Aug. 16, 1955 B. LAFFERENTZ ET AL 2,715,436

RESONANT PULSE JET COMBUSTION HEATING DEVICE

Filed Aug. 5, 1952

Fig. 1

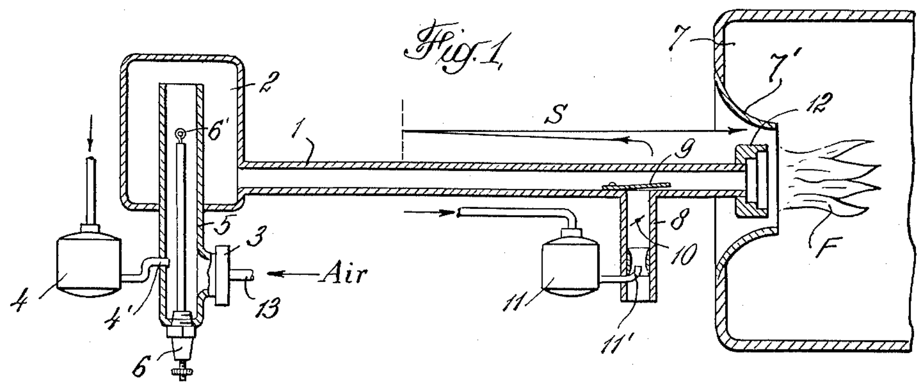


Fig. 2

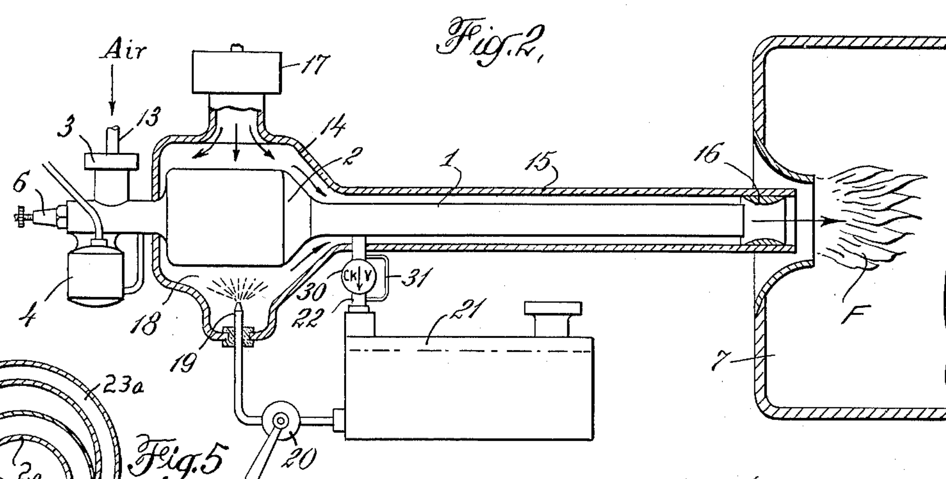


Fig. 5

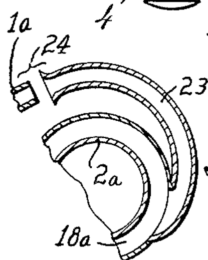


Fig. 3

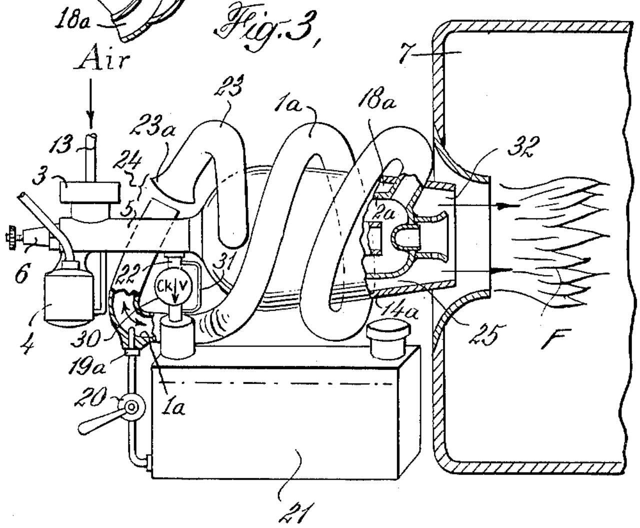
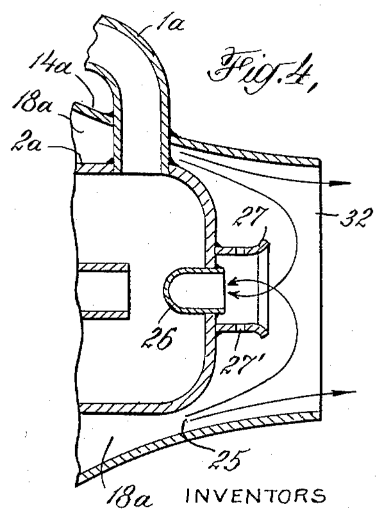


Fig. 4



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RESONANT PULSE JET COMBUSTION HEATING DEVICE

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11 Claims. (Cl. 158—4)

This invention relates to a heating device which utilizes the operating features of a resonant pulse jet combustion device, that is, a device having a combustion chamber which, with a connected valveless exhaust pipe, forms a resonator that is excited at its natural frequency by periodic detonations of a combustible mixture which occur in the combustion chamber at acoustic frequency.

Resonant pulse jet combustion devices of the type described have heretofore had only limited application to heating installations because previously known forms thereof operate reliably only with relatively expensive high volatile fuels, and for the further reason that the range within which the heat output of such devices can be varied without interrupting operation thereof is quite narrow.

It is proposed, in accordance with the present invention, to provide a resonant pulse jet combustion device which is provided with a firing fuel feed independent of the fuel which is detonated in the combustion chamber. The independently fed firing fuel is introduced into the exhaust pipe of the device under the control of a valve and at such a distance from the combustion chamber that it is not carried back into the combustion chamber of the device even during the vacuum phase of its operation. Since only a small proportion, of the order of 10 to 20%, of the heat output of the improved device need be produced by the combustion that takes place in the resonant pulse jet device itself, it is possible, by varying the amount of independently fed firing fuel, to obtain a heat output that is variable over a wide range, of the order of from 1 to 5, to from 1 to 10, without interfering with or interrupting the continuous resonant operation of the pulse jet device. Further, the invention makes possible the use of relatively inexpensive low volatile fuels even in a resonant pulse jet combustion device having an exhaust pipe of considerably smaller section than its combustion chamber and which is subject to carbon deposit or coking but is highly stable in its resonant operation.

We have found it advantageous to introduce the independently fed firing fuel into the exhaust pipe of the resonant pulse jet combustion device only during the vacuum phase of its operation. With this arrangement, such fuel is sprayed into the fresh air which is drawn into the exhaust pipe behind the return flowing exhaust gas plug and is there subjected to a mechanical and thermal mixing with this air and preparation for combustion. We have also found it advantageous when using as the independently fed firing fuel, high boiling fuels such as fuel oil or Diesel oil, to bring these fuels into heat exchanging relation with the outer wall of the combustion chamber of the resonant pulse jet device in order to preheat such fuels. This procedure also desirably cools the combustion chamber. For this purpose, the independently fed firing fuel, usually mixed with a small amount of air, may be conducted in a spiral duct around the combustion chamber or through the space between the combustion chamber and a surrounding jacket, or by both

such means. It is usually preferred to propel the independently fed firing fuel from the exhaust pipe of the resonant jet combustion device through an injector which, in addition to the fuel, carries fresh air into the jacket space surrounding the combustion chamber, which space also acts as a silencer. In this way, it is possible to obtain a fuel and air mixture which is so rich in fuel that some low temperature carbonization takes place within the jacket, and this results in a particularly effective chemical preparation of the fuel for combustion. Flashing back of the flame of the firing fuel may be prevented by blowing the fuel tangentially into the jacket space and by providing a narrow exit gap from this space within which the velocity of flow exceeds the speed of propagation of the flame. In order to positively prevent extinguishing of the flame, a hot spot or element may be provided in the wall of the combustion chamber adjacent the point where the independently fed firing fuel leaves the jacket space and is burned.

In describing the invention in detail, reference will be made to the accompanying drawings, in which certain embodiments thereof are illustrated.

In the drawings:

Fig. 1 is an elevation, partly in section, diagrammatically illustrating a resonant pulse jet combustion device in which independently fed firing fuel is drawn into the exhaust pipe through a check valve and throttle valve;

Fig. 2 is an elevation similar to Fig. 1, diagrammatically illustrating a modification of the invention, in which a preheated fuel and air mixture is propelled and ignited by a resonant pulse jet combustion device;

Fig. 3 is an elevation, partly in section, illustrating a further modification of the invention, in which the independently fed firing fuel is mechanically propelled in the exhaust pipe of the pulse jet combustion device and is propelled through a jacket space around the combustion chamber;

Fig. 4 is an enlarged sectional elevation of a portion of the device illustrated in Fig. 3; and

Fig. 5 is a sectional view of the injector connection of the device illustrated in Fig. 3.

Referring to the modification illustrated in Fig. 1, the resonant pulse jet combustion device consists essentially of an exhaust pipe **1** directly connected to and extending laterally from a combustion chamber **2**. During the vacuum phase of its operation, air is drawn into the combustion chamber through the check valve **3** and inlet duct **5** and fuel is drawn in with such air from the jet **4'** of the carburetor **4**. The fuel and air mixture is ignited in the inlet duct **5** by the glow coil **6'** at the inner end of the ignition plug **6** and upon ignition detonates, propelling a jet or plug of hot exhaust gases through the exhaust pipe **1** into the fire box **7**. The movement of the exhaust gas plug-out of the pipe **1** produces a vacuum phase in the combustion chamber **2** following the detonation phase and as a consequence, a new charge of fuel and air is thereby drawn into the combustion chamber. The described cycle of operations comprising the succeeding detonation and vacuum phases is repeated periodically at an acoustic frequency corresponding to the natural period of the resonator formed by the combustion chamber **2** and the exhaust pipe **1**. This operation of a resonant pulse jet combustion device is explained, for example, in Patent No. 2,644,512. The described arrangement provides means for automatically feeding fuel to support the detonations during each succeeding vacuum phase of operation. The heat output of the resonant pulse jet combustion device thus far described is limited and is variable only within a very narrow range if resonant operation is to be maintained. According to the invention, there is connected to the exhaust pipe **1**, near its outer end, a branch tube

8, and a check valve illustrated as a spring leaf **9** is provided at the mouth of the tube **8** where it enters the pipe **1**. A throttle valve **10** is provided in the tube **8**. The jet **11'** of a carburetor **11** opens into the tube **8** below the throttle valve **10**. The carburetor **11** is supplied with the independently fed firing fuel from a suitable source. With this arrangement, the independently fed firing fuel is drawn into the exhaust pipe **1** from the tube **8** only during a vacuum phase of the operation of the resonant pulse jet combustion device. In order to increase the vacuum produced in the exhaust pipe **1**, that pipe may be provided at its mouth with a stepped attachment **12** which retards return flow at this point by the formation of eddies or turbulence in the flowing gas or air. The resonant pulse jet combustion device is started by connecting a small air pump or blower to the pipe **13** to force air into the inlet duct **5**. The air so introduced draws fuel from the jet **4'** and the fuel and air mixture is ignited by the glow coil **6'** which is heated by energization of the ignition plug **6**. As soon as resonant combustion has started, the throttle valve **10** is opened, whereupon the lower volatile firing fuel is drawn into the tube **8** from the jet **11'** of the carburetor **11** and is introduced into the exhaust pipe **1** through the check valve **9**. In the exhaust pipe **1**, the separately fed firing fuel is picked up by the oscillating gas column which, during each cycle of operation, first propels this fuel toward the combustion chamber **2** to about the midpoint of the pipe **1** during the vacuum phase of the cycle, and then, during the ensuing detonation phase, blows the fuel out of the pipe **1** into the fire box **7**, where the fuel entrains air to support combustion at the outlet of the exhaust pipe and burns in a flame F. During this process, the firing fuel mixed with air is thoroughly prepared both mechanically by mixing and thermally by heating, so that when it leaves the exhaust pipe **1**, it burns with a clean blue flame, the heat output of which may be variably controlled over a wide range by adjustment of the throttle valve **10**.

As indicated by the arrow S, representing the movement thereof, the firing fuel does not move inward into the combustion chamber **2**, but is ignited only in the fire box **7**. For this reason, combustion of the separately fed firing fuel does not interfere with the pulsation of the resonant pulse jet combustion device **1, 2** nor does such combustion produce carbon deposits or coking within such device.

In a modified form of the invention illustrated in Fig. 2, the combustion chamber **2** is provided with a jacket **14** that communicates with a jacket tube **15** surrounding the exhaust pipe **1**. The mouth of the jacket tube **15** is provided with a constriction **16** and forms an injector with the mouth of the exhaust pipe **1**. Following a detonation phase of operation a plug of hot exhaust gas passes thrugh this injector and draws in fresh air through the filter **17** and the jacket space formed by the jacket **14** and tube **15**, which air cools the combustion chamber **2** and is thus heated to a few hundred degrees centigrade. This heated air, with firing fuel introduced as explained below, is thereafter mixed with the exhaust gases of the resonant pulse jet combustion device at the injector and is blown into the fire box **7** by such gases as hereinafter explained.

The independently fed firing fuel flows from a tank **21** through a control valve **20** to a jet **19**, which projects into the space **18** between the jacket **14** and the combustion chamber **2**. The tank **21** is tightly closed, and super-atmospheric pressure of about 0.5 to 1 atmosphere is supplied to the head space thereof to force the fuel from the jet **19**. The pipe **22** connects the head space of the tank **21** to the exhaust pipe **1** through a check valve **30** provided with a restricted bypass **31**. The peak pressures of the periodic detonations of the device are transmitted to the fuel tank head space through the check valve, while the building up of excessive pressure in the tank or the persistence of pressure when the device is inactive is prevented.

The amount of air entering through the filter **17** is so small in proportion to the amount of fuel from the jet **19** that the fuel-air mixture in the jacket space **18** is not detonated but is merely heated with a slight low temperature carbonization of the firing fuel. At the mouth of the exhaust pipe **1**, this fuel and air mixture that has been drawn to this point by the injector at the end of a detonation phase of operation is drawn back into the exhaust pipe during each succeeding vacuum phase of operation, but only to a point therein short of the combustion chamber **2**. The mixture thus drawn in is mixed with the inflowing exhaust gases in the pipe **1**, and these exhaust gases, although not materially cooled by the fuel-air mixture, do not increase the igniting ability of the mixture. Air sufficient to support combustion first enters the mixture at the mouth of the jacket tube **15** as the mixture enters the fire box **7**, and the prepared firing fuel burns at this point in a clean blue flame F.

A compact and particularly desirable embodiment of the invention is illustrated in Figs. 3 and 4. The combustion chamber **2*a*** is disposed within a jacket **14*a*** around which the exhaust pipe **1*a*** is wound in spiral turns, as shown. An inlet tube **23** having an inlet mouth in the shape of a funnel **23*a*** is connected tangentially through the jacket **14*a*** to the jacket space **18*a*** surrounding the combustion chamber **2*a***. The outlet mouth of the exhaust pipe **1*a*** forms an injector **24** with the inlet mouth **23*a*** of the inlet tube **23**.

The relatively low volatile firing fuel is fed under pressure from the closed tank **21** through the control valve **20** and jet **19*a*** into the exhaust pipe **1*a*** adjacent its mouth. Fuel feeding pressure is maintained in the head space of the tank **21** by a pipe **22** connected to the inlet tube **5** of the resonant pulse jet combustion device and provided with a bypassed check valve **30, 31**, as in the embodiment of Fig. 2. The fuel entering the exhaust pipe **1*a*** is mechanically and thermally conditioned for combustion therein, as explained in connection with the modification of Fig. 1, and is then blown through the injector **24** and the inlet tube **23** in a tangential course into the circular jacket space **18*a*** between the jacket **14*a*** and the combustion chamber **2*a***. The fuel thus circulates around the combustion chamber **2*a*** in a spiral path and is thereby further prepared for combustion and finally flows out of the jacket mouth **32** and is injected into the fire box **7**, where is entrains and is mixed with more air passing through the inlet **7'** and burned in a hot clean flame F.

In the embodiment of Figs. 3 and 4, it is possible to maintain such a high speed of flow at the injector **24** that no ignition of the fuel takes place at this point. Ignition within the jacket space **18*a*** is prevented by providing a narrow annular gap or constriction **25** to maintain a high flow speed of the fuel-air mixture as it travels from the jacket space to the jacket mouth **32**. Ignition of the flame F and maintenance of ignition can be assured by providing in the end wall of the combustion chamber **2*a*** adjacent the jacket mouth **32** a small thin walled cup **26** of non-scaling metal, such as stainless steel. This cup is maintained at a red heat during operation of the device and so acts as a hot ignition spot which effectively ignites the fuel-air mixture and keeps it ignited. A ring **27** having radial holes **27'** therethrough may be secured around the cup **26** to insure circulation of a small part of the fuel-air mixture into contact with the cup **26**.

All of the described embodiments of the invention operate without a blower and are much more simple and compact than previously known liquid fuel and fuel oil burners. The mechanical feeding of fuel is required only until the resonant pulse jet combustion device is in proper pulsating operation. The firing fuel is so well prepared and conditioned mechanically and thermally that relatively heavy oils may be burned without formation of carbon or coking. Extinguishing of the flame is avoided because the exhaust gases of the resonant pulse jet device act as a constant source of ignition.

Due to the low weight of the heating devices of the invention, they are particularly suited for use as portable heating plants, such as field kitchens, tent heaters and warming installations for construction projects and airports. Since the devices produce excess pressure in the firebox, they do not require a stack or chimney. The widely variable range of heat output of the improved devices makes them also useful in heat engines, such as hot air engines and steam engines with flash boilers.

We claim:

1. A combustion heating device comprising a resonant pulse jet combustion device including a combustion chamber, an elongated exhaust pipe directly connected to said combustion chamber and forming therewith a resonator, means for automatically feeding fuel and air to said combustion chamber to produce successive detonation phases and intervening vacuum phases of operation, a jacket spaced from and enclosing at least a portion of the combustion chamber, means for introducing a firing fuel and air into the space between the jacket and the combustion chamber for preheating, said jacket having an outlet for the discharge of the preheated firing fuel and air mixture, and means operatively associated with the outlet of said exhaust pipe for propelling said fuel and air mixture through said jacket and to a zone for combustion.

2. A combustion apparatus according to claim 1 having valve-control means for regulating the amount of firing fuel introduced into the space between said jacket and the combustion chamber.

3. A combustion heating apparatus according to claim 1 in which the exhaust pipe includes a section extending around said jacket.

4. A combustion apparatus according to claim 1 in which the jacket, adjacent the outlet therefrom for the discharge of preheated firing fuel and air, is positioned sufficiently close to the combustion chamber to provide a passageway sufficiently restricted in size as to so increase the speed of the firing fuel and air passing therethrough that flashing back of flame into the space between the jacket and the combustion chamber is prevented.

5. A combustion apparatus according to claim 1 in which the combustion chamber has a portion so positioned that on operation of the pulse jet combustion device it is heated to a temperature sufficiently high to

ignite the firing fuel and air, said portion being so positioned that the firing fuel and air passing through the space between the jacket and combustion chamber to the outlet from the jacket is caused to be brought into contact therewith.

6. A combustion apparatus according to claim 5 in which said portion of the combustion chamber includes an inwardly recessed part and a perforated collar surrounding the entrance to the recess of said recessed part.

7. A combustion apparatus according to claim 6 in which said portion of the combustion chamber comprises a cup of non-scaling metal.

8. A combustion apparatus according to claim 1 including an injector means for conducting the firing fuel and air expelled from the space between said jacket and the combustion chamber and for mixing additional air therewith to form a combustible mixture.

9. A combustion apparatus according to claim 1 in which the combustion chamber and the surrounding jacket are circular in cross-section and the means for introducing the firing fuel and air is so positioned as to cause the firing fuel and air to be introduced tangentially into the annular space between said jacket and the combustion chamber, whereby said firing fuel and air is caused to flow around the combustion chamber within said jacket.

10. A combustion device according to claim 1 having means adjacent said outlet opening of the jacket for supplying additional air to support combustion of the firing fuel.

11. A combustion device according to claim 1 in which said second named means includes means for introducing the firing fuel into the exhaust pipe, and means for aspirating the air into the mixture of exhaust gases and firing fuel before it is conducted through said jacket space.

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