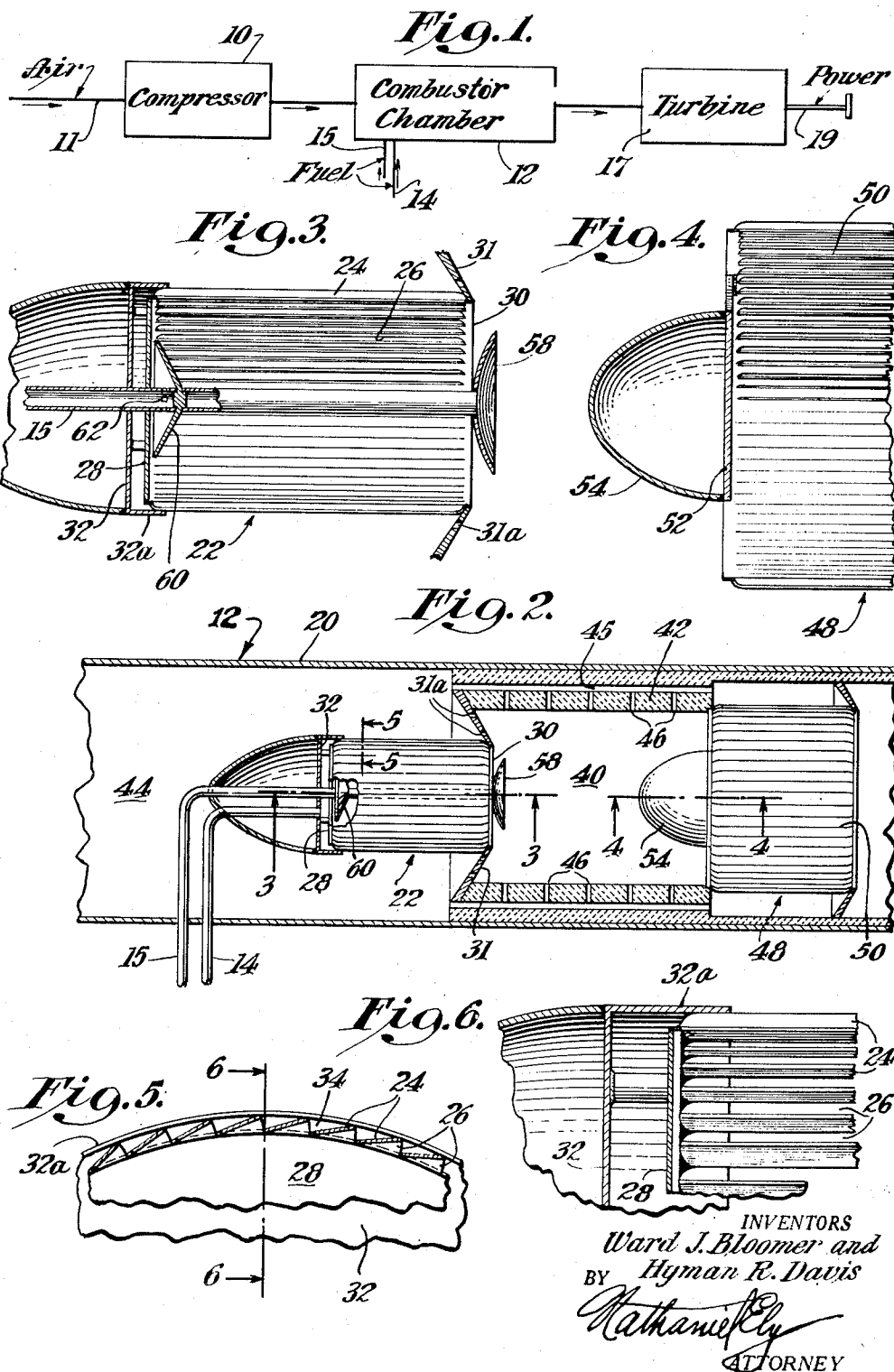


Dec. 28, 1954

W. J. BLOOMER ET AL
COMBUSTION FOR LIQUID FUELS

2,698,050

Filed June 10, 1949



1

2,698,050

COMBUSTION FOR LIQUID FUELS

Ward J. Bloomer, Westfield, N. J., and Hyman R. Davis, Jackson Heights, N. Y., assignors to The Lummus Company, New York, N. Y., a corporation of Delaware

Application June 10, 1949, Serial No. 98,214

3 Claims. (Cl. 158-4)

This invention relates to fuel burners and combustion chambers especially adapted to power plant operation such as of the gas turbine and other high duty type.

During the past ten years there has been an increasing development of the so-called gas or air turbine which generally includes in association some form of gas compressor device, gas combustion apparatus and suitable turbine construction. To increase the efficiency it has also been the practice to utilize one or more stages of gas compression, as well as to use one or more combustion chambers and heat recovery units for the desired operation. In many cases the turbines also have been operated in one or more stages or in multiple units depending upon the desired operating results and the need for varying the load over the operating range.

With appropriate variations in apparatus it is now possible to obtain overall plant efficiencies which are greater than in a comparable steam plant and approximately equal to the best that can be obtained with the most efficient diesel plants. Furthermore, it has been found that the gas turbine can be built not only in a relatively small space and with a relatively low weight per horse-power but it is possible to build the units for continuous operation over very long periods.

In most all cases the effectiveness of the gas turbine has been dependent upon the availability of premium fuel which materially increases the cost of operation.

The extension of commercial development of the gas turbine thus depends largely upon the effectiveness of the burners within the combustion chamber and the prospect of using lower quality fuels over long operating periods to match competitive power units.

The principal object of our invention is to provide a combustion chamber and method of burning fuel therein which is particularly adaptable to use in a gas or air turbine, the expected operating period of which may be in excess of months of continuous operation.

A further object of our invention is to provide an improved combustion chamber which is particularly adaptable to various liquid, solid and gaseous fuels and with which sustained periods of high operating efficiency can be obtained.

A more specific object of our invention is to provide a simplified combustion chamber in which highly efficient combustion can be obtained simultaneously with an effective adjustment of the temperature of the products of combustion for more effective use in available gas turbine units.

Further objects and advantages of our invention will appear from the following description of a preferred form of embodiment thereof taken in connection with the attached drawing in which:

Fig. 1 is a diagrammatic view of one form of gas turbine plant showing the principal elements thereof.

Fig. 2 is an enlarged central vertical cross sectional view of the combustion chamber.

Figs. 3, 4 and 5 are detailed vertical sections taken on the line of 3-3, 4-4, and 5-5 of Fig. 2 respectively showing features of construction.

Fig. 6 is a transverse detail taken on the line 6-6 of Fig. 5.

In general, the operation of a gas turbine is based upon the feed to it of compressed air and fuel and in a highly diagrammatic manner, Fig. 1 represents the essential elements. The compressor 10 receives air at 11 and raises it to a substantial pressure. High pressure air is then discharged to combustor 12 to which fuel is introduced at 14 and 15. The products of combustion may then be effectively passed to a turbine generally indicated at 17 and the net power generated is transmitted by shaft 19. It

2

will be understood that in practice cross drive or other turbine arrangements are used to compress the air and utilize the products of combustion and as a result it is common to have a plant efficiency of over 30%.

A particular feature of our invention relates to the internal construction of the combustor 12 which includes the combustion chamber and the burner as particularly shown in Fig. 2. Generally this includes an external jacket or cylinder or shell 20 having a hollow cylindrical tuyère 22 the side of which consists of a series of blades 24. These are disposed at a common angle to a tangent in such a manner as to establish gas passages 26 into the tuyère as shown in Fig. 5. Under the predetermined conditions as hereinafter described this gas passage will establish a vortex in the tuyère 22, the axis being perpendicular to the base 28 and with a component of gas flow helically out of the open end 30 of the tuyère. The base or closed end 28 of the tuyère is provided with a fuel feeding means 32 which in the particular case includes a cup or container surrounding the outside edge of the blades substantially as shown and described in copending application of Ward J. Bloomer, Serial Number 22,982, now abandoned. The tuyère and certain associated parts are shown and described in issued Patents 2,560,074; 2,560,076; and 2,560,078.

As shown in Figs. 5 and 6, the fuel enters the pan 32 from the conduit or pipe 14 and surrounds the tuyère base 28 and tends to pass axially along the length of the tuyère between the blade openings formed by the blades 24 and the periphery 32a of the feed pan. This establishes a series of substantially uniform openings 34 surrounding the closed end of the tuyère. As the fuel flows through these openings 34 into the path of the air flow, it is entrained in the air and thence carried into the tuyère where it is subjected to a shearing action and intimate contact with the air with such a fine dispersion that the fuel-air mixture discharged from the open end of the tuyère is completely and substantially instantaneously combustible.

Conveniently, the amount of air which is supplied to the tuyère blades is that theoretically required for the combustion of the fuel with the result that a relatively complete combustion is accomplished within combustion chamber 40. This is preferably lined with refractory material 42 having a diameter approximately 1½ to 3 times the diameter of the tuyère opening and a length of from 2 to 4 times the tuyère diameter. The combustion chamber 40 operates at the combustion temperature which may vary from 2,500° F. to 3,500° F. depending upon the type of fuel and amount of air. This in turn develops a radiant zone which effectively controls the continuous burning irrespective of fluctuating fuel or air.

Combustion temperatures of this order cannot now be used in gas turbines because of the limits of material and the temperature is modified in accordance with our invention by introducing some of the high pressure air from the inlet chamber 44 through path 45 past the walls 42 of the combustion chamber without entraining fuel and then directing the air through openings 46 into the combustion chamber. The products of combustion are thus reduced to the desired outlet temperature which may run from 1,000° F. to 2,000° F. This also cools the shell or jacket 20. Suitable volume controls for path 45 (not shown) may be used.

A secondary tuyère 48 may be used to aid this mixing. This tuyère has similar but coarser tangential blades 50 with the products of combustion entering the partially closed end 52. In addition air from chamber 44 will pass between the blades 50 and cause a further helical and vortical movement which accomplishes the desired dilution of the products of combustion. If desired, a fairing means 54 extending toward the combustion space 40 may be used over the central bottom portion only of tuyère 50 to reduce eddy currents caused by the flow of gas into the secondary tuyère.

It is known that the heat release of fuels is some function of the fuel particle size and we find that with preheated air in chamber 44 of the order of 700° F. to 900° F. a particle size of even asphalt can be obtained which is in the range of 20 microns or less and with a pressure drop allowable in the order of one pound p. s. i. g. it is possible to obtain a heat release of from 5 to 100 million

3

B. t. u.'s per hour in a tuyère which is in the range of 3 to 15 inches in diameter and from 3 to 22 inches in length.

A unit of this type is considered to have substantially unlimited heat release because of the high velocity of the gases through the unit which is far greater than its application to any other form of heat exchanger such as boilers or oil heating furnaces and the efficiencies of such a unit are substantially greater than can be accomplished by long flame types of burning.

There is the further advantage to this method of burning in that with the high atomization and distribution of the fuel with the theoretical air it is possible to materially limit the length of the combustion chamber and to immediately establish a large volume of highly heated air at controlled temperatures for the high pressure turbine which may be closely mounted with respect to the combustion chamber.

Burners of this type may be operated on gas and solid fuels as well as on various types of the so-called liquid fuels which range from distillates on through to asphalt. In fact, sustained runnings on asphalt have been particularly successful with preheated air at 450° F. the combustion being complete in less than 2 tuyère diameters and with no smoke.

For the purpose of a stationary turbine of 15,000 to 20,000 horsepower requiring a heat release of 150 to 200 million B. t. u.'s per hour, a single combustion chamber can be constructed. It is our belief, however, that it is desirable to provide several chambers each being not greater than eight inches in tuyère opening. This reduces the overall size of the unit and makes for easier maintenance. The burners have a range of successful operation of from 70% to 150% of capacity and normally with the use of a refractory throat such as shown at 42 there is no substantial danger of the flame being blown out.

Our invention is also applicable for use in ram jets or other high speed operating vehicles and may be installed in a series of parallel units although it is found to be particularly efficient when installed as a single tuyère as shown in Fig. 2. The overall size is so small as to not interfere with other equipment. In such case inlet air pressures may be of the order of 20 p. s. i. g., and temperatures are in the order of 150° F. to 300° F.

It may be found desirable for the purpose of maintaining temperature control on the burner to introduce secondary air through openings in the tuyère face plate 31 as indicated at 31a. Although secondary air is not essential either for combustion or flame pattern, the passage of air through openings 31a has been found helpful.

The feed to the burner may be inside the tuyère or outside the tuyère as shown in Fig. 3 or both. In some cases it has been found desirable to start up with gas and thereafter to switch to oil or heavy fuel. As shown in Fig. 3 a secondary fuel feed in line 15 may enter the base 28. Immediately within the tuyère, a shield or dispersion plate 60 may be used, such plate overlapping the lateral fuel openings 62 in the central fuel pipe 15 so as to intercept fuel discharged from openings 60 and to distribute the liquid to the edge of the tuyère and entirely within the intermediate pressure zone of the vortex.

This type of central feeding device may also be used to support a vortex flame arrester 53 which is a disc shaped member smaller than the tuyère opening and mounted adjacent the outer side of the tuyère opening. It has been found that the recirculation or return flow of furnace gases back into the low pressure zone of the vortex within the tuyère caused some objectionable operating difficulties. The vortex flame arrester 53 immediately deflects these return gases into the principal vortical pattern, and the tuyère runs substantially cooler thereby.

The actual dimensions of the tuyère 22 will, of course, vary with the overall duty required. In general the ratio of blade width to blade opening should be in the range of 3:1 to 5:1. Other dimensions on a 3 x 3 tuyère are approximately as follows:

Height of tuyère.....	inches.....	3
Length of tuyère.....	do.....	3
Number of blades.....		18
Width of blades.....	inch.....	0.525
Area of inlets.....	sq. in.....	4.08
Cross sectional area.....	sq. in.....	7.06
Area ratio.....		0.58

4

Heat release based on the supply of preheated air at approximately 750° F. at a pressure of approximately 90 p. s. i. g. and utilizing fuel having a heat value of 15,000 B. t. u./lb. for a burner of this size is 3.5 million B. t. u./hr. air is to be understood to comprehend combustion supporting gases as well, where in such special cases, this is found desirable.

We claim:

1. In an axially elongated combustor for the burning of liquid fuels and the discharging of hot reaction products having a straight tubular jacket: a fuel atomizing device within one end of the jacket, said fuel atomizing device comprising a first cylindrical, hollow tuyère having a closed end wall, a side wall spaced inwardly of the jacket and provided with a plurality of blades forming inwardly convergent air paths, and an open end; liquid fuel feeding means extending through the closed end wall of the first tuyère and discharging within said first tuyère adjacent the closed end wall thereof; air under pressure being supplied to said jacket and through said air paths between said blades for entraining fuel and mixing it with said air for discharge through the open end of said tuyère as a vortical fuel-air column; an elongated liner of circular internal cross section of greater diameter than said first tuyère but not more than about three times the diameter thereof and having an annular end wall receiving the open end of said first tuyère, said liner defining a combustion space within said jacket and being formed to provide an outer space for directing air under pressure past said combustion space; a second cylindrical, hollow tuyère spaced inwardly from the jacket and being internally in communication at one end with the discharge of the products of combustion from said combustion space, said second tuyère being open at the other end and having a side wall provided with a plurality of blades forming inwardly convergent air paths externally open to the surrounding outer space within the jacket and communicating with the said outer space whereby the air directed past said combustion space enters the convergent air paths of the second tuyère and is mixed with the products of combustion for temperature control before discharge of the hot reaction products; means closing the end of said surrounding outer space at the open discharge end portion of the second tuyère; and means disposed over the central bottom portion only of the second tuyère adjacent the combustion space to reduce gas eddy currents in said second tuyère.

2. The combination of claim 1 in which the liquid fuel feeding means includes a central fuel pipe having openings therein, and dispersion plate means carried by said pipe beyond the pipe openings and intercepting fuel discharged from said openings and distributing the fuel intercepted to a zone adjacent the side wall of said first tuyère.

3. In an axially elongated combustor for the burning of liquid fuels and the discharging of hot reaction products having a straight tubular jacket: a fuel atomizing device within one end of the jacket, said fuel atomizing device comprising a first cylindrical, hollow tuyère having a closed end wall, a side wall spaced inwardly of the jacket and provided with a plurality of blades forming inwardly convergent air paths, and an open end; liquid fuel feeding means extending through the closed end wall of the first tuyère and discharging within said first tuyère adjacent the closed end wall thereof, air under pressure being supplied to said jacket and through said air paths between said blades for entraining fuel and mixing it with said air for discharge through the open end of said tuyère as a vortical fuel-air column; an elongated refractory liner of circular internal cross section of greater diameter than said first tuyère but not more than about three times the diameter thereof and having an annular end wall receiving the open end of said first tuyère, said liner defining a combustion space within said jacket and being formed to provide an outer space for directing air under pressure past said combustion space; a second cylindrical, hollow tuyère spaced inwardly from the jacket and being internally in communication at one end with the discharge of the products of combustion from said combustion space, said second tuyère being open at the other end and having a side wall provided with a plurality of blades forming inwardly convergent air paths externally open to the surrounding outer space within the jacket and communicating with the said outer space whereby the air directed past said combustion space

5

enters the convergent air paths of the second tuyère and is mixed with the products of combustion for temperature control before discharge of the hot reaction products; means closing the end of said surrounding outer space at the open discharge end portion of the second tuyère; and fairing means disposed over the central bottom portion only of the second tuyère adjacent the combustion space and extending toward the combustion space to reduce gas eddy currents in said second tuyère.

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6

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