

Aug. 25, 1964

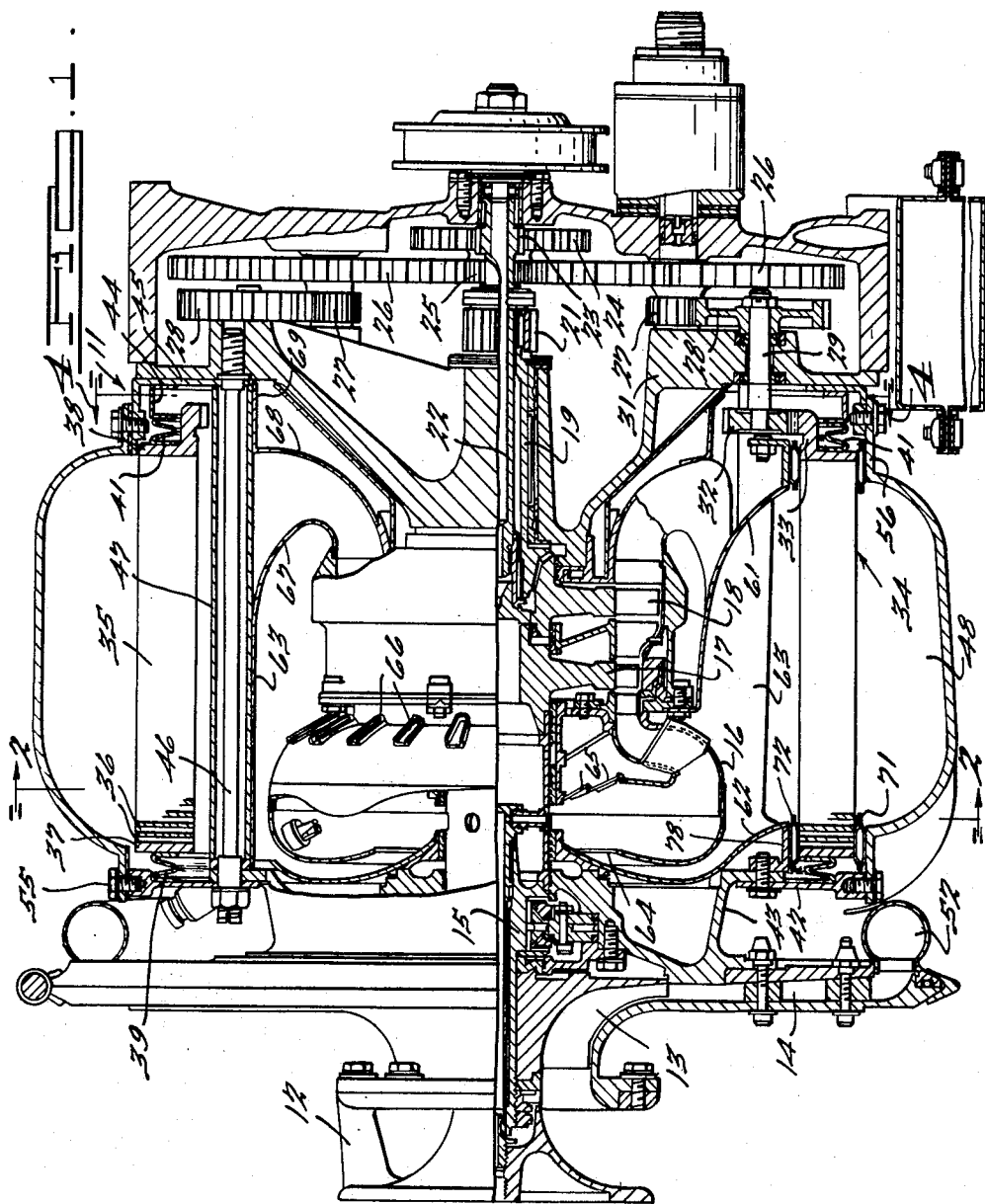
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3,145,534

HEAT EXCHANGER FOR GAS TURBINES

Original Filed Jan. 20, 1960

3 Sheets-Sheet 1



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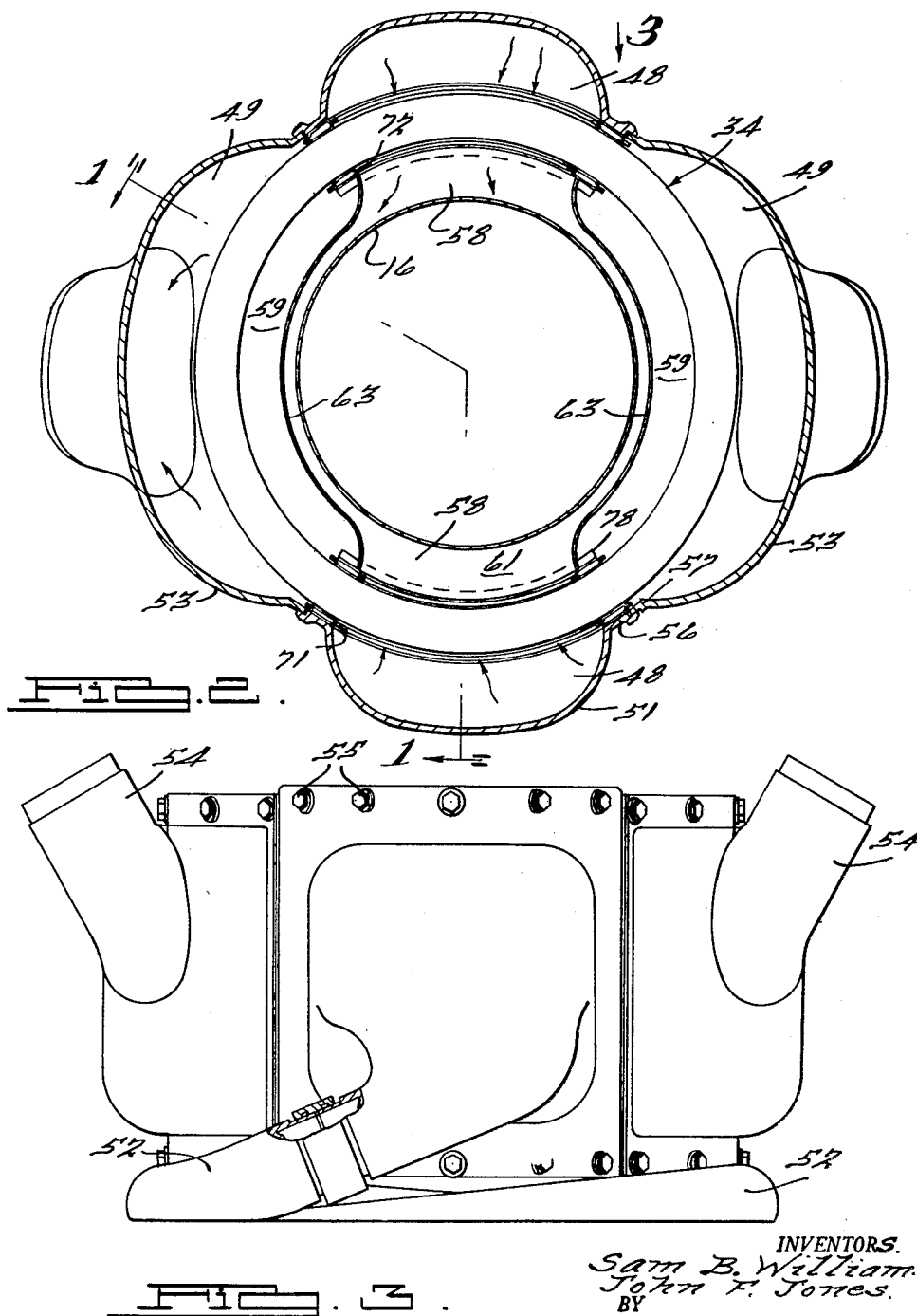
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Original Filed Jan. 20, 1960

3 Sheets-Sheet 2



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HEAT EXCHANGER FOR GAS TURBINES

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3 Sheets-Sheet 3

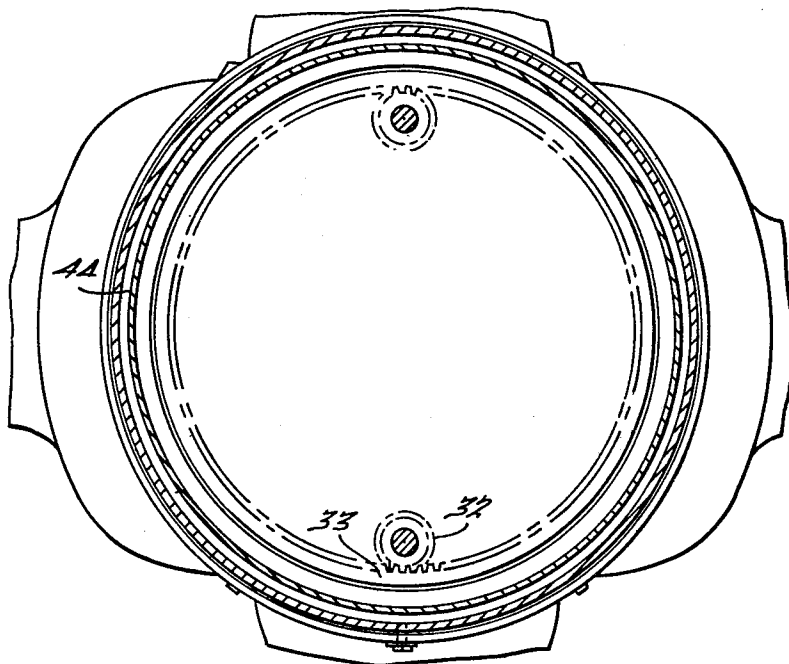


FIG. 4.

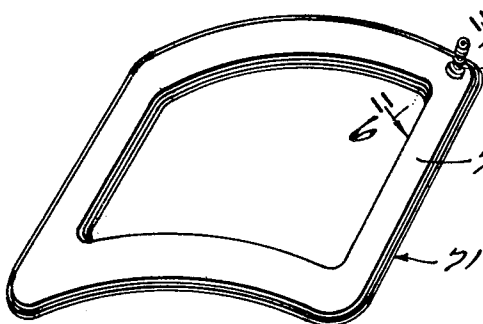


FIG. 5.

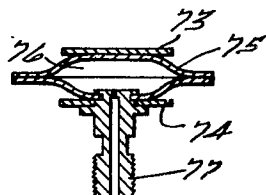


FIG. 6.

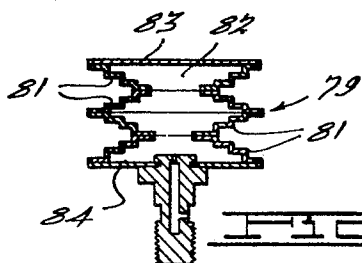


FIG. 7.

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## HEAT EXCHANGER FOR GAS TURBINES

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Original application Jan. 20, 1960, Ser. No. 3,691.  
Divided and this application Jan. 6, 1961, Ser. No.  
87,478

1 Claim. (Cl. 60—39.51)

This application is a division of our application Serial  
No. 3,691 filed January 20, 1960.

This invention relates to gas turbines, and more particularly to heat exchangers of the rotary type for transferring heat in such turbines from the exhaust gases to the intake air.

It is an object of the invention to provide a novel and improved heat exchanger apparatus which permits a substantially greater flow area through the heat exchanger matrix for a given gas turbine housing diameter, and in which efficient flow paths for the intake and exhaust gases are maintained.

It is another object to provide an improved heat exchanger construction of this nature which permits greater flexibility in the overall layout of the gas turbine and in which the heat exchanger flow areas may be substantially increased without increasing the turbine diameter.

It is another object to provide a novel and improved heat exchanger construction of this character which includes improved sealing means for preventing gas flow between the adjacent heat exchanger sections.

Other objects, features and advantages of the present invention will become apparent from the subsequent description, taken in conjunction with the accompanying drawings.

FIGURE 1 is a side elevational view of a gas turbine partially in cross-section along the line 1—1 of FIGURE 2 and incorporating the novel heat exchanger construction of this invention;

FIGURE 2 is a cross-sectional view in elevation taken along the line 2—2 of FIGURE 1 and showing the arrangement of the intake and exhaust ducts;

FIGURE 3 is a top elevational view of the gas turbine housing taken in the direction of the arrow 3 of FIGURE 2 and showing the air collector scrolls and exhaust ports;

FIGURE 4 is a cross-sectional view taken along the line 4—4 of FIGURE 1 and showing the heat exchanger ring gear and driving pinions;

FIGURE 5 is a perspective view of one of the seals for the high pressure intake chambers;

FIGURE 6 is a cross-sectional view taken along the line 6—6 of FIGURE 5 and showing the seal construction; and

FIGURE 7 is a cross-sectional view similar to FIGURE 6 showing a modified form of this seal.

In general terms, the invention comprises a heat exchanger or regenerator of the cylindrical matrix type, the heat exchanger being of elongated annular cylindrical shape. The regenerator matrix surrounds the combustion chamber and turbine blades and extends axially a substantially greater distance than the matrix thickness between its inner and outer diameters. Intake chambers leading from the compressor diffuser and exhaust collection chambers are alternately arranged around the outer periphery of the matrix, while the inside of the matrix is connected to alternate intake and exhaust chambers leading to the combustion chamber and from the turbine respectively. Bellows type seals in the form of arcuately shaped closed loops serve to seal the high pressure chambers with respect to the matrix, these seals

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being engageable with the inner and outer matrix surfaces. Annular low pressure seals are engageable with the end surfaces of the matrix and serve to seal the exhaust chambers. The matrix is supported for rotation by a plurality of driving pinions engageable with an internal ring gear as well as by the seals.

Referring more particularly to the drawings, a gas turbine assembly incorporating the principles of the invention is generally indicated at 11 and comprises an air inlet 12 which leads to a compressor 13 and a diffuser 14. Compressor 13 is of a radial type and is driven by a shaft 15 which extends through an annular combustion chamber 16 and is connected to a first stage turbine 17. A second stage turbine 18 is connected to a shaft 19 which extends toward the other end of turbine assembly 11. Shaft 19 drives a power output pinion 21, and an accessory shaft 22 is disposed within shaft 19 and is connected to first stage turbine 17, shaft 22 driving a pinion 23. This pinion serves to drive the heat exchanger matrix through a gear train which includes a gear 24 meshing with pinion 23 and on a common shaft with a pinion 25 behind shaft 22 in FIGURE 1. Pinion 25 drives a pair of gears 26 having co-axial pinions 27 connected thereto, these pinions driving a pair of gears 28. Gears 28 are secured to shafts 29 rotatably mounted in a housing portion 31 of turbine 11, and the opposite ends of shafts 29 carry pinions 32 which mesh with an internal ring gear 33 on the heat exchanger matrix which is generally indicated at 34.

Matrix 34 is of elongated annular cylindrical shape and comprises a core section 35 having alternate passages 36 between the inner and outer matrix surfaces. As seen in FIGURE 1, the length of matrix 34 is substantially greater than the thickness between its inner and outer surfaces, and the matrix surrounds combustion chamber 16 as well as first and second stage turbines 17 and 18 and the outlet from the second stage turbine. It should be noted that the length of heat exchanger 34 could be varied within the principles of the invention in accordance with the desired flow areas, this variation being possible of course without increasing the diameter of the matrix.

A ring 37 is provided at one end of matrix 35, internal gear 33 having an annular flange 38 which is secured to the other end of the matrix. A pair of annular seals 39 and 41 are engageable with ring 37 and flange 38 respectively, these seals comprising expandable annular metal members in rubbing engagement with parts 37 and 38. Seal 39 is secured to a disc-like plate 42 which in turn is carried by a housing portion 43, while seal 41 is carried by an annular member 44 of channel shaped cross-section which is secured to a mounting ring 45. Bolts 46 extend between ring member 42 and housing portion 31, these bolts being surrounded by compression tubes 47 and serving to hold together the housing components.

The outer periphery of heat exchanger 34 is connected with a pair of high pressure intake chambers 48 and a pair of exhaust collector chambers 49, these chambers being in circumferentially spaced relation as seen in FIGURE 2. Intake chambers 48 are formed by dome-shaped housing members 51 which are connected to air collector scrolls 52 as seen in FIGURE 3, these scrolls leading from diffuser 14. Exhaust collector chambers 49 are formed by housing portions 53 which are likewise of dome-like shape and lead to a pair of exhaust ports 54 also seen in FIGURE 3, these ports leading toward the opposite end of the turbine assembly. It will thus be seen that intake air under high pressure will flow inwardly from chambers 48 through matrix 34 as indicated by the arrows in FIGURE 2 and the combustion

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gases will flow outwardly from the matrix into exhaust collector chambers 49. Housing members 51 and 53 are secured to ring member 42 and annular member 45 by bolts 55, and their adjacent edges have mating flanges 56 and 57 respectively which are closely adjacent the outer surface of matrix 34.

The inner surface of matrix 34 connects with a pair of high pressure heated air chambers 58 which are radially aligned with chambers 48 and a pair of hot exhaust plenum chambers 59, opposite chambers 49. Chambers 58 are formed by a pair of annular shields 61 and 62 which lead to the forward and rear portions of the combustion chamber respectively, as seen in FIGURE 1, and by a pair of axially extending shields 63 which extend between shields 61 and 62 and also between the upper and lower chambers 58, as seen in FIGURE 2. Shields 61, 62 and 63 together form a continuous chamber which surrounds the major portion of combustion chamber 16 and connects with both chambers 58, so that the heated air flowing inwardly from the matrix may flow through the combustion chamber louvers. As shown in FIGURE 1, these openings comprise an annular inner opening 64 at the rear of the combustion chamber, louvers 65 at the forward portion of the combustion chamber, and passages 66 which lead to the space adjacent louvers 65 and also directly into the combustion chamber adjacent the outlet thereof for secondary combustion air purposes. Exhaust plenum chambers 59 are formed by shields 63 which have curved portions 67 seen in FIGURE 1 which connect with the outlet of second stage turbines 18, an annular shield 68 leading from the turbine outlet in spaced relation with shield portions 67, and an annular member 69 connecting the outer portion of shield 68 with the inner edge of annular member 45 and substantially aligned with the main portions of shields 63, as seen in FIGURE 1. It will be noted that the passages formed by shields 67 and 68 will be curved in the direction of gas flow.

The sealing means for the various chambers connected to exchanger 34 comprises seals 39 and 41 as well as a pair of seals generally indicated at 71 for chambers 48 and a pair of seals generally indicated at 72 for chambers 58. As indicated previously, seals 39 and 41 are of a low pressure type and serve to seal chambers 59 from chambers 49, the exhaust gases in these two chambers being at low pressures relative to the pressures in chambers 48 and 58. Seals 39 and 41 also serve to support matrix 34 in an axial direction as seen in FIGURE 1. Seals 71 and 72 are similar to each other in construction, one such seal being shown in detail in FIGURES 5 and 6. The seal is of bellows construction and comprises a pair of shoes 73 and 74 each of which forms a closed loop of generally rectangular shape which is arcuately curved to conform to the corresponding duct opening. Shoes 73 and 74 are disposed on opposite sides of a flexible bellows 75 formed of strips of elastic material which forms an annular pressure chamber 76. The shoes are preferably fabricated of relatively thin material so that they may flex during assembly and will conform to any irregularities in the adjacent surfaces of matrix 34 as the latter rotates. Bellows portion 75 is so constructed as to be expandable in a direction so as to separate shoes 73 and 74 as seen in FIGURE 6. The seal may be constructed by first bending the components to the proper arcuate shape and then brazing or otherwise fastening them together, after which the assembly will still be capable of slight bending as necessary during installation. For this purpose, the inside shoe 74 may be constructed of a slightly smaller size than shoe 73 so that after the parts are bent to their arcuate shape the sizes will match. A pressurizing air connection 77 is preferably provided at one corner of the seal so that chamber 76 may be kept at proper pressure, this connection leading from any appropriate portion of the turbine assembly such as the diffuser.

As seen in FIGURES 1 and 2, seals 71 are disposed adjacent flanges 56 of housing portions 51, engaging these

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flanges as well as the adjacent portions of the outer surface of matrix 34. Seals 71 may be fastened in place or may be held in position by friction and pressure during operation. Seals 72 are preferably secured to supporting members 78 which are of rigid construction, conform to the openings of chambers 61, and are secured to housing members 31 and 43.

FIGURE 7 shows a modified form of bellows seal construction which may be used in appropriate circumstances, particularly where larger clearances between the matrix and adjacent parts are desired. This seal is generally indicated at 79 and comprises a plurality of corrugated elastic strips 81 joined alternately at their inner and outer edges and forming a single closed chamber 82. The outermost strips are secured to shoes 83 and 84 in the manner described above with respect to seals 71 and 72. It will be noted that by providing four elastic strips on each side of the seal, as seen in FIGURE 7, the available expansive movement of the bellows will be substantially greater than if only two strips are used as seen in FIGURE 6.

The operation of the novel heat exchanger construction will be evident from the foregoing description. Compressed air delivered from compressor 18 through air collector scrolls 52 will enter chambers 48 and will pass inwardly through the heat exchanger which is being rotated by meshing of pinions 32 with gear 33. This air will be heated as it passes through the matrix and will enter chambers 58 from where it will flow at high pressure into combustion chamber 16. After the burning gases have left second stage turbine 18 they will pass through chambers 59 and outwardly through the matrix into chambers 49, heating the matrix as they flow through its passages. It will be observed that the total flow area for the gases flowing inwardly or outwardly will be determined by the axial extent of the heat exchanger as well as the circumferential distance allotted to each chamber. Because of the difference in pressures, the circumferential distance may be somewhat greater for the exhaust chambers than for the high pressure intake chambers. In any event, since the heat exchanger may extend the entire axial distance between the rear of the combustion chamber and the second stage turbine outlet, the available flow areas will be substantial for a given total outside diameter of the housing. At the same time, the sealing means for the various chambers are efficiently and compactly arranged without complicated sealing structures being required. The matrix will be supported by pinions 32 and seals 39 and 41 so that it may rotate without undue restriction while maintaining its proper position with respect to the seals.

While it will be apparent that the preferred embodiments of the invention disclosed are well calculated to fulfill the objects above stated, it will be appreciated that the invention is susceptible to modification, variation and change without departing from the proper scope of fair meaning of the subjoined claim.

What is claimed is:

In a gas turbine, a compressor, an annular combustion chamber co-axial with and spaced axially from said compressor, a turbine wheel spaced axially from and connected to the outlet of said combustion chamber remote from said compressor, a heat exchanger matrix of annular cylindrical shape surrounding said combustion chamber and turbine wheel, the axial length of said matrix being substantially greater than the thickness thereof between its inner and outer surfaces and also substantially greater than the axial length of the combustion chamber which it surrounds, a substantial portion of said matrix being disposed between two imaginary parallel planes extending at right angles to the turbine axis and just containing said combustion chamber, high pressure inlet chambers formed outwardly of said matrix and facing the outer surface thereof, means connecting said compressor to said chambers, a pair of heated air chambers formed

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radially inwardly of said high pressure chambers and facing the inner matrix surface, annular shield means connecting said heated air chambers to said combustion chamber and forming a continuous annular space exposed to the combustion chamber, a pair of exhaust plenum chambers circumferentially spaced from said heated air chambers and facing the inner matrix surface, duct means connecting the outlet of said turbine wheel to said plenum chambers, and a pair of exhaust collector chambers formed outwardly of the matrix and aligned with said plenum chambers.

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**References Cited in the file of this patent****UNITED STATES PATENTS**

|           |          |               |
|-----------|----------|---------------|
| 2,969,644 | Williams | Jan. 31, 1961 |
| 3,032,989 | Oprecht  | May 28, 1962  |

(Corresponding to French Patent 1,205,792)

**FOREIGN PATENTS**

|           |               |               |
|-----------|---------------|---------------|
| 1,185,339 | France        | Feb. 16, 1959 |
| 1,205,792 | France        | Aug. 17, 1959 |
| 620,602   | Great Britain | Mar. 28, 1949 |