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(54) PULSE COMBUSTION INSTALLATIONS

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ABSTRACT

A pulse combustion installation is disclosed dispensing with mechanical valves in the combustion air supply and relying on resonant conditions to induce the flow of combustion gases through the installations. The installation includes a tubular combustion chamber closed at one end and formed with a neck at the other end. A combustion gases outlet duct extends divergently from the neck and co-axially therewith and a combustion air inlet duct extends convergently to the neck co-axially and partly co-extensively with the outlet duct. The inlet duct is formed with a lip at the end thereof remote from the neck adapted aerodynamically to impede air flow other than toward the neck. A transition region is provided between the neck and an entry portion of the inlet duct having an aerodynamically unimpeded form relative to air flow toward the neck and the combustion chamber and an entry portion of the outlet duct co-act to direct combustion gases discharged from the combustion chamber to the outlet duct, the lengths of the inlet and outlet duct and the combustion chamber being such as to produce resonant conditions upon combustion of fluent fuel within the combustion chamber.

This invention relates to a pulse combustion installation and, more particularly, to a pulse combustion installation dispensing with mechanical valves in the combustion air supply and relying on resonant conditions to induce the flow of combustion gases through the installations.

According to the present invention there is provided a pulse combustion installation including a tubular combustion chamber closed at one end and formed with a neck at the other end, a combustion gases outlet duct extending divergently from the neck and co-axially therewith, a combustion air inlet duct extending convergently to the neck co-axially and partly co-extensively with the outlet duct at the neck formed with a lip at the end thereof remote from the neck adapted aerodynamically to impede air flow other than toward the neck, a transition region between the neck and an entry portion of the inlet duct having an aerodynamically unimpeded form relative to air flow toward the neck and the combustion chamber and an entry portion of the outlet duct co-acting to direct combustion gases discharged from the combustion chamber to the outlet duct, the lengths of the inlet and outlet duct and the combustion chamber being such as to produce resonant conditions upon combustion of fluent fuel within the combustion chamber.

The invention will now be described, by way of example, with reference to the accompanying, partly diagrammatic drawings, in which:-

Figure 1 is a longitudinal cross-section of a pulse combustor;

Figure 2 is a cross-section of the pulse combustor taken at the line II-II of Figure 1;

Figure 3 is a longitudinal cross-section of an alternative form of pulse combustor; and

Figure 4 is a cross-section of the alternative form of combustor taken at the line III-III ~~IV-IV~~ of Figure 3.

Referring to Figures 1 and 2 of the drawings, a cylindrical combustion chamber 2 is formed with a re-entrant neck 4 having an outer wall 6 of frusto-conical form of an inlet duct 8 diverging smoothly therefrom. A wall 10 of an outlet duct 12 - which forms in conjunction with an inner wall 14 of the inlet duct a water jacket 16 - extends co-axially within and beyond the inlet duct walls 6 and 14 of the neck to form a cylindrical inlet gap 22. The intake end 24 of the inlet duct outer wall 6 is formed with an outwardly directed lip 26 which co-acts with a blanked-off frusto-conical sleeve 28 aligned with the inlet duct 8 to form an aerodynamic valve enhancing the inflow and inhibiting the outflow of air to the inlet duct.

A pair of axial baffles 30 are positioned between the inner and outer walls 6 and 14 of the inlet duct from adjacent the lip 26 to adjacent the cylindrical inlet gap 22 to form a duct 31 of cross-sectional area approximating to 1/6 of the total cross-sectional flow area and the discharge outlet from a forced draft fan 32 is connected to supply air to the duct for starting purposes.

A pressure jet atomising burner nozzle 34 giving an 80° spray cone is positioned within the combustion chamber 2 adjacent the front end wall 36 thereof, the associated burner barrel 38 extending through the wall together with ignition and instrumentation probes 40 and 42.

A flow restrictor 44 is provided in the fuel circuit to limit discharge of fuel during start up. Since the pressure in the combustion chamber 2 rises upon successful ignition a pressure tapping is provided by the instrumentation probe 42 and connected to a pressure sensing device actuating a valve ~~66~~ 46 in the fuel supply to provide full fuel flow upon ignition.

The outlet duct discharges to a water heating unit (not shown) which may take the form either of a unit with smoke tubes extending helically around the outlet duct axis within a water space of annular cross-section between a cylindrical flue and a cylindrical vessel, or with annular cross-section smoke ducts alternating with water ways within a cylindrical vessel.

In operation, to initiate start-up, air is supplied from a forced draft fan 32 along the duct 31 in the inlet duct 8 and circulates in the combustion chamber 2. Fuel is supplied at a low rate to the chamber and ignited to heat the walls of the chamber until the temperature within the chamber is such that resonant condition arises. Upon this condition arising, the rate of fuel supply is increased to the required operating flow and the forced draught fan 32 de-energised and the combustion process becomes self-sustaining.

The blanked-off frusto-conical sleeve 28 serves as a reflector to attentuate sound at the inlet duct, whilst sound at the outlet is attenuated by virtue of provision of a reflector in conjunction with the outlet from the outlet duct and the extended length of the flue gas path within the water heating unit.

Since the successful operation of the combustion process depends upon the sustained resonant vibrations, the fuel supply to the burner head may be, with advantage, pulsated in phase with the vibrations either mechanically or by a physical connection between the combustion chamber and the fuel supply line at a pressure only slightly in excess of supply pressure.

From theoretical considerations in conjunction with experimental results it would appear that for an arrangement in which the combustion chamber is formed with a sharp-edged and/or re-entrant orifice 48 the following proportions should be utilised.

1. Ratio of the cross-sectional area of the outlet duct 12 at the entry thereto, perpendicular to gas flow in the duct, to the cross-sectional area of the orifice 48, should be between 0.9 and 1.3 preferably approximately 1.0.

2. Ratio of the cross-sectional area of the inlet duct 8 at the neck perpendicular to air flow in the duct, to the cross-sectional area of the orifice 48, should be between 1.0 and 1.4.

3. Angle between discharge portion of the inlet duct 8 adjacent the neck 4 and the central axis of the outlet duct 12 should be between 45° and 60°, preferably approximately 52°.

4. Ratio of the equivalent length of outlet duct 12 to the equivalent length of the inlet duct 8 should be approximately 2.4, these lengths being the lengths of cylindrical ducts of equal diameter acoustically equivalent to the actual ducts.

5. Ratio of combustion chamber diameter to length approximately 1.4.

In the alternative arrangement shown in Figures 3 and 4 a cylindrical combustion chamber 52 is formed with a re-entrant neck 54 having an adjacent end portion 56 of frusto-conical form of a wall 58 of an inlet duct 60 diverging smoothly therefrom. A wall 62 of frusto-conical form of an outlet duct 64 extends from an inner wall 66 of the inlet duct 60 co-axially of the combustion chamber 52, an end portion adjacent the neck 54 co-acting with an edge portion of the neck to form a cylindrical inlet gap 68. Adjacent the cylindrical inlet gap 68, the inlet duct 60 divides into two pairs of passageways 70, 72 each of generally rectangular cross-section, one pair 70, disposed symmetrically to either side of the horizontal plane, each extending over approximately 150° to 140° of arc of the cylindrical inlet gap and the other pair 72, disposed symmetrically to either side of the vertical plane, each extending over approximately 30° to 40° of arc. Each of the passage ways 70, 72 is smoothly swept through 180° to extend forwardly parallel to the combustion chamber axis and diverges to a circular cross-section intake portion 74, 76. The intake portions 74 of the horizontal pair 70 are formed with bell-mouth inlets 78 whilst the intake portions of the vertical pair 72 are formed with re-entrant inlets 80. The inlets are positioned within a windbox 82 adjacent the front of the combustion chamber and each has a helmholtz resonator 84, 86 aligned therewith tuned to the fundamental frequency of resonance for noise attenuation and recovery of part of the resonant energy. The resonators aligned with the respective pairs of passageways may be interconnected to enhance performance thereof. An impeller fan 88 is positioned in the windbox to deliver air through ducts to the inlets of the vertical pair of passageways for start-up purposes. Air is supplied to the windbox through a rearwardly extending intake 90 of venturi form having a bell-mouthed inlet.

A pressure jet atomising burner nozzle 92 giving an 80° spray cone is positioned within the combustion chamber adjacent the front end wall thereof, the associated burner barrel 94 extending through the windbox together with instrumentation and ignition probes 96, 98.

A flow restrictor valve 100 is connected in the burner oil fuel supply line 102 and is actuated by a signal derived from a pressure tapping in the combustion chamber.

As in the arrangement described previously, the outlet duct 64 discharges to a water heating unit of the form described. However, since the passageways 70, 72 of the inlet duct are swept through 180° to a windbox at the front of the combustion chamber, more satisfactory attenuation of noise may be achieved by providing a reflector space within the flue tube. The re-entrant inlets 80 to the vertical pair of passageways 72 restrict inflow of combustion gases to those passageways, so that on the intake portion of the sequence, unburnt air is immediately drawn into the combustion chamber.

In operation, to initiate start-up, air is supplied from the fan impeller along the vertical passageways of the inlet duct and circulates in the combustion chamber. Fuel is supplied at a low rate to the chamber and ignited to heat the walls of the chamber until the temperature within the chamber is such that resonant condition arises. Upon this condition arising, the rate of fuel supply is increased to the required operating flow and the fan impeller de-energised and the combustion process becomes self-sustaining.

WHAT WE CLAIM IS:-

1. A pulse combustion installation including a tubular combustion chamber closed at one end and formed with a neck at the other end, a combustion gases outlet duct extending divergently from the neck and co-axially therewith, a combustion air inlet duct extending convergently to the neck co-axially and partly co-extensively with the outlet duct at the neck formed with a lip at the end thereof remote from the neck adapted aerodynamically to impede air flow other than toward the neck, a transition region between the neck and an entry portion of the inlet duct having an aerodynamically unimpeded form relative to air flow toward the neck and the combustion chamber and an entry portion of the outlet duct co-acting to direct combustion gases discharged from the combustion chamber to the outlet duct, the lengths of the inlet and outlet duct and the combustion chamber being such as to produce resonant conditions upon combustion of fluent fuel within the combustion chamber.

2. A pulse combustion installation as claimed in Claim 1, wherein the junction of a wall of the combustion air inlet duct and a wall of the tubular combustion chamber forms a sharp-edged orifice at the neck.

3. A pulse combustion installation as claimed in Claim 2, wherein the wall of the tubular combustion chamber

is directed toward the combustion chamber interior such that the sharp-edged orifice is of re-entrant form.

4. A pulse combustion installation as claimed in Claim 2 or Claim 3, wherein the ratio of cross-sectional area of the outlet duct at the entry thereto perpendicular to gas flow in the duct to the cross-sectional area of the sharp-edged orifice is between 0.9 and 1.3.

5. A pulse combustion installation as claimed in Claim 2 or Claim 3, wherein the ratio of cross-sectional area of the outlet duct at the entry thereto perpendicular to gas flow in the duct to the cross-sectional area of the sharp-edged orifice is approximately unity.

6. A pulse combustion installation as claimed in Claim 2 or Claim 3, wherein the ratio of the cross-sectional area of the inlet duct at the neck perpendicular to air flow in the duct to the cross-sectional area of the orifice is between 1.0 and 1.4.

7. A pulse combustion installation as claimed in Claim 2 or Claim 3, wherein the angle between a discharge portion of the inlet duct immediately adjacent the neck and the central axis of the outlet duct is between 45° and 60°.

8. A pulse combustion installation as claimed in Claim 2 or Claim 3, wherein the angle between a discharge portion of the inlet duct immediately adjacent the neck and the central axis of the outlet duct is approximately 52°.

9. A pulse combustion installation as claimed in Claim 2 or Claim 3, wherein the ratio of the length of a cylindrical duct acoustically equivalent to the outlet duct to the length of a cylindrical duct acoustically equivalent to the inlet duct is approximately 2.4.

10. A pulse combustion installation as claimed in Claim 2 or Claim 3, wherein the ratio of the combustion chamber diameter to axial length is approximately 1.4.

11. A pulse combustion installation as claimed in Claim 2 or Claim 3, wherein a helmholtz resonator means aligned with the entry portion of the inlet duct is arranged to attenuate noise and recover part of the resonant energy by being tuned to the fundamental frequency of resonance.

12. A pulse combustion installation as claimed in Claim 2, wherein the inlet duct extends around and co-axially of the outlet duct.

13. A pulse combustion installation as claimed in Claim 12, wherein an axial passage is formed by radially extending webs intermediate the adjacent walls of the inlet and outlet ducts for the forced flow of air during establishment of combustion and resonant conditions.

14. A pulse combustion installation as claimed in Claim 2, wherein the inlet duct is branched into passageways swept through 180° to extend adjacent to the combustion chamber and parallel to the axis thereof such that air flow at the entry is in the same direction as the direction of flow of combustion.gases in the outlet duct.

15. A pulse combustion installation as claimed in Claim 14, wherein the inlet duct is branched into diametrically opposed pairs of passageways of generally rectangular cross-section remote from the entries thereto.

16. A pulse combustion installation as claimed in Claim 15 wherein each passageway of one pair of passageways extends over about 140°-150° of arc and each passageway of the other pair of passageways extends over about 40° to 30° of arc and is arranged to receive a forced flow of air during the establishment of combustion and resonant conditions.

17. A pulse combustion installation as claimed in Claim 15 or Claim 16, wherein entries to one pair of passageways are of re-entrant form and the entries to the other pair of passageways are of bell-mouthed form.

18. A pulse combustion installation as claimed in Claim 2 or Claim 3, wherein a pressure jet atomising is positioned in the combustion chamber for the supply of fuel thereto.

19. A pulse combustion installation as claimed in Claim 2, wherein the outlet duct is positioned within a combustion flue tube of a water heating unit and the combustion gases are arranged to flow in heat exchange relationship with a body of water within the unit.

20. A pulse combustion installation as claimed in Claim 19, wherein the combustion flue tube is provided with baffle means to attenuate noise and assist recovery of resonant energy.

FIG. 1

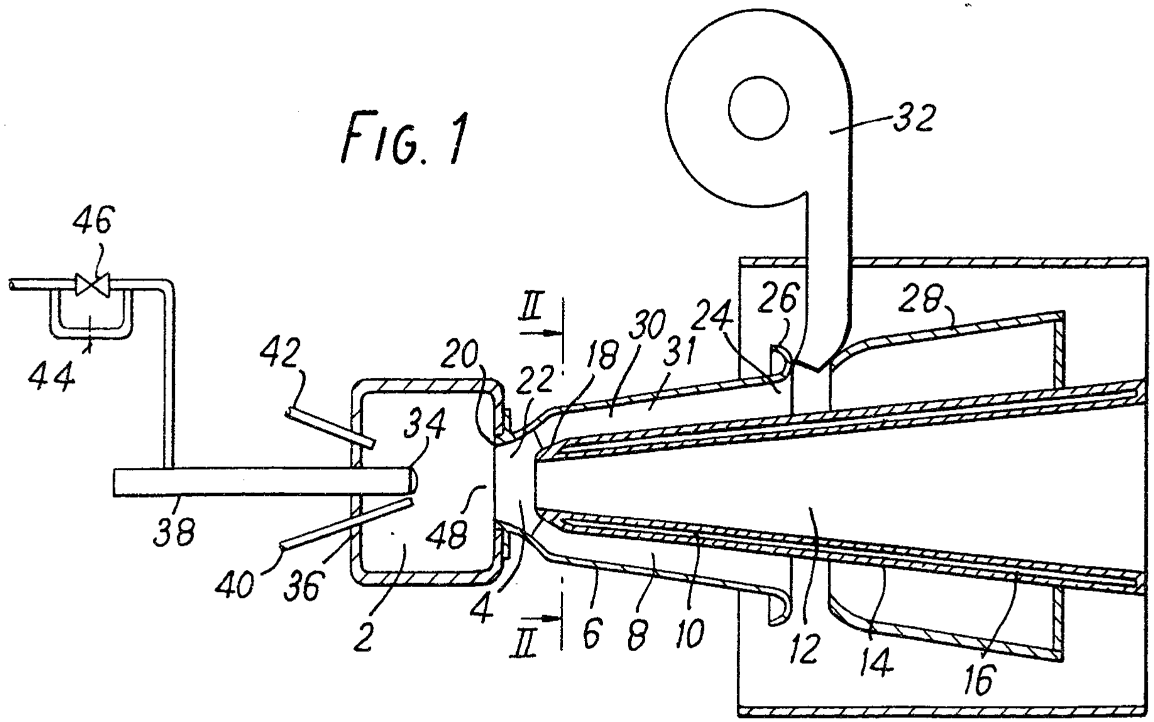
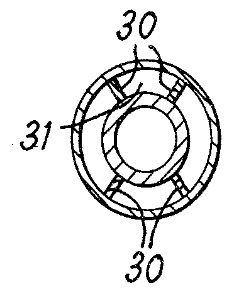


FIG. 2



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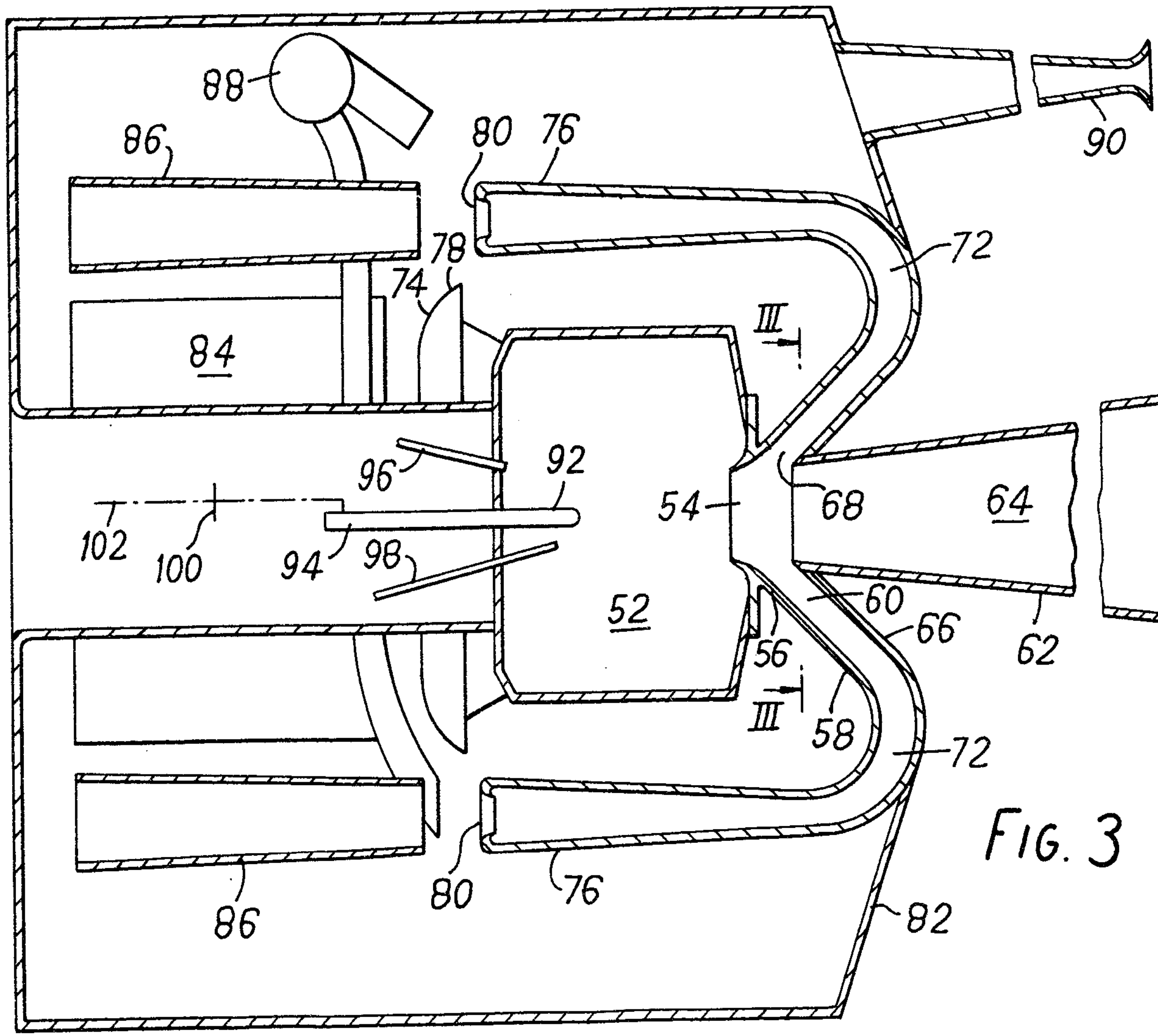

FIG. 3

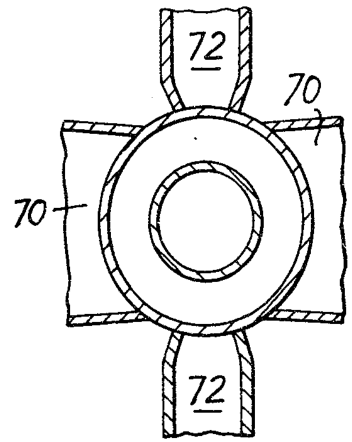

FIG. 4

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