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(54) **DETONATIVE CLEANING APPARATUS**

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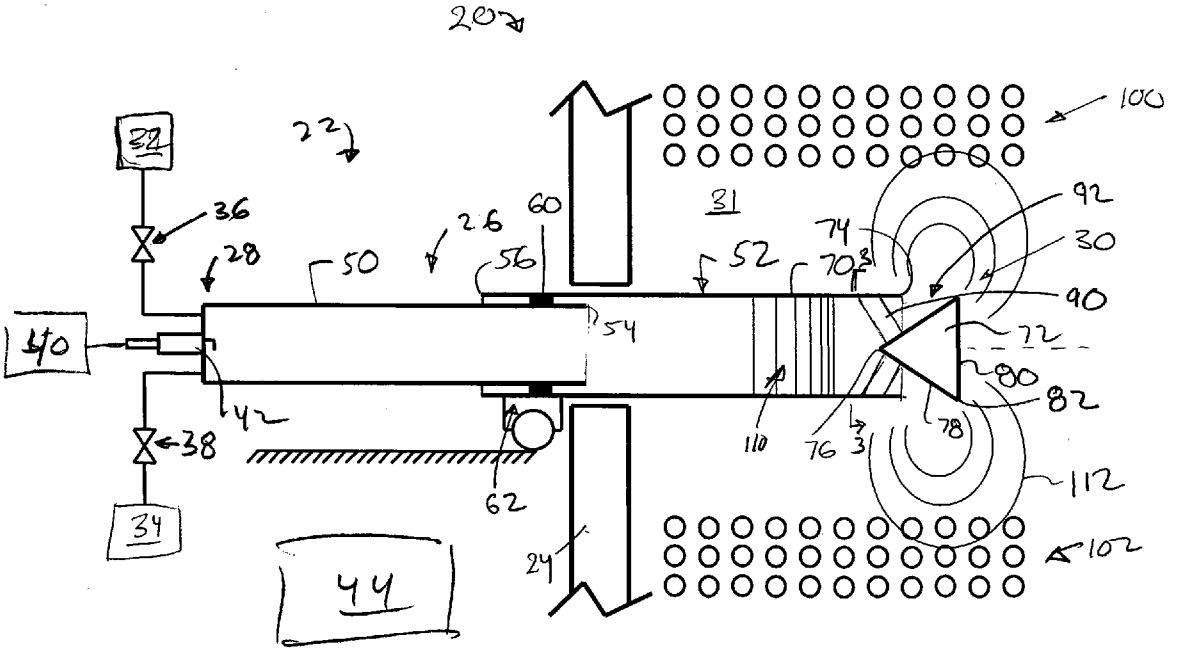
(57) **ABSTRACT**

An apparatus is provided for cleaning a surface within a vessel. A vessel wall separates a vessel exterior from a vessel interior and has a wall aperture. The apparatus comprises an elongate conduit having an upstream first end and a downstream second end. The conduit is positioned to direct a shock wave from the second end into the vessel interior. A source of fuel and oxidizer is coupled to the conduit to deliver the fuel and oxidizer to the conduit. An initiator is positioned to initiate a combustion of the fuel and oxidizer. The conduit comprises a first portion and a second portion downstream of the first portion. The second portion is extensible and contractible relative to the first portion to selectively position the second end at a desired location within the vessel. The conduit downstream end comprises a centerbody positioned to direct the shock wave essentially axisymmetrically.



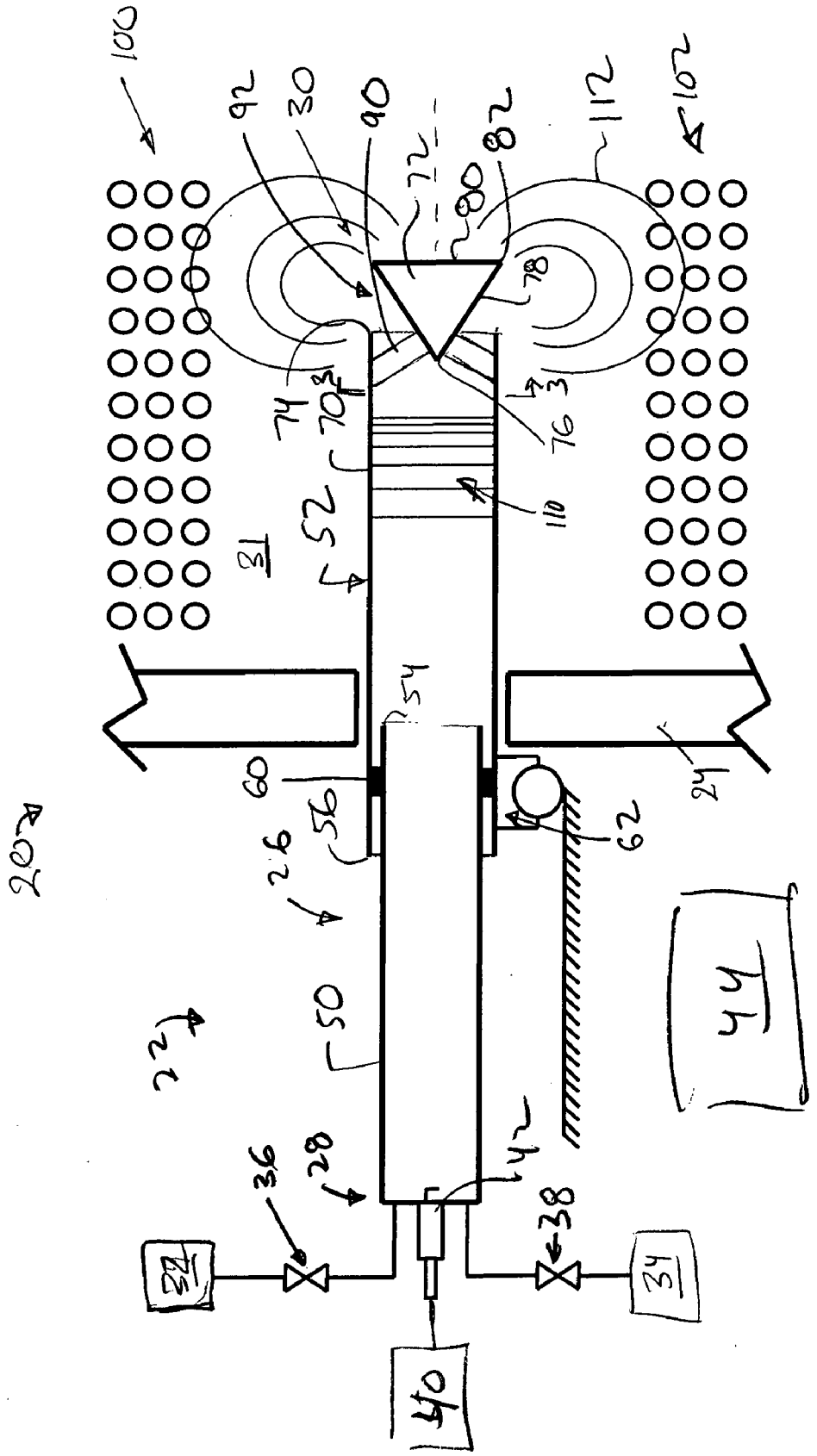

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FIG. 1

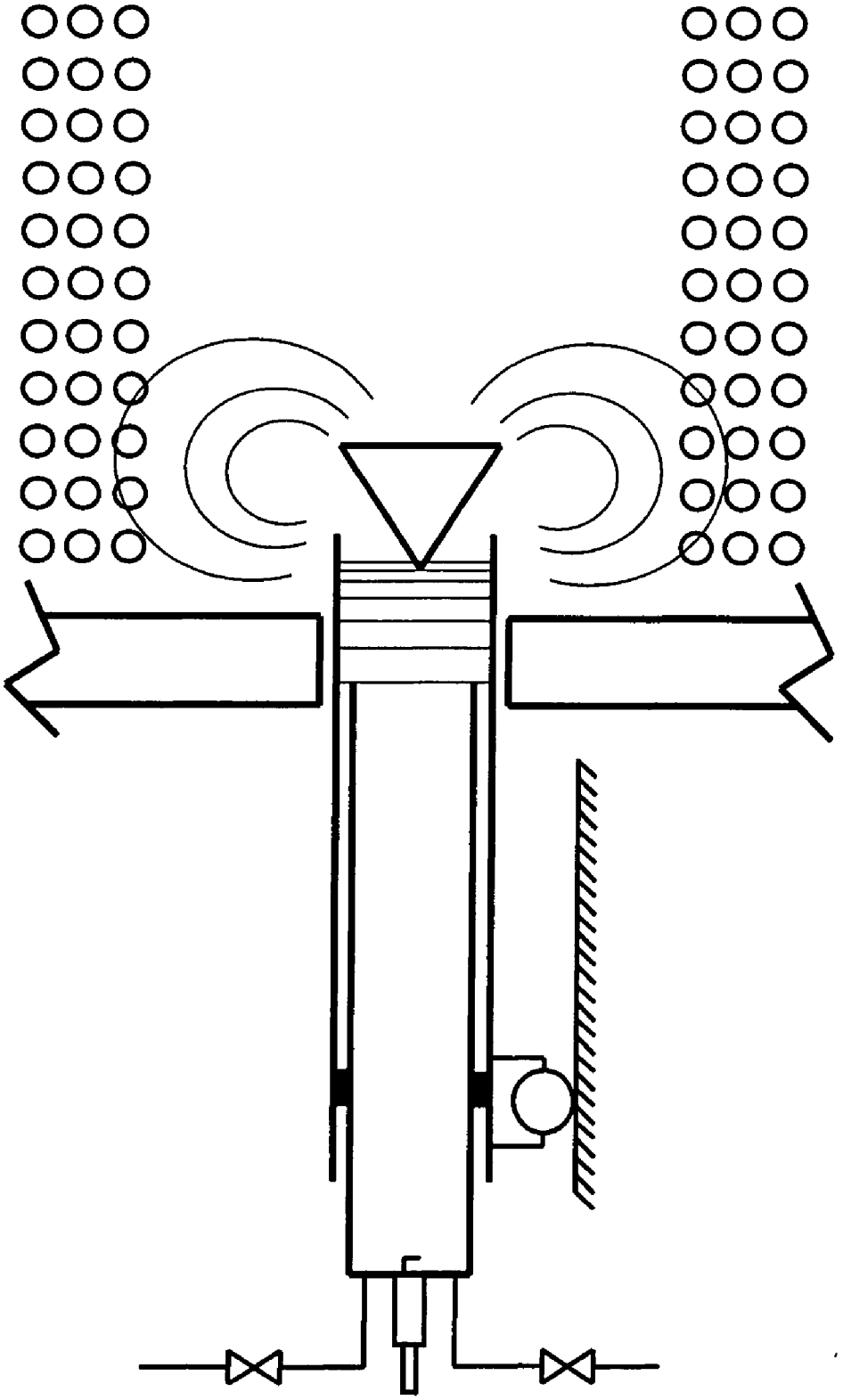

FIG 2

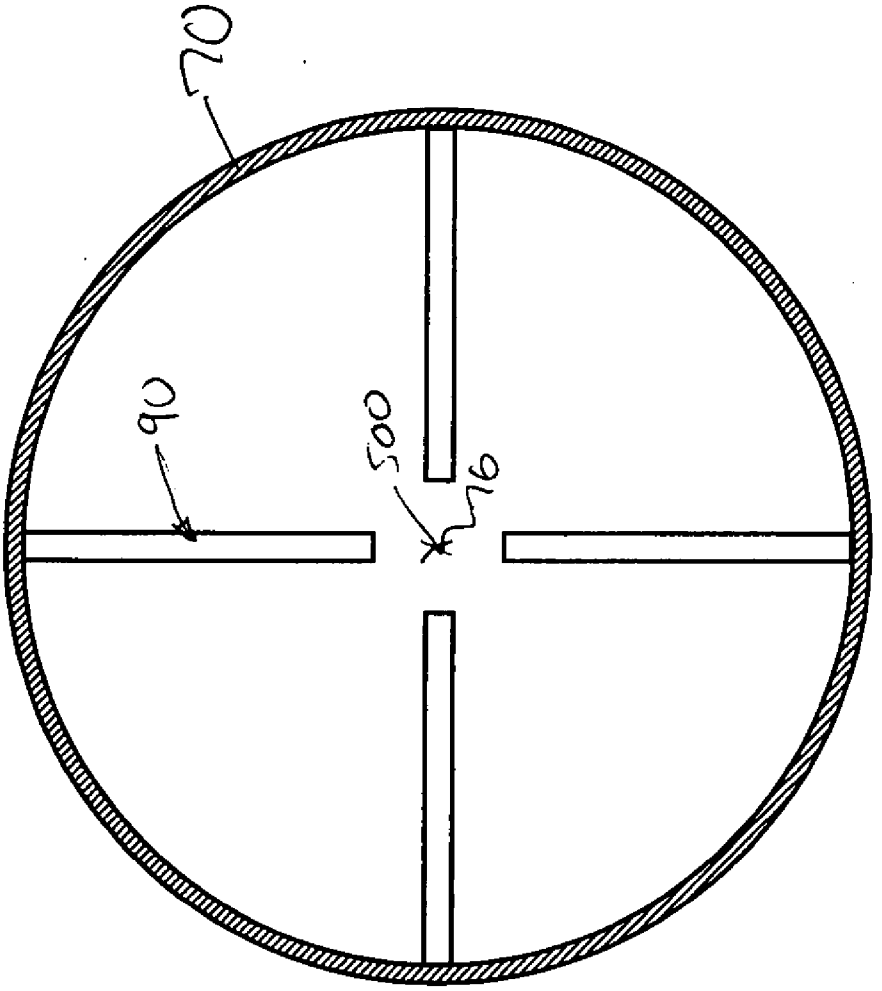

FIG 3

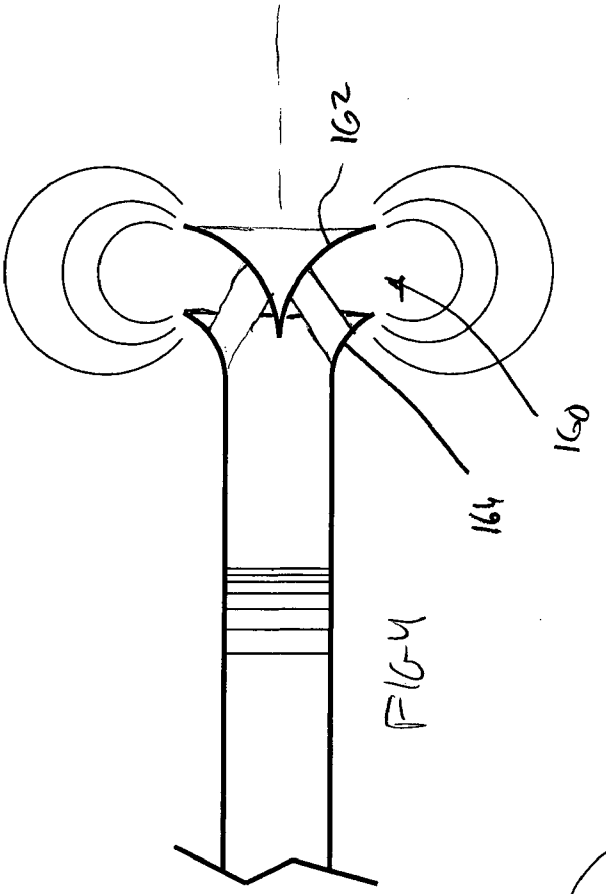

FIG 4

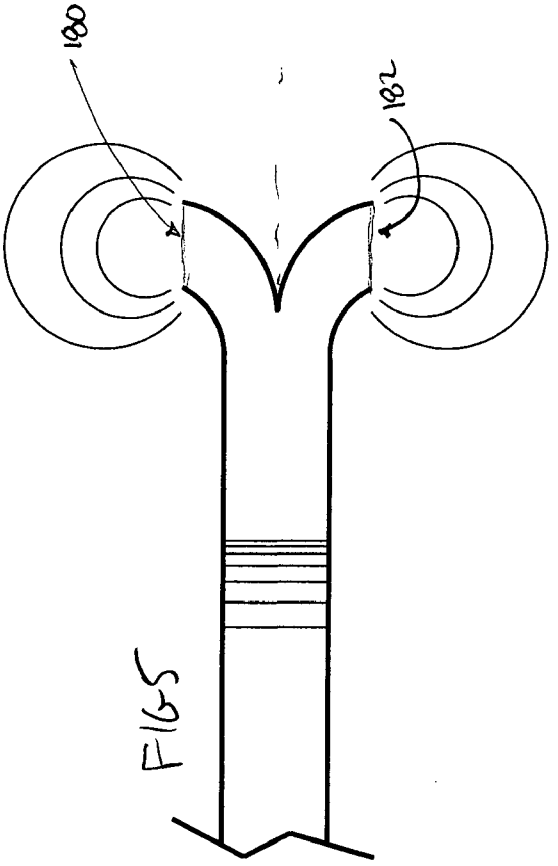

FIG 5

DETONATIVE CLEANING APPARATUS

BACKGROUND

[0001] The disclosure relates to industrial equipment. More particularly, the disclosure relates to the detonative cleaning of industrial equipment.

[0002] Surface fouling is a major problem in industrial equipment. Such equipment includes furnaces (coal, oil, waste, etc.), boilers, gasifiers, reactors, heat exchangers, and the like. Typically the equipment involves a vessel containing internal heat transfer surfaces that are subjected to fouling by accumulating particulate such as soot, ash, minerals and other products and byproducts of combustion, more integrated buildup such as slag and/or fouling, and the like. Such particulate build-up may progressively interfere with plant operation, reducing efficiency and throughput and potentially causing damage. Cleaning of the equipment is therefore highly desirable and is attended by a number of relevant considerations. Often direct access to the fouled surfaces is difficult. Additionally, to maintain revenue it is desirable to minimize industrial equipment downtime and related costs associated with cleaning. A variety of technologies have been proposed.

[0003] By way of example, various technologies have been proposed. A retractable pulsed detonation soot blower is discussed in Huque, Z., et al., Quarterly Research Report (Reporting Period: Mar. 1, 1997-Jun. 30, 1997) on Slag Characterization and Removal Using Pulse Detonation for Coal Gasification, DE-FG22-95MT95010, U.S. Department of Energy Pittsburgh Energy Technology Center, Pittsburgh, Pa., 1997.

[0004] Additional technology is disclosed in Huque, Z. Experimental Investigation of Slag Removal Using Pulse Detonation Wave Technique, DOE/HBCU/OMI Annual Symposium, Miami, Fla., Mar. 16-18, 1999. Particular blast wave techniques are described by Hanjalić and Smajević in their publications: Hanjalić, K. and Smajević, I., Further Experience Using Detonation Waves for Cleaning Boiler Heating Surfaces, International Journal of Energy Research Vol. 17, 583-595 (1993) and Hanjalić, K. and Smajević, I., Detonation-Wave Technique for On-load Deposit Removal from Surfaces Exposed to Fouling: Parts I and II, Journal of Engineering for Gas Turbines and Power, Transactions of the ASME, Vol. 1, 116 223-236, January 1994. Such systems are often identified as "soot blowers" after an exemplary application for the technology. U.S. Pat. No. 7,011,047, the disclosure of which is incorporated by reference herein as if set forth at length, discloses several structural and process variations.

[0005] Nevertheless, there remain opportunities for further improvement in the field.

SUMMARY

[0006] One aspect of the disclosure involves an apparatus for cleaning a surface within a vessel. A vessel wall separates a vessel exterior from a vessel interior and has a wall aperture. The apparatus comprises an elongate conduit having an upstream first end and a downstream second end. The conduit is positioned to direct a shock wave from the second end into the vessel interior. A source of fuel and oxidizer is coupled to the conduit to deliver the fuel and oxidizer to the conduit. An initiator is positioned to initiate a combustion of the fuel and oxidizer. The conduit comprises a first portion and a second portion downstream of the first portion. The second portion is extensible and contractible relative to the first portion to selectively position the second end at a desired location within the vessel. The conduit downstream end comprises a centerbody positioned to direct the shock wave essentially axisymmetrically.

[0007] In various implementations, an actuator may be coupled to the conduit second portion to extend and contract the second portion relative to the first portion. The second portion may be irrotatable (e.g., neither the actuator nor any other actuator being configured to rotate the second portion relative to the first portion about a longitudinal axis). The centerbody may define an only outlet of the conduit. The centerbody may be essentially axisymmetric and held by a plurality of struts. The centerbody may have an upstream surface concave in central longitudinal section and essentially axisymmetric.

[0008] Another aspect of the disclosure involves such a cleaning apparatus wherein the conduit downstream end comprises a centerbody positioned to direct the shock wave from an opening of essentially 360°.

[0009] Another aspect of the disclosure involves a method for cleaning a surface within such a vessel. The shock wave is discharged from an opening essentially circumscribing an axis of the conduit between a centerbody and a portion of the conduit upstream of the centerbody.

[0010] The details of one or more embodiments are set forth in the accompanying drawings and the description below. Other features, objects, and advantages will be apparent from the description and drawings, and from the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] FIG. **1** is a partially schematic view of a soot blower in an extended condition.

[0012] FIG. **2** is a view of the soot blower of FIG. **1** in a retracted condition.

[0013] FIG. **3** is a transverse sectional view of an outlet end portion of the soot blower of FIG. **1**.

[0014] FIG. **4** is a partially schematic longitudinal sectional view of an alternate soot blower outlet.

[0015] FIG. **5** is a partially schematic longitudinal sectional view of a second alternate soot blower outlet.

[0016] Like reference numbers and designations in the various drawings indicate like elements.

DETAILED DESCRIPTION

[0017] FIG. **1** shows a furnace **20** having an associated soot blower **22** along a vessel (e.g., furnace) wall **24**. Other configurations are possible (e.g., a group of soot blowers, one or more soot blowers on each of multiple levels, and the like).

[0018] The soot blower **22** includes an elongate combustion conduit **26** extending about/along an axis **500** from an upstream end **28** away from the furnace wall **24** to a downstream end **30** within the furance interior **31**. In operation of the soot blower, combustion of a fuel/oxidizer mixture within the conduit **26** is initiated proximate the upstream end **28** (e.g., within an upstreammost 10% of a conduit length) to produce a detonation wave which is expelled from the downstream end as a shock wave along with associated combustion gases for cleaning surfaces within the interior.

[0019] The soot blower may be associated with a fuel/oxidizer source. Such source, or one or more components thereof, may be shared amongst the various soot blowers if

multiple blowers are present. An exemplary source includes a liquefied or compressed gaseous fuel cylinder **32** and an oxygen cylinder **34**. In the exemplary embodiment, the oxidizer is a first oxidizer such as essentially pure oxygen. A second oxidizer and/or a second fuel may be used (e.g., as discussed in U.S. Pat. No. 7,011,047). Each exemplary source is coupled to the associated conduit **26** by appropriate plumbing (e.g., including valves **36** and **38**). Alternatively, the source may premix the fuel and oxidizer upstream of the conduit (e.g. and deliver the mixture to the conduit along a single line (e.g., from a remote location)). Similarly, the soot blower includes a spark box **40** connected to a sparkplug **42** for initiating combustion of the fuel oxidizer mixture and which, along with the source **32**, is controlled by a control and monitoring system **44**.

[0020] The exemplary conduit **26** is an extensible conduit having a proximal section **50** and a distal section **52** extensible and contractible (retractable) relative thereto. A variety of extensible constructions are known from steam-operated soot blowers. The exemplary upstream end **28** is along the section **50** and the exemplary downstream end **30** is along the section **52**. The section **50** further includes its own downstream end **54**. The section **52** further includes its own upstream end **56**. A seal **60** may be provided between the sections **50** and **52**. An actuator **62** may be provided for extending and retracting the downstream section **52**. The actuator **62** may comprise pneumatic, hydraulic, or electric position transducers or may include a powered carriage. The upstream section **50** and the conduit as a whole may also be movable by other actuators or the like (not shown).

[0021] The exemplary section **52** includes the combination of a tube **70** and a centerbody **72** adjacent a downstream rim **74** of the tube **70**. The centerbody **72** includes a leading/upstream end/tip **76**. A downstream divergent sidewall **78** extends downstream from the tip **76** to an end face **80** having a periphery or rim **82**. The exemplary tip **76** is positioned slightly upstream of the rim **74**. The centerbody **72** is held by the tube **70** via a plurality of struts **90**. A radially-outward facing annular outlet opening **92** is formed between the rim **74** and the rim **82** of the centerbody. The exemplary outlet **92** may be positioned adjacent the surfaces to be cleaned. In the illustrated embodiment, the outlet **92** is between a pair of two bundles **100** and **102** within the vessel interior **31**.

[0022] FIG. **1** shows a relatively extended position whereas FIG. **2** shows a relatively contracted/retracted position. In an exemplary cleaning cycle, the section **52** may be progressively extended or retracted between firing cycles or groups thereof. Each firing causes a wave **110** with a deflagration-to-detonation transition to move down the conduit and be discharged from the outlet as an essentially axisymmetric shockwave **112**. Whereas a typical steam lance soot blower includes one or two discrete radial openings discharging steam, the relatively high available power afforded by detonation facilitates an essentially 360° discharge (e.g., with minor fluctuations likely caused by the presence of the struts occupying at most a small total of the circumference (e.g., less than 20%)). The outward redirection of the shockwave by the centerbody may impose substantial mechanical stresses on the centerbody and struts. A sufficient number and robustness of struts must be chosen for structural integrity. However, it is also desirable to limit the interference of the struts with the flow of combustion products and discharge of the shockwave. Exemplary struts may be of teardrop/streamlined cross-section.

[0023] FIG. **4** shows an alternate outlet **160** formed by a horn-like centerbody **162** and flared downstream tube downstream end portion **164**.

[0024] FIG. **5** shows a non-axisymmetric outlet wherein the conduit downstream section splits into two branches with mirror image outlet openings **180** and **182**. The openings are thus, axially aligned (i.e., as distinguished from axially/longitudinally spaced-apart) and diametrically opposed. Rather than produce an axisymmetric shockwave, a pair of opposite shockwaves are discharged. The mirror image nature of the outlets provides a reaction force balance which would not be present with a single laterally directed outlet and which would be more balanced than with axially spaced-apart/offset openings. Such mirror image openings may conveniently allow the conduit to be positioned between symmetric surfaces (e.g., tube bundles on respective sides of the conduit to clean both surfaces simultaneously).

[0025] The branched conduit of FIG. **5** may be configured to provide more locally intense shockwaves with longer-range effects than the axisymmetric embodiments. However, for full shockwave coverage, a rotation mechanism may be required to rotate the downstream section about its axis.

[0026] One or more embodiments have been described. Nevertheless, it will be understood that various modifications may be made. For example, the teachings may be adapted for use with a variety of industrial equipment and with variety of soot blower technologies. This may include reengineering of existing soot blower configurations or remanufacturing/retrofit of existing soot blowers. In an exemplary reengineering of an extensible steam lance, the conduit sections may be replaced by stronger sections and the fuel and oxidizer sources and initiator may be added along with associated equipment. Carriages and/or other actuators, access devices, and the like may be preserved. Aspects of the existing equipment and technologies may influence aspects of any particular implementation. Other shapes of combustion conduit (e.g., non-straight conduits or sections thereof to navigate external or internal obstacles and non-circular cross-sections of the conduits or sections thereof) may be possible. Accordingly, other embodiments are within the scope of the following claims.

What is claimed is:

1. An apparatus for cleaning a surface within a vessel having a vessel wall separating a vessel exterior from a vessel interior and having a wall aperture, the apparatus comprising:

an elongate conduit having an upstream first end and a downstream second end and positioned to direct a shock wave from the second end into the vessel interior; and

a source of fuel and oxidizer coupled to the conduit to deliver the fuel and oxidizer to the conduit; and

an initiator positioned to initiate a combustion of the fuel and oxidizer,

wherein:

the conduit comprises a first portion and a second portion downstream of the first portion and extensible and contractible relative to the first portion to selectively position the second end at a desired location within the vessel; and

the conduit downstream end comprises a centerbody positioned to direct the shock wave essentially axisymmetrically

2. The apparatus of claim 1 further comprising:
an actuator coupled to the conduit second portion to extend and contract the second portion relative to the first portion.
3. The apparatus of claim 2 wherein:
neither the actuator, nor any other actuator, is configured to rotate the second portion relative to the first portion about a longitudinal axis.
4. The apparatus of claim 1 wherein:
the centerbody defines an only outlet.
5. The apparatus of claim 1 wherein:
the centerbody is essentially axisymmetric and held by a plurality of struts.
6. The apparatus of claim 1 wherein:
the centerbody has an upstream surface concave in central longitudinal section.
7. An apparatus for cleaning a surface within a vessel having a vessel wall separating a vessel exterior from a vessel interior and having a wall aperture, the apparatus comprising:
an elongate conduit having an upstream first end and a downstream second end and positioned to direct a shock wave from the second end into the vessel interior; and
a source of fuel and oxidizer coupled to the conduit to deliver the fuel and oxidizer to the conduit; and
an initiator positioned to initiate a combustion of the fuel and oxidizer,
wherein:
the conduit comprises a first portion and a second portion downstream of the first portion and extensible and contractible relative to the first portion to selectively position the second end at a desired location within the vessel; and
the conduit downstream end comprises a centerbody positioned to direct the shock wave from an opening of essentially 360°.
8. The apparatus of claim 7 further comprising:
an actuator coupled to the conduit second portion to extend and contract the second portion relative to the first portion.
9. An apparatus for cleaning a surface within a vessel having a vessel wall separating a vessel exterior from a vessel interior and having a wall aperture, the apparatus comprising:
an elongate conduit having an upstream first end and a downstream second end and positioned to direct a shock wave from the second end into the vessel interior; and
a source of fuel and oxidizer coupled to the conduit to deliver the fuel and oxidizer to the conduit; and
an initiator positioned to initiate a combustion of the fuel and oxidizer,
wherein:
the conduit comprises a first portion and a second portion downstream of the first portion and extensible and contractible relative to the first portion to selectively position the second end at a desired location within the vessel; and
the conduit downstream end comprises a pair of axially aligned outlet openings.
10. The apparatus of claim 9 wherein:
the outlet openings are diametrically opposed.
11. A method for cleaning a surface within a vessel having a vessel wall separating a vessel exterior from a vessel interior and having a wall aperture, the method comprising:
introducing of fuel and oxidizer to an elongate conduit having an upstream first end and a downstream second end, the second end within the vessel;
initiating a combustion of the fuel and oxidizer; and
discharging a shock wave from the second end into the vessel interior;
wherein:
the discharging is from an opening essentially circumscribing an axis of the conduit between a centerbody and a portion of the conduit upstream of the centerbody.
12. The method of claim 11 wherein:
the conduit comprises a first portion and a second portion downstream of the first portion, the centerbody being along the second portion; and
the method includes at least one of extending and contracting the second portion relative to the first portion to selectively position the second end at a desired location within the vessel between a plurality of cycles of the discharging.
13. The method of claim 12 wherein:
an overall cleaning cycle is performed including a plurality of movements in the absence of a rotation of the second portion.

* * * * *