CONTINUOUS FLOW COMBUSTION ENGINE

Filed June 8, 1966

FIG. 1

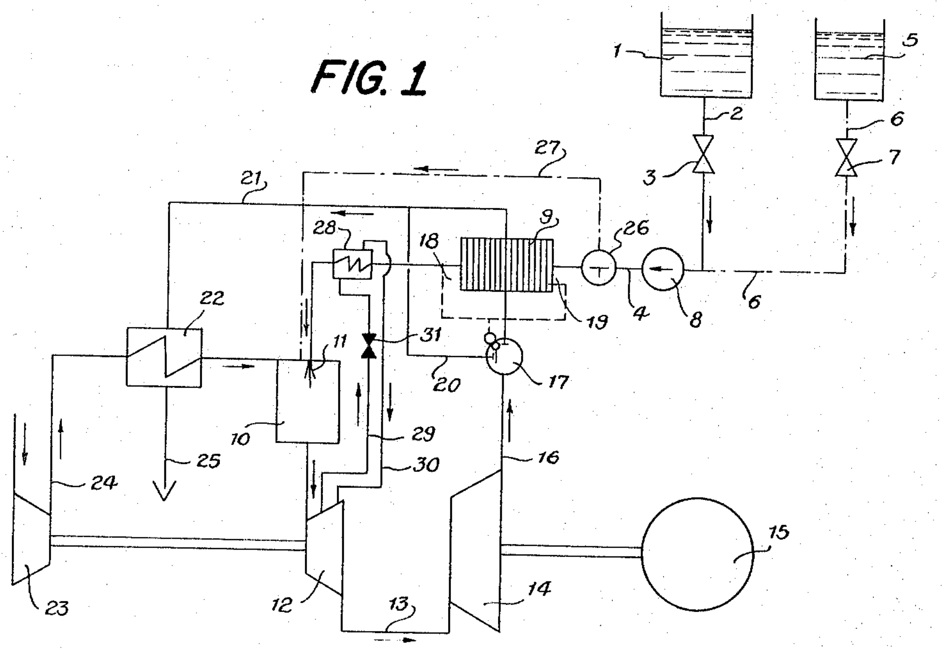


FIG. 2

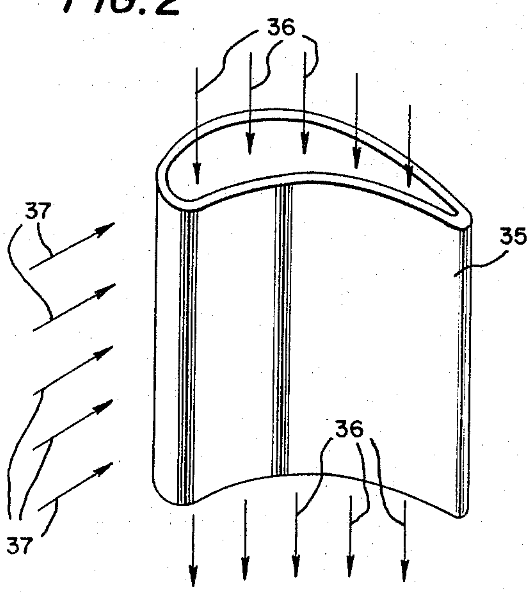
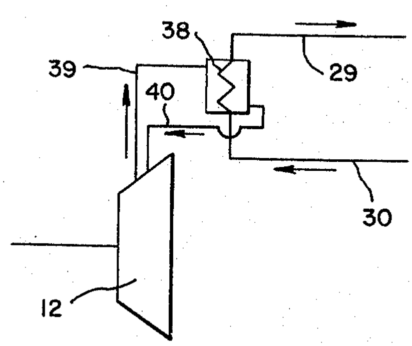


FIG. 3



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CONTINUOUS FLOW COMBUSTION ENGINE

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This invention relates to an internal combustion engine having continuous combustion, such as in a gas turbine.

U.S. Patent No. 3,167,913 to Mühlberg discloses a method of operating a continuous flow internal combustion engine such as a gas turbine in which means are provided for regaining the heat lost by an endothermic reaction between the initial fuel and water taking place outside of the combustion engine and using a suitable catalyst. The combustion of the fuel is used for this purpose. This is done by producing a strong endothermic reaction between the water and the hydrocarbon fuel in the absence of air and oxygen. This necessitates an endothermic reaction. A known technique is used for the production of oxygen in which water and hydrocarbon fuel are reacted into a mixture of carbon monoxide and hydrogen.

The above method produces the endothermic reaction in such a way that an especially comprehensive regeneration of heat is obtained for various fuels, as for hydrocarbon fuels having different boiling points and ignition points. It is accomplished by producing reaction conditions suitable with regard to the temperature, pressure, dwell time, suitable catalysts, as well as the shape of the reaction chamber, and finally with regard to the ratio of weight of the elements to the reaction, namely a hydrocarbon fuel and water.

According to the above process, the heat of reaction (reaction enthalpy ΔIB) required for the 1 gram mol of the amount of hydrocarbon fuel supplied is taken exclusively from the waste heat of the engine in such a way that the liquid or gaseous hydrocarbon fuels mixed with water produce, by the endothermic process, a gaseous mixture of carbon monoxide and hydrogen which is fed to the combustion chamber. A catalyst is used if necessary. In this manner, the reaction chamber is heated in the absence of oxygen.

Thus a direct reaction of hydrocarbon fuels with water proceeds according to the equation

$$C_nH_m+nH_2O=nCO+\left(n+\frac{m}{2}\right)H_2$$

with the result that a strong endothermic reaction produces a mixture of fuel gas composed of hydrocarbon and hydrogen which is especially rich in energy and practically free of the inert gas CO_2. The described method also discloses that the heat for the endothermic reaction comes from the sensible heat of the waste exhaust gases from the engine. For doing such, the reaction chamber is constructed as a heat exchanger mounted in the waste gas line from the turbine. This has the advantage that the waste gas line can be short and very little heat lost. Also, a conventional heat exchanger can be used. The disadvantage may exist that in order to obtain a complete reaction between the initial fuel and water, high temperature waste gases must be used which would mean a less efficient turbine operation. The system can be used at a relatively low waste gas temperature if the heat is taken through the walls of the combustion chamber. This, however, means a lowering of the temperature in the combustion chamber and a less efficient process.

The object of this invention is to produce an improvement in the described process in which the heat required for the reaction process is partially supplied by the waste heat of the exhaust gases and additionally supplied in such a way that the entire system is not materially affected.

In general, in this invention, this additional heat is obtained by taking gas from between two turbine stages which is at a temperature as low as possible to complete the endothermic reaction in the heat exchanger or a second heat exchanger.

In this invention, the final heat in the waste gas is removed at an efficient low temperature and used for the partial heat needed for the endothermic reaction and thus a system is thermally dynamically efficient. The additional heat taken from between the two turbine stages has already produced work in the continuous process so that there has been little loss of energy. After completing the endothermic reaction, the gas removed from the turbine is returned to the turbine in a following stage.

Another feature of this invention is that the heat exchange can take place in hollow stator blades of the turbine through which one of the gaseous elements of the initial fuel and water can be passed. Further, a liquid heat carrier can be put through the hollow stator blades of the turbine and then cycled through the heat exchanger for the endothermic reaction. Also, the gas removed can be put through a second heat exchanger through which a liquid heat carrier is circulated for obtaining heat for the endothermic reaction process.

The means by which the objects of the invention are obtained are described more fully with reference to the accompanying schematic drawings.

FIGURE 1 shows a gas turbine power plant with gases tapped from a turbine stage.

FIGURE 2 shows a turbine blade heat exchanger.

FIGURE 3 shows gases from a turbine heating an intermediate fluid.

In the gas turbine system of this invention, the two elements used for the endothermic reaction are in the form of an emulsion, solution, or mixture of the hydrocarbon fuel and water. (Referring to FIGURE 1 of the drawings.) These flow from a tank **1** through pipe **2** and valve **3** to a pump **8**. The mixture is thereby pumped through a pressure pipe **4** into the reaction chamber **9** which is heated by the waste exhaust gas emitted from the turbine and thus, depending upon the pressure, temperature, mixture ratio and stabilizing conditions depending upon the catalyst used, is changed into carbon monoxide and hydrogen. This mixture of carbon monoxide and hydrogen which may be saturated with water vapor and may contain fuel vapor and possibly smaller amounts of the side reaction products, then flows to the combustion chamber **10** and through a gas burner nozzle **11** and mixed with air for providing a good combustion of the carbon monoxide and hydrogen. The combustion gases then flow to a compressor turbine **12** which functions as the high pressure step of the system. The output gases of the turbine **12** flow to the working turbine **14**. Otherwise there is no mechanical connection between turbines **12** and **14**. The working turbine **14** is the low pressure step of the system. Turbine **14** is mechanically coupled with a machine such as a generator **15**. The waste exhaust gases from turbine **14** flow through pipe **16** into the reaction chamber **9** for producing at least a part of the heat needed for forming the endothermic reaction between the mixture of hydrocarbon fuel and water. The valve **17** in pipe **16** is used for regulating the flow of the waste exhaust gases into the reaction chamber. The heat regulating valve **17** is constructed, for example, as a waste gas control valve to control the heat exchange in the chamber **9** dependent upon the temperature of the fuel gas mixture at the discharge outlet of the reaction chamber, which temperature is measured by a heat sensitive element **18** or, on the other hand, dependent upon the temperature of the wall of the reaction chamber or the temperature within the reaction chamber as determined by the heat sensitive element **19**.

The waste gas control valve **17** is also usable to shut off the flow of the waste gas into chamber **9** so that the entire waste gas can be led through by-pass line **20** directly into a waste gas line **21** extending from chamber **9** to another heat exchanger **22**. This makes it possible to change over from the normal operation of the system to a liquid non-reacted cold fuel so that the reaction chamber **9** can be shut down and inspected and repaired without stopping the entire system.

The waste exhaust gas entering heat exchanger **22** has additional heat removed from it to preheat the combustion air compressor **23** and flowing through pipe **24** to the combustion chamber **10**. Finally, the waste gas in heat exchanger **22** is discharged into the atmosphere via pipe **24**. Air compressor **23** is driven by the high pressure turbine **12**.

A change-over valve **26** is provided for the purpose of starting the turbines or for an alternate operation. After valve **3** has been closed, unadulterated fuel in tank **5** can flow through pipe **6** and open valve **7** through valve **26** and pipe **27** to the fuel nozzle **11** in combustion chamber **10** so that conventional fuel can be burned for running turbines **12** and **14**.

According to this invention, the endothermic reaction can be obtained and still retain a low waste exhaust gas temperature, and consequently an efficient thermodynamic operation of the entire system. The heat required to permit the endothermic reaction is obtained by removing gas from between two stages of turbine **12** or from turbine **14**. This gas flows through pipe **29** into a second heat exchanger **28** where it completes the heating of the at least partially heated mixture of fuel and water coming from chamber **9**. The waste gas is then returned to a following stage in turbine **12** through pipe **30** or in a similar manner returned to turbine **14**. A control valve **31** in pipe **29** is for the purpose of controlling the gas extraction from the turbine.

According to this invention heat exchange can take place in hollow stator blades **35** of the turbine (see FIGURE 2 of the drawings) through which one of the gaseous elements of the initial fuel and water or another liquid heat carrier can be passed, shown by the arrows **36**.

The hot gas in said turbine passing the stator blades **35** is shown by arrows **37**. FIGURE 3 supplements FIGURE 1 whereby the gas removed from between two stages of the turbine **12** can be put to a second heat exchanger **38** through which a liquid heat carrier is circulated for obtaining heat for the endothermic reaction process. The heat exchanger **38** is connected with the gas carrying pipes **29**, **30** corresponding to those of FIGURE 1 and is con-

nected again with the pipes **39**, **40** coming from and leading to the turbine **12**.

Having now described the means by which the objects of the invention are obtained,

I claim:

1. In a process for generating power in a power plant having a combustion engine including a combustion chamber wherein fuel is burned and the resulting hot products of combustion are used as the working fluid for the engine, such as a gas turbine, and in which liquid hydrocarbon fuel is mixed with water in a proportion such that in the presence of heat substantially all of said liquid fuel and at least part of said water will be converted to hydrogen and carbon monoxide, said mixture of fuel and water being heated at least partially to an endothermic reaction by waste heat from the turbine to form a gaseous fuel containing hydrogen and carbon monoxide having a higher heat content than said liquid fuel, said gaseous fuel being burned in said combustion chamber to produce hot combustion gas, and passing the hot combustion gas into said engine for actuating said engine, the improvement comprising using the heat of the combustion gas between two stages in the turbine and at a high enough temperature to complete said endothermic reaction.

2. In a process as in claim **1**, further comprising removing the gas from between said two turbine stages to complete said reaction, and then returning said gas to said turbine.

3. In a process as in claim **1**, further comprising passing said mixture of fuel and water through hollow stator blades in said turbine for using the heat of the gas to complete said reaction.

4. In a process as in claim **2**, further comprising circulating a liquid heat carrier between the gas removed from said turbine and said mixture of fuel and water to use the heat of the gas in said turbine for completing said reaction.

5. In a process as in claim **1**, further comprising circulating a liquid heat carrier between hollow stator blades in said turbine and said mixture of fuel and water to use the heat of the gas in said turbine for completing said reaction.

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