to the main combustion chamber (12) of the or each cylinder (11), and wherein via a second air path (21) a fuel gas-air mixture can be compressed with a second compressor (22) and fed to the precombustion chamber (13) of the or each cylinder (11).
2. The gas engine according to Claim 1, characterized in that the first air path (17) and the second air path (21) are coupled via a non-return valve (27) in such a manner that from the second air path (21) a part of the fuel gas-air mixture compressed in the second compressor (22) can be conducted into the first air path (17) downstream of the first compressor (18).
3. The gas engine according to Claim 1 or 2, characterized in that the first compressor (18) of the first air path (17) compresses a fuel gas-air mixture feeding it to the main combustion chamber (12) of the or each cylinder (11).
4. The gas engine according to any one of the Claims 1 to 3, characterized in that an exhaust gas recirculation (32, 33) interacts with the first air path (17) but not with the second air path (21).
5. The gas engine according to Claim 4, characterized in that the exhaust gas recirculation (32) branches off exhaust gas upstream of the turbine (16), feeding the same to the first air path (17) downstream of the first compressor (18).

6. The gas engine according to Claim 4 or 5, characterized in that the exhaust gas recirculation (33) branches off exhaust gas downstream of the turbine (16), feeding it to the first air path (17) upstream of the first compressor (18).
- 5 7. The gas engine according to any one of the Claims 1 to 6, characterized in that the second air path (21) is assigned a further compressor (37) downstream of the second compressor (22).
- 10 8. The gas engine according to Claim 2 and 7, characterized in that the further compressor (37) in the second air path (21) is arranged downstream of the second compressor (22), wherein a coupling line (26) of the first and second air path (17, 21) comprising the non-return valve (27) branches off the second air path (21) in the direction of the first air path (19) between the second compressor (22) and the further compressor (37).
- 15 9. The gas engine according to any one of the Claims 1 to 8, characterized in that the first compressor (18) and the second compressor (22) can be jointly driven starting out from a common turbine (16).
- 20 10. The gas engine according to any one of the Claims 1 to 8, characterized in that the first compressor (18) and the second compressor (22) can be driven starting out from separate turbines (16).
- 25 11. A method for operating a gas engine (10), in particular a gas engine according to any one of the Claims 1 to 10, wherein the gas engine (10) comprises at least one cylinder (11), wherein the or each cylinder (11) comprises a main combustion chamber (12) for combusting a fuel gas-air mixture and a scavenged precombustion chamber (13), and wherein the gas engine (10) comprises at least one exhaust gas turbocharger (15), which comprises a turbine (16) for expansion of the exhaust gas leaving the or each cylinder (11) and a compressor (18, 22) for compressing air to be fed to the or each cylinder (11), characterized in that via a first air path (17) at least air is compressed with a first compressor (18) and fed to the main combustion chamber (12) of the or each cylinder (11), and in that via a second air path (21) a fuel gas-air mixture is
30 compressed with a second compressor (22) and fed to the precombustion chamber (13) of the or each cylinder (11).
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12. The method according to Claim 11, characterized in that from the second air path (21) a part of the fuel gas-air mixture compressed in the second compressor (22) is conducted into the first air path (17) downstream of the first compressor (18).

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13. The method according to Claim 11 or 12, characterized in that in the first compressor (18) of the first air path (17) a fuel gas-air mixture is compressed.

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14. The method according to any one of the Claims 11 to 13, characterized in that exhaust gas is fed to the first air path (17) but not to the second air path (21) via an exhaust gas recirculation (32, 33).

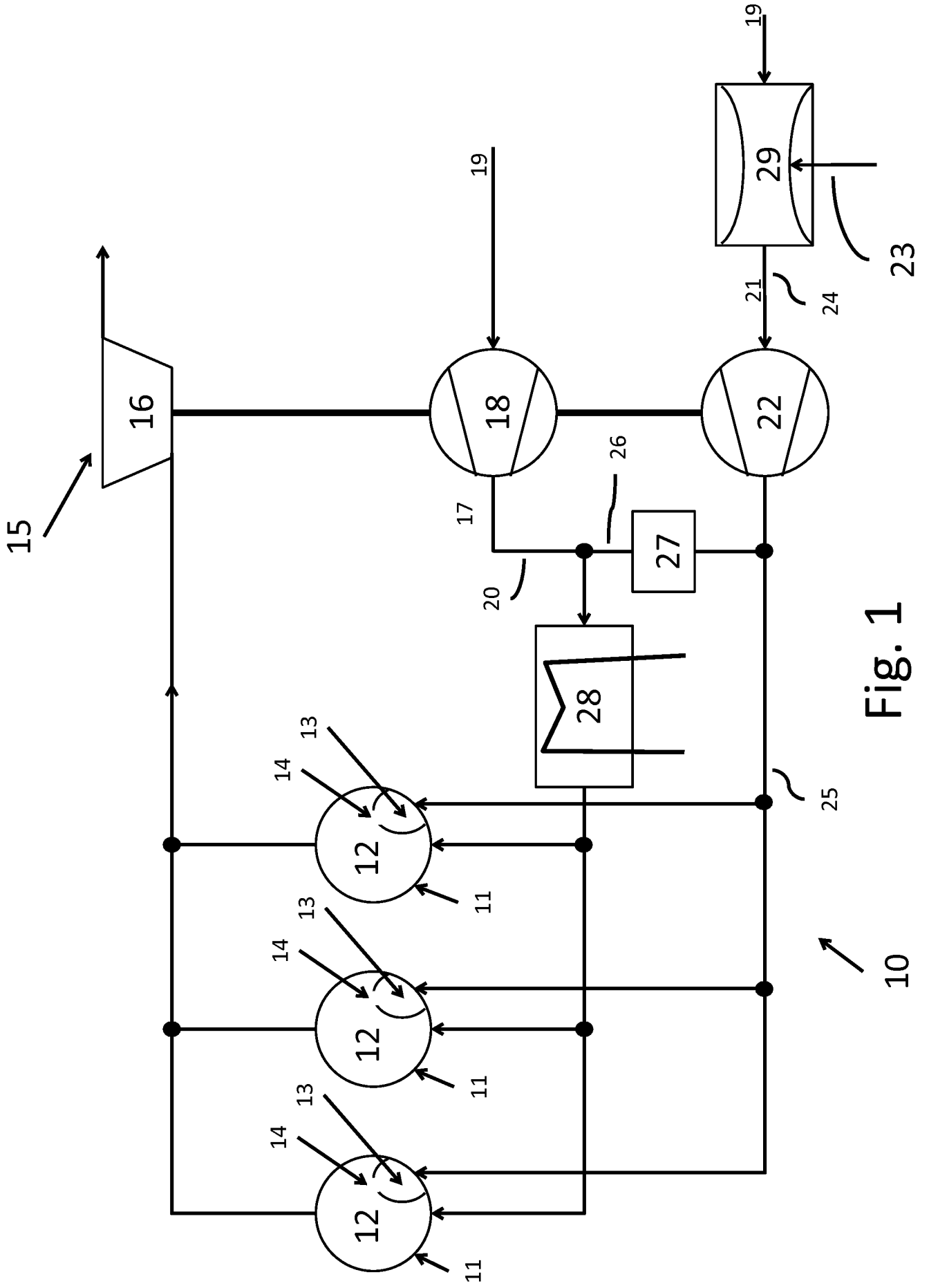


Fig. 1

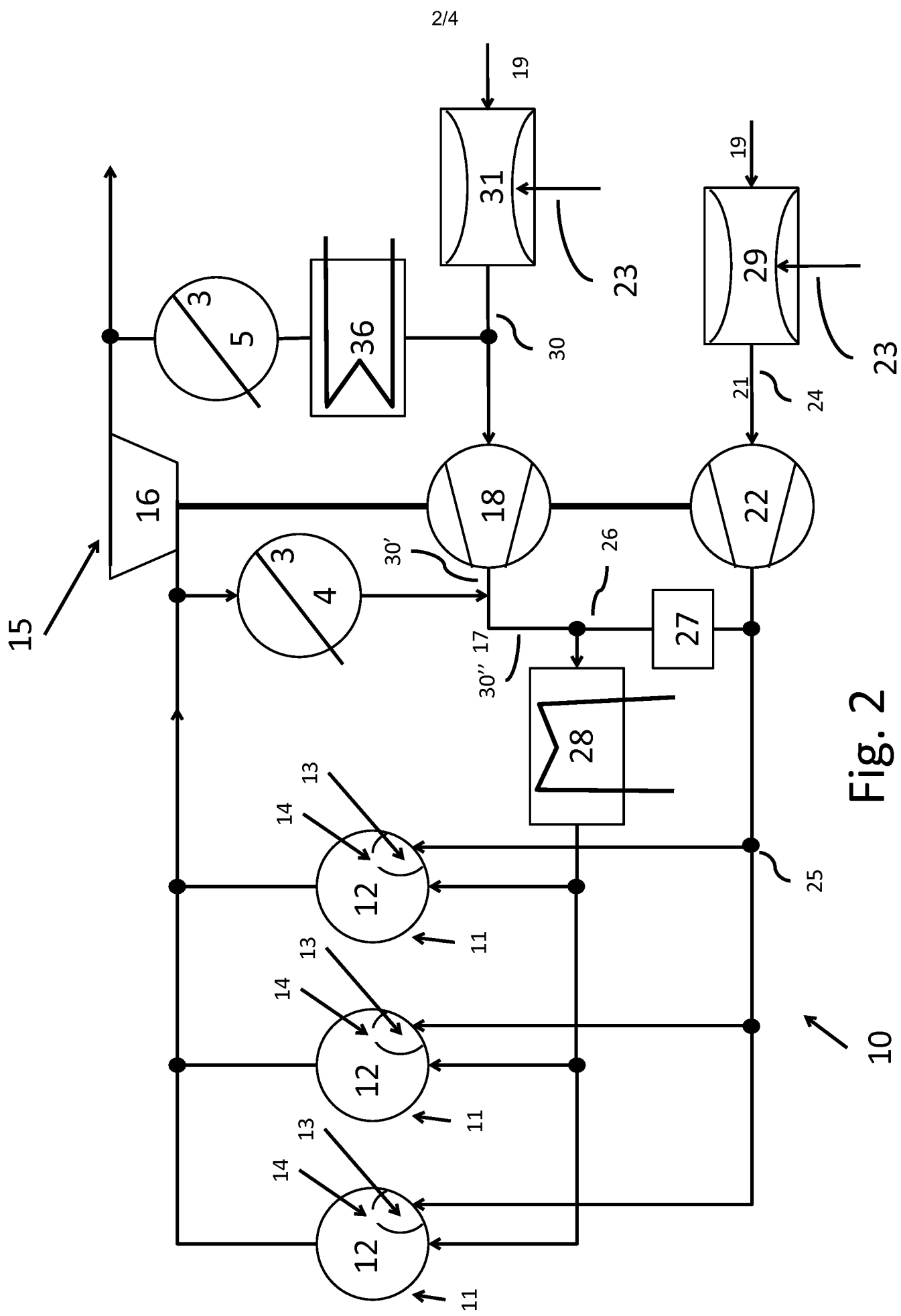
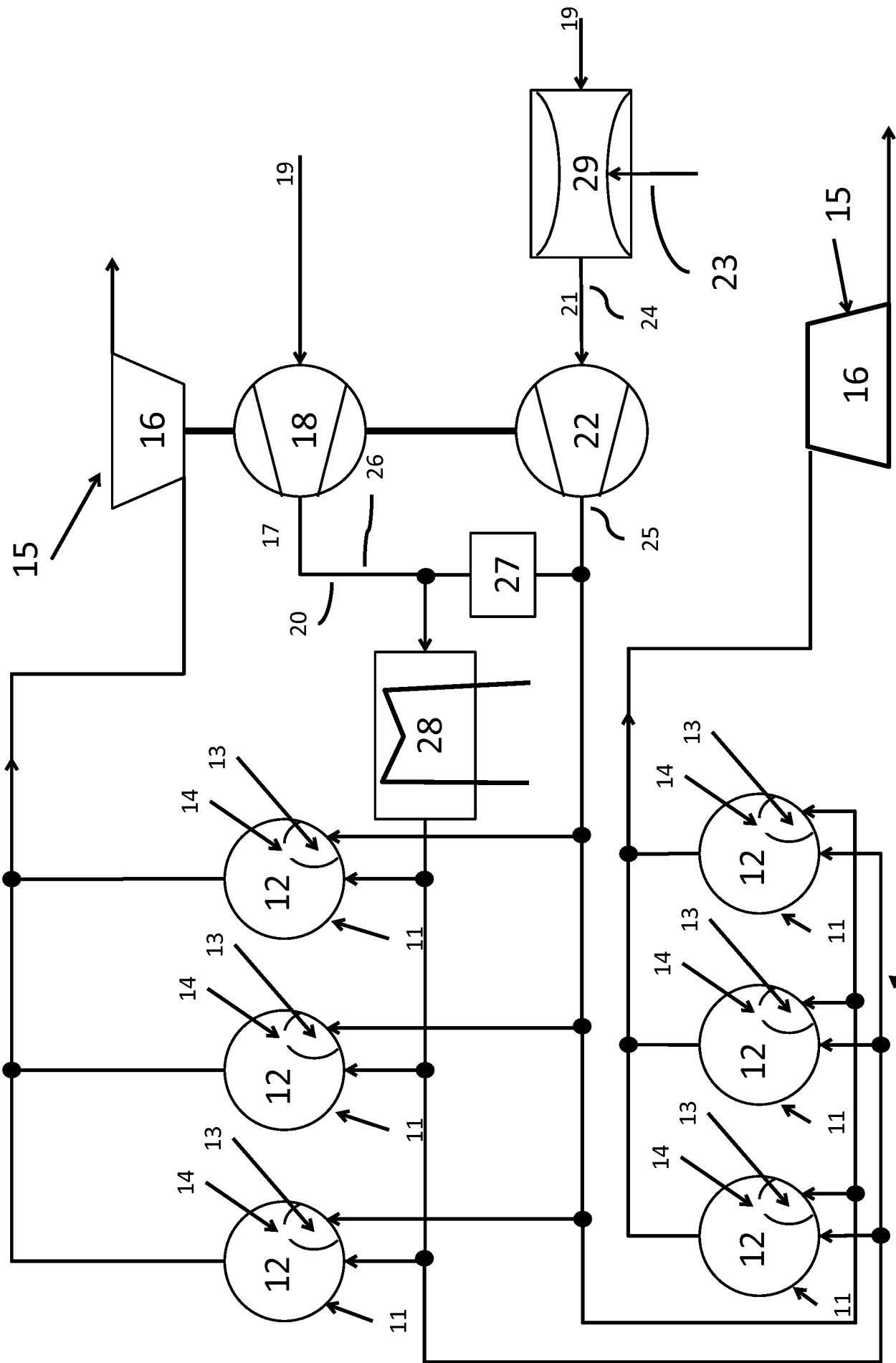


Fig. 2



Fi 3

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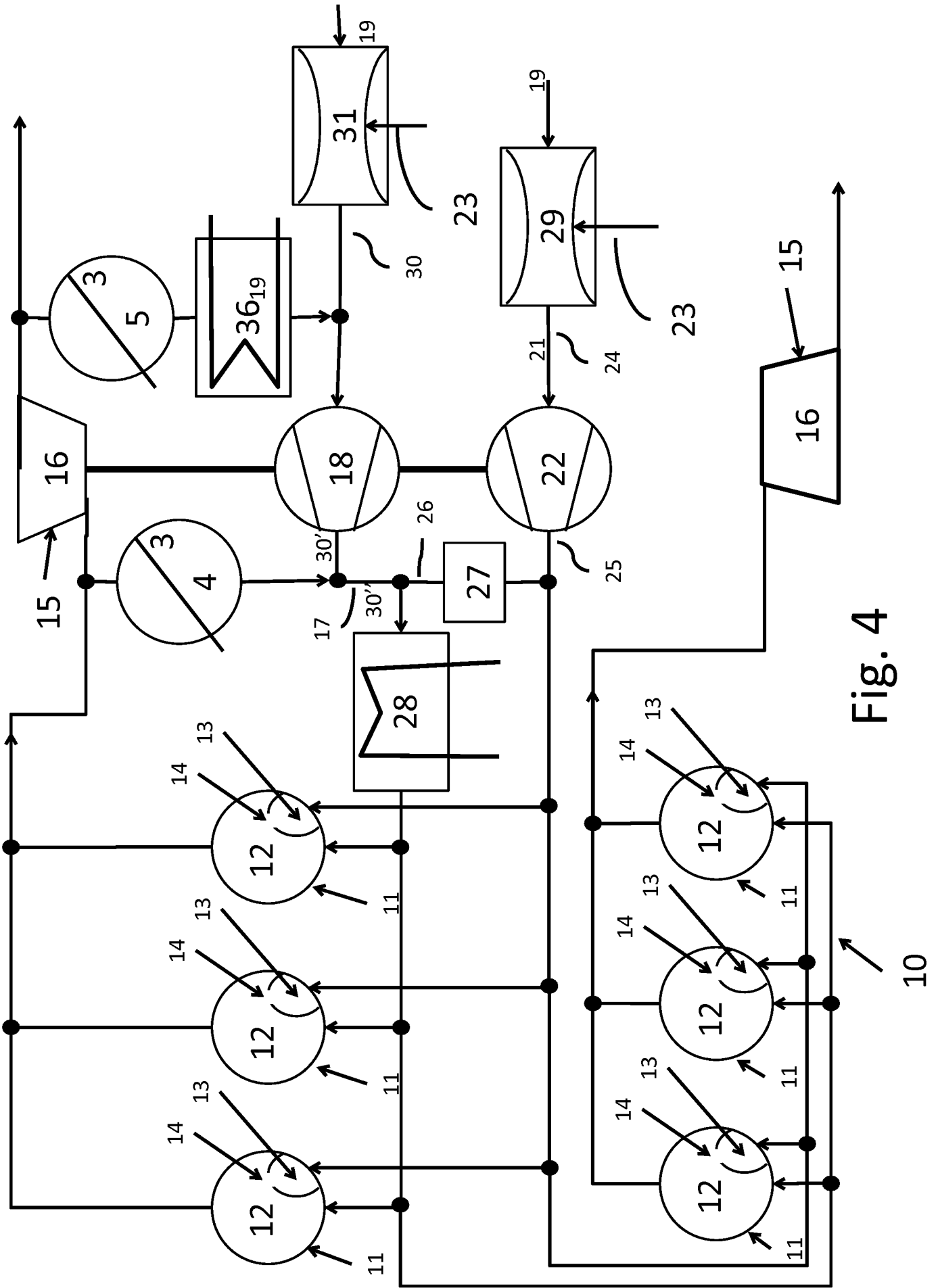


Fig. 4