



(22) Date de dépôt/Filing Date: 1993/02/11

(41) Mise à la disp. pub./Open to Public Insp.: 1993/09/24

(45) Date de délivrance/Issue Date: 2002/05/28

(30) Priorité/Priority: 1992/03/23 (856,318) US

(51) Cl.Int.⁵/Int.Cl.⁵ F01P 11/10

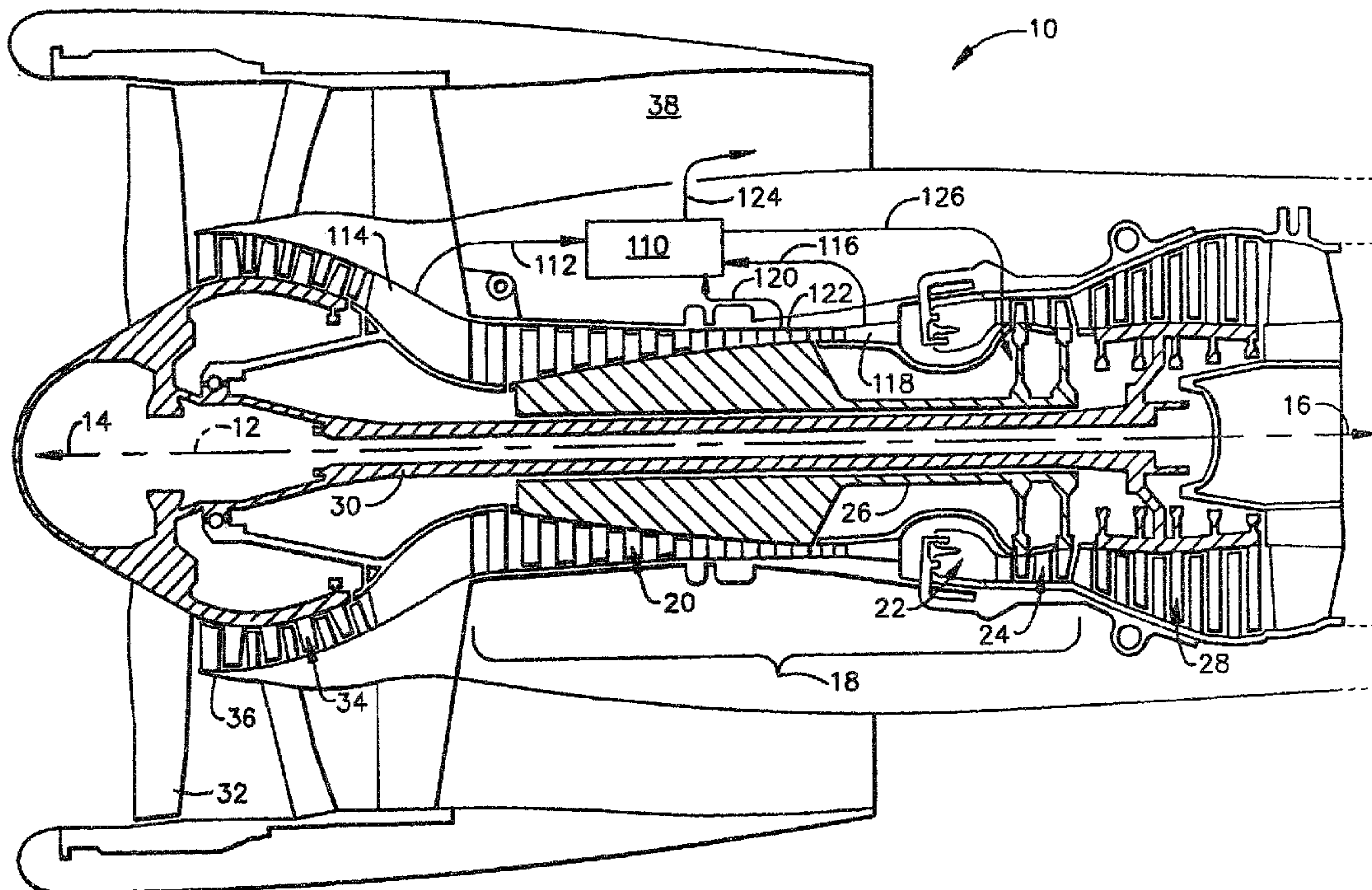
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(54) Titre : SYSTEME DE REFROIDISSEMENT DESTINE A UNE TURBOMACHINE

(54) Title: GAS TURBINE ENGINE COOLING SYSTEM



(57) Abrégé/Abstract:

A gas turbine engine cooling system. A first turbocompressor and a heat exchanger are fluidly interconnected and are each in fluid communication to receive air of differing pressures and temperatures. Typically, such air is received from various regions of the engine low pressure compressor and the engine high pressure compressor. The system delivers air through a duct to a portion of the engine for cooling, such as the engine high pressure turbine region, at lower temperatures and higher pressures than if cooling air were directly ducted from the engine compressor to the engine turbine.

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PATENT 13DV-11100

ABSTRACT OF THE DISCLOSURE

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interconnected and are each in fluid communication to
5 receive air of differing pressures and temperatures.
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the engine low pressure compressor and the engine high
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a duct to a portion of the engine for cooling, such as
10 the engine high pressure turbine region, at lower
temperatures and higher pressures than if cooling air
were directly ducted from the engine compressor to the
engine turbine.

GAS TURBINE ENGINE COOLING SYSTEM

BACKGROUND OF THE INVENTION

5 The present invention relates generally to gas turbine engines, and more particularly to a system for cooling such an engine.

Gas turbine engines (such as turbojet engines, bypass turbofan engines, turboprop engines, turboshaft engines, etc.) may be used to power flight vehicles (such as planes, helicopters, and missiles, etc.) and
10 may also be used to power ships, tanks, electric power generators, pipeline pumping apparatus, etc. For purposes of illustration, the invention will be described with respect to an aircraft bypass turbofan gas turbine engine. However, it is understood that the
15 invention is equally applicable to other types and/or uses of gas turbine engines.

A gas turbine engine includes a core engine having, in serial flow relationship, high pressure compressor (also called a core compressor) to compress
20 the airflow entering the core engine, a combustor in which a mixture of fuel and the compressed air is burned to generate a propulsive gas flow, and a high pressure turbine which is rotated by the propulsive gas flow and which is connected by a larger diameter shaft
25 to drive the high pressure compressor. A typical aircraft bypass turbofan gas turbine engine adds a low pressure turbine (located aft of the high pressure

turbine) which is connected by a smaller diameter coaxial shaft to drive a front fan (located forward of the high pressure compressor) which is surrounded by a nacelle and which may also drive a low pressure compressor (located between the front fan and the high pressure compressor). The low pressure compressor sometimes is called a booster compressor or simply a booster. It is understood that the term "compressor" includes, without limitation, high pressure compressors and low pressure compressors. A flow splitter, located between the fan and the first (usually the low pressure) compressor, separates the air which exits the fan into a core engine airflow and a surrounding bypass airflow. The bypass airflow from the fan exits the fan bypass duct to provide most of the engine thrust for the aircraft. Some of the engine thrust comes from the core engine airflow after it flows through the low and high pressure compressors to the combustor and is expanded through the high and low pressure turbines and accelerated out of the exhaust nozzle.

Aircraft bypass turbofan gas turbine engines are designed to operate at high temperatures to maximize engine thrust. Cooling of engine hot section components (such as the combustor, the high pressure turbine, the low pressure turbine, and the like) is necessary because of the thermal "redline" limitations of the materials used in the construction of such components. Typically such cooling of a portion of the engine is accomplished by ducting (also called "bleeding") cooler air from the high and/or low pressure compressors to those engine components which require such cooling. Unfortunately the relatively low pressure and hot temperature of the compressor air limits its ability to be used to cool such engine components.

SUMMARY OF THE INVENTION

It is an object of the invention to provide a system for improved cooling of the hot section components and other portions of a gas turbine engine.

5 In a first embodiment, the invention provides a system for cooling a portion of a gas turbine engine and includes a turbocompressor and a first heat exchanger. The first heat exchanger has an inlet and an outlet for a first fluid flow providing cooling to
10 the first heat exchanger and has an inlet and an outlet for a second airflow receiving cooling from the first heat exchanger. The first fluid flow inlet is in fluid communication with lower temperature fluid (e.g., lower pressure and temperature discharge air from the
15 booster compressor section of the engine compressor). The second airflow inlet is in fluid communication with higher temperature air from the engine compressor (e.g., higher pressure and temperature discharge air from the high pressure compressor section of the engine
20 compressor). The second airflow outlet is in fluid communication with the inlet of the compressor section of the turbocompressor. The outlet of the compressor section of the turbocompressor is in fluid communication with the portion of the engine requiring
25 the cooling.

 In a similar second embodiment of the invention, the first airflow inlet is in fluid communication with lower temperature fluid (e.g., lower pressure and temperature discharge air from the booster compressor
30 section of the engine compressor). The second airflow inlet is in fluid communication with the outlet of the compressor section of the turbocompressor. The inlet of the compressor section of the turbocompressor is in fluid communication with higher temperature air from
35 the engine compressor (e.g., higher pressure and temperature discharge air from the high pressure compressor section of the engine compressor). The

second airflow outlet is in fluid communication with the portion of the engine requiring the cooling.

Several benefits and advantages are derived from the gas turbine engine cooling system of the invention.

5 Use of the turbocompressor and heat exchanger of the invention permit higher pressure and lower temperature air to be used for cooling portions of the engine such as engine hot section components. Maximum engine thrust, which is especially important during takeoff
10 and climb, can be increased for a particular "redline" temperature limit for the engine hot section components by using the higher pressure and lower temperature cooling air of the invention, as can be appreciated by those skilled in the art.

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BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings illustrate several preferred embodiments of the present invention wherein:

Figure 1 is a schematic side view of an aircraft
20 bypass turbofan gas turbine engine (with the exhaust nozzle omitted for clarity) which employs the engine cooling system of the invention to cool a high pressure turbine portion of the engine;

Figure 2 is a block diagram of a the engine cooling
25 system of Figure 1 including a turbocompressor and a heat exchanger;

Figure 3 is a block diagram of an alternate embodiment of the engine cooling system of Figure 2;

Figure 4 is a schematic side view of an aircraft
30 bypass turbofan gas turbine engine (with the exhaust nozzle omitted for clarity) which employs the engine cooling system of the invention to cool both a high pressure turbine portion and a low pressure turbine portion of the engine;

Figure 5 is a block diagram of a the engine cooling
35 system of Figure 4 including a turbocompressor and two heat exchangers; and

Figure 6 is a block diagram of an alternate embodiment of the engine cooling system of Figure 5.

In the drawings, like reference numerals designate identical or corresponding parts throughout the respective figures.

DETAILED DESCRIPTION OF THE INVENTION

Referring now to Figure 1, there is illustrated an aircraft bypass turbofan gas turbine engine 10 having a generally longitudinally extending axis or centerline 12 generally extending forward 14 and aft 16. The bypass turbofan engine 10 includes a core engine (also called a gas generator) 18 which comprises a high pressure compressor or core compressor 20, a combustor 22, and a high pressure turbine 24, all arranged in a serial, axial flow relationship. A larger diameter annular drive shaft 26, disposed coaxially about the centerline 12 of the engine 10, fixedly interconnects the high pressure compressor 20 and the high pressure turbine 24.

The core engine 18 is effective for generating combustion gases. Pressurized air from the high pressure compressor 20 is mixed with fuel in the combustor 22 and ignited, thereby generating combustion gases. Some work is extracted from these gases by the high pressure turbine 24 which drives the high pressure compressor 20. The combustion gases are discharged from the core engine 18 into a low pressure or power turbine 28. The low pressure turbine 28 is fixedly attached to a smaller diameter annular drive shaft 30 which is disposed coaxially about the centerline 12 of the engine 10 within the larger diameter annular drive shaft 26. The smaller diameter annular drive shaft 30 rotates a forward row of fan rotor blades 32. The smaller diameter annular drive shaft 30 also rotates a low pressure compressor 34 (also called a booster compressor or simply a booster). A flow splitter 36,

located between the fan blades 32 and the low pressure compressor 34, separates the air which exits the fan into a core engine airflow which exits the exhaust nozzle (not shown) and a surrounding bypass airflow which exits the fan bypass duct 38.

Figure 1 shows a first application of the engine cooling system 110 of the invention used for cooling a first portion of the engine 10, wherein the first portion comprises the high pressure turbine 24. The cooling system 110 receives air: from a duct 112 which bleeds air from the low pressure compressor discharge region 114; from a duct 116 which bleeds air from the high pressure compressor discharge region 118; and from a duct 120 which bleeds air from a region 122 in between such low and high pressure compressor discharge regions 114 and 118. The cooling system 110 discharges air: to a duct 124 which routes air to the fan bypass duct 38; and to a duct 126 which routes air to the high pressure turbine 24 region.

Figure 2 shows a first embodiment 110' of the engine cooling system 110 comprising a turbocompressor 128 and a first heat exchanger 130. The turbocompressor 128 has a compressor section 132 including an inlet 134 and an outlet 136 and has a turbine section 138 including an inlet 140 and an outlet 142. Preferably the turbocompressor 128 has air bearings. The first heat exchanger 130 has an inlet 144 and an outlet 146 for a first airflow providing cooling to the first heat exchanger 130 and has an inlet 148 and an outlet 150 for a second airflow receiving cooling from the first heat exchanger 130. The first airflow inlet 144 of the first heat exchanger 130 is in fluid communication with lower pressure and temperature air (such as with a portion of the air from the low pressure compressor discharge region 114 through duct 112/112a as shown in Figures 1 and 2). The second airflow inlet 148 of the first heat exchanger 130 is in fluid communication with higher

pressure and temperature air from the engine compressor (such as with a portion of the air from the high pressure compressor discharge region 118 through duct 116 as shown in Figures 1 and 2). The first
5 airflow outlet 146 of the first heat exchanger 130 preferably is in fluid communication with the fan bypass duct 38 through duct 124a (and preferably discharges such air into the fan bypass duct 38 with an aft component of velocity). The second airflow outlet
10 150 of the first heat exchanger 130 is in fluid communication with the inlet 134 of the compressor section 132 of the turbocompressor 128 through duct 152. The outlet 136 of the compressor section 132 of the turbocompressor 128 is in fluid communication with
15 the high pressure turbine 24 through duct 126 to cool at least a portion of the high pressure turbine 24. The inlet 140 of the turbine section 138 of the turbocompressor 128 is in fluid communication with intermediate pressure and temperature air from the
20 engine compressor (such as with a portion of the air from the eighth stage high pressure compressor region 122 through duct 120 as shown in Figures 1 and 2). As can be appreciated by those skilled in the art, the higher pressure and temperature air has a higher
25 pressure and temperature than that of the lower pressure and temperature air, and the intermediate pressure and temperature air has a pressure and temperature intermediate that of the lower pressure and temperature air and the higher pressure and temperature
30 air. It is understood that the term "pressure" means total pressure (i.e., static pressure plus dynamic pressure). The outlet 142 of the turbine section 138 of the turbocompressor 128 preferably is in fluid communication with the fan bypass duct 38 through duct
35 124b (and preferably discharges such air into the fan bypass duct 38 with an aft component of velocity).

In an alternate embodiment (not shown), the turbine section 138 of the turbocompressor 128 has its inlet

140 in fluid communication with the second airflow outlet 150 of the first heat exchanger 130 instead of being in fluid communication with the intermediate pressure and temperature air region 122. This
5 embodiment drives the turbine section 138 of the turbocompressor 128 with higher pressure air. Preferably, in this embodiment, the outlet 142 of the turbine section 138 of the turbocompressor 128 is in fluid communication with the engine low pressure
10 turbine instead of being in fluid communication (via duct 124b) with the fan bypass duct 38. This embodiment cools both the high and low pressure turbines of the engine with the use of a single heat exchanger.

15 Figure 3 shows a second embodiment 110'' of the engine cooling system 110 which is identical to the first embodiment 110' of Figure 2 previously discussed, but with three differences. First, the second airflow outlet 150 of the first heat exchanger 130 is in fluid
20 communication with the high pressure turbine 24 through duct 126 to cool at least a portion of the high pressure turbine 24. Second, the inlet 134 of the compressor section 132 of the turbocompressor 128 is in fluid communication with higher pressure and
25 temperature air from the engine compressor (such as with a portion of the air from the high pressure compressor discharge region 118 through duct 116 as shown in Figures 1 and 3). Third, the outlet 136 of the compressor section 132 of the turbocompressor 128
30 is in fluid communication with the second airflow inlet 148 of the first heat exchanger 130.

Figure 4 shows a second application of the engine cooling system 210 of the invention used for cooling a first portion of the engine 10, wherein the first
35 portion comprises the high pressure turbine 24 and also for cooling a second portion of the engine 10, wherein the second portion comprises the low pressure turbine 28. The cooling system 210 as shown in Figure 4 is

identical to the first application's cooling system 110, as shown in Figure 1, but with one addition. The cooling system 210 also discharges air to a duct 154 which routes air to the low pressure turbine 28 region.

Figure 5 shows a first embodiment 210' of the engine cooling system 210 which is identical to the first embodiment 110' of the engine cooling system 110 of Figure 2 previously discussed, but with one addition and one difference. Briefly, the addition is a second heat exchanger 156, and the difference is in the duct which is in fluid communication with the outlet 142 of the turbine section 138 of the turbocompressor 128. More particularly, the second heat exchanger 156 has an inlet 158 and an outlet 160 for a third airflow providing cooling to the second heat exchanger 156 and has an inlet 162 and an outlet 164 for a fourth airflow receiving cooling from the second heat exchanger 156. The first airflow inlet 158 of the second heat exchanger 156 is in fluid communication with lower pressure and temperature air (such as with a portion of the air from the low pressure compressor discharge region 114 through duct 112/112b as shown in Figures 4 and 5). The second airflow inlet 162 of the second heat exchanger 156 is in fluid communication with the outlet 142 of the turbine section 138 of the turbocompressor 128 through duct 166. The first airflow outlet 160 of the second heat exchanger 156 preferably is in fluid communication with the fan bypass duct 38 through duct 124c (and preferably discharges such air into the fan bypass duct 38 with an aft component of velocity). The second airflow outlet 164 of the second heat exchanger 156 is in fluid communication with the low pressure turbine 28 through duct 154 to cool at least a portion of the low pressure turbine 28.

Figure 6 shows a second embodiment 210'' of the engine cooling system 210 which is identical to the

second embodiment 110'' of Figure 3, but with the one addition (the second heat exchanger 156) and the one difference (the duct which provides fluid communication from the outlet 142 of the turbine section 138 of the
5 turbocompressor 128) as previously discussed.

Conventional engine cooling techniques duct compressor air directly to the high pressure turbine 24 region and the low pressure turbine 28 region of the engine 10. The cooling system of the invention can be
10 used to augment such conventional engine cooling techniques or it can be used to substitute for such conventional techniques.

The operation of the first embodiment 210' of the engine cooling system 210 is typical of the other
15 embodiments, and will be described with reference to a numerical example based on engineering analysis where the pressure P is measured in psia and the temperature T is measured in degrees R. Referring to Figures 4 and 5, it is seen that air ($P=34.8$, $T=810$) from the low
20 pressure compressor discharge region 114 is carried by duct 112a to the first heat exchanger 130 to cool air ($P=497$, $T=1689$) from the high pressure compressor discharge region 118 carried by duct 116 entering the first heat exchanger 130 so that the airflow receiving
25 cooling will exit the first heat exchanger 130 as air ($P=462$, $T=1369$) carried by duct 152 to the compressor section 132 of the turbocompressor 128. The compressor section 132 is driven by the turbine section 138 from air ($P=277$, $T=1486$) from the intermediate compressor
30 region 122 carried by duct 120. Air ($P=497$, $T=1416$) leaves the compressor section 132 of the turbocompressor 128 in duct 126 to cool the high pressure turbine 24. (Conventional cooling of the high pressure turbine directly with air from the high
35 pressure compressor discharge region would deliver such air at $P=464$ and $T=1647$.) In a similar fashion, air ($P=140$, $T=1109$) leaves the second heat exchanger 156 in duct 154 to cool the low pressure turbine 28.

(Conventional cooling of the low pressure turbine directly with air from the intermediate compressor region would deliver such air at $P=130$ and $T=1186$.) The greater engine cooling capacity of the system of the invention achieves a net thrust of 51878 pounds compared with 45139 pounds of net thrust using conventional cooling (with the high temperature turbine blade temperature at a "redline" limit of 1838 for both the cooling system of the invention and the conventional cooling). The improvement in net thrust for the engine cooling system of the invention is nearly fifteen percent.

The foregoing description of a preferred embodiment of the invention has been presented for purposes of illustration. It is not intended to be exhaustive or to limit the invention to the precise form disclosed, and obviously many modifications and variations are possible in light of the above teachings. For example, it is understood that the phrase "engine compressor" includes any low, intermediate, and/or high pressure engine compressor. Also, various portions of the engine which may be cooled by the engine cooling system of the invention include those portions involving high pressure turbine cooling, low pressure turbine cooling, combustor cooling, compressor disc cooling, compressor discharge cooling, compressor and turbine case cooling, clearance control cooling, etc. Additionally, lower pressure and temperature air may be bled or ducted from the fan region, the fan bypass region, etc. as well as from the low pressure compressor region. Further, the invention is applicable to gas turbine engines having axial, radial, or other types of gas turbine engine compressors and/or turbines. It is likewise understood that in some applications, the engine cooling system of the invention may employ valves to control the airflow in the various ducts, and/or the engine cooling system of the invention may be employed in those engines

having variable turbine nozzles where greater cooling is required when the turbine nozzle area is reduced. It is noted that the first airflow can be generalized as a first fluid flow having a higher temperature than that of the second airflow, and that such first fluid flow can be engine fuel wherein, for example, duct 112 would convey some fuel from the fuel tank to the heat exchanger(s) and duct 124 would convey the fuel from the heat exchanger(s) back to the fuel tank or to the combustor, etc. (such arrangement not shown in the drawings). Such modifications and variations, and other modifications and variations, are all within the scope of the claims appended hereto.

I claim:

1. A system for cooling a first portion of a gas turbine engine, said engine having an engine compressor, and said cooling system comprising:

5 (a) a turbocompressor having a compressor section and a turbine section each with an inlet and an outlet; and

10 (b) a first heat exchanger having an inlet and an outlet for a first fluid flow providing cooling to said first heat exchanger and having an inlet and an outlet for a second airflow receiving cooling from said first heat exchanger, said first fluid flow inlet of said first heat exchanger in fluid communication with lower temperature fluid, said second airflow inlet of said first heat exchanger in fluid communication with higher temperature air from said engine compressor, said second airflow outlet of said first heat exchanger in fluid communication with said inlet of said compressor section of said turbocompressor, and said outlet of said compressor section of said turbocompressor in fluid communication with said first portion of said engine for said cooling of said first portion of said engine and wherein said higher temperature air has a higher temperature than that of said lower temperature fluid.

2. The cooling system of claim 1, wherein said first fluid flow is a first airflow, said first fluid flow

inlet is a first airflow inlet, said first fluid flow
outlet is a first airflow outlet, said lower
temperature fluid is lower temperature air, and said
higher temperature air has a higher pressure and
5 temperature than that of said lower temperature air.

3. The cooling system of claim 2, wherein said engine
includes a fan bypass duct and said first airflow
outlet of said first heat exchanger is in fluid
communication with said fan bypass duct.

4. The cooling system of claim 2, wherein said engine
compressor includes a high pressure compressor and said
higher pressure and temperature air includes a portion
of discharge air from said high pressure compressor.

5. The cooling system of claim 2, wherein said inlet
of said turbine section of said turbocompressor is in
fluid communication with intermediate pressure and
temperature air from said engine compressor, wherein
5 said intermediate pressure and temperature air having a
pressure and temperature intermediate that of said
lower pressure and temperature air and said higher
pressure and temperature air.

6. The cooling system of claim 5, also including a
second heat exchanger having an inlet and an outlet for
a third airflow providing cooling to said second heat
exchanger and having an inlet and an outlet for a
5 fourth airflow receiving cooling from said second heat
exchanger, said third airflow inlet of said second heat
exchanger in communication with air having a pressure
and temperature lower than that of said intermediate
pressure and temperature air, said fourth airflow inlet
10 of said second heat exchanger in communication with
said outlet of said turbine section of said
turbocompressor, and said fourth airflow outlet of said
second heat exchanger in communication with a second

15 portion of said engine for cooling of said second
portion of said engine.

7. The cooling system of claim 6, wherein said engine includes a fan duct and said third airflow outlet of said second heat exchanger is in fluid communication with said engine fan duct.

8. The cooling system of claim 6, wherein said engine compressor includes a high pressure compressor and said higher pressure and temperature air includes a portion of discharge air from said high pressure compressor.

5 9. The cooling system of claim 6, wherein said engine includes a booster compressor, said lower pressure and temperature air includes a portion of discharge air from said booster compressor, and said bleed air in communication with said third airflow inlet of said second heat exchanger having generally the same pressure and temperature as that of said lower pressure and temperature air.

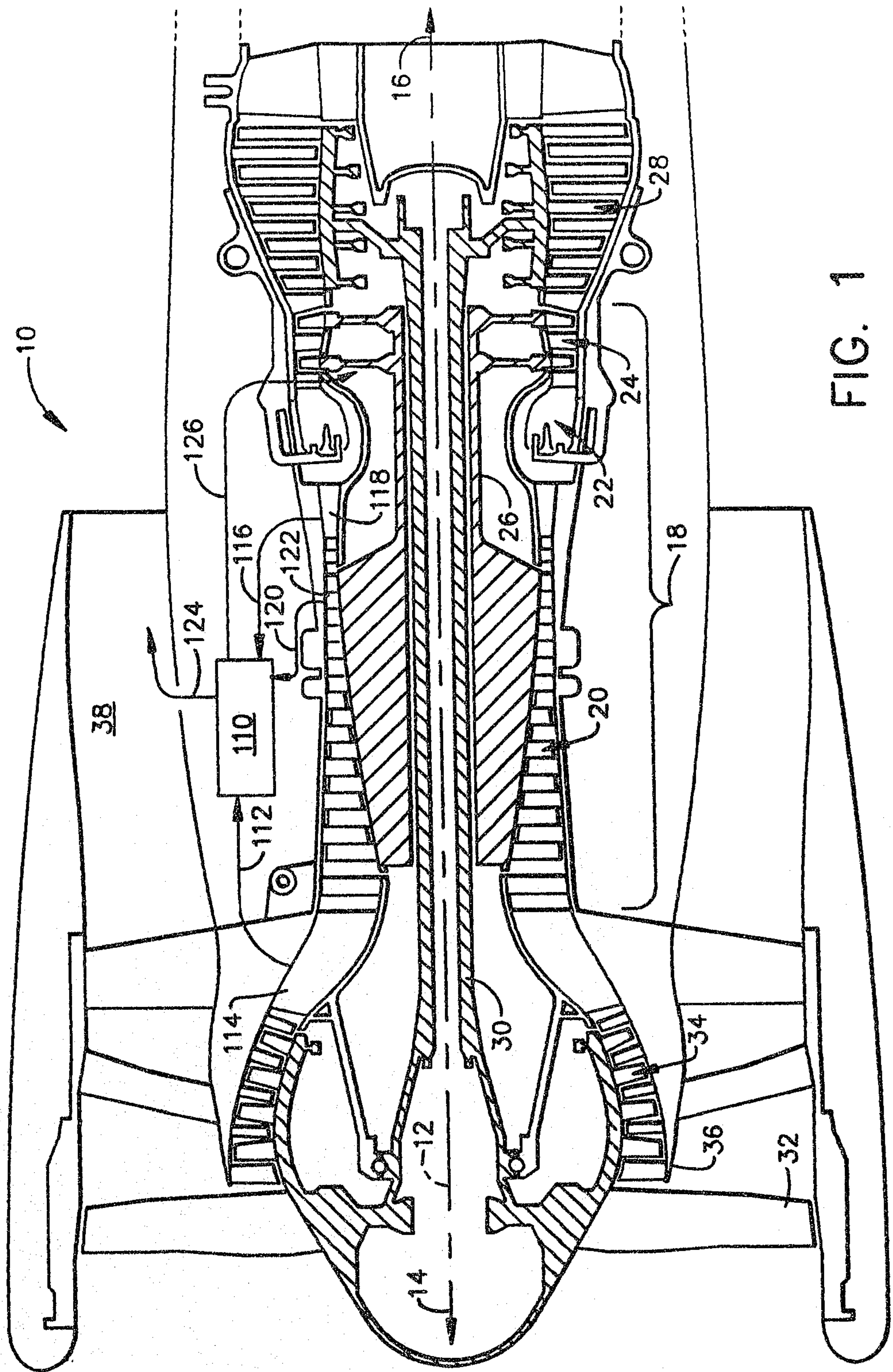
10. A system for cooling a first portion of a gas turbine engine, said engine having an engine compressor, and said cooling system comprising:

5 (a) a turbocompressor having a compressor section and a turbine section each with an inlet and an outlet; and

10 (b) a first heat exchanger having an inlet and an outlet for a first fluid flow providing cooling to said first heat exchanger and having an inlet and an outlet for a second airflow receiving cooling from said first heat exchanger, said first fluid flow inlet of said first heat exchanger in fluid communication with lower temperature fluid, said second airflow inlet of said first heat exchanger in fluid communication with
15 said outlet of said compressor section of said turbocompressor, said inlet of said compressor section

5 of said turbocompressor in fluid communication with
higher temperature air from said engine compressor and
said second airflow outlet of said first heat exchanger
in fluid communication with said first portion of said
engine for said cooling of said first portion of said
engine and wherein said higher temperature air has a
higher temperature than that of said lower temperature
fluid.

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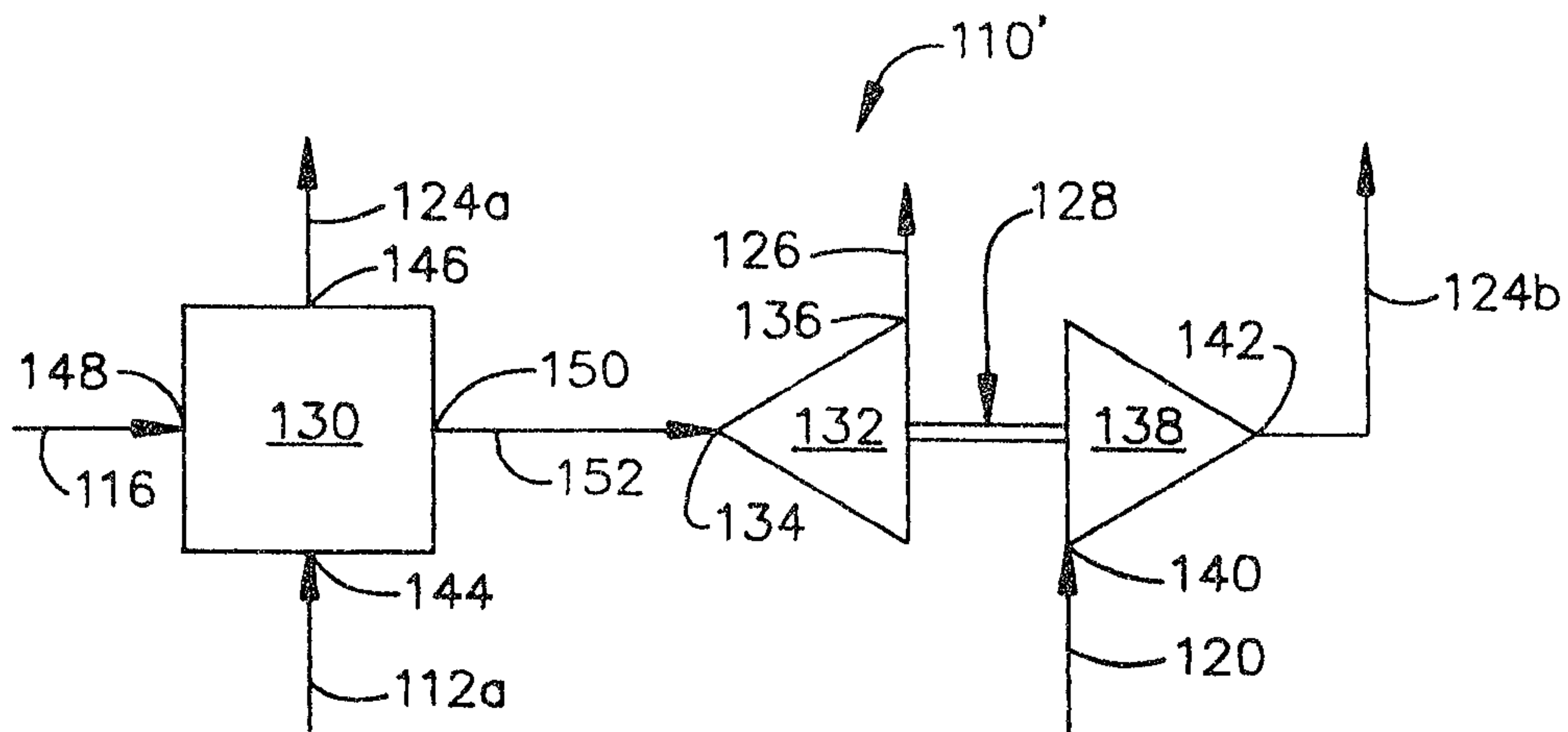


FIG. 2

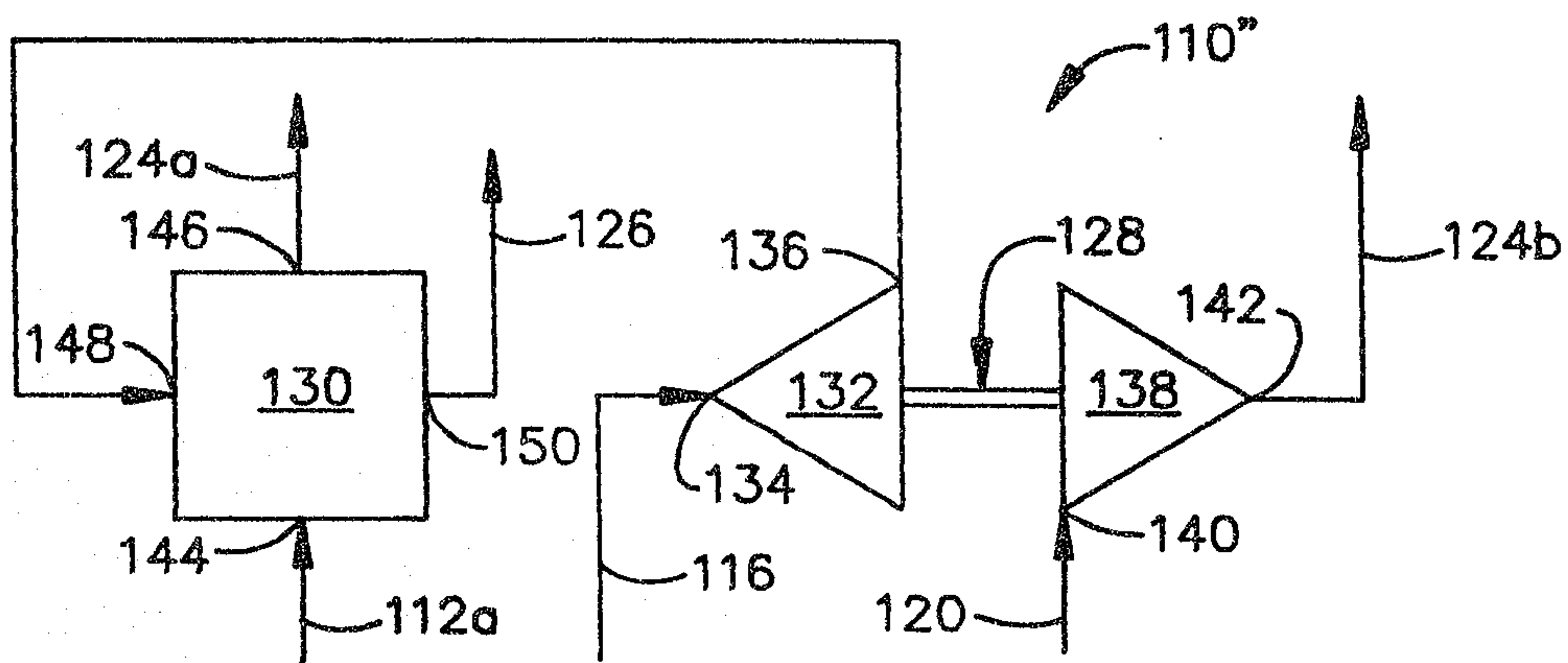


FIG. 3

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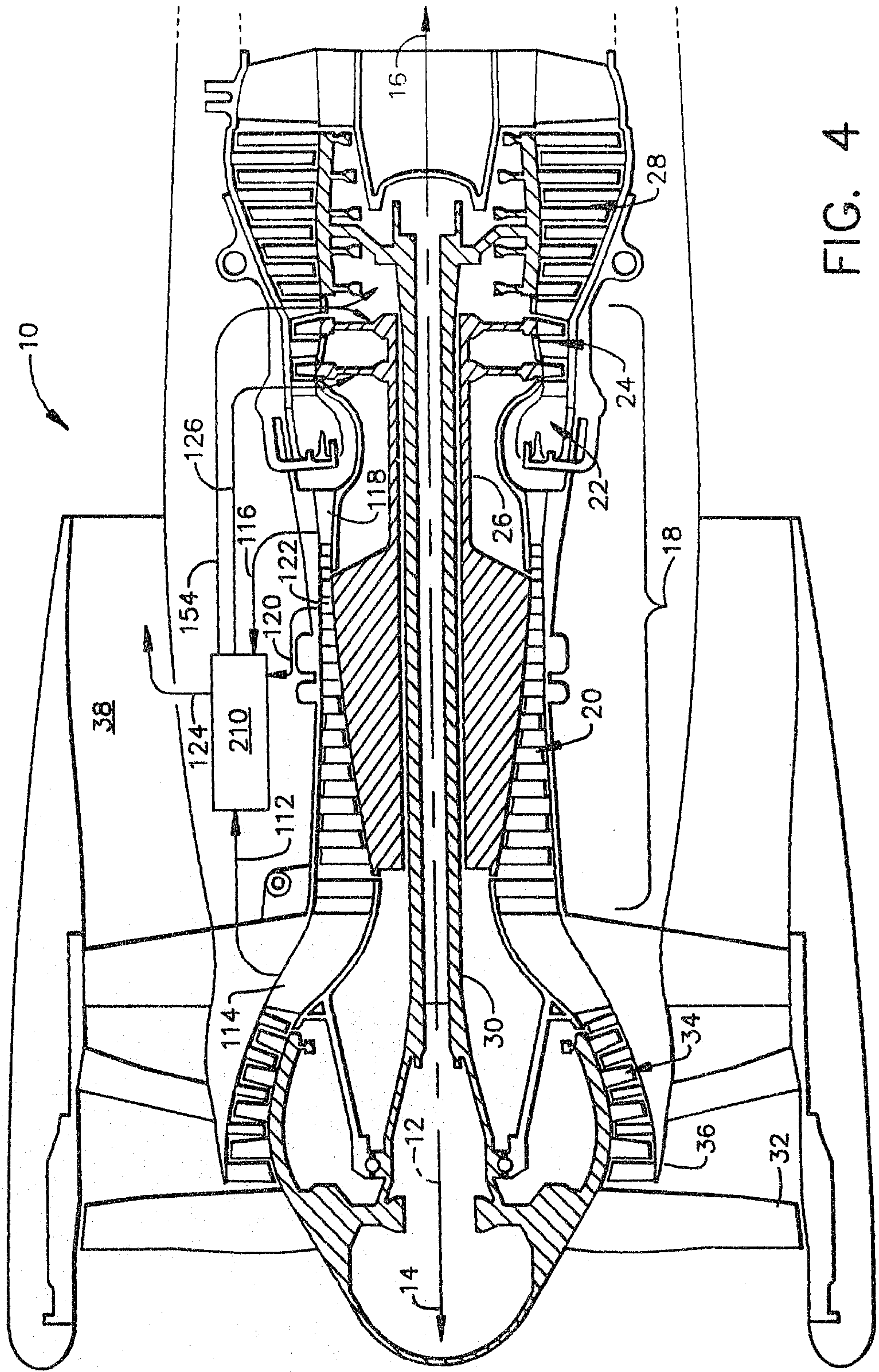


FIG. 4

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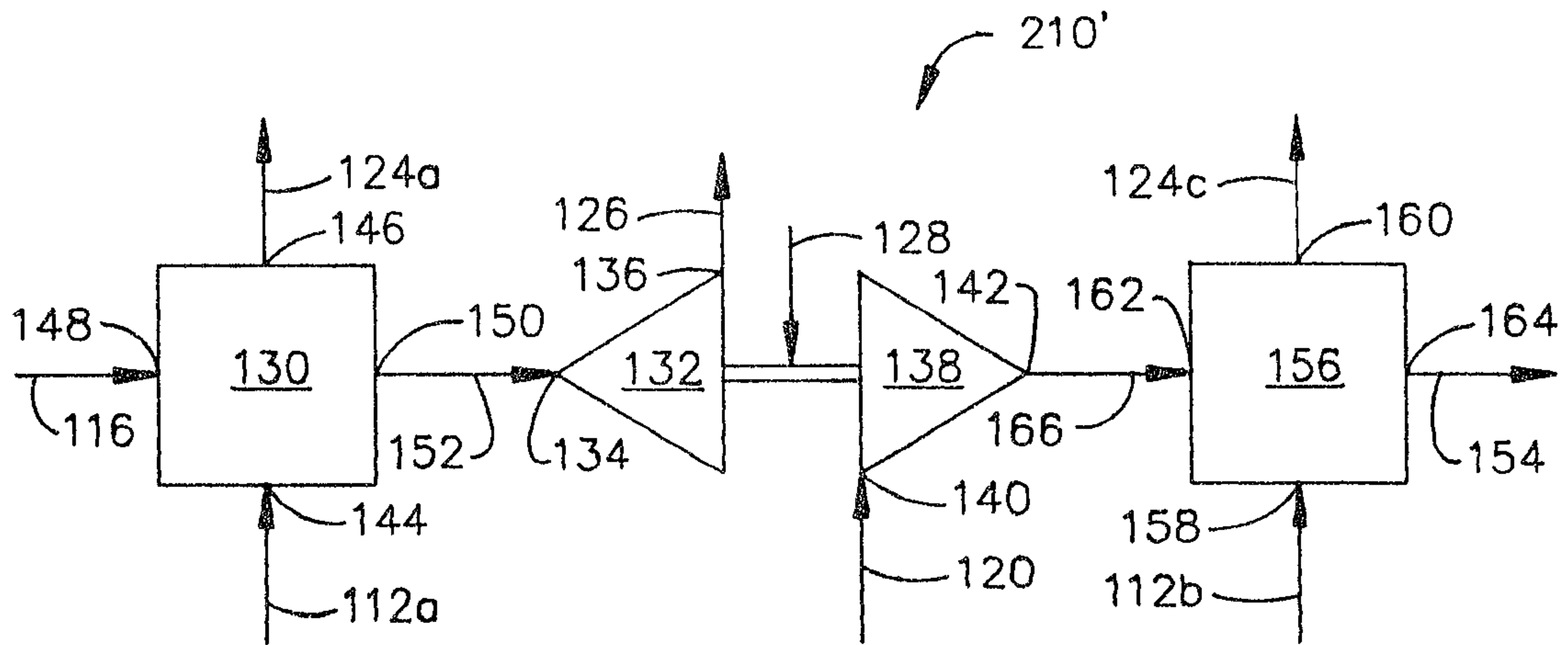


FIG. 5

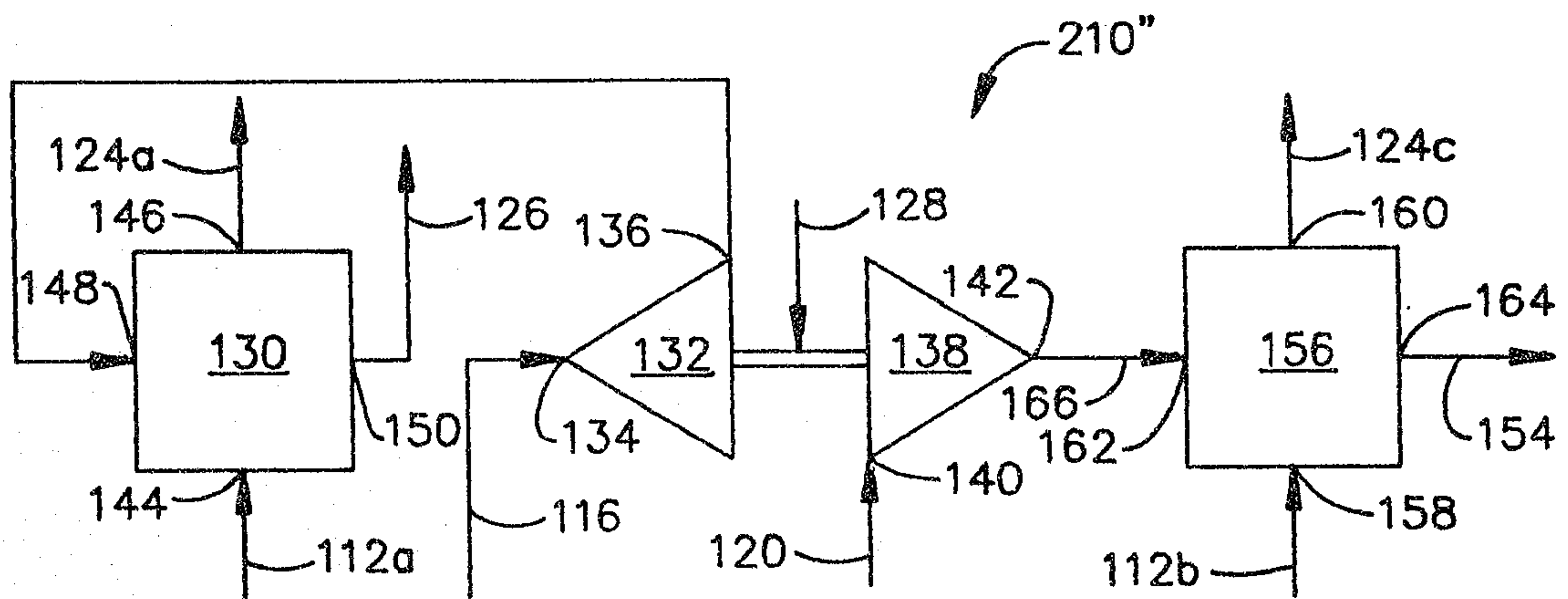


FIG. 6

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