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(54) INJECTOR APPARATUS AND METHOD FOR COMBUSTING A FUEL FOR A GAS POWERED TURBINE

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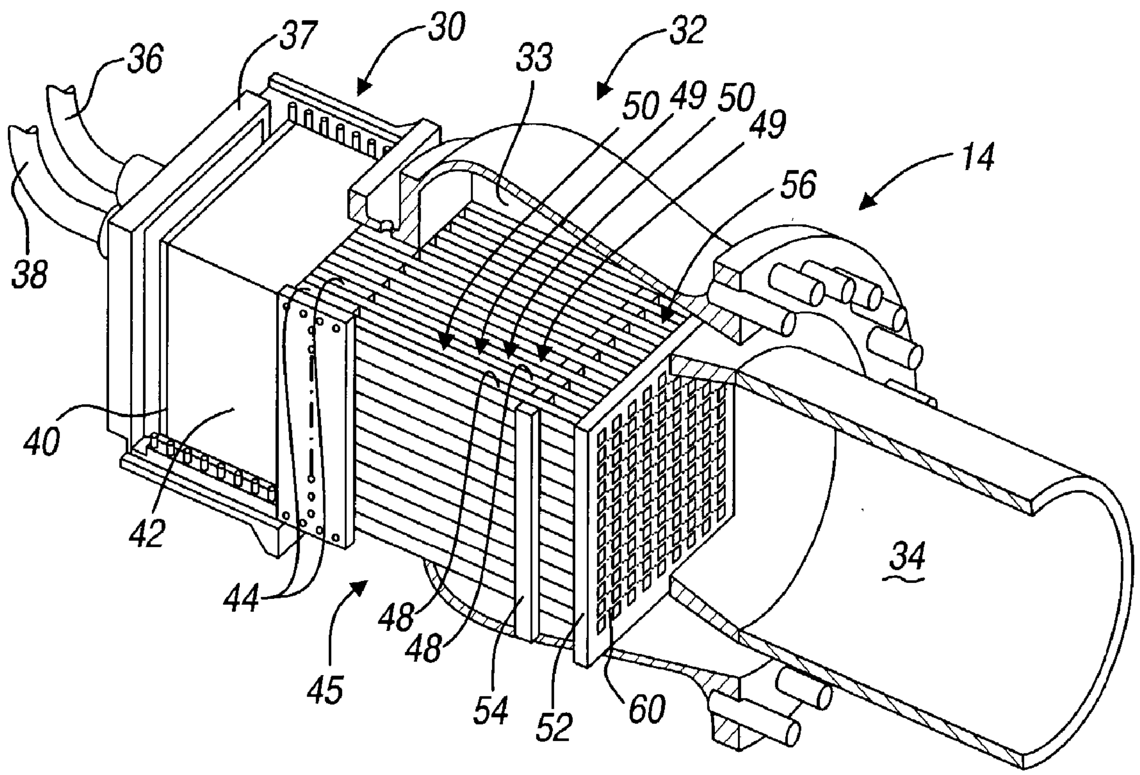
(57) **ABSTRACT**

A combustor for a gas powered turbine which employs a hypergolic or high energy air stream and an injector design to mix fuel with the high energy hypergolic air stream faster than the combustion rate of the fuel. A heat exchanger and a catalyst combusts a first portion of fuel in air without the production of undesired chemical species. A gas powered turbine requires expanding gases to power the turbine fans or blades. Fuel is generally combusted to produce the required gases. A catalyst is employed to lower the combustion temperature of the fuel. The catalyst is placed on a set of tubes in a heat exchanger such that a portion of the thermal energy may be transferred to the air before it engages the catalyst. After encountering the catalyst, the fuel that was combusted increases the temperature of the air to an auto-ignition temperature so that no other ignition source is needed to combust additional fuel added later. Therefore, as the air exits the heat exchanger, it enters a main combustion chamber and is mixed with a second portion of fuel at a rate that is greater than the combustion reaction rate of the fuel.



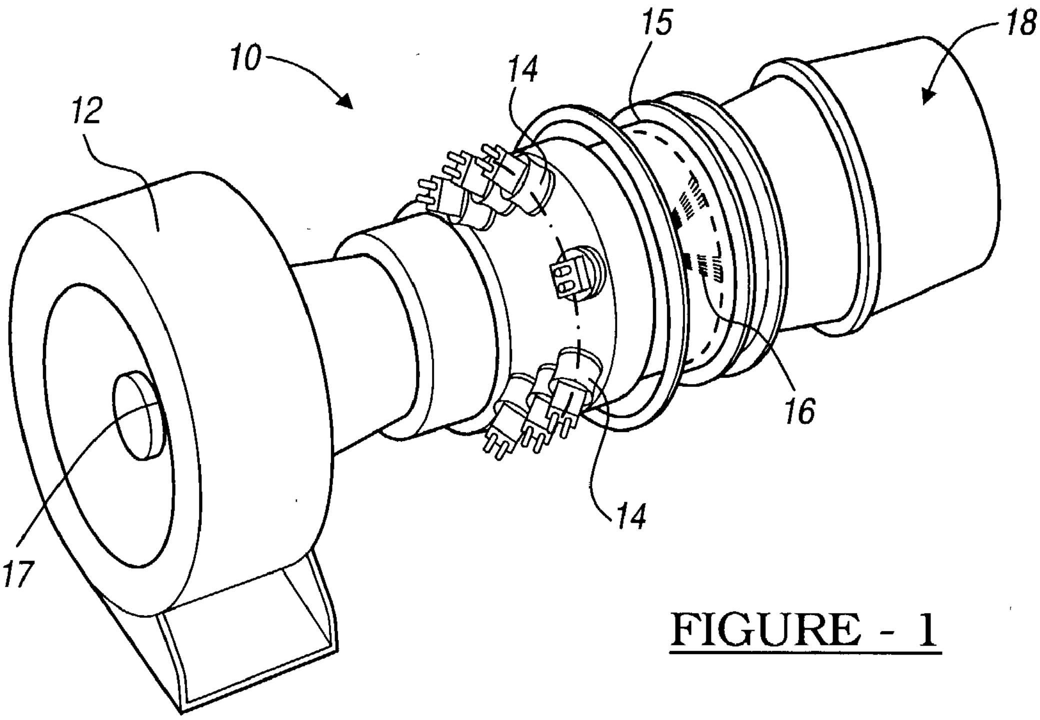


FIGURE - 1

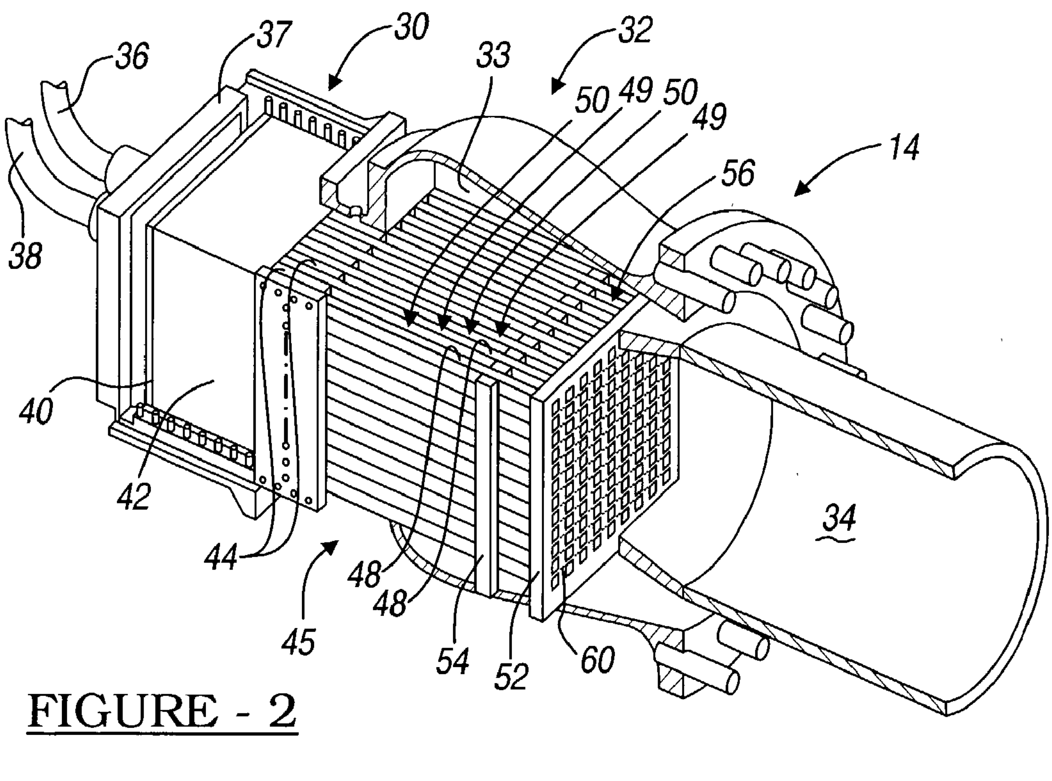


FIGURE - 2

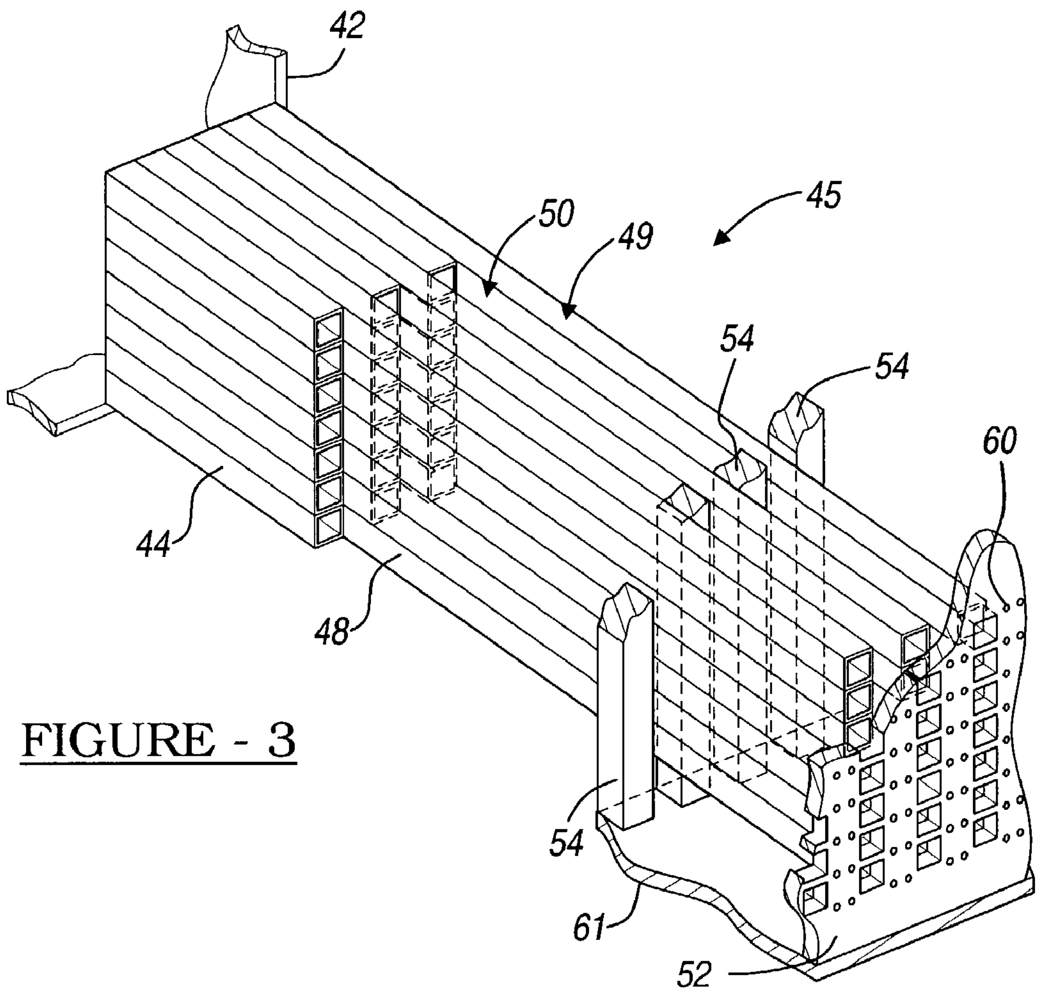


FIGURE - 3

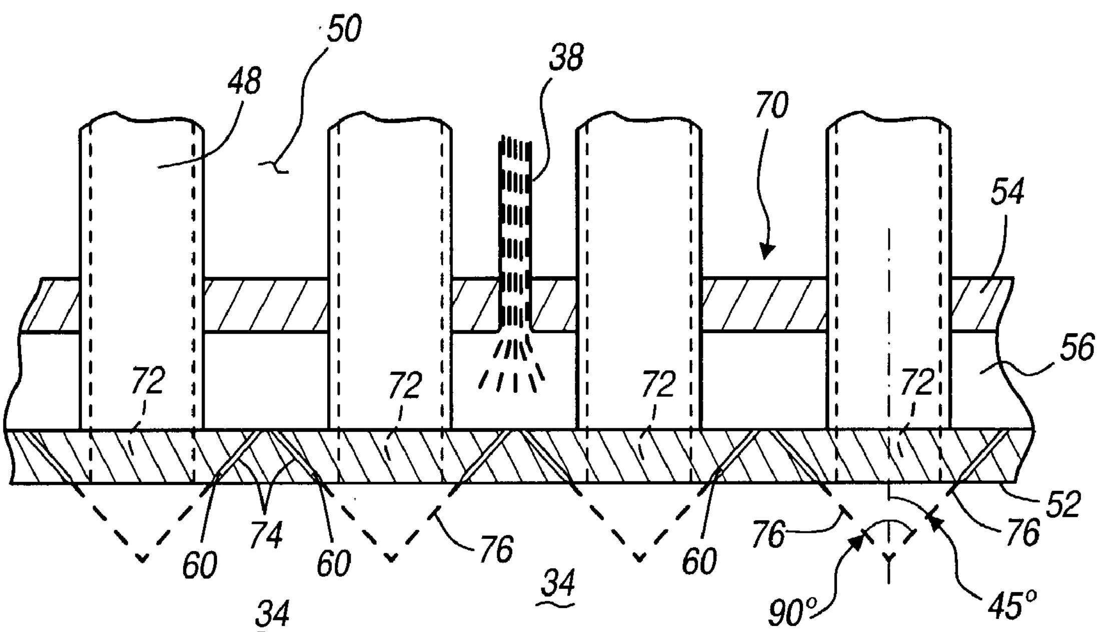


FIGURE - 4

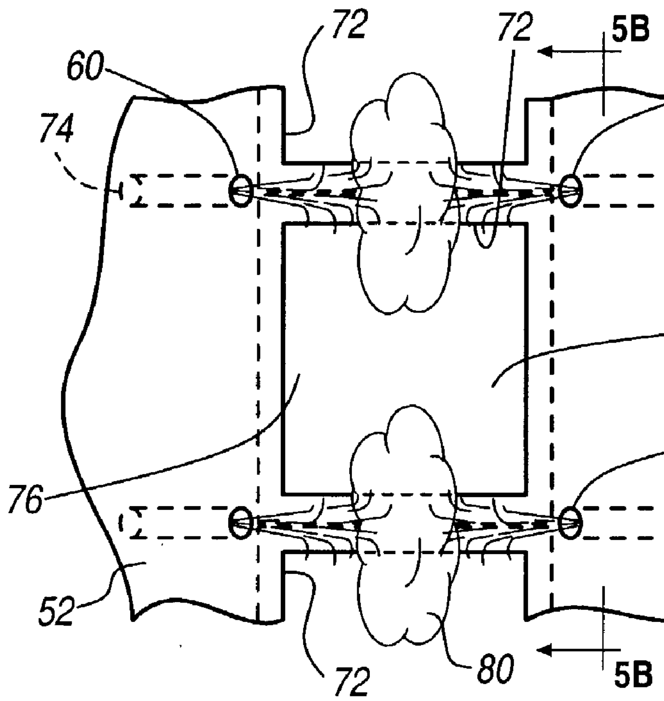


FIGURE - 5A

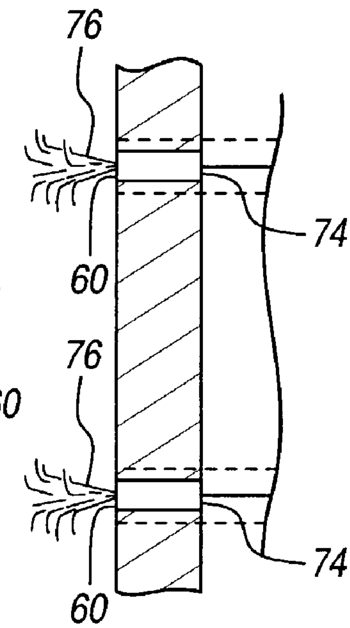


FIGURE - 5B

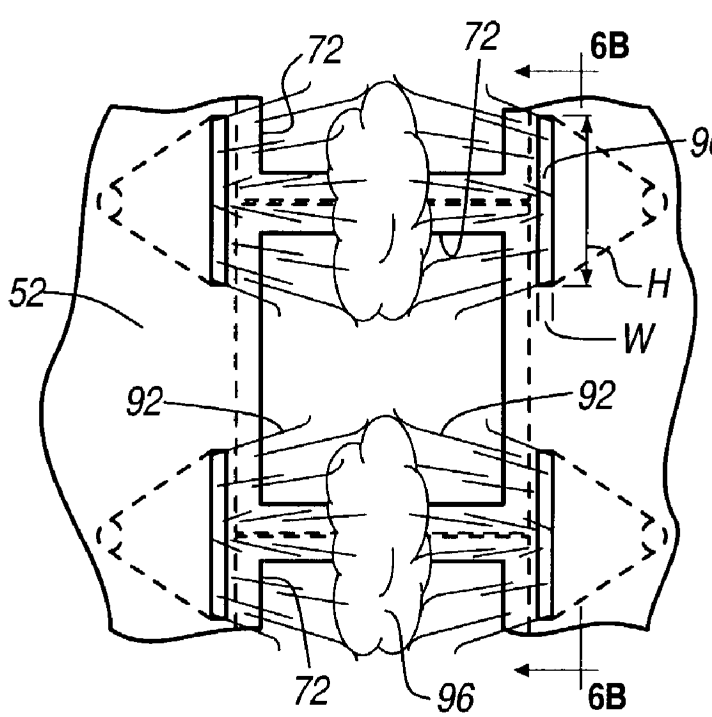


FIGURE - 6A

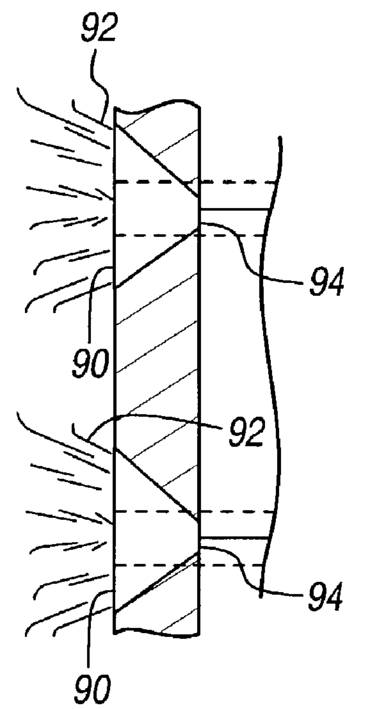


FIGURE - 6B

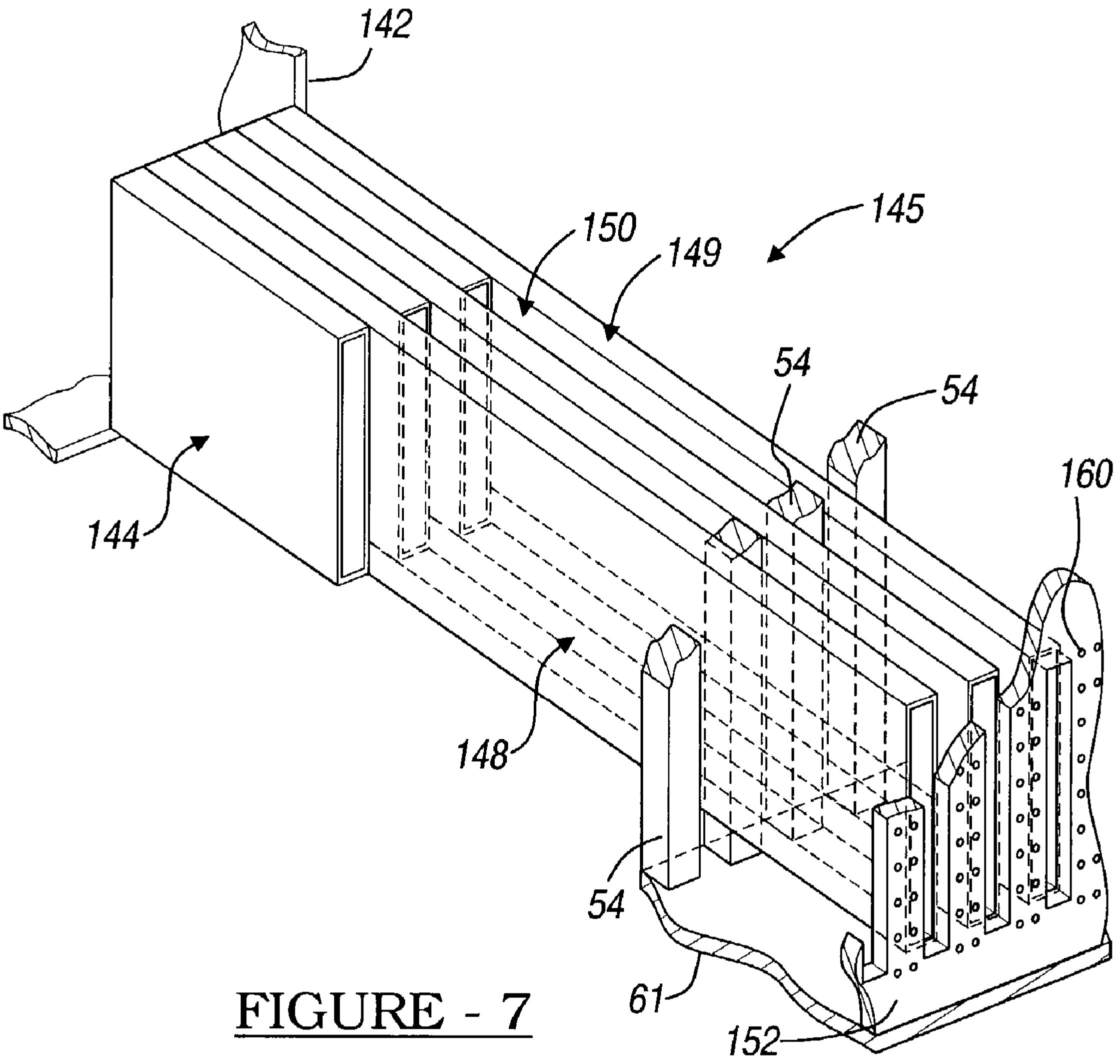


FIGURE - 7

INJECTOR APPARATUS AND METHOD FOR COMBUSTING A FUEL FOR A GAS POWERED TURBINE

FIELD OF THE INVENTION

[0001] The present invention relates to gas turbine power plants, and more particularly relates to main combustion injectors for catalytic drive, substantially no noxious oxide emission power plants.

BACKGROUND OF THE INVENTION

[0002] It is generally known in the art to power turbines with gases being expelled from combustion chambers. These gas powered turbines can produce power for many applications such as terrestrial power plants. In the gas powered turbine a fuel, such as a hydrocarbon (for example methane or kerosene) or hydrogen, is combusted in an oxygen rich environment. The oxygen is generally provided from atmospheric sources which also contains nitrogen and other compounds. These combustion systems often have high emissions of undesirable compounds such as nitrous oxide compounds (NOX) and carbon containing compounds. It is generally desirable to decrease these emissions as much as possible so that undesirable compounds do not enter the atmosphere. In particular, it has become desirable to reduce NOX emissions to a substantially low amount and more preferably to a point where emissions are virtually eliminated. Emissions of NOX are generally accepted to be non-existent if they are equal to or less than about one part per million volume of dry weight emissions.

[0003] In a combustion chamber, fuel, such as methane, is combusted in atmospheric air where temperatures generally exceed about 1420° C. (about 2600° F.). This is especially true if flame holding zones or high temperature pilot flames are used to stabilize the combustion process. When temperatures are generally above about 1420° C., the nitrogen and oxygen compounds, both present in atmospheric air, undergo chemical reactions which produce nitrous oxide compounds. The energy provided by the high temperatures allows the breakdown of dinitrogen and dioxygen, especially in the presence of other materials such as various metals, to produce NOX compounds such as NO_2 and NO.

[0004] Attempts have been made to reduce production of NOX compounds by initially heating the air before it enters the combustion chambers to an auto-ignition temperature. If the air enters the combustion chamber at or above an auto-ignition temperature, then pilot flames or recirculation flame holding zones are not necessary to combust the fuel. Auto-ignition temperatures are usually lower than pilot flame temperatures or the temperatures inside recirculation flame holding zones. One such method for heating air to the auto-ignition temperature is to mix the fuel in the air before it reaches the combustion chamber. This vitiated air, that is air which includes the fuel, is then ignited in a pre-burner where at least a portion of the entrained fuel is combusted. This raises the temperature of the air before it reaches the main combustion chamber. This decreases NOX production and emissions substantially. Nevertheless, NOX emissions still exist due to the initial pre-burning.

[0005] In view of the foregoing, it will be appreciated that it is desirable to decrease or eliminate pre-burning, thereby substantially eliminating all NOX emissions. Although the air is heated before entering the main combustion chamber, it may still need to be ignited in the combustion chamber to combust the remaining fuel. Therefore, an additional flame or arc is used to combust remaining fuel in the main combustion chamber. This reduces the temperature that the igniter must be at but still increases the temperature of the combustion chamber. In addition, no fuel is added to the air as it enters the combustion chamber. Rather all the fuel has already been entrained in the air before it enters the combustion chamber to be combusted. This greatly reduces control over where combustion occurs and the temperature in the combustion chamber.

[0006] Other attempts to lower NOX emissions include placing catalysts in catalytic converters on the emission side of the turbines. This converts the NOX compounds into more desirable compounds such as dinitrogen and dioxygen. These emission side converters, however, are not one hundred percent efficient thereby still allowing NOX emissions to enter the atmosphere. The emission converters also use ammonia NH_3, gas to cause the reduction of NOX to N_2. Undesirably, some of this ammonia is discharged into the atmosphere. Also, these converters are expensive and increase the complexity of the turbine and power production systems. Therefore, it is also desirable to eliminate the need for emission side catalytic converters.

SUMMARY OF THE INVENTION

[0007] The present invention is directed to a combustor and a combustion chamber for a gas powered turbine. A heat exchanger and a catalyst combust a first portion of fuel intermixed with air without the production of undesired chemical species. The gas powered turbine requires expanding gases to power the turbine fans or blades. Fuel is generally combusted to produce the required gases. A catalyst is employed to lower the combustion temperature of the fuel. The catalyst is placed on a set of tubes in a heat exchanger such that a portion of the thermal energy may be transferred to the air before it engages the catalyst. After encountering the catalyst, the fuel that was combusted increases the temperature of the air to an auto-ignition temperature so that no other ignition source is needed to combust additional fuel added later. Therefore, as the air exits the heat exchanger, it enters a main combustion chamber, is mixed with a second portion of fuel where it is auto-ignited and burned.

[0008] One preferred embodiment of the present invention includes a combustion system for use in a gas powered turbine which combusts a fuel in the presence of air while substantially eliminating nitrous oxide emissions. The system includes a pre-heater to heat compressed air to form a hypergolic air. An injector plate injects a fuel into the hypergolic air. An injector port, defined by the injector plate, provides the fuel to the hypergolic air before a substantial portion of the fuel combusts. Substantially all the fuel provided through the injector port reaches its hypergolic temperature at substantially the same time.

[0009] A second preferred embodiment of the present invention provides a gas powered turbine. The gas powered turbine includes a compressor that produces compressed atmospheric air to provide an oxidizer for the gas powered turbine. A combustion system mixes and combusts a fuel injected into the compressed atmospheric air to produce an expanding gas. A turbine fan is powered by the expanding gases.

[0010] The combustion system of the second preferred embodiment includes a pre-heat area, a first fuel line, a second fuel line, and an injector system. The first fuel line supplies a first portion of fuel to the compressed atmospheric air which is combusted in the pre-heat area to heat the compressed atmospheric air to a hypergolic temperature so as to produce hypergolic air. The second fuel line supplies a second portion of fuel to the hypergolic air. The injector system provides the second portion of fuel to the hypergolic air before any substantial portion of the second portion of fuel combusts. In addition, substantially all of the second portion of fuel combusts at substantially the same time such that the turbine emits substantially no nitrous oxide compounds.

[0011] The present invention provides for a new and unique method of combusting a fuel for a gas powered turbine in the presence of atmospheric air while substantially eliminating the emission of nitrous oxide compounds. The method includes providing a pre-heater. A first fuel-air mixture is formed by mixing a first portion of the fuel and the air. An auto-ignition air stream is produced by combusting the first fuel-air mixture. A second portion of the fuel is then added to the auto-ignition air stream. The second portion of fuel is then mixed with the auto-ignition air stream before substantially any of the second portion of fuel combusts.

[0012] Further areas of applicability of the present invention will become apparent from the detailed description provided hereinafter. It should be understood that the detailed description and specific examples, while indicating the preferred embodiment of the invention, are intended for purposes of illustration only and are not intended to limit the scope of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] The present invention will become more fully understood from the detailed description and the accompanying drawings, wherein:

[0014] **FIG. 1** is a perspective view of a gas powered turbine including a combustor in accordance with the present invention;

[0015] **FIG. 2** is a partial cross-sectional perspective view of a single combustor;

[0016] **FIG. 3** is a detailed, partial cross-sectional, perspective view of a portion of the heat exchanger; and

[0017] **FIG. 4** is a detailed, cross-sectional view of a portion of the main injectors according to the present invention;

[0018] **FIG. 5*a*** is a detailed, elevational view of the downstream side of the main injector plate according to a first embodiment of the present invention;

[0019] **FIG. 5*b*** is a detailed cross-sectional view of the main injector plate taken along line **5*b*** in **FIG. 5*a*;**

[0020] **FIG. 6*a*** is a detailed elevational view of a downstream side of the main injector plate according to a second embodiment of the present invention;

[0021] **FIG. 6*b*** is a detailed cross-sectional view of the injector plate taken along line **6*b*** in **FIG. 6*a***; and

[0022] **FIG. 7** is a detailed, partial cross-sectional, perspective view of a portion of the heat exchanger according to the second embodiment.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0023] The following description of the preferred embodiment(s) is merely exemplary in nature and is in no way intended to limit the invention, its application, or uses.

[0024] Referring to **FIG. 1, a** gas powered turbine in accordance with a preferred embodiment of the present invention is shown. The gas powered turbine **10** may use several different gaseous fuels, such as hydrocarbons (including methane and propane) and hydrogen, that are combusted and that expand to move portions of the gas powered turbine **10** to produce power. An important component of the gas powered turbine **10** is a compressor **12** which forces atmospheric air into the gas powered turbine **10**. Also, the gas powered turbine **10** includes several combustion chambers **14** for combusting fuel. The combusted fuel is used to drive a turbine **15** including turbine blades or fans **16** which are axially displaced in the turbine **15**. Generally, a plurality of turbine fans **16** are incorporated, however, the actual number depends upon the power the gas powered turbine **10** is intended to produce. Only a single turbine fan is illustrated for clarity.

[0025] In general, the gas powered turbine **10** ingests atmospheric air, combusts a fuel in it, and powers the turbine fans **16**. Essentially, air is pulled in and compressed by the compressor **12**, which generally includes a plurality of concentric fans which grow progressively smaller along the axial length of the compressor **12**. The fans in the compressor **12** are all powered by a single axle. The high pressure air then enters the combustion chambers **14** where fuel is added and combusted. Once the fuel is combusted, it expands out of the combustion chamber **14** and engages the turbine fans **16** which, due to aerodynamic and hydrodynamic forces, spins the turbine fans **16**. The gases form an annulus which spins the turbine fans **16**, which are in turn affixed to a shaft (not shown). Generally, at least two turbine fans **16** are incorporated. One or more of the turbine fans **16** engage the same shaft that the compressor **12** engages. The gas powered turbine **10** is self-powered since the spinning of the turbine fans **16** also powers the compressor **12** to compress air for introduction into the combustion chambers **14**. Other turbine fans **16** are affixed to a second shaft **17** which extends from the gas powered turbine **10** to power an external device. After the gases have expanded through the turbine fans **16**, they are expelled out through an exhaust port **18**. It will be understood that gas powered turbines are used for many different applications such as engines for vehicles and aircraft or for power production in terrestrially based gas powered turbine power system.

[0026] The gases which are exhausted from the gas powered turbine **10** include many different chemical compounds that are created during the combustion of the atmospheric air in the combustion chambers **14**. If only pure oxygen and pure hydrocarbon fuel were combusted, absolutely completely and stoichiometrically, then the exhaust gases would include only carbon dioxide and water. Atmospheric air, however, is not pure oxygen but rather includes a majority nitrogen and other trace compounds. Therefore, in the high energy environment of the combustion chambers **14**, many different compounds may be produced. All of these compounds are exhausted from the exhaust port **18**. It is generally known in the art that an equivalence ratio is determined by dividing the actual ratio of fuel and air by a stoichiametric ratio of fuel to air (where there is not an excess of one starting material). Therefore, a completely efficient combustion of pure fuel and oxygen air would equal an equivalence ratio of one. It will be understood that although atmospheric air in a hydrocarbon fuel may be preferred for economic reasons other oxidizers and fuels may be provided. The air simply provides an oxidizer for the fuel to be combusted in. Therefore, other oxidizing materials such as pure oxygen may be used in the gas powered turbine **10**. In addition, other fuels may be combusted which are not necessarily simply hydrocarbons. Regardless, the present invention may be used with any oxidizer or fuel which is used to power the gas powered turbine **10**.

[0027] It will be understood that the gas powered turbine **10** may include more than one combustion chamber **14**. A reference to only one combustion chamber **14**, herein, is merely for simplifying the following discussion. With reference to **FIG. 2**, an exemplary combustion chamber **14** is illustrated. The combustion chamber may comprise any appropriate combustion chamber such as the one described in U.S. patent application Ser. No. 10/120,268 filed Apr. 10, 2002 entitled, "A Catalytic Combustor For Substantially Eliminating Nitrous Oxide Emissions," incorporated herein by reference. The combustion chamber **14** includes a premix section or area **30**, a heat exchange or pre-heat section **32**, generally enclosed in a heat exchange chamber **33**, and a main combustion section **34**. A first or premix fuel line **36** provides fuel to the premix area **30** through a fuel manifold **37** while a second or main fuel line **38** provides fuel to the main combustion section **34** through a main injector **52**. Positioned in the premix area **30** is a premix injector **40** that injects fuel from the first fuel line **36** into a premix chamber **42**. Air from the compressor **12** enters the premix area **30** through a cooling tube **44** of a heat exchanger or pre-heater **45** (detailed in **FIG. 3**). The premix chamber **42** encompasses a volume between the premix injector **40** and the exit of the cooling tubes **44**.

[0028] With further reference to **FIG. 2, a** plurality of catalytic heat exchange or catalyst tubes **48** extend into the heat exchange area **32**. The heat exchange tubes **48** are spaced laterally apart. The heat exchange tubes **48**, however, are not spaced vertically apart. This configuration creates a plurality of columns **49** of heat exchange tubes **48**. Each heat exchange tube **48**, and the column **49** as a whole, define a catalyst pathway. The columns **49**, in turn, define a plurality of channels **50** therebetween. Extending inwardly from the walls of the heat exchange chamber **33** are directing fins (not particularly shown). The directing fins direct the flow of air to the top and the bottom of the heat exchange chamber **33** so that air is directed to flow vertically through the channels **50** defined by the heat exchange tubes **48**.

[0029] Near the ends of the heat exchange tubes **48**, where the heat exchange tubes **48** meet the main combustion section **34**, is a main injector **52**. The second fuel line **38** provides fuel to the main injector **52** so that fuel may be injected at the end of each heat exchange tube **48**. Spaced away from the main injector plate **52**, towards the premix area **30**, is an intra-propellant plate **54**. The intra-propellant plate **54** separates the air that is traveling through the channels **50** and the fuel that is being fed to the fuel manifold region **56** between the main injector face **52** and intra-propellant plate **54**. It will be understood that the intra-propellant plate **54** is effectively a solid plate, though not literally so in this embodiment. Because the heat exchange tubes **48** are spaced apart the intra-propellant plate **54** is segmented wherein one portion of the intrapropellant plate **54** is placed in each channel **50** between two columns **49**.

[0030] Air that exits out the heat exchange tubes **48** is entrained with fuel injected from an injector port **60** (illustrated more clearly herein) in the main injector plate **52** and this fuel then combusts in the main combustion section **34**. The main combustion section **34** directs the expanding gases of the combusted fuel to engage the turbine fans **16** so that the expanded gases may power the turbine **10**.

[0031] Turning to **FIG. 3**, an enlarged portion of the heat exchanger **45** including a catalyst is shown. Although the heat exchanger **45** includes a large plurality of tubes, as generally shown in **FIG. 2**, only a few of the heat exchange tubes **48** and cooling tubes **44** are illustrated for greater clarity. The heat exchanger **45** includes a plurality of cooling tubes **44** disposed parallel to and closely adjacent the heat exchange tubes **48**. Each of the cooling tubes **44** and the heat exchange tubes **48** have a generally rectangular cross section and can be made of any generally good thermally conductive material. Preferably, the heat exchange tubes **48** and the cooling tubes **44** are formed out of stainless steel. It will be appreciated that while the cooling tubes **44** and the heat exchange tubes **48** are shown as being substantially square, the cross-sectional shape of the components could comprise a variety of shapes other than squares. It is believed, however, that the generally square shape will provide the best thermal transfer between the tubes **44** and **48**.

[0032] The cooling tubes **44** extend parallel to the heat exchange tubes **48** for a portion of the length of the heat exchange tubes **48**. The cooling tubes **44** extend between the columns **49** of the heat exchanger tubes **48**. The cooling tubes **44** and the heat exchange tubes **48** form the heat exchanger **45** which can provide a surface-to-surface exchange of heat. It will be understood, however, that air traveling in the channels **50** between the heat exchange tubes **48** will also become heated due to the heat transferred from the heat exchange tubes **48** to the air in the channels **50**.

[0033] Referring further to **FIG. 3**, fuel injector ports **60** are formed in the main injector **52**. The injector ports **60** may be provided in any appropriate number, however, preferably there is at least one injector port **60** for each heat exchange tube **48**, and more preferably at least two injector ports **60** for each heat exchange tube **48**. The fuel is provided to the manifold region **56** which is bound by the inter-propellant plate **54**, the main injector plate **52**, and a manifold plate **61**. The manifold plate **61** may underlay, overlay, or both the manifold region **56**. This provides fuel to each of the injector ports **60** without requiring an individual fuel line to each injector port **60**. Therefore, as air exits the heat exchange tube **48**, fuel is injected from the injector port **60** to the stream of air emitted from each heat exchange tube **48**. In this way, the fuel can be very efficiently and quickly distributed throughout the air flowing out of the heat exchanger **45**, as discussed further herein.

[0034] On the interior walls of each heat exchange tube **48** is disposed a coating of a catalyst. The catalyst may be any appropriate catalyst that is able to combust a hydrocarbon fuel, but preferably includes a mixture of platinum and palladium. The catalyst is able to combust a hydrocarbon fuel, such as methane, without the presence of a flame or any other ignition source. The catalyst is also able to combust the fuel without generally involving any side reactions. Therefore, the combustion of fuel does not produce undesired products. It will be understood that if the fuel is not a hydrocarbon then a different, appropriate catalyst is used. The catalyst allows combustion of the fuel without an additional heat source.

[**0035**] After the air enters the premix chamber **42**, it then flows out through the pathway formed by the heat exchange tubes **48**. In the heat exchange tubes **48**, the fuel in the air combusts as it engages the catalyst which has been coated on the inside walls of the heat exchange tubes **48**. As the fuel combusts, the temperature of the air rises to between about 768° C. and 930° C. (between about 1400° F. and about 1700° F.). As the temperature of the air rises, it becomes highly energetic to form high energy air, wherein high energy air exits the heat exchange tubes **48**. The temperature the high energy air reaches in the heat exchange tubes **48** is at least the hypergolic or auto-ignition temperature of the fuel being used in the gas powered turbine **10**. Therefore, the high energy air that exits the heat exchange tubes **48** is, and may also be referred to as, hypergolic or auto ignition air. The auto-ignition temperature of the air is the temperature that the air may be at or above so that when more fuel is injected into the hypergolic air the fuel ignites automatically without any other catalyst or ignition source.

[**0036**] Additional fuel is injected through the main injector **52** as the air exits the heat exchange tubes **48** and enters the main combustion section **34**. The fuel injected from the main injector **52** is injected through the individual injector ports **60**. As described above, the ratio of heat exchange tubes **48** to fuel injector ports **60** is preferably about one to one. It will be understood, however, that a different ratio of heat exchange tubes **48** to fuel injector ports **60** may be used to suit a specific application. Therefore, all of the air exiting the heat exchanger **45** is thoroughly mixed with fuel. Any additional fuel to power the gas powered turbine **10** is injected at this point, such that fuel is only added to the air at the premix chamber **42** and from the injector parts **60**.

[**0037**] The gas powered turbine **10** operates as generally described below. Air is forced from the compressor **12** into the heat exchange chamber **33**. The air then travels through the channels **50** and through the cooling tubes **44** into the premix chamber **42**. At this point a first or premix portion of fuel is intermixed with the air. The air then travels downstream through the heat exchange tubes **48** until the air is expelled from the heat exchange tubes **48** past the main injector **52** and to the combustion area **34** as hypergolic air.

[**0038**] As the air travels through the heat exchange tubes **48**, the fuel that was entrained in the air in the premix chamber **42** is combusted by the catalyst. This raises the temperature of the air from the temperature that it enters the heat exchange chamber **33**. In particular, the temperature of the air is raised to preferably between about 700° C. and 880° C. (between about 1300° F. and about 1600° F.). This temperature is generally the hypergolic temperature so that the fuel combusts spontaneously when added through the injector port **60**. It will be understood that different fuels have different hypergolic temperatures. Therefore, the amount of fuel added in the premix section **42** may be altered to determine the temperature of the air exiting the heat exchange tubes **48**.

[**0039**] With reference to **FIG. 4**, the heat exchange tubes **48** extend from an upstream side **70** through the intra-propellant plate **54** and terminate into the main injector **52**. A face of the injector **52***a* is downstream of the heat exchange tubes **48**. Fuel is provided through the main fuel line **38** to the manifold region **56** which is the area between the intra-propellant plate **54** and the main injector **52**. Although only one main fuel line **38** is illustrated, it will be understood that more than one main fuel line may be provided. Formed in the main injector plate **52** are oxidizer passages or pathways **72** which are extensions of the heat exchange tubes **48** formed in the main injector plate **52**. The hypergolic air from the heat exchange tubes **48** passes through the oxidizer pathways **72** and exits into the main combustion area **34**.

[**0040**] Extending back from the injector port **60** is a fuel injection path **74**. Each fuel injector port **60** includes at least one fuel pathway **74**. The fuel pathway **74** is preferably a bore formed in the main injector plate **52** to allow access between the fuel manifold region **56** so that the fuel which is provided to the fuel manifold region **56** from the main fuel line **38** can reach the combustion area **34**. Generally, the fuel pathways **74** are formed in the main injector plate **52** and the spaces or lands between the oxidizer pathways **72** which extend from the heat exchange tubes **48**.

[**0041**] The fuel exits the injector ports **60** as a fuel stream **76** in line with the fuel pathway **74** provided in the main injector plate **52**. Preferably, the fuel stream **76** has a half angle of between about 40° and about 50° and preferably of about 45°. Therefore as two of the fuel streams **76** intersect, in an area of the combustion chamber **34**, which is downstream of the face **52***a* of the injector plate **52**, the streams intersect at about an 80° to 100° angle. It will be understood, however, that the fuel streams **76** may intersect at a slightly different angle. For example, the fuel streams may intersect at angles ranging between about 20° and about 150°.

[**0042**] With reference to **FIGS. 5***a* and **5***b*, a first embodiment of the fuel injector port **60** is illustrated. The hypergolic air, which acts as an oxidizer, exits from the oxidizer pathways **72**. As this is happening, fuel exits from the injector ports **60** and is transmitted along fuel streams **76**. Because the two fuel streams **76** are angled, they intersect at a point downstream of the oxidizer pathways **72** and between the oxidizer pathways **72** in a land region **77**. As discussed above, preferably two fuel streams **76** intersect at an angle of about 90°. When this intersection occurs, the two fuel streams interrupt each other and produce a fuel plume **80** which spreads into the appropriate oxidizer pathways **72**. The fuel plume **80** is a substantially and finely atomized from the fuel streams **76** that are spreading out extremely rapidly. This allows the fuel in the fuel streams **76** is to intermix very quickly with the hypergolic air as it exits the oxidizer pathways **72**.

[**0043**] As discussed above, the air exits the oxidizer pathways **72** at approximately the auto-ignition or hypergolic temperature of the fuel in the fuel streams **76**. Therefore, as soon as the fuel from the fuel streams **76** is raised to the temperature of the hypergolic air exiting the oxidizer pathways **72**, the fuel will ignite. Therefore, if the fuel is able to mix substantially well with the air as it exits the oxidizer pathways **72**, the entire amount of fuel injected with the fuel streams **76** will ignite at substantially the same time. When this occurs, the ignition of fuel from the fuel streams **76** across the face **52***a* of the injector plate **52** will be substantially constant and equal. Therefore, there are substantially no hot spots created, thus keeping the temperature of the combustion chamber **34** to one which allows substantially no nitrous oxide compounds to be produced. Because the fuel in the fuel plume **80** is spreading out so quickly into the high energy air exiting the oxidizer pathways **72**, the fuel mixes with the hypergolic air and becomes heated to the hypergolic temperature faster than the ignition or combustion rate of the fuel. Therefore, substantially all of the fuel that is injected from the injector port **60** reaches the hypergolic temperature at the same time. Therefore, substantially all the fuel combusts at substantially the same time, not allowing the creation of any discrete hot spots.

[**0044**] With references to **FIGS. 6***a* and **6***b*, a fuel injector port **90** according to a second preferred embodiment of the present invention is illustrated. With this embodiment, heated air still exits the main injector **52** through the oxidizer pathways **72**. Fuel streams **76** are also produced as fuel exits injector ports **90**. The injector ports **90** are not circular but rather are generally rectangle in shape having a height of H which substantially greater than a width W. The height H of the injector port **90** extends substantially parallel to the height of the oxidizer pathways **72**. Therefore, a fuel stream or fan **92** is produced by the fuel injectors **90** that is substantially spread out or flattened, as it exists the injector port **90**, as opposed to the fuel stream **76** described previously herein.

[**0045**] Fuel may enter the fuel pathway **74** through any appropriately shaped port but as the pathway **74** nears the injector port **90**, the pathway becomes substantially rectangular having a height H which is much greater than a width W. With particular reference to **FIG. 6***b*, the upstream side of the main injector plate **52** includes an inlet port **94**, that is substantially circular in shape. Nevertheless, the injector port **90** is substantially rectangular in shape. The fuel stream **92** this produces is already substantially spread out or thinned before it reaches an intersection point with another fuel stream **92**. As two fuel streams **92** intersect, they produce a fuel plume **96** which allows the fuel provided through the injector ports **90** to be mixed with the hypergolic air exiting the oxidizer pathways **72** before the fuel, provided in the fuel streams **92**, reaches its ignition temperature.

[**0046**] This allows a substantial intermixing of the fuel with the air exiting the oxidizer pathways **72** before the fuel combusts so that the combustion in the combustion chamber **34**, across the face of **52***a* of the main injector plate **52**, is substantially even. This does not generally allow hot spots in the combustion area **34** to form, thereby substantially eliminating the production of NOX chemicals. It will be appreciated that in this second embodiment, opposing fuel fans **92** are not necessary to provide an appropriate fuel plume **96**. Because the injector port **90** produces a fuel fan **92** which is already substantially spread out and dispersed, the impingement of two fuel streams is not generally necessary.

[**0047**] As discussed above, the air that exits the heat exchanger **45** is at the auto-ignition or hypergolic temperature of the fuel used in the gas powered turbine **10**. Therefore, as soon as the fuel reaches the temperature of the air, the fuel ignites. Since the fuel has been thoroughly mixed with the air, using the fuel injector ports **60** and **90**, the combustion of the fuel is nearly instantaneous and will not produce any localized or discrete hot spots. Since the fuel is so well mixed with the air exiting the heat exchanger **45**, there will be no one point or area which has more fuel than any other point, which could also create hot spots in the main combustion section **34**. Therefore, the temperature of the air coming from the main injector **52** and into the main combustion section **34** is substantially uniform. During operation of the gas powered turbine **10**, the fuel's characteristic mixing rate is shorter than the combustion rate of the fuel.

[**0048**] The temperature of the air, after the additional fuel has been combusted from the main injector **52**, is between about 1315° C. and 1595° C. (about 2400° F. and about 2800° F.). Preferably, the temperature, however, is not more than about 1426° F. (about 12600° F.). Different fuel to air ratios may be used to control the temperature in the main combustion section **34**. The main combustion section **34** directs the expanding gases into a transition tube (not shown) so that it will engage the turbine fans **16** in the turbine area **15** at an appropriate cross sectional flow shape.

[**0049**] The use of the heat exchanger **45** raises the temperature of the air to create hot or heated air. The hot air allows the catalyst to combust the fuel that has been entrained in the air in the premix chamber **42** without the need for any other ignition sources. The catalyst only interacts with the hydrocarbon fuel and the oxygen in the air to combust the fuel without reacting any other chemical species. Therefore, the products of the combustion in the heat exchange tubes **48** are substantially only carbon dioxide and water due to the catalyst placed therein. No significant amounts of other chemical species are produced because of the catalyst. Also, the use of the heat exchange tubes **48**, with a catalyst coated therein, allows the temperature of the air to reach the auto-ignition temperature of the fuel so that no additional ignition sources are necessary in the main combustion section **34**. Therefore, the temperature of the air does not reach a temperature where extraneous species may be easily produced, such as NOX chemicals. Due to this, the emissions of the gas powered turbine **10** of the present invention has virtually no NOX emissions. That is, that the NOX emissions of the gas powered turbine **10** according to the present invention are estimated to be generally below about 1 part per million volume dry weight.

[**0050**] Also, the use of the heat exchanger **45** eliminates the need for any other pre-burners to be used in the gas powered turbine **10**. The heat exchanger **45** provides the thermal energy to the air so that the catalyst bed is at the proper temperature. Because of this, there are no other areas where extraneous or undesired chemical species may be produced. Additionally, the equivalence ratio of the premix area is generally between about 0.20 and 0.30, while the equivalence ratio of the main injector **52** is between about 0.50 and about 0.60. This means that the fuel combustion will occur as a lean mixture in both areas. Therefore, there is never an excessive amount of fuel that is not combusted. Also, the lean mixture helps to lower temperatures of the air to more easily control side reactions. It will be understood that different fuel ratios may be used to produce different temperatures. This may be necessary for different fuels.

[0051] With reference to **FIG. 7, a** detail portion, similar to the portion illustrated in **FIG. 3**, of an alternative preferred heat exchanger **145** is illustrated. A premix chamber **142** allows air from the compressor to be mixed with a first portion of fuel. Air comes from the compressor and travels through a cooling fin **144** rather than through a plurality of cooling tubes **44**, as discussed above in relation to the first embodiment. The cooling fin **144** is defined by two substantially parallel plates **144***a* and **144***b*. It will be understood, however, that other portions, such as a top **144***c* and a bottom **144***d* will be included to enclose the cooling fin **144**. Additionally, a heat exchange or catalyst fin **148** is provided rather than heat exchange tubes **48**, as discussed above in the first embodiment. Again, the catalyst fin **148** is defined by a top, and a bottom, and walls wherein the walls define a column **149**. Each catalyst column **149**, however, is defined by a single catalyst fin **148** rather than a plurality of catalyst tubes **48**, as discussed above. The cooling fin **144** may include a plurality of cooling fins **144**. Each cooling fin **144**, in the plurality, defines a cooling pathway. Similarly, the heat exchange fin **148** may include a plurality of heat exchange **148** fins. Each, or the plurality of, the heat exchange fins **148** defines a heat exchange or catalyst pathway.

[0052] Channels **150** are still provided between each of the catalyst fins **148** so that air may flow from the compressor through the cooling fins **144** into the premix chamber **142**. Air is then premixed with a first portion of fuel and flows back through the catalyst fins **148** to the main injector plate **152**. Injection ports **160** are provided on the main injector plate **152** to inject fuel as the air exits the catalyst fin **148**. A suitable number of injection ports **160** are provided so that the appropriate amount of fuel is mixed with the air as it exits the catalyst fins **148**. An intra-propellant plate **54** is also provided.

[0053] Injector ports **60** or **90** are still provided on the main injector plate **152** to provide fuel streams **76** or **92** as heated air exits the oxidizer paths (not particularly shown) from the catalyst fins **148**. Either of the previously described injector ports **60** or **90** may be used with the second embodiment of the heat exchanger **145** to provide a substantial mixing of the fuel with the air as it exits the catalyst fins **148**. This still allows a substantial mixture of the fuel with the air as it exits the catalyst fins **148** before the fuel is able to reach its ignition temperature. Therefore, the temperatures across the face of the main injector **152** and in the combustion chamber **34** are still substantially constant without any hot spots where NOX chemicals might be produced.

[0054] The present invention thus provides an apparatus and method that virtually or entirely eliminates the creation of NOX emissions. Advantageously, this is accomplished without significantly complicating the construction of the gas powered turbine **10** or the combustors **14**.

[0055] The description of the invention is merely exemplary in nature and, thus, variations that do not depart from the gist of the invention are intended to be within the scope of the invention. Such variations are not to be regarded as a departure from the spirit and scope of the invention.

What is claimed is:

1. A combustion system for use in a gas powered turbine which combusts a fuel in the presence of air while substantially eliminating nitrous oxide emissions, comprising:

a pre-heater to heat a volume of an oxidizer to form a volume of high energy;

an injector member to inject a fuel, including a high temperature, into said volume of high energy oxidizer;

an injector port, defined by said injector member, to provide the fuel to said volume of high energy oxidizer before a substantial portion of the fuel combusts; and

wherein substantially all the fuel provided through said injector port reaches its said high temperature at substantially the same time.

2. The combustion system of claim 1, wherein said pre-heater comprises:

a fuel supply system to provide a fuel to said volume of oxidizer:

a heat exchanger including:

a catalyst pathway extending along a first axis;

a cooling pathway extending along a second axis;

wherein said catalyst pathway is in thermal contact with said cooling pathway;

wherein the oxidizer is adapted to first flow through said cooling pathway and then through said catalyst pathway;

a catalyst, placed within said catalyst pathway, and adapted to combust the fuel with said volume of oxidizer; and

wherein said volume of oxidizer is adapted to first flow past said catalyst pathway and through said cooling pathway, thereby receiving thermal energy from said catalyst pathway.

3. The combustion system of claim 2,

wherein said catalyst pathway comprises a plurality of catalyst tube, that form a plurality of catalyst tube columns each spaced apart transversally to said first axis and which define a plurality of channels adapted for allowing the oxidizer to flow therethrough;

wherein said cooling pathway comprises a plurality of cooling tubes that form a plurality of cooling tube columns each spaced apart transversally to said second axis; and

wherein said cooling tubes extend substantially adjacent said catalyst tubes along said second axis for at least a portion of the length of said catalyst tubes.

4. The combustion system of claim 1, further comprising:

at least a first and a second of said injector ports;

a first fuel stream produced by said first injector port;

a second fuel stream produced by said second injector port;

wherein said first fuel stream and said second fuel stream impinge into one another to form a fuel plume prior to intersecting the high energy air.

5. The combustion system of claim 4, wherein said first fuel stream and said second fuel stream intersect at an angle between about 20° and about 150°.

6. The combustion system of claim 4, further comprising:

a fuel path formed in said injector member such that the first fuel stream and the second fuel stream provided by said first and second injector ports intersect to produce said fuel plume.

7. The combustion system of claim 1, wherein said injector port is substantially rectangular in shape such that a fuel stream is flattened as said fuel stream exits said injector port.

8. A gas powered turbine, comprising:

a compressor to produce compressed atmospheric air to provide an oxidizer for the gas powered turbine;

a combustion system for mixing and combusting a fuel injected into the compressed atmospheric air to produce an expanding gas;

a turbine fan which is powered by the expanding gases:

wherein said combustion system comprises:

a pre-heat area;

a first fuel line to supply a first portion of fuel to the compressed atmospheric air which is combusted in the pre-heat area to heat the compressed atmospheric air to a hypergolic temperature so as to produce hypergolic air;

a second fuel line to supply a second portion of fuel to the hypergolic air;

an injector system to provide said second portion of fuel to said hypergolic air before any substantial portion of said second portion of fuel combusts; and

wherein substantially all of said second portion of fuel combusts at substantially the same time such that the gas powered turbine emits substantially no nitrous oxide compounds.

9. The turbine of claim 8, wherein said pre-heat area includes a heat exchanger including:

a catalyst pathway extending along a first axis;

a cooling pathway extending along a second axis which is parallel to said first axis;

wherein said catalyst pathway forms a plurality of columns spaced transversally to said first axis and defining a plurality of channels; and

wherein said cooling pathway extends a distance along said catalyst pathway and generally perpendicular to said channels.

10. The turbine of claim 9, wherein said catalyst pathway includes a plurality of catalyst tubes and said cooling pathway includes a plurality of cooling tubes.

11. The turbine of claim 8, further comprising:

a pre-mix area for mixing the fuel from said first fuel supply with the air before the air enters the pre-heat area;

a main injector plate comprising at least a first and a second of said injectors; and

a combustion area wherein said second supply of fuel is combusted.

12. The turbine of claim 11, further comprising:

a first fuel stream produced by said first injector port;

a second fuel stream produced by said second injector port;

wherein said first fuel stream and said second fuel stream impinge into one another forming a fuel plume prior to intersecting the hypergolic air.

13. The turbine of claim 12, wherein said first fuel stream and said second fuel stream intersect at an angle between about 20° and about 150°.

14. The turbine of claim 12, further comprising

a fuel path formed in said main injector plate such that fuel provided by said first and second injector ports intersects to produce said fuel plume.

15. The turbine of claim 8, wherein said injector port is substantially rectangular in shape such that a fuel stream is flattened as said fuel stream exits said injector port.

16. A method of combusting a fuel for a gas powered turbine in the presence of atmospheric air while substantially eliminating the emission of nitrous oxide compounds, the method comprising:

producing an auto-ignition air stream wherein a fuel homogeneously combusts spontaneously upon reaching the temperature of said auto-ignition air stream;

providing a first portion of the fuel to said auto-ignition air stream;

mixing said first portion of fuel with said auto-ignition air stream before substantially any of said first portion of fuel combusts to thereby substantially eliminate emission of nitrous oxide compounds.

17. The method of claim 16, further comprising:

producing an expanding gas by combusting said first portion of fuel in said auto-ignition air-stream, said expanding gas occurring when said portion of fuel in said auto-ignition air-stream combusts upon reaching the temperature of the auto-ignition air stream.

18. The method of claim 17, further comprising powering a turbine with said expanding gas.

19. The method of claim 16, wherein said auto-ignition air stream has a temperature between about 1400° F. and 1600° F.

20. The method of claim 16, wherein mixing said first portion of fuel further comprises:

impinging a first fuel stream upon a second fuel stream to form a fuel plume prior to intersecting the auto-ignition air stream.

21. The method of claim 20, wherein impinging said first fuel stream upon said second fuel stream occurs at an angle between about 20° and about 150°.

22. The method of claim 21, further comprising:

forming said first fuel stream and said second fuel stream as substantially flat streams before allowing said streams to impinge one another.

23. The method of claim 16, wherein mixing said first portion of fuel further comprises providing a substantially flat fuel stream to said auto-ignition air stream.

24. The method of claim 16, wherein producing an auto-ignition airstream further comprises:

forming a fuel-air mixture by mixing a second portion of fuel with a volume of air; and

combusting said second portion of fuel in said volume of air, wherein combusting said second portion of fuel increases the temperature of said volume of air to an auto-ignition temperature.

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