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Dooley

[15] **3,685,287**

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[54] **RE-ENTRY TYPE INTEGRATED GAS TURBINE ENGINE AND METHOD OF OPERATION**

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[52] **U.S. Cl.** **60/39.02,** 60/39.43, 417/406
[51] **Int. Cl.** **F02c 3/04**
[58] **Field of Search**..............60/39.45, 39.43, 39.44; 415/177, 170, 168, 213 T, 199, 53 T; 417/406, 60

[56] **References Cited**

UNITED STATES PATENTS

2,138,220	11/1938	Trumpler	60/39.43
3,095,820	7/1963	Sanborn	415/168
2,807,217	9/1957	Krzyszczuk	415/53 T
3,095,704	7/1963	Spalding	60/39.45
3,545,890	12/1970	Hubbard et al	415/168

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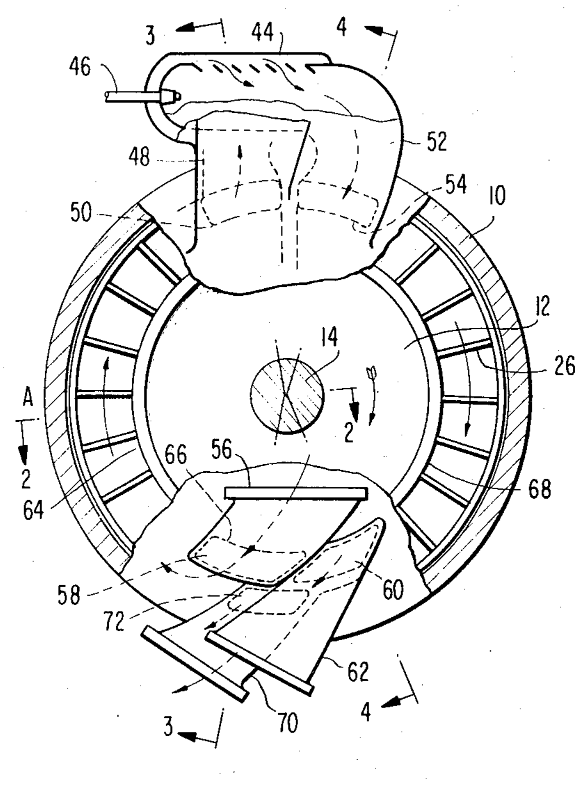
[57] **ABSTRACT**

A gas turbine engine of the integrated type having a single rotor with all working blades subjected to alternate periods of cooling and heating. The rotor is mounted for rotation in a casing and performs the dual functions of compressing primary air and driving a turbine shaft in response to the expansion of combustion gases. The rotor includes two annular channels for receiving the working blades therein in an equally spaced manner. The annular channels and blades define a dual symmetrical series of pockets. The casing includes flush ports which are formed generally adjacent the inlet and exhaust ports. The flush ports cooperate with the inlet ports to purge carry-over gases remaining in the rotor pockets after exhaustion. The flushed pockets cooperate with surrounding annular channels defined by the casing to perform reentry compression on the primary air introduced into the casing annular channels and flushed pockets through inlet ports in the casing. Approximately mid-way between the inlet and exhaust ports, the casing annular channels lead into a combustion chamber into which the compressed primary air is directed. In the combustion chamber, the compressed primary air is mixed with fuel and ignited to form the products of combustion. The products of combustion expand into the casing annular channels and flushed pockets in the direction of the exhaust ports to effect the turbine shaft drive. Sealing blocks are provided in the casing annular channels to properly direct the compressed primary air into the combustion chamber and the expanding exhaust gases out the exhaust ports.

15 Claims, 5 Drawing Figures



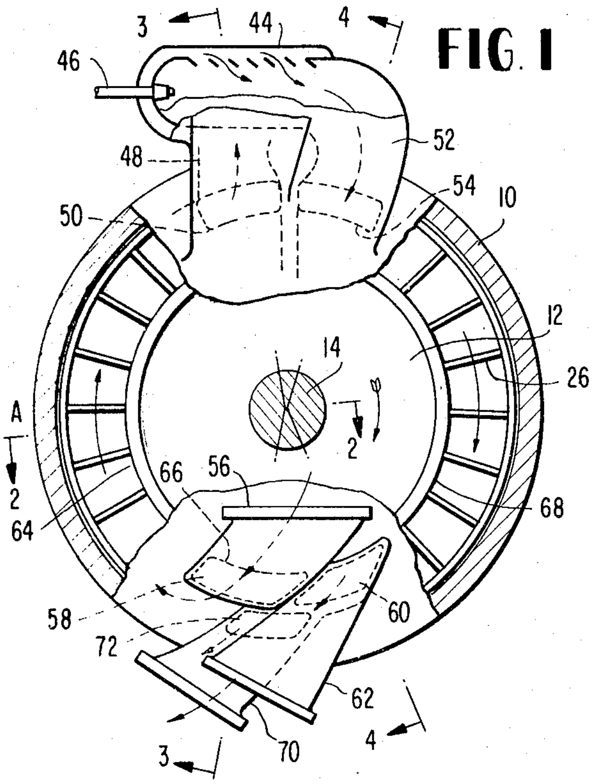


FIG. 1

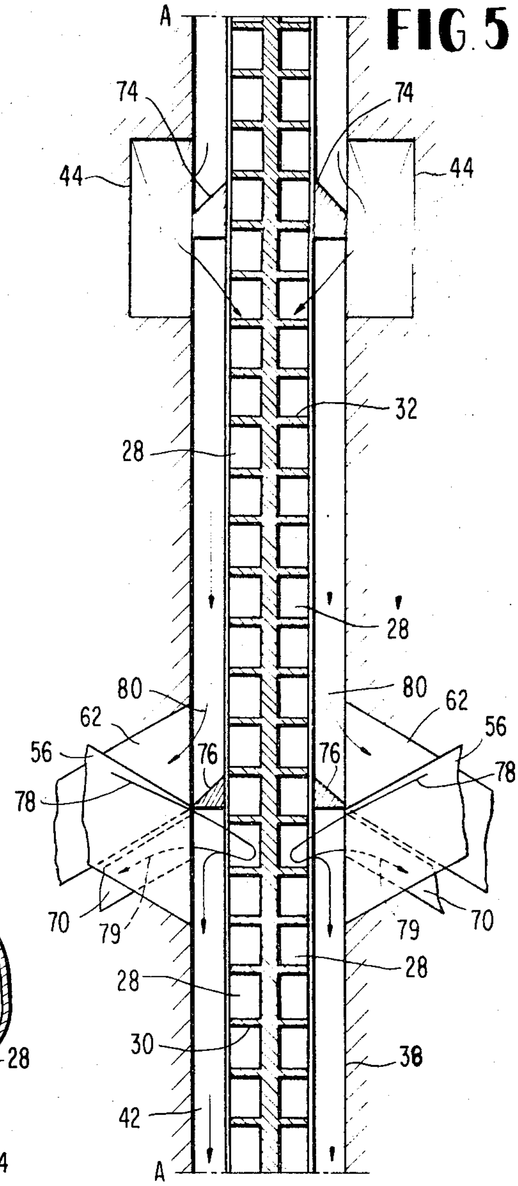


FIG. 5

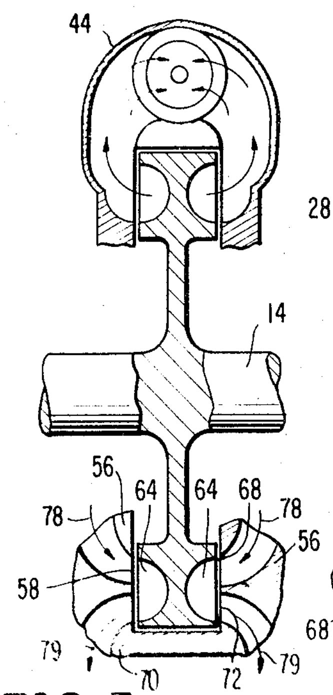


FIG. 3

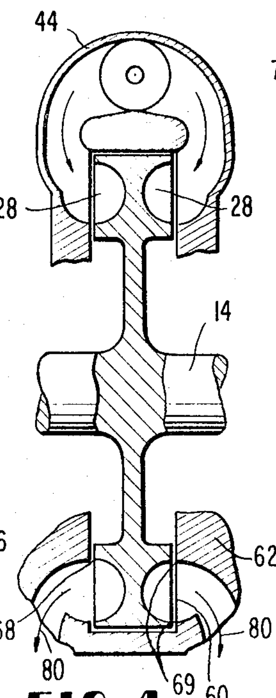
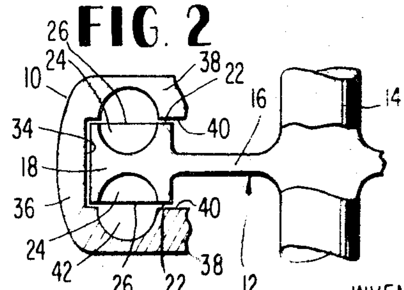


FIG. 4

FIG. 2



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RE-ENTRY TYPE INTEGRATED GAS TURBINE ENGINE AND METHOD OF OPERATION

BACKGROUND OF THE INVENTION

This invention relates to gas turbine engines and, more specifically, to a single stage gas turbine engine in which a single rotor unit acts as both a compressor and turbine.

The typical gas turbine engine consisting essentially of a separate compressor and turbine connected by a combustion chamber is one of the oldest forms of combustion engines known. For the most part these engines are not well suited for use in handling relatively light loads that would, for example, be offered by fluid pumps and the like. In addition, due to the generally critical tolerances associated with conventional gas turbine engines, it is a difficult matter to scale turbines down in size, or to reduce the cost of manufacturing, without sacrificing reliability. Also, due to the high operating temperatures associated with conventional turbine performance, the expense of materials for rotors and related equipment within such gas turbine engines has heretofore been so substantial as to preclude the gas turbine engine as a practical prime mover for a variety of applications. As a result, a need for highly reliable and inexpensive gas turbine engines which may be powered on low grade fuel and which may be adapted to a wide spectrum of operational sizes and applications has existed now for several years.

The development in the prior art toward integration wherein a combined compressor and turbine rotor is employed is one way of adapting the gas turbine engine to serve some of the needs described above. Integration reduces the size and expense of the engine by confining the two functions into a single rotor. This development has taken a number of different forms. For example, in U.S. Pat. No. 3,156,093, a single rotor thermodynamic engine is disclosed including structurally different and independently functioning compressor and turbine sections. During the operation of this disclosed engine, only blades of the turbine section will experience the high temperatures associated with the products of combustion. These "hot blades" are necessarily of primary concern since they must be capable of withstanding the high temperatures. The consequent structural and metallurgical problems may render this type of engine costly to fabricate, as may the need for forming the rotor with separate compressor and turbine sections.

It would therefore be desirable to have an integrated gas turbine engine in which a single rotor is adapted so that each blade on the rotor has both a compressor and turbine function, thereby eliminating the "hot blade" and its associated problems. It would also be desirable to provide such an engine wherein the blades may be uniformly configured on a symmetrical rotor.

In U.S. Pat. Nos. 3,269,120, 3,290,879 and 3,310,940, examples of integrated gas turbine engines in somewhat complex forms are disclosed. In U.S. Pat. No. 3,269,120, there is disclosed a gas turbine engine having axial flow compressor passages and radial flow turbine passages as well as fan blades for generating propulsive forces in a single rotor element. The provision for both axial and radial flow with a single rotor makes for a rather complex rotor element which in turn increases the manufacturing costs. In U.S. Pat. No. 3,290,879, there is disclosed an engine where the turbine blades are mounted in groups at the outer periphery of the rotor with the compressor blades longitudinally spaced from the turbine blades and extending the full diameter of the rotor. A plurality of combustion chambers, one for each group of turbine blades, are equally spaced in a circle in a combustion chamber block. This combined arrangement also makes for a rather complex rotor with the consequences mentioned above. In addition, the turbine blades are "hot blades" which present the high temperature problems referred to above. In U.S. Pat. No. 3,310,940, there is disclosed a gas turbine in which a combination compressor-turbine rotor is used. In this case, the compressor portion is situated on the front face of the rotor while the turbine portion is situated on the back face of the same rotor. The blades and the passages defined thereby exhibit a somewhat intricate pattern which inevitably leads to a more expensive gas turbine.

It would therefore be desirable to have an integrated gas turbine engine in which a single rotor is adapted so that each blade on the rotor has both a compressor and turbine function and where such undesirable features as, for example, complexity of arrangement and high fabrication costs are significantly reduced. It would also be desirable to have an integrated gas turbine engine which is of balanced design, thereby lending itself to ease of manufacture and assembly.

Further, it would be desirable to have an integrated gas turbine engine in which the low thermodynamic cycle peak gas temperatures with consequent low cycle efficiency and low useful life due to sustained constant temperatures prevalent in many existing gas turbines is substantially eliminated while at the same time attaining high compression ratios without resorting to excessively high rim speeds or to multi-staging.

The present invention is directed toward providing desirable features such as those noted above and to this end employs a reentry compressor structure described more fully hereinafter. While a similar structure has in the past been employed in a pump environment, its modification or utilization in an integrated turbine assembly has not been appreciated. Such a structure is disclosed in U.S. Pat. No. 3,095,820 issued to Sanborn at al., and assigned to the assignee of the present invention.

The disclosed fluid pump is adapted to convert the kinetic energy gained by the fluid into potential energy in the form of static pressure head throughout the entire cycle of movement. Moreover, the fluid pump employs bleed ports which are incorporated into the pump casing to bleed trapped warm or hot compressed gas from the pump to prevent recirculation thereof. As a result, the head developing ability of the pump is substantially improved. These ports, however, are sealed from the inlet ports to prevent mixing of warm bleed gas with inlet gas.

Although the provision of bleed ports is adequate to achieve the necessary purging effect of the pump to substantially improve the head developing ability thereof, such a provision falls short when attempting to reach the air compression values necessary in a gas turbine engine.

It would therefore be desirable to have an integrated gas turbine engine in which a portion of the inlet air is used to effect a positive flushing of the carry-over exhaust gases, so that sufficient compression of the remaining inlet air can take place, thereby permitting utilization of a single rotor, which is adapted so that each blade on the rotor has both a compression and turbine function.

OBJECTS AND SUMMARY OF THE PRESENT INVENTION

It is therefore an object of the present invention to provide a simple low-cost gas turbine engine which obviates or minimizes many of the drawbacks of previously developed gas turbines such as those noted above.

It is another object of the present invention to provide a novel simple low-cost gas turbine engine which is particularly adaptable to being scaled down in size.

It is still another object of the present invention to provide a simple low-cost novel gas turbine engine wherein high compression ratios may be obtained using a low rotor rim speed.

It is yet another object of the present invention to provide a novel gas turbine engine of the integrated type having a single rotor in which a portion of the engine inlet air is used to effect a positive flushing of the carry-over exhaust gases.

It is a further object of the present invention to provide a novel gas turbine engine of the integrated type having a single rotor wherein each rotor blade serves as both a compressor blade and a turbine blade.

It is a still further object of the present invention to provide a novel gas turbine engine which substantially reduces the windage and frictional losses attending conventional gas turbine engines.

It is still another object of the present invention to provide a novel gas turbine engine wherein gas seal losses are reduced to a minimum.

It is yet another object of the present invention to provide a novel gas turbine engine which may be easily pressure balanced.

Another object of the present invention is to provide a novel gas turbine engine which is susceptible to a minimum of pressure or heat distortions and which tends to distribute the heat and pressure so that any distortion would be symmetrically balanced.

At least some of the above-listed objects are achieved by the provision of a gas turbine engine having a single rotor mounted within a surrounding casing. The rotor includes an annular rim having annular channels disposed therein with one on each side of a radial center line of the rotor. A plurality of blades, disposed within these channels, are uniformly angularly disposed with respect to a radial center line of a radially extending web portion of the rotor thereby defining with said channels a plurality of pockets within which primary air is received during the compression phase and expanding gases of combustion are received during the turbine phase of the operating cycle of the engine. The casing includes an annular recess for receiving the annular rim of the rotor therein. Annular channels are disposed within side walls which partially define the casing recess. The channels are each in mirror-like relationship with one of the annular channels within the rim of the rotor. Inlet ducts with inlet ports are provided for directing primary air to the rotor, and exhaust ducts with exhaust ports are provided for directing the products of combustion from the rotor. Flush ducts with flush ports are disposed generally adjacent but circumferentially spaced from the inlet and exhaust ports and cooperate with the inlet ports to insure that the plurality of pockets are purged of substantially all carry-over exhaust gases. A combustion chamber disposed approximately mid-way between the inlet and outlet ports has fuel injecting and igniting means disposed therein for combining with the delivered primary air to produce the products of combustion.

The engine relies on a reentry principle to effect a sufficiently high compression ratio so that the primary air is delivered to the combustion chamber at a pressure level sufficient for combustion, thereby permitting use of the rotor as both a compressor and a turbine. The practice of this principle is made possible by the purging of substantially all carry-over exhaust gases from the plurality of pockets and the combined utilization of the plurality of pockets and the annular channels of the engine casing, so that the path of traverse of the primary air within the space defined by the plurality of pockets and the annular channels is essentially a spiral. This spiral traverse permits a conversion of the kinetic energy of the primary air, which is essentially free of carry-over contamination, to be converted into a static pressure accumulation, which reaches the desired pressure level for combustion.

For a further and more detailed understanding of the present invention and the various additional objects and advantages accomplished thereby, reference is made to the following detailed description and the accompanying drawings, wherein:

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a front elevation view in partial cross section of a gas turbine engine according to the present invention;

FIG. **2** is a partial sectional view of the apparatus shown in FIG. **1** taken along the line **2—2** thereof;

FIG. **3** is a partial sectional view of the apparatus shown in FIG. **1** taken along line **3—3** thereof;

FIG. **4** is a partial sectional view of the apparatus shown in FIG. **1** taken along line **4—4** thereof; and

FIG. **5** is a schematic diagram illustrating a series of rotor blades of the apparatus shown in FIG. **1** displayed in a flat pattern.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Detailed Structure

Referring now to the drawings in which like numerals are used to indicate like parts throughout the various views thereof, FIG. **1** shows a gas turbine engine according to the present invention in which a generally cylindrical casing **10** is provided for housing a rotor **12** which is mounted for rotation within casing **10** by, for example, an integrally formed shaft extension **14**. Shaft **14** may, in turn, be connected with a load to be driven (not shown). The load may comprise a fluid pump, or the like.

Referring to FIG. **2**, it can be seen that the rotor **12** includes in addition to the shaft **14**, an annular web **16** and an annular rim **18**. The annular web **16** extends radially outwardly from the shaft **14** and at its free end away from the shaft **14** has extending radially therefrom the annular rim **18**. The rim **18** has a transverse as well as a radial and annular extent, so that in cross section the transverse extent is symmetrically disposed with respect to a radial center line of the annular web **16**. The outer transverse extent of the rim **18** is defined by annular planar surfaces **22**, with an annular channel **24** extending concavely into the rim **18** from each surface **22**, although it is to be understood that another configuration of channel may be used if so desired to effect a similar result. These channels **24** serve as blade receiving means into which a plurality of blades **26** are positioned. These blades conform to the particular channel configuration and are preferably equally spaced along the length thereof. The blades **26** may be formed so that any two adjacent blades define with the channel **24** in which they are positioned, a generally semi-cylindrical pocket **28**. Preferably, the result of the combination of the annular channels **24** and the plurality of blades **26**, a dual symmetrical series of pockets **28**.

The blades **26**, as illustrated, are disposed normally with respect to the radial center line of the annular web **16** (as best seen in FIG. **5**). With this arrangement, during the turbine stage, described hereinafter, a greater amount of exposed blade face area is initially presented to the expanding gases of combustion than would be the case if the blades were canted, for example, so that surface **32** formed an acute angle with the radial center line of the annular web **16**. On the other hand, it is contemplated that other blade configurations, for example the canted configuration described above, may be employed where optimum conditions dictate. In such an arrangement, during the compressor stage, described hereinafter, the surface **30**, which would form an obtuse angle with the radial center line of the annular web **16**, would not only impart a direction of flow (relative to the blade) to the inlet air along channels **42**, but also a direction flow (relative to the blade) into channels **42**.

The rim **18** fits within a recess **34** defined by annular transversely extending wall **36** and annular radially extending walls **38** of the casing **10**. The annular radially extending walls **38** are formed integrally with annular transversely extending wall **36** so that the recess **34** formed thereby is symmetrical with respect to the radial center line of the web **16**. Annular radially extending walls **38** terminate transversely inwardly with annular planar surfaces **40** which surfaces form two sides of recess **34**. An annular channel **42** extends concavely into the annular radially extending walls **38** from each surface **40**. These channels may be in mirror image relationship with the annular channels **24** within rim portion **18** so that the channels **24** and **42** form two annular channels having approximately circular cross-sectional configurations. Together the channels **24** and **42** generally define a torus.

A combustion chamber **44** may be connected with the annular channels **42** formed within the casing **10** or, alternatively, combustion means may be disposed directly within these channels so as to maintain the path of gases therethrough as an annular flow not having the torturous path shown in FIG. **1**. However, it may be desirable to provide the torturous path of FIG. **1** in order to insure more complete mixing of fuel and air within the combustion chamber **44**.

The combustion chamber **44** may be of a conventional configuration and is provided with a fuel injection means **46**. Compressed air is provided to the combustion chamber **44** by means of ducts **48** communicating with the channels **42** through ports **50** and the expanding gases of combustion are directed back to the blades **26** of the rotor **12** through combustion gas ducts **52** communicating with the channels **42** through ports **54**.

Primary air ducts **56** may be formed in the casing **10** to communicate with the annular channels **42** through inlet ports **58** at a point approximately 180° from the combustion chamber **44**. Exhaust ports **60** are formed in the casing **10** generally adjacent the inlet ports **58** through which exhaust gases pass into exhaust ducts **62**. The rotor **12** may be mounted for rotation in a clockwise direction (as viewed in FIG. **1**) to pick up primary air at the inlet ports **58** and to carry it to the compressed air ducts **48** leading to the combustion chamber **44**. In carrying the air to the combustion chamber, the generally semi-cylindrical pockets **28** defined between adjacent blades **36** receive the inlet air in radially upper portions **64** thereof as seen in FIGS. **1** and **3**. Inlet ports **58** are provided arcuate portions **66** which substantially conform with the radially inward peripheral edge **68** of channel **25** so that the inlet air delivered to the radially upper portion **64** of the generally semi-cylindrical pockets **28** will enter without any significant shock or frictional effects taking place. In like manner, exhaust ports **60** are provided with arcuate portions **69** which substantially conform with the peripheral edges of channel **24** as best seen in FIG. **4**, so that any back pressure problems are minimized.

Reentry compressors have heretofore not been considered practical for gas turbine engine machines. It has been found that such reentry compressors have not provided sufficient pressure developing capabilities. According to the present invention, the use of a reentry compressor may indeed produce sufficient compression ratios for gas turbine engines since the carry-over recirculation of exhaust gas from the combustor is minimized. Generally, without provision to the contrary, the exhaust gas carry-over would be caused by gas trapped within the generally semi-cylindrical pockets **28**. The recirculated exhaust gas, because of its heat content, is not as compressible as cooler charge air and thus the recirculated exhaust gases decrease the compression ratio attainable by the compressor portion of the gas turbine.

In order to preclude exhaust gas carry-over, ducts **70** are provided with flush ports **72** for communicating with the channels **42**. The ducts **70** are aligned between the inlet ducts **56** and the exhaust ducts **62**, as shown in FIGS. **1**. Thus, when air is drawn into the engine through the inlet ports **58**, a portion of this inlet air, after approximately following the cross-sectional contour of generally semi-cylindrical pockets **28**, travels out through the flush ducts **70** with substantially all of the carry-over exhaust gases. This insures that only fresh charge air remains. The flushing feature is provided to augment the operation of the exhaust ducts **62**.

Two sets of sealing blocks **74** and **76** are provided. The sealing blocks **74** are located in the annular channels **42** in the vicinity of the combustion chamber **44** and adapted to direct the compressed primary air to the combustion chamber. The sealing blocks **76** are located in the annular channels **42** in the vicinity of the exhaust port **60** and adapted to direct the exhaust gases out from the channel **42**. These sealing blocks create buffer zones which serve to stabilize the pressure distributions in the engine by confining the pressure associated with a particular phase of the engine operating cycle to a defined region of the engine. Also, because of the flushing feature, the differential pressure across the sealing blocks **74** and **76** is very low, so that sealing-block carry-over is significantly reduced which in turn contributes to a more efficient engine.

MODE OF OPERATION

The operation of the integrated gas turbine engine of the present invention may best be understood in connection with FIGS. **3** and **5** of the drawings. Atmospheric or low pressure air indicated by arrow **78** is drawn into the engine through the inlet ports **58** of the inlet ducts **56**. Under the influence of its own inlet velocity and the centrifugal force acting thereon, the atmospheric or low pressure air enters generally semi-cylindrical pockets **28** through the radially upper portion **64** thereof and generally follows the contour of the pockets. A portion of the atmospheric or low pressure air indicated by arrow **79** passes outwardly into the flush ducts **70** through flush ports **72** after mixing with a substantial part of the carry-over exhaust gases within generally semi-cylindrical pockets **28**. The remaining atmospheric or low pressure air is then directed into the channels **42** where it is constrained to follow the contour thereof back into a pocket **28**. The centrifugal force will, as stated above, cause the remaining inlet air to follow the contour of the pockets **28** back into channels **42**, and the surfaces **30** of the blades **26** will impart to the remaining inlet air as it leaves pockets **28** a direction of flow along channel **42** as well. So then, the inlet air alternately enters the flushed pockets **28** in the channels **25** and the channels **42** in casing **10** defining a substantially spiral path of travel through the two annular channels. The kinetic energy of the inlet air is converted into potential energy in the form of static pressure in the casing annular channels **42** because of fluid deceleration in these channels. This delivery of kinetic energy to the annular channels **42** occurs many times before the air arrives at the compressed air ducts **48**, i.e., on every loop of the spiral the air is delivering imparted kinetic energy to channels **42**, so that an accumulation of pressure head in the direction of the combustion chamber results. It is this later conversion of kinetic energy within a substantially flushed path which produces a pressure head rise providing the overall gas turbine engine with a sufficiently high compression ratio without using multiple rotors, multi-staging methods or high rotor tip speeds. The compressed air is then directed with the aid of the sealing blocks **74** through the ports **50** to the combustion chamber **44** where fuel is added to create a combustible charge which is fired by an igniting means (not shown). Once ignition occurs, combustion proceeds as a steady non-pulsating burn of the subsequently entering charge. After combustion, high temperature combustion gases of about 2,500° F. are directed through the combustion gas ducts **52** back to the rotor through the ports **54**. The rotor now functions as a turbine. The expanding gases flow into the generally semi-cylindrical pockets **28** and the channels **42** as before but this time impart kinetic energy to the blades when striking the surfaces **32** of blades **26**. In proceeding toward the exhaust ports, the expanding gases spiral in the opposite direction from the compressing function. This spiralling continues until the stored kinetic energy of the expanding gases is spent. The expanding gases then come under the influence of a low pressure region communicated to the channels **42** through the exhaust ports **60**, and with the aid of the sealing blocks **76** the low pressure region causes the gases to finally exhaust out through the exhaust ports **60** and into the exhaust ducts **62**, as indicated by arrow **80**.

SUMMARY OF ADVANTAGES

As stated above, a reentry principle is utilized along with means to effect exhaust gas carry-over flushings from the pockets formed in the rotor in order to achieve a practical integrated gas turbine engine. Thus, it can be seen that a gas turbine engine has been provided wherein each blade of the rotor element is exposed, alternately, to hot gases in a turbine expansion process and then cold gases in an air compression process. Such a feature permits a very high thermodynamic cycle peak gas temperature which provides a high theoretical cycle efficiency without operating the rotor blades at sustained high temperatures.

The use of a reentry compressor principle provides high compression ratios without requiring excessively high rotor rim speeds and without multi-staging compressor elements. The simplicity of such a reentry compressor reduces the cost of the rotor and obviates the need for extensive speed reduction equipment such as gearing and the like.

Although the rotor rim and blades are not limited to such materials, these elements can be fabricated of common, inexpensive, high temperature steels. The compressor section and bearing structure may be made of aluminum alloy. The overall construction is very rugged and permits the use of low cost rotors without the usual critical tolerances. Such rotors are not sensitive to fouling from ingested foreign material or from combustion gas ingredients.

Of independent significance is the provision of a synergistic arrangement wherein each element of the rotor alternately goes through hot and cold zones so that the combustion gas temperatures can be much higher than those ordinarily encountered in similar gas turbine engines. Conventionally, such temperatures may be in the range of 1,800° F. Engines embodying the present invention may run as high as 2,500° F. The compression ratio of the present invention can be much higher than conventional single stage gas turbines due to the multi-staging effect of the reentry principle.

Because the rotative speeds of the rotor are rather low, windage and frictional losses are held to a minimum and no reduction gearing losses are incurred.

Since there is no abrupt pressure change along the path of gases within the annular channels of the gas turbine engine of the present invention in any of the defined regions thereof, gas sealing problems are reduced to a minimum. Gas seal losses are quite high in conventional machines and the reduction of these losses in the present invention substantially increases the overall efficiency of the engine.

Due to the inherently symmetrical nature of apparatus according to the present invention, pressure and heat balancing is easily attained so that leakage from distortions is minimized.

Due to the uncomplicated nature of the apparatus according to the present invention, there is provided a gas turbine engine which is particularly adaptable to being scaled down in size. The increased reliability of gas turbine engines according to the present invention permits such apparatus to be practically utilized in remote locations where a minimum of observation and maintenance is available.

While that has been described is a preferred embodiment of the present invention, it is of course understood that various modifications and changes may be made therein without departing from the invention. It is therefore intended to cover in the appended claims all such modifications and changes as may fall within the true spirit and scope of the present invention.

What I claim is:

1. An integrated gas turbine engine of the reentry type comprising:

a. a casing including a plurality of channels disposed therein;

b. a rotor mounted for rotation within said casing and including: a shaft portion and a radially extending web portion terminating in a rim portion,
said rim portion having a plurality of blade receiving means disposed therein,
said blade receiving means communicating with said plurality of channels within said casing;

c. a plurality of blades supported by said plurality of blade receiving means;

d. said plurality of blades and said plurality of blade receiving means being configured to define a plurality of pockets;

e. air inlet means formed in said casing for admitting low pressure primary air into said casing;

f. combustion means connected to said casing and including means for igniting a compressed air and fuel mixture within said combustion means to form expanding gases;

g. first exhaust gas means formed in said casing for exhaustion of said expanding gases;

h. said plurality of channels, blade receiving means and blades cooperating to compress said low pressure primary air for delivery to said combustion chamber means and to receive in driven relationship therewith the expanding gases of combustion for delivery of power to said shaft; and

i. carry-over exhaust gas flushing means comprising a second exhaust means aligned in said casing between said air inlet means and said first exhaust gas means whereby a portion of the low pressure primary air entering said air inlet means is operable to purge adjacent pockets of remaining expanded gases of combustion carried over from said first exhaust means.

2. A gas turbine engine according to claim **1**, wherein said plurality of blades and said plurality of blade receiving means are configured to form a plurality of generally semi-cylindrical pockets.

3. A gas turbine engine according to claim **1** wherein said combustion means is operable to cause a steady, non-pulsating burn of said resulting mixture.

4. A gas turbine engine according to claim **1** wherein said plurality of blades are uniformly angularly disposed with respect to a radial center line of said radially extending web portion.

5. A gas turbine engine according to claim **1** wherein each of said plurality of pockets is operable to receive primary air from said air inlet means and to cooperate with two immediately adjacent blades and one of said plurality of channels to compress said air as said air travels in a path from one pocket into one of said plurality of channels and into an adjacent pocket until said air is delivered to said combustion means.

6. In a gas turbine engine including a casing, a rotor supported for rotation by said casing, combustion means cooperating with said casing and said rotor, a plurality of air inlet ports and a plurality of exhaust ports both attached to said casing, the improvement comprising:

a. two annular channels formed in said casing and symetrically disposed axially of said rotor with each said channel communicating with at least one of said inlet ports and at least one of said exhaust ports;

b. two sets of a plurality of pockets formed in said rotor by a plurality of blades and an annular rotor channel, the pockets of each said set cooperating respectively with a portion of one of said annular channels to receive inlet air from said air inlet ports; and

c. at least two flushing ports formed in said casing, one each communicating with one of said channels and with the associated one of said at least one of said air inlet ports to direct a portion of the inlet air out from said pockets before said air reaches said combustion means, so that said plurality of pockets and said cooperating annular channels are purged of substantially all carry-over expanded gases of combustion.

7. The improvement of claim **6** wherein said rotor channels within said rotor are symmetrically disposed with respect to a center-line of said rotor so that each of said annular channels formed in said casing is in mirror-like relationship with one of said rotor channels.

8. An integrated gas turbine engine of the reentry type comprising:

a. a casing including at least one annular channel disposed therein;

b. air inlet means formed in said casing for admitting low pressure primary air into said at least one annular channel;

c. a rotor mounted for rotation within said casing and including: a shaft portion, a web portion and a rim portion;

d. said rim portion having at least one annular channel disposed therein in mirror-like relationship with said at least one annular disposed in said casing;

e. a plurality of blades supported within said at least one annular channel within said rim portion to define a plurality of pockets therewith, said plurality of pockets cooperating with said at least one annular channel within said casing to receive air from said air inlet means;

f. combustion chamber means connected to said casing and including means for igniting a compressed air and fuel mixture therein to form expanding gases;

g. exhaust means formed in said casing and communicating with said at least one annular channel in said casing for exhaustion of said expanding gases; and

h. flushing means formed in said casing and communicating with said at least one annular channel in said casing and said air inlet means to direct a portion of the inlet air out from said engine before said air reaches said combustion chamber means so that said plurality of pockets and said cooperating annular channels within said casing are purged of substantially all carry-over expanded gases of combustion;

i. said at least one annular channel within said casing, said plurality of blades and said plurality of pockets cooperating to compress said low pressure primary air for delivery to said combustion chamber means and to receive in driven relationship therewith the expanding gases of combustion for delivery of power to said shaft portion.

9. A gas turbine engine according to claim **8** and further including:

first sealing block means disposed in said at least one annular channel in said casing between said exhaust means and said air inlet means and said flushing means; and

second sealing block means disposed in said at least one annular channel in said casing adjacent said combustion chamber means.

10. An integrated gas turbine engine of the reentry type comprising:

a. a casing including an annularly extending, recirculating gas flow zone;

b. a rotor including a plurality of radially disposed, circumferentially spaced blades projecting outwardly of the radial extent of said rotor and defining a plurality of outwardly facing rotor reentry pockets between said blades and disposed adjacent said annularly extending, recirculating gas flow zone;

c. said annularly extending, recirculating gas flow zone being disposed so as to face and communicate with said rotor reentry pockets;

d. inlet means communicating with said annularly extending, recirculating gas flow zone for directing gas to said rotor reentry pockets for compression by said blades through sequential recirculation in said gas flow zone and reentry into said pockets;

e. exhaust means communicating with said annularly extending, recirculating gas flow zone for exhausting gas;

f. flushing means communicating with said annularly extending, recirculating gas flow zone adjacent said inlet means for flushing said reentry pockets; and

g. combustion means communicating with said annularly extending, recirculating gas flow zone at a circumferential location between the adjacent said inlet means and flushing means and said exhaust means.

11. The gas turbine engine according to claim **10** wherein said exhaust means is circumferentially disposed adjacent said inlet means and including:

seal means disposed in said annularly extending, recirculating gas flow zone between said exhaust means and the adjacent said inlet means and flushing means.

12. A method of driving a shaft of a single rotor encased turbine engine, in which said rotor has formed thereon a plurality of symmetrically arrayed pockets and in which the encasement has provided thereon a plurality of inlet air ports, exhaust gas ports, flush ports, annular channels and combustion chamber means, said plurality of said symmetrically arrayed pockets cooperating with said annular channels and said plurality of inlet air, exhaust and flush ports, the method comprising:

a. admitting air to said engine through said inlet ports;

b. diverting a portion of said inlet air out through said flush ports, after said portion of inlet air has passed within a portion of said cooperating plurality of pockets and channels adjacent said flush ports to flush said adjacent portion of substantially all carry-over gases of combustion;

c. repeatedly directing the remaining portion of said inlet air into said annular channels from said pockets in a spiral path between said inlet ports and said combustion means; to compress said air to an air pressure sufficient for combustion;

d. injecting fuel into said compressed air to provide a combustible mixture;

e. igniting said mixture;

f. directing the gases of combustion into a spiral path within an adjacent portion of said cooperating plurality of pockets and channels, said gases of combustion imparting kinetic energy to said rotor to drive said shaft; and

g. exhausting said gases of combustion.

13. The method of claim **12** wherein said inlet air spiral and said combustion gas spiral are oppositely directed

14. A method of driving a shaft of a single rotor encased, integrated gas turbine engine of the reentry type, the engine including: a casing provided with an annularly extending gas flow zone; a rotor provided with a plurality of radially disposed, circumferentially spaced blades projecting outwardly of the radial extent of the rotor and defining a plurality of outwardly facing rotor pockets between the blades adjacent and facing said flow zone; and a plurality of ports communicating with the gas flow zone; the method comprising:

a. admitting inlet gas to the engine through an inlet one of said ports;

b. flushing the rotor pockets adjacent the inlet one of said ports through a flushing one of said ports disposed adjacent the inlet one of said ports;

c. compressing remaining inlet gas with the blades through sequential recirculation in the gas flow zone and re-entry into the flushed pockets;

d. combusting the compressed gas;

e. driving the rotor with the combusted compressed gas;

f. exhausting gas from the gas flow zone through an exhaust one of said ports; and

g. repeating the admitting, flushing, compressing, combusting, driving and exhausting steps.

15. The method according to claim **14** wherein the step of exhausting is performed adjacent the inlet one of said ports and further including the step of:

sealing the gas flow zone between the exhaust one of said ports and the adjacent inlet and flushing ones of said ports.

* * * * *

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,685,287 Dated August 22, 1972

Inventor(s) James L. Dooley

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Col. 2, line 44 after "modification" change "or" to --for--.

Col. 5, line 22 after "26" add --is--.

Col. 5, line 41 after "direction" add --of--.

Col. 6, line 25 after "blades" change "36" to --26--.

Col. 6, line 27 after "provided" add --with--.

Col. 6, line 29 after "channel" change "25" to --24--.

Col. 7, line 43 after "channels" change "25" to --24--.

Col. 7, line 54 after "this" change "later" to --latter--.

Col. 9, line 16 after "While" change "that" to --what--.

Col. 10, line 23 before "disposed" change "symetrically" to --symmetrically--.

Signed and sealed this 30th day of January 1973.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR. ROBERT GOTTSCHALK
Attesting Officer Commissioner of Patents

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