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Melton, Jr.

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[54] **VALVELESS COMBUSTION APPARATUS**

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[52] **U.S. Cl.** **239/13;** 239/81; 431/158

[51] **Int. Cl.²** ... **B05B 1/24;** B05B 17/04; F23R 1/00

[58] **Field of Search** ..... 239/79–81, 239/85, 13; 110/22 B; 117/105.2; 431/1, 2, 8, 158; 219/76

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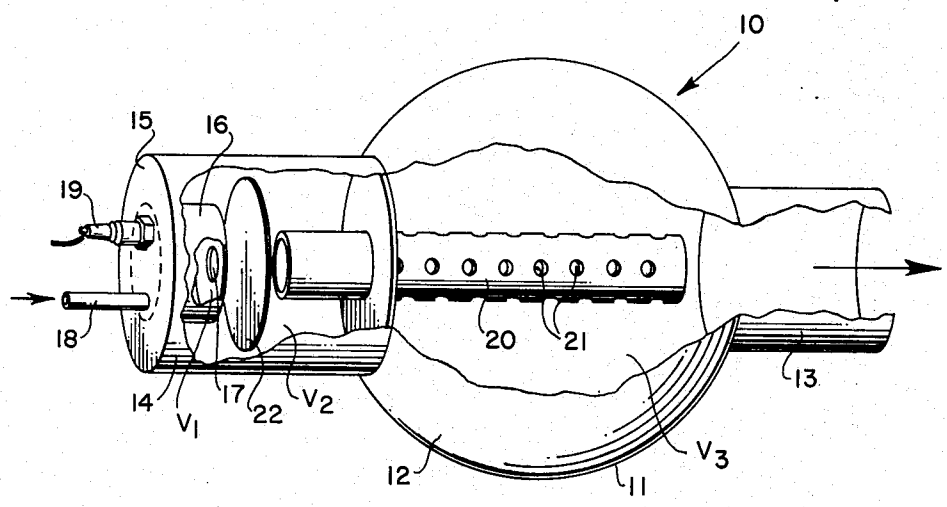
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Primary Examiner—Robert S. Ward, Jr.

[57] **ABSTRACT**

Valveless combustion apparatus are disclosed in which a flame front from gas ignited in one part of the apparatus is utilized to ignite a charge of gas in another part of the apparatus that is open to atmosphere or other relatively low pressure. The ignition occurs before the charge of gas is dissipated from the part of the apparatus open to the lower pressure so that a high energy blast of gas can be directed from the apparatus to perform work. In one form of the combustion apparatus of this invention, the ignition provided by the flame front is progressive to provide an enhanced discharge pressure. Also, the combustion apparatus of this invention is illustrated as providing for the coating of a workpiece with a particulate material.

25 Claims, 9 Drawing Figures



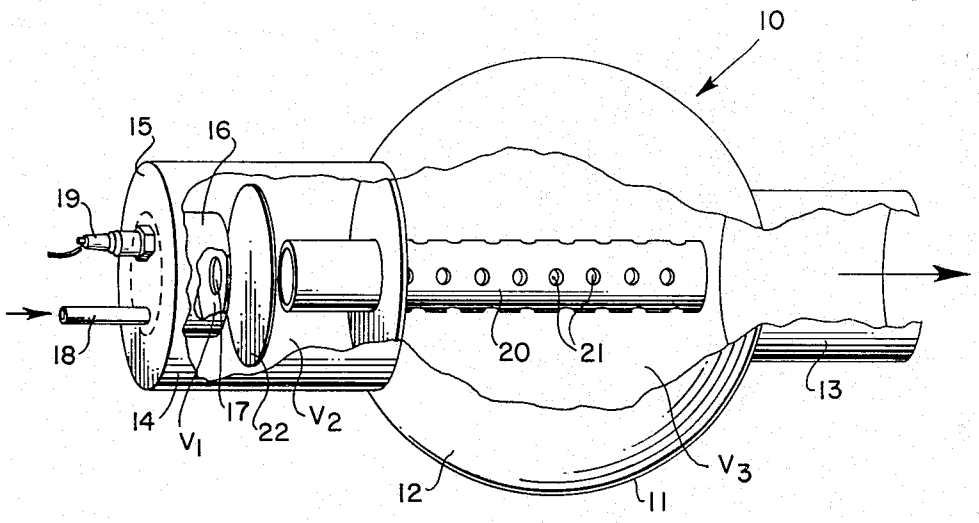


FIG. 1

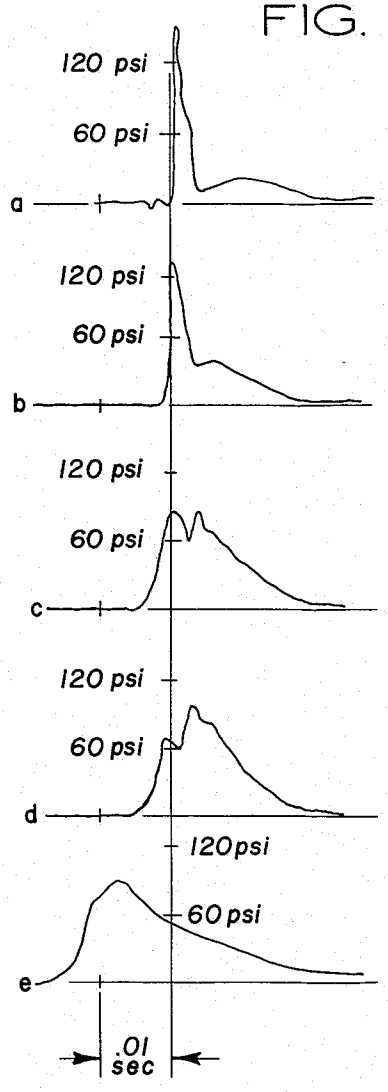


FIG. 2B

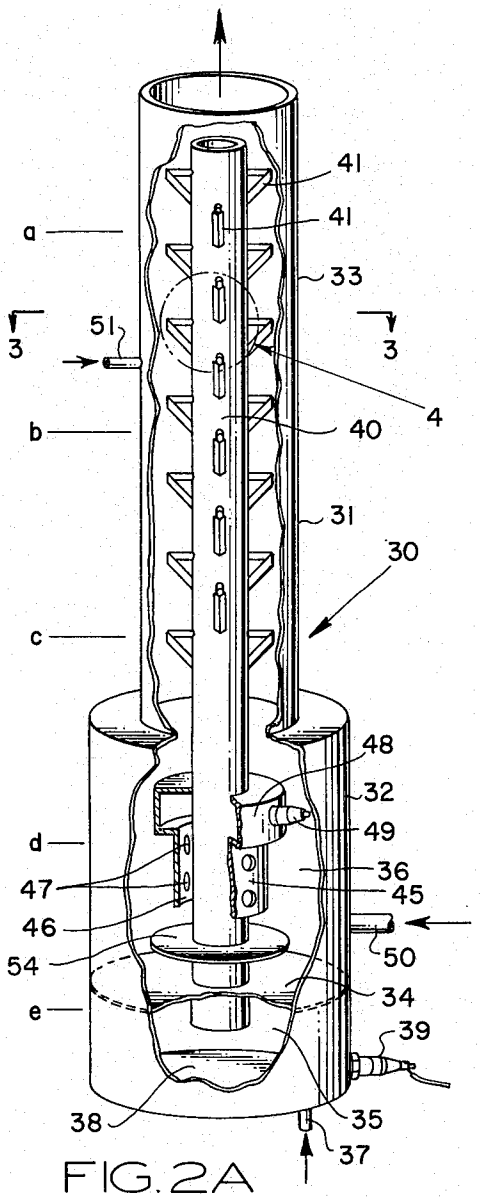


FIG. 2A

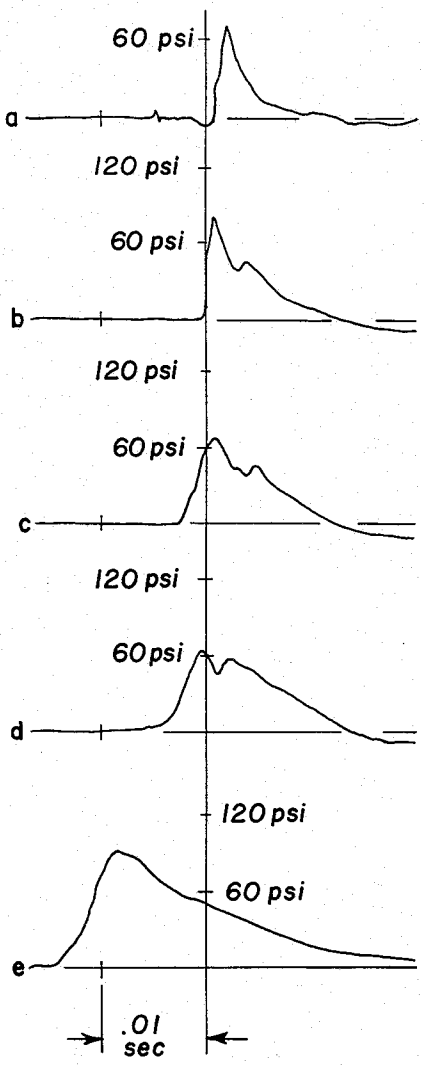


FIG. 5B

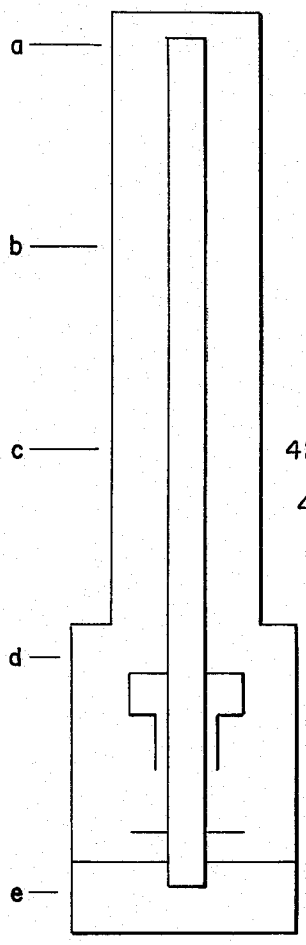


FIG. 5A

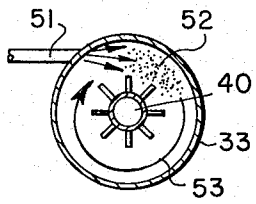


FIG. 3

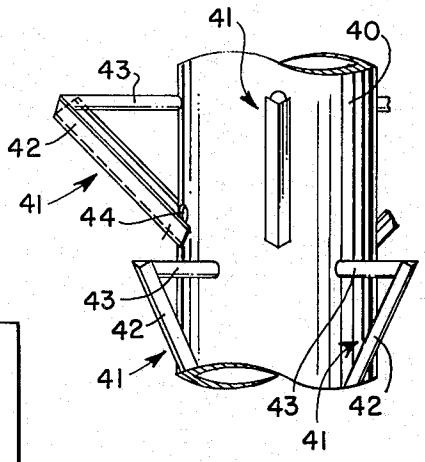


FIG. 4

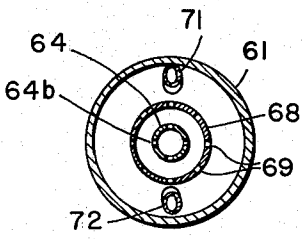


FIG. 7

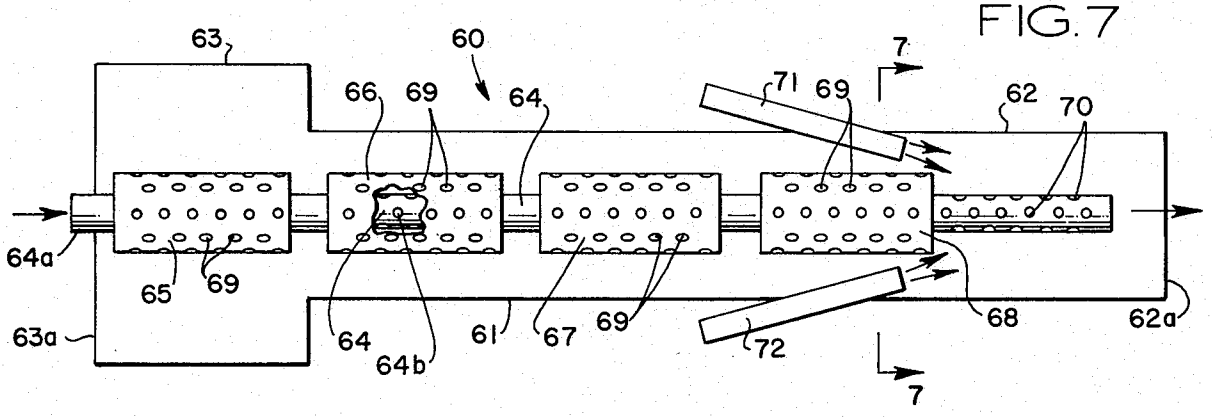


FIG. 6

VALVELESS COMBUSTION APPARATUS

This invention relates to valveless combustion apparatus for providing and directing a high pressure blast of gas to accomplish work. In one of its aspects, it relates to such an apparatus which may be used to coat a workpiece with a particulate material.

The term "valveless" is used herein to refer to the use of an apparatus including a chamber in which the relatively high pressure blast is generated that is open at one end to atmosphere or some other relatively low pressure, and does not require an outlet valve to hold pressure therein prior to discharge.

There are a number of situations in which a fuel-air explosion may be utilized to provide a directed blast of gas to accomplish a particular task. Samples of such situations are shown in U.S. Pat. Nos. 3,461,577, **3,572,273,** and 3,713,496, all related to earth moving or fracturing, and the principles of the present invention are applicable to such. Another important example of the use of such a directed blast of gas is the application of a particulate coating material to a workpiece, such as the coating of stainless steel with tungsten carbide. In the prior art, numerous apparatus and systems have been provided for this type of application. For example, in one such prior system, a combustible gaseous mixture is ignited in a combustion chamber at the upstream end of a barrel which is sufficiently long to permit a supersonic detonation wave to be established and travel down the barrel. By the use of special "detonable" fuels which react rapidly and easily once the process starts, unignited gas is ignited by compression, sustaining the detonation wave. Downstream of the combustion chamber, particulate coating materials are fed into the gun barrel so that the particles are carried down the barrel at high velocity and directed against a suitable workpiece. However, the size of this particular apparatus has proven to limit its use and also its use involves a certain amount of danger because the use of highly volatile materials to obtain the detonation waves at sufficient energy.

In order to obviate some of the difficulties of this type of apparatus, apparatus was developed as described in U.S. Pat. No. 3,801,346, entitled METHOD AND APPARATUS FOR APPLYING PARTICULATE COATING MATERIAL TO A PIECE OF WORK. The apparatus disclosed therein directs a particulate coating material against a workpiece in a series of pulses, and does not require the generation of a detonation wave. Each pulse includes an initial step of feeding a charge of gaseous combustible mixture into a combustion chamber provided with an outlet nozzle. The combustible mixture is ignited and the outflow of gaseous mixture through the nozzle is constricted sufficiently to cause a rapid pressure rise during combustion of the mixture to peak value followed by a period of falling pressure during the continued outflow of the combusted mixture through the nozzle. A charge of the particulate coating material is injected into the combustion chamber for a period commencing just prior to ignition and the outflow of combustion mixture and entrained particulate material is directed against the workpiece at high velocity to cause the particulate material to form a coating on the workpiece.

In the type of applications discussed, the gas discharge must be released in no more than about 10 milliseconds from the apparatus and sometimes in less time. If an outlet valve is used for closing a chamber to permit pressure to build up therein, this means that the valve must open up in 10 milliseconds, or preferably in less time. The design and utilization of such a valve adds complications and cost to any of the apparatus described, and effects its reliability. An important feature of the apparatus of U.S. patent application Ser. No. 198,806 is that it does not employ an outlet valve, but rather an open but restricted outlet. By causing complete combustion to occur in a relatively short time, the combustion will be complete in substantially less time than is needed for the escape of gas from the combustion chamber through the restricted opening.

The present invention is directed to improved combustion apparatus which provides for even more rapid combustion to permit the generation of a high pressure blast of gas which simulates a detonation wave without the use of highly volatile fuels needed to obtain a detonation wave, or the use of an outlet valve from a charging chamber.

In all the embodiments of this invention, an initially ignited fuel-air mixture is utilized to ignite unburned fuel-air mixture as it moves out of the apparatus so that ignition will be complete in substantially less time than is needed for escape of the fuel-air mixture from the apparatus. This is accomplished by providing a combustion apparatus including an ignition chamber connected to a source of a fuel-air mixture, and a main discharge chamber, which may include a barrel extension, and which is open at one end to the atmosphere, or some pressure lower than the charge pressure in the chamber. The chambers are initially charged with a fuel-air mixture and means is provided between the chambers for conducting ignited fuel-air mixture in the ignition chamber into the main chamber to aid in the combustion of the fuel-air mixture in the main chamber. As a preferred form of the present invention, this means is an elongated tube including spaced perforations therein so that as a compression wave passes by each of the perforations, it is progressively ignited by a flame front directed into the elongated tube. Means may be connected into the apparatus for injecting a quantity of a particulate coating material therein which is then discharged from the apparatus by the blast of high pressure gas and directed to coat a workpiece.

Referring now to the drawings, wherein like reference numerals are used throughout to designate like parts, and wherein preferred embodiments of the present invention are illustrated,

FIG. **1** is a perspective view with a partial cutaway of one form of the combustion apparatus of the present invention;

FIG. **2A** is a perspective view with partial cutaway of another form of the present invention;

FIG. **2B** is a graph showing the pressure at various points in the apparatus of FIG. **2A**;

FIG. **3** is a sectional view taken at **3—3** in FIG. **2A**;

FIG. **4** is an enlarged view taken at **4** in FIG. **2A**;

FIG. **5A** is a diagrammatic view and FIG. **5B** is a graph illustrating the decreased discharge pressure provided when the apparatus of FIG. **2A** is not utilized.

FIG. **6** is a diagrammatic view of another form of the present invention which is illustrated as being adapted for a particulate coating application; and

FIG. **7** is a sectional view taken at **7—7** in FIG. **6.**

Referring now to FIG. **1,** a relatively simple apparatus is shown therein which provides very rapid combustion of a fuel-air mixture, without the use of detonable

fuels. As illustrated in FIG. 1, a combustion apparatus 10 is provided which includes a housing 11 having an enlarged, generally spherical, intermediate section 12 having a hollow interior, a discharge section 13 in the form of a hollow cylinder connected for communication at one end into section 12, and open to atmospheric pressure at its other end to form a discharge outlet for apparatus 10, and a cylindrical section 14 mounted on the opposite side of section 12 from section 13. Cylindrical section 14 is also hollow and is closed at its end opposite to the end connected to section 12 by a wall 15. Mounted inside of section 14, on the inside of end wall 15, is a smaller cylindrical member 16 which includes an opening 17 at its end opposite to end wall 15. Member 16 is also hollow and a fuel-air mixture inlet 18 is connected through wall 15 into the interior of member 16 to permit the interior of member 16 and the interior of section 14, through opening 17, to be charged with a fuel-air mixture, such as gasoline or propane and air. A spark plug 19 or other ignition means is illustrated as mounted on wall 15 and extending into the interior of member 16 in order to ignite the fuel-air mixture therein.

Also mounted on the interior of section 14 and extending through the wall of section 12 and into the interior thereof is a tube 20 having spaced perforations 21 therein. Tube 20 is hollow and open at both ends so that the charging fuel-air mixture inside of section 14 is also caused to move through tube 20 into the interior of section 12. Perforated tube 20 extends through a substantial length of section 12 and ends adjacent to discharge outlet 13 as shown in FIG. 1.

Also mounted in section 14, between cylindrical member 16 and perforated tube 20 is a baffle plate 22 which functions to disperse flame emerging from opening 17 throughout the interior of cylindrical section 14.

As is apparent from the above description, combustion apparatus 10 includes three separate chambers, i.e., a preignition chamber V_1 formed by cylindrical member 16, an igniting chamber V_2 formed by cylindrical section 14, and a main chamber V_3 formed by enlarged spherical section 12. With this arrangement, fuel-air mixture enters inlet 18 displacing burned gas from a previous operation and charges the three chambers described. If desired, separate charging inlets could be provided for each of the chambers, although the arrangement described has proven to be satisfactory. Upon filling the respective chambers, and before the fuel-air mixture in chamber V_3 has a chance to escape out discharge outlet 13, spark plug 19 is activated to ignite the mixture in chamber V_1 which then expels flame out opening 17 and into chamber V_2. Baffle plate 22 serves to cause the flame to spread out over a wide area in chamber V_2 in order to increase the process of inflammation. The chamber V_2 then rapidly becomes filled with the flaming gas and as the chamber becomes filled, flaming gas reaches the input of perforated tube 20. The entrance to tube 20 is located in the central portion of chamber V_2 and behind baffle plate 22 so that the flame reaches it last, after inflammation is nearly total. Consequently, once the flame begins to flow down perforated tube 20, it does so with nearly the maximum possible combustion pressure driving it ensuring that the ignition applied to chamber V_3 will begin abruptly and forcefully rather than building up slowly from a weak start. As the flame moves down tube 20, it is vigorously expelled from the tube through perforations 21 and causes near simultaneous, rapid combustion in every portion of chamber V_3 and the ignited gas in chamber V_3 is then discharged as a blast from discharge outlet 13.

With the arrangement described, the combustion is so rapid in chamber V_3 that the requirement for an outlet valve in order to permit the pressure to build up is obviated. This is accomplished by utilizing a part of the fuel-air mixture initially ignited to ignite the rest of the fuel-air mixture to provide a vigorous, widely distributed ignition in the main chamber. The apparatus of FIG. 1 has proved satisfactory for maintaining volumes from 1.2 cubic feet up to 40 cubic feet and it is believed that this can be extended to larger or smaller sizes. As is obvious, it contains no moving parts and achieves burning of gas in the main chamber at times of 2 to 5 milliseconds depending on its size.

In order to improve the rate of combustion and increase the discharge pressure, it is possible to coordinate ignition and combustion in an elongated tube so that the first part of the gas to burn (at the rear of the tube) would compress the unburned gas ahead of it. This compressed gas would then itself be ignited and burned, producing a higher pressure and a stronger blast than could be obtained by burning a volume of gas essentially instantaneously and then allowing it to rush out of a tube. To make this process work, it is necessary to control the progress of combustion in a coordinated fashion by shooting flame down a perforated central tube from which jets of flaming gas would be expelled to burn the surrounding gas. In this manner, progressive combustion is provided which enhances the force of the resulting blast.

FIGS. 2–7 show embodiments of this invention which are similar to that in FIG. 1, but in which progressive combustion such as described is employed in order to enhance the force of the resulting blast and increase the efficiency of the device. FIG. 2A illustrates one form of apparatus employing the progressive combustion concept which has proved to be satisfactory, and FIG. 6 illustrates a modified version of this device. Both the embodiments of FIG. 2A and FIG. 6 are shown for a specific application of a coating of a particulate material on a workpiece, however, it is to be understood that these devices may be used for many other applications where it is desired to direct a high energy blast of gas for work.

As shown in FIG. 2A, a combustion apparatus 30 includes an elongated cylindrical housing 31 having a main chamber portion 32 of relatively large diameter and a barrel portion 33 of relatively smaller diameter extending from portion 32. As illustrated, the end of portion 32 away from barrel portion 33 includes a partition 34 dividing portion 32 into an ignition chamber 35 and a main chamber 36. Main chamber 36 is in communication with the interior of barrel portion 33 and the end of barrel portion 33 opposite from portion 32 is open to the atmosphere.

A fuel-air mixture inlet 37 is connected through an end wall 38 of main portion 32 to permit the mixture to charge chamber 35. Also, a spark plug or other ignition means 39 is connected through the wall portion 32 into chamber 35 to provide for ignition in this chamber.

An elongated igniter tube 40 extends from chamber 35, through partition 34 into chamber 36 and through a substantial portion of the length of barrel portion 33. Beginning from a point just beyond where tube 40

emerges from chamber **36** into the interior of barrel **33**, a plurality of spaced prongs **41** are provided as illustrated in FIG. **2A**. Prongs **41** may be provided in spaced rows of four prongs which are equally spaced about the periphery of tube **40** and each adjacent row of four prongs may be offset by 45° from the adjacent row (only two such prongs in each row are illustrated in FIG. **2A** for simplicity). As illustrated in FIG. **4**, prongs **41** include member **42**, which may be of angle iron, disposed at an angle, for example, 45°, with respect to tube **40**, and a strut member **43** connecting the outer end of angle member **42** to tube **40**. Member **42** is located on tube **40** so as to be directly over one of a plurality of spaced perforations or openings **44** provided in tube **40** to permit flame from the interior of tube **40** to be conducted into the interior of the barrel **33**. In this manner each of prongs **41** is disposed over an opening **44** to act as a flame holder to control flame emerging from each of the openings **44**.

Unlike the apparatus of FIG. **1**, ignition of the gas charge in main chamber **36** is provided by a separate ignition means than that provided in chamber **35**. For this purpose a small sleeve **45** open at one end and encircling tube **40** at the other end is provided in the section of chamber **36** formed by portion **32** of housing **31**. Sleeve **45** includes a first cylindrical portion **46** having spaced openings **47** and a second cylindrical portion **48** of a larger diameter than portion **46**, and a spark plug **49** or other ignition means is mounted in portion **48** for igniting a charge of gas therein which is then expelled out the open end of sleeve **45** and out openings **47**. A baffle plate **54** also may be provided adjacent the open end of sleeve **45** for dispersing the ignited gas into chamber **36**. An inlet **50** may be provided in the wall of portion **32** of housing **31** for connection to a source of fuel-air mixture (not shown), such as propane or gasoline, for charging the interior of chamber **36** prior to ignition.

Thus, as the fuel-air mixture charge in chamber **35** is ignited, a flame front is caused to move down igniter tube **40** to provide progressive sources of ignition as flame emerges from openings **44**. Also, as fuel-air mixture charge in chamber **36** is ignited, starting inside of sleeve **45**, the charge in chamber **36** is compressed and moves as a compression wave along chamber **36** towards the outlet thereof. As the compressed gas flows by the various openings **44**, combustion progressively occurs to simulate detonation that occurs with a detonation wave, causing a higher outlet pressure than if the progressive combustion were not employed. The graph of FIG. **2B** illustrates the relative pressure at various stages of the apparatus. In contrast, FIGS. **5A** and **5B** represent the discharge pressure obtained with a similar apparatus except without the spaced openings **44** so that the progressive combustion following compression does not occur. As noted by comparing FIGS. **2B** and **5B**, with the use of progressive combustion provided by igniter tube **40**, a peak pressure near the outlet of the apparatus of about twice of that without progressive combustion is provided.

By way of example, the apparatus of FIG. **2A** can be used to coat a workpiece (not shown) with a particulate coating material. For this purpose, means such as an inlet conduit **51** (see FIG. **3**) may be provided to permit the injection of a coating material **52** into and about the interior of barrel portion **33** of housing **31**. It is preferred that inlet conduit **51** be offset from the center of barrel portion **33** so that the particulate material will be injected substantially on the path shown by arrow **53**. Conduit **51** can be connected to suitable apparatus (not shown) for providing a source of particulate material such as illustrated and described in co-pending patent application Ser. No. 198,806, referenced above.

Referring now to FIGS. **6** and **7**, a form of this invention is illustrated that is particularly adapted to apply a coating to a workpiece at a relatively high impact velocity to thereby form relatively dense and adherent coatings. As illustrated, a combustion apparatus **60** is provided which includes a cylindrical housing **61** having an elongated barrel portion **62** forming a main duct, and an ignition portion **63** of larger diameter than barrel portion **62**. Portion **63** forms a drive chamber and is in open communication with barrel portion **62**. The end **62***a* of barrel portion **62** away from ignition portion **63** is open to atmosphere and the opposite end **63***a* of housing **61** is closed.

Centrally mounted in housing **61** and extending from wall **63***a* to adjacent open end **62***a* is an igniter tube **64** which includes a plurality of retarder sleeves, shown as four sleeves **65, 66, 67** and **68**, spaced along it. Each of the retarder sleeves includes a plurality of spaced perforations **69**, and the end of igniter tube **64** adjacent open end **62***a* includes spaced perforations **70**. The interiors of igniter tube **64** and retarder sleeves **65–68** are hollow and in communication with each other. As illustrated, an end **64***a* of igniter tube extends through wall **63***a* for receipt of a charge of a fuel-air mixture such as gasoline or propane.

A pair of conduits **71** and **72** are connected into barrel portion **62** as illustrated, generally near open end **62***a*, for the injection of a particulate coating material into housing **61**. Again, conduits **71** and **72** may be connected to suitable apparatus (not shown) for providing a source of particulate material such as illustrated and described in co-pending patent application Ser. No. 198,806, referenced above.

In operation, housing **61** is filled initially, including all of the internal piping, with a flammable mixture which can consist of air plus almost any fuel, by injecting the mixture into the open end **64***a* of igniter tube **64**. A small quantity of powdered coating material having the right size and composition is then injected into the main duct formed by barrel portion **62**, where it will remain suspended momentarily. Next, by appropriate means (not shown) high pressure burning gas (the result of burning some of the same fuel-air mixture, usually) is injected into the igniter tube **64**. This gas rushes down the tube and initiates burning in the retarder sleeves **65–68** as it reaches each in turn and finally ignites the gas in the main duct at the far end of the igniter tube. There is a delay between the time at which the igniting gas issues through perforations **64***b* in tube **64** and ignites the retarder sleeve contents and the time that flame spurts from the retarder sleeves through perforations **69** to ignite the gas around it; this delay is made to be greatest for the first retarder sleeve **65** and least for the retarder sleeve **68**. This gives an apparent rate of progress of ignition of (and combustion in) the main duct which greatly exceeds the actual rate of progress of the igniting gas down igniter tube **64** and the result is that a strong blast wave is generated which would not otherwise result and the suspended, injected powder is first accelerated and subsequently heated,

being finally blown out the end of the main duct, impinging on and adhering to a surface (not shown) to form a coating.

The blast wave generated results from the unburned gas first being compressed due to an explosion in the driving chamber formed by portion **63** of housing **61**, and second being burned by ignition from the retarder sleeves. The net effect of compression followed by combustion is to produce a much stronger and faster-moving disturbance than would result from a gas explosion in just the driver chamber.

This blast wave has much in common with a so-called detonation wave (probably the most violent combustion mechanism observed in gaseous combustion) except that detonation occurs only with certain special fuels and/or oxygen-enriched mixtures while this invention accomplishes the same result with essentially any fuel. A detonation wave depends on self-ignition of a combustible mixture behind a combustion-produced pressure wave, and there are not very many mixtures which will self-ignite from their own combustion pressure and, therefore, detonate. If on the other hand, progressive ignition is supplied externally with the right timing and at the correct location, the disturbance created is not in any essential respect different from a detonation, except that a "non-detonatable" mixture is involved.

Use of progressive combustion will tend to produce maximum coating powder velocity and only a moderate amount of exposure to hot gas, due to the high velocity of expulsion and the short residence time in the barrel. The concept of progressive combustion is flexible with respect to the type of combustion produced if one ignites the driving duct in other ways and possibly omits the driving chamber. For instance, using the igniter tube (retarder sleeve concept) it is easily possible to ignite the whole duct essentially simultaneously and obtain less particle velocity and more particle heating, allowing coatings to be made with powders suited to these conditions. Finally, one can ignite from the open end of the main duct back towards the closed end, producing a low velocity expulsion of gas that would be appropriate for powders requiring low impact velocity but extended heating time.

From the foregoing it will be seen that this invention is one well adapted to attain all of the ends and objects hereinabove set forth, together with other advantages which are obvious and which are inherent to the apparatus.

It will be understood that certain features and subcombinations are of utility and may be employed without reference to other features and subcombinations. This is contemplated by and is within the scope of the claims.

As many possible embodiments may be made of the invention without departing from the scope thereof, it is to be understood that all matter herein set forth or shown in the accompanying drawings is to be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. A combustion apparatus for generating and directing a high pressure blast of gas comprising, in combination:

a housing;

a first chamber in said housing having a fuel-air mixture inlet;

a second chamber in said housing in communication with and adjacent said first chamber at one end, said second chamber being open at its other end to the atmosphere to form a discharge outlet for said housing;

means for igniting said fuel-air mixture in said first chamber; and

means extending from said first chamber into said second chamber to distribute ignited fuel-air mixture from said first chamber into said second chamber to cause combustion of a fuel-air mixture in said second chamber.

2. The combustion apparatus of claim **1** wherein said last mentioned means is a tube having spaced perforations therein extending from said first chamber into a substantial portion of said second chamber.

3. The combustion apparatus of claim **2** further including a plurality of flame holders disposed on said tube, each of said flame holders being adjacent a perforation therein.

4. The combustion apparatus of claim **3** wherein each of said flame holders is disposed at an acute angle with respect to said tube.

5. The combustion apparatus of claim **1** further including means for injecting a particulate coating material therein to be carried from said apparatus by said high pressure blast.

6. The combustion apparatus of claim **3** further including means for injecting a particulate coating material therein to be carried from said apparatus by said high pressure blast.

7. The combustion apparatus of claim **1** further including baffle means located in said first chamber for dispensing ignited gases therein.

8. The combustion apparatus of claim **1** further including means for igniting said fuel-air mixture in said second chamber to establish a moving front of ignited gas moving towards said discharge outlet, and wherein said last mentioned means provides for progressive ignition of said front as it moves toward said outlet.

9. The combustion apparatus of claim **2** wherein said tube includes a plurality of retarder sleeves spaced along it, each of said retarder sleeves including spaced perforations therein.

10. The combustion apparatus of claim **9** further including means for injecting a particulate coating material therein to be carried from said apparatus by said high pressure blast.

11. A method of generating and directing a high pressure blast of gas, comprising the steps of:

charging a first zone and a second zone open to a relatively low pressure region with a combustible fuel-air mixture, said first zone and second zone being formed within an integral housing;

igniting the fuel-air mixture in said first zone; and

conducting said ignited mixture from said first zone into said second zone by means of a conducting means extending from said first zone to said second zone and attached to disperse said ignited mixture in order to ignite the fuel-air mixture in said second zone before it is dispersed out of said second zone to cause said high pressure blast of gas.

12. The method of claim **11** further including the step of progressively igniting the fuel-air mixture in said second zone with ignited mixture from said first zone.

13. The method of claim **11** further including the step of injecting a particulate coating material into said sec-

ond zone and directing the resulting high pressure blast of gas to coat a workpiece with said particulate material.

14. The method of claim **12** further including the step of injecting a particulate coating material into said second zone and directing the resulting high pressure blast of gas to coat a workpiece with said particulate material.

15. A combustion apparatus for generating and directing a high pressure blast of gas containing a quantity of a particulate coating material comprising, in combination:

a housing;

a first chamber in said housing having a fuel-air mixture inlet;

a second chamber in said housing in communication with and adjacent said first chamber at one end, said second chamber being open at its other end to the atmosphere to form a discharge outlet for said housing;

means for injecting a particulate coating material into said second chamber;

means for igniting said fuel-air mixture in said first chamber; and

means extending from said first chamber into said second chamber to distribute ignited fuel-air mixture from said first chamber into said second chamber to cause the combustion of a fuel-air mixture in said second chamber.

16. The combustion apparatus of claim **15** wherein said last mentioned means is a tube having spaced perforations therein extending from said first chamber into a substantial portion of said second chamber.

17. A combustion apparatus for generating and directing a high pressure blast of gas, comprising, in combination:

a first pressure zone in which a fuel-air mixture can be ignited;

a second pressure zone adapted to be charged by a fuel-air mixture and in communication with said second zone, said second zone being open to a relatively low pressure as compared to the pressure of the fuel-air mixture charging said second zone; and

means extending from said first pressure zone into said second pressure zone for conducting ignited fuel-air mixture from said first zone into said second zone for igniting the fuel-air mixture in said second zone.

18. The combustion apparatus of claim **17** wherein said last mentioned means provides for progressive combustion in said second zone.

19. A combustion apparatus for generating and directing a high pressure blast of gas comprising, in combination:

a housing;

a first chamber in said housing having a fuel-air mixture inlet;

a second chamber in said housing in communication with and adjacent said first chamber at one end, said second chamber being open at its other end to the atmosphere to form a discharge outlet for said housing;

means for igniting said fuel-air mixture in said first chamber; and

a tube having spaced perforations therein extending from said first chamber into said second chamber to distribute ignited fuel-air mixture from said first chamber into said second chamber to cause combustion of a fuel-air mixture into said second chamber.

20. The combustion apparatus of claim **19** further including a plurality of flame holders disposed on said tube, each of said flame holders being adjacent a perforation therein.

21. The combustion apparatus of claim **20** wherein each of said flame holders is disposed at an acute angle with respect to said tube.

22. The combustion apparatus of claim **20** further including means for injecting a particulate coating material therein to be carried from said apparatus by said high pressure blast.

23. The combustion apparatus of claim **19** wherein said tube includes a plurality of retarder sleeves spaced along it, each of said retarder sleeves including spaced perforations therein.

24. The combustion apparatus of claim **23** further including means for injecting a particulate coating material therein to be carried from said apparatus by said high pressure blast.

25. A combustion apparatus for generating and directing a high pressure blast of gas containing a quantity of a particulate coating material comprising, in combination:

a housing;

a first chamber in said housing having a fuel-air mixture inlet;

a second chamber in said housing in communication with and adjacent said first chamber at one end, said second chamber being open at its other end to the atmosphere to form a discharge outlet for said housing;

means for injecting a particulate coating material into said second chamber;

means for igniting said fuel-air mixture in said first chamber; and

a tube having spaced perforations therein extending from said first chamber into a substantial portion of said second chamber to distribute ignited fuel-air mixture into said second chamber to cause combustion of a fuel-air mixture into said second chamber.

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