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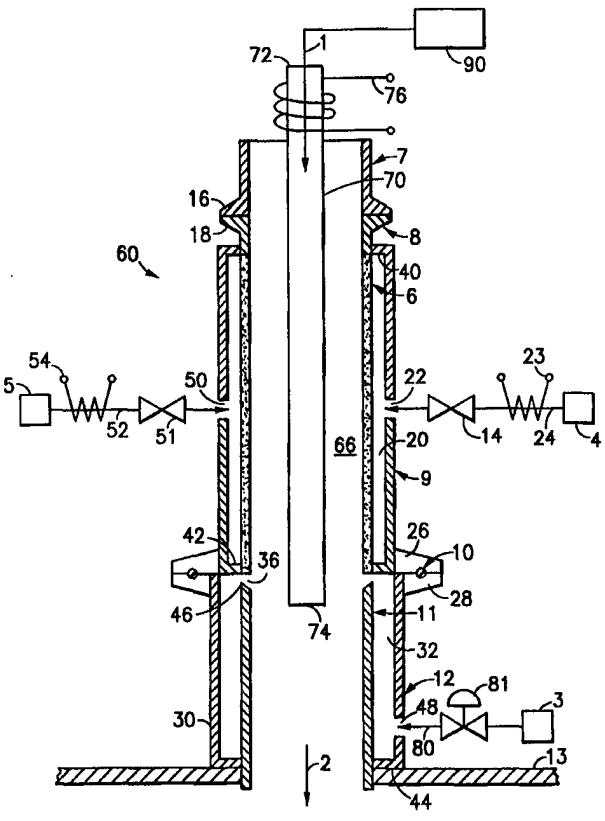
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(54) Title: INLET STRUCTURES FOR INTRODUCING A PARTICULATE SOLIDS–CONTAINING AND/OR SOLIDS–FORMING GAS STREAM TO A GAS PROCESSING SYSTEM

(57) Abstract

An inlet structure (60) for passage of a gas stream from an upstream source (90) of gas to a downstream locus, wherein the inlet structure (60) is constructed, arranged and operated to suppress particulate and film deposition and formation, as well as to suppress adverse hydrodynamic effects.



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INLET STRUCTURES FOR INTRODUCING A PARTICULATE SOLIDS-CONTAINING AND/OR SOLIDS-FORMING GAS STREAM TO A GAS PROCESSING SYSTEM

DESCRIPTION

Field of the Invention

This invention relates to inlet structures for introducing gas streams to downstream process equipment, such as downstream gas treatment apparatus. In specific aspects the invention relates to clogging-resistant entry structures for introducing a particulate solids-containing and/or solids-forming gas stream to a gas processing system.

Description of the Related Art

In the processing of particulate solids-containing and/or solids-forming gas streams for treatment thereof, clogging of inlet structures of process equipment with particulate solids from such streams is frequently a problem. As the particulate solids-containing and/or solids-forming gas stream is flowed through the process equipment, solids may be deposited on the surfaces and in the passages of the inlet structure.

If the particulate solids accumulate with continued operation of the process equipment, the inlet structure of such equipment may become occluded to sufficient extent as to plug entirely, or alternatively the solids build-up may not occlude the inlet of the process unit, but may so impair the flows and increase the pressure drop in the system as to render the process equipment grossly inefficient for its intended purpose.

In general, particulates associated with the gas stream can come from various sources, including: (i) particulate generated in an upstream process unit which comes downstream to the inlet structure with the gas stream; (ii) particulate formed in the system lines by the reaction of a process gas component with oxygen from leaks coming into the lines; (iii) particulate formed in the system lines due to reaction of two or more process off-gases during flow of the gas stream coming downstream to the inlet structure; (iv) particulate formed by (partial) condensation of off-gases coming downstream to the inlet structure; and (v) particulate formed by reaction of process gases with back-diffusing oxygen or water vapor from a downstream gas stream treatment unit such as for example a downstream water scrubber. In some instances, where the particulate is formed by condensation, it may be possible to ameliorate the problem by heating of process lines, to eliminate the condensable portion of the gas stream. Even with such line heating, however, the problems of particulate from other sources still remain.

Particularly in the field of semiconductor manufacture, inlet clogging is prone to occur from: (a) back-migration to the inlet of water vapor, or liquid water via capillary action, as a combustion product of downstream oxidation operations and/or water scrubbing operations employed to treat the gas stream, causing hydrolysis reactions in a heterogeneous or homogeneous fashion with incoming water-sensitive gases such as BCl_3, WF_6, DCS, TCS, SiF_4; (b) thermal degradation of incoming thermally-sensitive gases; and (c) condensation of incoming gases due to transition points in the system.

The aforementioned inlet clogging problems may require the incorporation of plunger mechanisms or other solids removal means to keep the inlet free of solids

accumulations, however these mechanical fixes add considerable expense and labor to the system and may damage the entry over time. In other instances, the inlet clogging problems may be systemic and require periodic preventative maintenance to keep the inlet free of solids accumulations. Such maintenance, however, requires shut-down of the system and loss of productivity in the manufacturing or process facility with which the inlet is associated.

Considering specifically the occurrence of water vapor, or liquid water via capillary action, backstreaming from a downstream water scrubber to an upstream inlet structure in a semiconductor process effluent gas stream treatment system, wherein water vapor released from the scrubber migrates back from the scrubber inlet toward the process tool, against the normal direction of process gas flow, various mechanisms may be involved in the transport of the back-migration of the water vapor.

One mechanism is gas-gas interdiffusion. The only practical way of avoiding this source of water vapor back migration is to add a diffusion boundary to the water scrubber inlet.

Another mechanism for such back-diffusion of water vapor is the so-called Richardson effect annular effect. All dry pumps create a certain amount of pressure oscillation in the gas flow stream. These pressure oscillations create a counterflow transport mechanism that pumps gases against the direction of normal gas flow. This phenomenon is a consequence of the boundary layer annular effect. Because of this effect, the backflow migration velocity is greatest a small distance away from the wall surface.

If particulate solids continue to accumulate with continued operation of process equipment, the inlet structure of such equipment may become occluded to sufficient extent as to plug entirely, or alternatively the solids build-up may not occlude the inlet of the process unit, but may so impair the flows and increase the pressure drop in the system as to render the process equipment grossly inefficient for its intended purpose.

Particularly in the case of water scrubber equipment used for scrubbing of gas streams such as waste gas streams generated in the manufacture of semiconductor devices, the waste gas constituting the influent gas stream to the water scrubber may contain or produce (by reaction or condensation) significant fine particles content, e.g., submicron particles of silica, metals from CVD or other deposition operations, etc. Such waste gas streams tend to clog the inlet of the waste gas water scrubber very readily. As a result the inlet of the water scrubber requires manual cleaning on a frequent basis.

The inlet clogging susceptibility is a major shortcoming of current commercial water scrubber units used in the semiconductor industry. The time required to clog the entry of the water scrubber in such applications is process dependent and site-specific. Among the factors that affect the mean time to failure of the water scrubber due to the clogging of the inlet include: the process tool generating the particulates-containing process effluent stream being treated in the scrubber, the specific process recipes and chemistries employed in the upstream process generating the effluent being treated in the water scrubber, and the character of the inert gas purges used to purge pumps and process lines in the system. Other process conditions and factors are suspected of contributing to or affecting particle build-up in the process system, but are not yet clearly defined. See Abreu, R., Troup, A. and Sahm, M., "Causes of

anomalous solid formation in the exhaust systems of low-pressure chemical vapor deposition and plasma enhanced chemical vapor deposition semiconductor processes, J. Vac. Sci. Technol. B 12 (4), Jul/Aug 1994, 2763-2767.

In the case of operations such as treatment of effluent gases from semiconductor manufacturing operations, the waste gas may be subjected to oxidation treatment, to oxidatively abate hazardous oxidizable components of the effluent gas, by means of thermal oxidation, or other oxidation reaction processes. By such oxidation, it is possible to significantly reduce pyrophoric components and toxic components in the effluent stream, as well as to oxidatively remove other components which may be deleterious in release to the atmosphere from the process facility.

The effluent gases subjected to such treatment may contain not only significant fine particles content, e.g., submicron particles of silica, metals from CVD or other deposition operations, etc., but such gas streams may contain significant gaseous components which may be corrosive in the treatment environment, at the elevated temperatures typically employed for oxidation treatment. Such corrosive character thus poses a problem in respect of the hot effluent gas stream from the oxidation treatment, as well as the solids accumulation capability attributable to the particulates content of such effluent gas stream.

The particulate solids in such gas streams may clog downstream processing equipment, e.g., downstream processing operations including water scrubbing. Clogging of scrubbing equipment is a significant problem in the art. This is particularly the case when there exists a transition from hot oxidizing conditions inherent to a combustion device to the cool wet conditions of a quench chamber. By definition, there exists a transition zone in which the flow transition from hot

combustion conditions to wet quenching conditions take place. Associated problems in such oxidation/scrubbing/quench systems include particulate accumulation and eventual cross-section occlusion due to back-diffusion of moisture and spray from the wet quench zone creating a sticky adhering particulate that will accumulate in portions of the quench region immediately above the wetted zone.

Another problem is attributable to the lack of permanent definition of the location of the wet/dry interface. Because the location of the wet/dry interface can change as the fluid dynamics of the system change, it becomes correspondingly very difficult to precisely locate the wet/dry interface. Factors influencing the location of the interface include: (a) combustion off-gas flow rate and thermal duty, (b) quench spray flow rate and overflow weir flow rate, and (c) back mixing and eddying of the quench spray or overflow weir flow. The inability to fix the location of the wet/dry interface results in two difficulties: (1) regions are created which are susceptible to particulate agglomeration, and (2) corrosion of the materials of the quench region may resultingly occur.

Most alloys used for combustion and quenching equipment are corrosion-resistant for a specific set of conditions. Those alloys which will withstand hot oxidizing conditions are typically unsuitable for wet corrosion conditions and vice versa. This problem is further exacerbated when additional products may be present which accelerate corrosion or oxidation, such as the presence of halogens, sulfidizing agents, etc. Since it is impossible to precisely fix the material of construction specification transition, it then becomes necessary to use exotic materials of construction that tend to be excessively costly and to perform at only mediocre level.

Significant effort has been expended to solve such problem. To date no acceptable solutions have been found, and all proposed solutions suffer from a variety of deficiencies. Two approaches are typically used as a matter of necessity. The first is the use of an overflow weir to wet the walls at the transition. The second is the use of a submerged quench. The overflow weir performs the best job in preventing particulate accumulation but suffers from three primary deficiencies. The overflow weir does only a mediocre job of preventing particulate accumulation as it still has a wet/dry interface at the point of water introduction. The overflow weir requires significant levels of water in order to maintain minimum wetting rates of the metal surfaces. Additionally, the overflow weir requires precise leveling in order to maintain a uniform falling film to protect the metal of the quench region.

Of these problems, the most significant is the direct coupling of overflow weir water addition rate to minimum wetting rate and to levelness of the equipment. These factors preclude the minimization of water addition rates to the weir and constitute an unacceptable limitation. It is found in practice that no matter how much effort is put into leveling quench equipment, the inherent thermal stresses involved in combustion/quench processes require a constant re-leveling of the equipment in order to maintain quench levelness within tolerances. This circumstance entails an unacceptable maintenance effort. Discussions of the requirement for minimum wetting rate and for levelness can be found in "Chemical Engineers Handbook," ed.: Perry & Chilton, Fifth Edition, pp. 5-57. See also "Process Heat Transfer," by Hewitt, G.F., et al., CRC Press 1993, pp. 539-541, as well as page 475 of such reference for a depiction of submerged quench.

It is common in the treatment of industrial waste gas streams to integrate a cleaning apparatus downstream (relative to the direction of waste flow) of a

processing system. The function of the cleaning apparatus is to receive and process effluents produced in upstream process operations.

For example, in the semiconductor manufacturing industry, numerous integrated cleaning systems are commercially available and oftentimes employed for treating effluents and off-gases from semiconductor manufacturing processes. Semiconductor manufacturing processes may include chemical vapor deposition, metal etching, and etch and ion implantation operations. Examples of commercial integrated gas stream cleaning systems include the Delatech Controlled Decomposition Oxidizer, the Dunnschicht Analagen System Escape system, and the Edwards Thermal Processing Unit. Each of these systems include a thermal processing unit for oxidative decomposition of effluent gases, combined with a wet quench for temperature control of off-gases from a hot oxidation section, and wet scrubbing systems for a removal of acid gases and particulates found in the oxidation process.

Scrubbers, like the ones employed above, generally include elongated columns that accommodate effluents and subject them to a counter-current contacting with liquid solvents, reactant solutions, or slurries. The result of the counter-current contacting is an intimate mixing which assists the absorption process to effect removal of impurities from the effluents.

Integrated cleaning systems may be built into the manufacturing system to be an integral part of the manufacturing system. In contrast, stand-alone systems are maintained in a housing structure independent from the process or manufacturing system. Although such stand-alone units may be integrated to the process of the upstream equipment, stand-alone units enjoy a greater degree of mobility than their integrated cleaning system counterparts.

Use of scrubber technology is not limited to integrated cleaning systems but may also be incorporated in stand-alone operation systems. Examples include: a) unheated chemically reacting packed bed dry scrubbers, b) unheated chemisorptive packed bed dry scrubbers, c) heated chemically reacting packed bed dry scrubbers, d) heated catalytically reacting packed bed dry scrubbers, e) wet scrubbers, and f) flame-based thermal treatment units. Each of the aforementioned units is applicable to selected usages depending on the nature of the gas stream undergoing treatment.

Use of scrubber technology is accompanied by various deficiencies, including particulate clogging of the scrubber inlets, lines and manifolds. A line and/or manifold that is even partially clogged prevents the efficient flow of process gases therethrough. Partially clogged lines or manifolds could also interfere with the absorption processes occurring with the normal operations of a scrubber, e.g., dissolution of a gaseous component or components in a solvent medium.

In application to scrubbing of effluent gas streams, various causes for clogging of scrubbers have been suggested. Clogging can be caused by the reaction of silicon bearing in-coming species reacting with water, or water vapor, and depositing droplets of silicon-containing water in the inlet of a scrubber. This clog-formation mechanism is present for processes applied to semiconductor tools used for epitaxial growth on wafers and which tend to use trichloro silane and dichloro silane. Clogging can also be caused by the condensation deposition of condensable species in the inlet section to a water scrubber. Clogging may also be caused by the back-migration of water vapor from a water scrubber into the incoming process line. This back-migrating water vapor can then react with in-coming species and form materials with low volatility

and result in their depositing in the inlet to a water scrubber. This last mechanism is, for example, characteristic of scrubber abatement of tools for the metal etch process.

During metal etching machining, e.g., an off-gas such as BCl_3 (boron trichloride) may be produced. BCl_3 reacts with water vapor to form a non-volatile particulate boric acid which condenses, accumulates, and at least partially clogs inlet ports or inlet lines.

Existing practice has several methods to attempt to eliminate these types of clogs. One method attempts to flush the clog periodically with water. This subjects the clog to a pressurized water stream that dissolves the clog and the clog is flushed away. An undesirable effect of the flushing process is, however, the back migration of water will now originate from the point of introduction of flush water and result in increased hydrolysis reactions upstream with other water sensitive gases, such as WF6 (tungsten hexafluoride), and merely cause the clog to move further upstream.

Another method utilizes the introduction of a mechanical plunger mechanism or other solid removal means to keep the inlet and lines free of solids accumulations. However, such mechanical solutions are costly, labor-intensive, require significant maintenance and are susceptible to mechanical breakdown.

SUMMARY OF THE INVENTION

In a broad aspect, the present invention relates to an inlet structure for introducing a gas stream, e.g., a particulate solids-containing and/or solids-forming gas stream, to a downstream process unit such as a gas processing system, wherein the

structure is constructed, arranged and operated to minimize occlusion (e.g., from solids deposition, gas stream degradation, etc.) and adverse hydrodynamic effects, such as gas flow stream bypassing, short-circuiting, etc.

In one aspect, the inlet structure comprises a gas-permeable wall enclosing a gas flow path, and an outer annular jacket circumscribing the gas-permeable wall to define an annular gas reservoir therebetween. The outer annular jacket is provided with means for introducing a gas into the annular gas reservoir during the flow of the particulate solids-containing and/or solids-forming gas stream to a gas processing system through such inlet structure, e.g., a port in the jacket for attachment of a pressurized gas source vessel such as a conventional pressurized gas cylinder. In such structure, the gas supplied to the annular gas reservoir is at sufficiently pressurized to "bleed" through the gas-permeable wall for the purpose of combating the deposition or formation of solids on the interior surface of the gas-permeable wall.

As a further variant, the inlet structure described above may further optionally comprise a port for introducing a pulsed higher pressure gas into the annular reservoir, with the port being coupled with a source of higher pressure gas and means for pulsed delivery thereof from the source to the annular reservoir. In operation, such pulsed higher pressure gas introduction effects additional anti-clogging action on the gas-permeable wall, with the pulsatility serving to dislodge particulates that may form or otherwise deposit on the inner surface of the gas-permeable wall even with the lower pressure gas being constantly permeated though the wall. The port on the outer annular jacket may be constructed and arranged to provide a tangential flow of higher pressure gas into the annular reservoir.

As yet another variant of the inlet structure broadly described above, the gas-permeable wall and outer annular jacket may optionally be coupled to a downstream flow path section including a wall enclosing a corresponding further section of the gas flow path and forming with the gas permeable wall a slot therebetween. The wall of the downstream flow path section is circumscribed by an outer annular jacket to define an annular liquid reservoir therebetween in liquid overflow relationship with the slot so that when the annular liquid reservoir is filled with water or other liquid beyond a certain point determined by the height of the wall, the liquid flows over the wall and down the interior surface of the wall, as a falling liquid film thereon. Such falling liquid film thus provides a barrier or blanketing medium on the wall interior surfaces, to resist solids deposition or formation on such interior surfaces, and also serves to wash away any solids which nonetheless are deposited or formed on the interior surface of the wall.

The outer annular jacket of the downstream flow path section of the inlet structure may be provided with a port or other ingress means, coupled to a source of liquid, e.g., a vessel containing such liquid by a line or conduit containing a flow control valve or other flow-regulating means.

The port elements in the above-described structures may comprise a unitary opening, channel, feed-through, nipple, or other ingress structure, and/or a multiplicity of same, e.g., a series of vertically and/or circumferentially spaced apart ingress structures through which the fluid in each case is transferred into the interior volume of the annular reservoir with which the ports are associated.

In another aspect, the inlet structure of the invention comprises first and second generally vertically arranged flow passage sections in serial coupled

relationship to one another, defining in such serial coupled relationship a generally vertical flow passage through which the particulate solids-containing fluid stream and/or solids forming stream may be flowed, from an upstream source of the particulate solids-containing and/or solids forming fluid to a downstream fluid processing system arranged in fluid stream-receiving relationship to the inlet structure.

The first flow passage section is an upper section of the inlet structure and includes an inner gas-permeable wall which may be formed of a porous metal, porous ceramic, porous plastic, or other suitable material of construction, enclosing a first upper part of the flow passage. The porous inner wall has an interior surface bounding the upper part of the flow passage.

The gas-permeable wall is enclosingly surrounded by an outer wall in spaced apart relationship to the porous inner wall. The outer wall is not porous in character, but is provided with a gas flow port. By such arrangement, there is formed between the respective inner porous wall and outer enclosing wall an interior annular volume.

The gas flow port in turn may be coupled in flow relationship to a source of gas for flowing such gas at a predetermined low rate, e.g., by suitable valve and control means, into the interior annular volume, for subsequent flow of the gas from the interior annular volume into the flow passage. A high pressure gas flow port is also provided in the outer wall of the first flow passage section, coupled in flow relationship to a source of high pressure gas for intermittent flowing of such gas into the interior annular volume, such high pressure gas flow serving to clean the inner porous wall of any particulates that may have deposited on the inner surface thereof (bounding the flow passage in the first flow passage section). The high pressure gas

may likewise be controllably flowed at the desired pressure by suitable valve and control means.

The second flow passage section is serially coupled to the first flow passage section, for flowing of particulate solids-containing fluid downwardly into the second flow passage section from the first flow passage section. The second flow passage includes an outer wall having a liquid injection port therein, which may be coupled with a source of liquid such as water or other process liquid. The outer wall is culpable with the first flow passage section, such as by means of matable flanges on the respective outer walls of the first and second flow passage sections. The second flow passage includes an inner weir wall in spaced apart relationship to the outer wall to define an interior annular volume therebetween, with the inner weir wall extending toward but stopping short of the inner porous wall of the first flow passage section, to provide a gap between such respective inner walls of the first and second flow passage sections, defining a weir. When liquid is flowed into the interior annular volume between the outer wall of the second flow passage section and the inner wall thereof, the introduced liquid overflows the weir and flows down the interior surface of the inner wall of the second flow passage section. Such flow of liquid down the inner wall serves to wash any particulate solids from the wall and to suppress the deposition or formation of solids on the interior wall surface of the inner wall.

The flanged connection of the first and second flow passage sections with one another may include a quick-release clamp assembly, to accommodate ready disassembly of the respective first and second flow passage sections of the inlet structure.

Further, the first flow passage section of the inlet structure may be joined to an uppermost inlet structure quick-disconnect inlet section, which likewise may be readily disassembled for cleaning and maintenance purposes.

In still another aspect, the present invention relates to a gas flow stream-receiving structure which is resistant to deposition of solids, clogging and corrosion, when a hot, particulate-laden gas stream containing corrosive components is flowed therethrough. More specifically, this aspect of the invention relates to a gas/liquid interface structure useful for transport of a hot, particulate solids-containing gas stream from an upstream source of such gas stream to a downstream processing unit.

Such gas/liquid interface structure comprises:

a first vertically extending inlet flow passage member defining a first gas stream flow path therewithin, such inlet flow passage member having an upper inlet for introduction of the gas stream to the gas stream flow path and a lower exit end for discharge of the gas stream therefrom, subsequent to flow of the gas stream through the gas stream flow path within the inlet flow passage member;

a second flow passage member circumscribing the first flow passage member and in outwardly spaced relationship thereto, to define an annular volume therebetween, such second flow passage member extending downwardly to a lower exit end which is below the lower exit end of the first flow passage member, such second flow passage member having an upper liquid-permeable portion and a lower liquid-impermeable portion defining a gas stream flow path of the second flow passage member;

an outer wall member enclosingly circumscribing the second flow passage member and defining therewith an enclosed interior annular volume; and

a liquid flow inlet port in such outer wall member for introducing liquid into the enclosed interior annular volume between the outer wall member and the second flow passage member;

whereby liquid introduced via the liquid flow inlet port in the outer wall member enters the enclosed interior annular volume and weepingly flows through the upper liquid- permeable portion of the second flow passage member, for subsequent flow down interior surfaces of the liquid-impermeable portion of the second flow passage member, to provide a downwardly flowing liquid film on such interior surfaces of the liquid-impermeable portion of the second flow passage member, to resist deposition and accumulation of particulate solids thereon, and with the gas stream flowed through the first flow passage member being discharged at the lower exit end thereof, for flow through the flow path of the second flow passage member, and subsequent discharge from the gas/liquid interface structure.

By such arrangement, the gas stream is prevented from directly contacting the walls in the lower portion of the structure, in which the gas stream flow path is bounded by the interior wall surfaces of the second flow passage member. The falling film of water from the "weeping weir" upper portion of the second flow passage member resists particulate solids accumulating on the wall surfaces of the second flow passage member. The motive liquid stream on such wall surfaces carries the particulates in the gas stream contacting the water film, downwardly for discharge from the gas/liquid interface structure. Additionally, corrosive species in the gas

stream are prevented from contacting the wall, which is protected by the falling water film in the lower portion of the interface structure.

In a still further specific aspect, the invention is deployed between an upstream oxidizer unit, such as an electrical thermal oxidizer unit, and a downstream water scrubber in which the gas is scrubbed by water to remove the particulate solids therefrom.

The upper liquid permeable portion of the second flow passage member may be of suitable porous construction, and may for example comprise a porous sintered metal, porous plastic, or porous ceramic wall, with pore sizes which may for example be in the range of from about 0.5 micron to about 30 microns, or even larger pore diameters.

In an additional aspect, the present invention relates to an apparatus and method for cleaning inlet lines of a manifold, which conveys a process gas stream to a downstream treatment unit, e.g., a scrubber unit in the case of semiconductor manufacturing effluent gas streams.

The apparatus includes a manifold receiving gas from an upstream source, e.g., a semiconductor manufacturing process system or tool. The manifold includes first and second inlet lines, which are alternatingly employed to flow gas to a downstream process. These lines at their first (upstream) ends are joined to a manifold conduit, and each of the first and second inlet lines at their second (downstream) ends are joined in flow communication with the downstream process unit, which may for example comprise a scrubber unit.

Each of the first and second inlet lines includes a valve therein, e.g., a pneumatic valve, which is selectively openable or closeable to establish or discontinue flow of gas therethrough, respectively.

The manifold is arranged to receive gas from the upstream source and to flow the gas through the manifold and either the first or second inlet line, so that one of such lines is actively flowing gas from the upstream source to the downstream process, while the other is blocked by closure of the respective valve therein to flow of the gas therethrough.

A pressurized water source is coupled with the manifold, by water flow lines to each of the first and second inlet lines. Each of the water flow lines contains a valve, e.g., a pneumatic valve. Each of the valves is selectively openable or closeable to establish or discontinue flow of pressurized water therethrough, respectively.

A heat source may be thermally coupled to each of the first and second inlet lines, e.g., by a thermal jacket placed about each of the first and second inlet lines, to selectively elevate the temperature within at least one of the two inlet lines.

In operation, gas from the upstream process flows into the manifold. During active processing, the valve in one of the first and second inlet lines is open, while the valve in the other of the first and second inlet lines is closed, so that the gas entering the manifold is flowed through the specific one of the inlet lines containing the opened valve. In this manner, the gas flows through the specific one of the inlet lines containing the open valve, and passes to the downstream process. The inlet line containing the open valve is sometimes hereinafter for ease of reference referred to as the "open inlet line," while the other inlet line of the manifold is referred to as the

"off-stream line." In the off-stream line, the valve is closed to prevent flow of gas therethrough.

The valves of the inlet lines may be operationally coordinated and controlled by suitable cycle timer means and controls of a common and conventional type, as adapted to the apparatus of the present invention.

The off-stream line, while not flowing gas therethrough, is cleaned to regenerate same for further processing. Thus, in the continuous operation of the apparatus, the valves in the respective inlet lines are controlled so that one of such valves is open at any given time, while the other is closed for off-stream cleaning of the line and renewal of the line for subsequent on-stream operation.

The off-stream line is cleaned by admission of pressurized water from the pressurized water source to the off-stream line by opening of the valve in the water flow line communicating the pressurized water source with the off-stream line. In the other water flow line, the water flow line valve is closed, to prevent the flow of the pressurized water from the water source to the on-stream line.

In this manner, the off-stream line, now vacant due to its isolated state, is subjected to a vigorous cleaning including pressurized water washing.

Optionally, a pressurized drying gas source is coupled with the manifold, by drying gas flow lines to each of the first and second inlet lines. Each of the drying gas flow lines contains a valve, e.g., a pneumatic valve. Each of the valves is selectively openable or closeable to establish or discontinue flow of pressurized drying gas therethrough, respectively.

After pressurized water flow through the off-stream line, the off-stream line may be dried to ready it for subsequent renewed flow of gas from the upstream source to the downstream process. This is effected by closure of the valve in the pressurized water flow line, to discontinue the pressurized water flushing/scrubbing action of the water on the internal surfaces of the off-stream line. Concurrently, the valve in the drying gas flow line communicating with the off-stream line is opened to admit pressurized drying gas into the off stream line for flow therethrough, to dry the interior surfaces of the off-stream line, so that the flushing water is completely removed from the off-stream line of the manifold. In this manner, the off-stream line may be completely dried to avoid hydrolysis reactions in the subsequent operation of the overall system, when process gas flow through the cleaned and dried line is resumed, viz., when the off-stream line again becomes the on-stream line, and the former on-stream line is taken off-line.

The changeover operation for such sequence involves first opening the valve in the off-stream line to accommodate the subsequent flow of process gas therethrough. Once the valve in the off-stream line is verified open, the valve in the drying gas line is closed. This procedure prevents any occurrence of both valves being simultaneously closed and creating a deadhead condition in the upstream process flow.

In this manner, the manifolded gas processing system is operated so that gas is flowed from the upstream source through an inlet line to the downstream process, with the gas flow being alternatingly, and sequentially directed through each of the inlet lines, so that during the off-stream period of a given inlet line, it is being flushed with pressurized water, and optionally, and preferably, dried by flow therethrough of

pressurized drying gas, to renew the inlet line for subsequent flow of gas therethrough.

The water from the pressurized water flush and the pressurized gas drying steps may be flowed through the off-stream inlet line and may be discharged into the water scrubber, or alternatively may be vented from the off-stream line through valved discharge lines dedicated for such purpose. In the processing of semiconductor manufacture effluent gases by downstream scrubbing, it is generally advantageous to discharge the flush water and the pressurized drying gas into the downstream scrubber.

The first and second inlet lines may also be provided with associated heating means, such as an electrical resistance heater, stream tracing lines, or heating jackets, by which the drying process may be carried out more rapidly, and/or to provide process heat to otherwise facilitate the cleaning of the inlet lines of the manifold.

In a process aspect, the present invention relates to a method of flowing a gas from an upstream source to a downstream process through a manifold including two inlet lines through which gas may flow, by the steps of:

(a) flowing the gas through one of the inlet lines as an on-stream inlet line, while the other inlet line is isolated to flow of gas from the upstream source to the downstream process;

(b) flushing the isolated inlet line with pressurized water to remove particulate solids, water soluble solids, and the like from interior surfaces of the isolated inlet line;

(c) discontinuing the flow of pressurized water through the isolated inlet line;

(d) optionally, flowing pressurized drying gas through the isolated inlet line to dry said interior surfaces of said isolated inlet line;

(e) discontinuing the flow of the pressurized drying gas through the isolated inlet line;

(f) de-isolating the isolated inlet line, to constitute same an on-stream inlet line;

(g) discontinuing the flow of gas through the on-stream inlet line, and isolating the on-stream inlet line to constitute same an isolated off-stream inlet line;

(h) redirecting the flow of said gas from the upstream source to the downstream process through the de-isolated on-stream inlet line;

and cyclically, alternatingly and repetitively conducting steps (a) - (h), so that during flow of gas from the upstream source to the downstream process, one of the inlet lines has the gas from the upstream source flowed therethrough, and the other of the inlet lines is off-stream, and undergoes high-pressure water flushing and, optionally, drying.

The process may also optionally be carried out with heating of the inlet lines.

Other aspects, features and embodiments of the invention will be more fully appreciated from the ensuing disclosure and appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGURE 1 is a schematic representation of a clogging-resistant inlet structure according to an illustrative embodiment of the present invention;

FIGURE 2 is a schematic representation of a clogging-resistant inlet structure according to an alternative embodiment of the present invention;

FIGURE 3 is a schematic representation of a clogging-resistant inlet structure according to a further alternative embodiment of the present invention.

FIGURE 4 is a schematic representation of a clogging-resistant inlet structure according to a yet another alternative embodiment of the present invention.

FIGURE 5 is a schematic cross-sectional elevation view of a gas/liquid interface structure in accordance with an illustrative embodiment of the invention.

FIGURE 6 is a top plan view of the apparatus of FIGURE 5, showing a tangential feed arrangement for the liquid passed to the enclosed interior annular volume of the interface structure shown in FIGURE 5.

FIGURE 7 is a schematic representation of a system including (1) an upstream semiconductor manufacturing system; (2) a manifold assembly; and (3) a downstream scrubber unit.

FIGURE 8 is a schematic representation of an illustrative embodiment of the invention.

FIGURE 9 is a block diagram of the steps of a cleaning cycle as may be carried out in the illustrative embodiment of FIGURE 8.

DETAILED DESCRIPTION OF THE INVENTION AND PREFERRED EMBODIMENTS THEREOF

Referring now to the drawings, FIGURE 1 is a schematic representation of a clogging-resistant inlet structure according to an illustrative embodiment of the present invention.

The inlet structure is shown in FIGURE 1 as being connectable to process piping for coupling the inlet structure with a source of the gas stream being introduced to such inlet structure. Such upstream piping may be suitably heat-traced in a conventional manner, from the upstream source of the gas stream, e.g., a semiconductor manufacturing tool, to the inlet flange on the inlet structure as shown. The purpose of such heat-tracing is to add sufficient energy to the gas stream in the piping to prevent components of such gas stream from condensing or subliming in the inlet structure.

The inlet structure 60 shown in FIGURE 1 comprises an inlet section 7 including an inlet flange 16. The inlet flange is matably engageable with the flange 18 of upper annular section 8 which terminates at its upper end in such flange. The inlet section may be coupled with an upstream particulate solids-containing and/or

particulate solids-forming stream generating facility 90, as for example a semiconductor manufacturing tool.

The annular section 8 comprises an inner porous wall 6 which is of appropriate porosity to be gas-permeable in character, and an outer solid wall 9 defining an annular interior volume 20 therebetween. The interior surface of the inner porous wall 6 thus bounds the flow passage 66 in the upper annular section 8. The outer solid wall 9 at its upper and lower ends is enclosed in relation to the inner wall 6, by means of the end walls 40 and 42 to enclose the annular interior volume. The outer wall 9 is provided with a gas inlet port 22 to which is joined a gas feed line 24. The gas feed line 24 is connected at its outer end to a source 4 of gas. A check valve 14 is disposed in the gas feed line 24, to accommodate the flow of gas into the annular interior volume 20. The feed line 24 may also be provided with other flow control means (not shown) for selectively feeding the gas from the source 4 into the annular interior volume 20 in a desired amount and at a desired flow rate, in the operation of the system.

A means for heating gas feed line 24 may be included to elevate the temperature of the gas permeating the porous wall 6. A means for heating gas feed line 24 may include an electrical resistance heater, stream tracing lines, heating jackets, or any other heating systems that are known to the skilled artisan and useful for transferring thermal energy to the internal passages of gas feed line 24 to increase the temperature of the gas. For purposes of illustration, the heating means employed in the FIGURE 1 embodiment are constituted by heating coils 23. A thermal jacket may also cooperate with the heating means to raise the internal temperature of gas line 24.

The upper annular section 8 may also be provided with an optional high pressure gas injection port 50 to which is joined high pressure gas feed line 52 joined in turn to high pressure gas supply 5. The gas feed line is shown with a flow control valve 51 therein, which may be joined to flow controller means (not shown) for operating the flow control valve 51 in accordance with a predetermined sequence. The high pressure gas feed line 52 alternatively may be disposed at any suitable angle in relation to the high pressure gas injection port 50, e.g., at an oblique angle.

The optional high pressure gas injection port 50 and high pressure gas feed line 52 are advantageous if solids accumulation occurs on the interior wall surface of the gas-permeable wall, despite the constant flux (or "bleed-through") of the lower pressure gas introduced in line 24 to the annular interior volume 20. A means for heating high pressure gas feed line 52 may be included to elevate the temperature of the gas. A means for heating gas feed line 52 may include an electrical resistance heater, stream tracing lines, heating jackets, or any other heating systems that are known to the skilled artisan and useful for transferring thermal energy to the internal passages of gas feed line 52 to increase the temperature of the gas. For purposes of illustration, the heating means employed in the FIGURE 1 embodiment are constituted by heating coils 54. A thermal jacket may also cooperate with the heating means to raise the internal temperature of gas line 52.

The upper annular section 8 terminates at its lower end in a flange 26 which mates and engages with flange 28 of the lower annular section 30. The flanges 26 and 28 may be sealed by the provision of a sealing means such as the O-ring 10 shown in FIGURE 1.

The lower annular section 30 includes an outer wall 12 terminating at its upper end in the flange 28. The outer wall is a jacket member which at its lower end is joined to the inner weir wall 11 by means of the end wall 44, to form an annular interior volume 32 between the outer wall 12 and the inner weir wall 11. The inner weir wall 11 extends vertically upwardly as shown but terminates at an upper end 46 in spaced relation to the lower end of inner porous wall 6 of upper annular section 8, so as to form a gap 36 therebetween defining an overflow weir for the lower annular section 30.

The outer wall 12 of the lower annular section 30 is provided with a water inlet port 48 to which may be joined a water feed line 80 joined to water supply 3 having liquid flow control valve 81 therein which may be operatively coupled with other flow control means for maintaining a desired flow rate of liquid to the lower annular section 30. Water inlet port 48 may be affixed to lower annular section 30 in a radial orientation or in a tangential orientation. A preferred embodiment of this invention places water inlet port 48 affixed to lower annular section 30 in a tangential orientation so that the water momentum jet introduced to the lower annular section is not directed against fixed walls, yet, rather dissipates itself by setting up a tangential swirl of the overflow water in the lower annular section. Tangential water introduction then optimizes the levelness of the water film overflowing the lower annulus section as momentum perturbations to the top level of the water film.

An extended gas stream delivery tube 70 may be used to introduce the particulate solids-containing and/or particulate solids-forming gas stream at a specific location of the inlet structure. Delivery tube 70 is coupled in gas-flow receiving relationship with upstream source 90 and directs and exhausts the gas stream to a suitable location within interior gas flow passage 66 to minimize the formation of

solids within the inlet structure. The delivery tube 70 is circumscribed by outer solid wall 9 with inlet 7 modified to accommodate delivery tube 70. Delivery tube 70 may be heated to combat condensation of the gas stream flowing through tube 70.

In the inlet structure shown in FIGURE 1, tube 70 is circumscribed by inner porous wall 6 and is coaxial with porous wall 6. An exterior surface of delivery tube 70 and interior surface of porous wall 6 define an annular volume therebetween. Gas delivery tube 70 includes a first end 72 coupled in gas flow receiving relationship with gas stream source 90 and a second end 74 exhausting the gas stream within gas flow passage 66. Second end 74 may exhaust the gas stream in gas flow passage 66 contained within upper annular section 8 or contained within lower annular section 30. In the embodiment shown, tube 70 exhausts the gas stream at a point about one-half inch below weir wall upper end 46, although tube 70 may extend further below weir wall upper end 46, or may terminate above weir wall upper end 46, depending upon the gas stream, process use, and conditions.

Delivery tube 70 may, for example, be constructed of stainless steel of approximately one-half to approximately four inches inner diameter. Those skilled in the art will recognize that tube 70 may be constructed of various materials, of various sizes, of various cross-sections, and of various configurations. The co-annular flow pattern, created by the placement of delivery tube 70 relative to porous wall 6 and overflow weir 11, serves to minimize mixing of process gas with water vapor from weir 11 as the process gas exits the delivery tube and enters region 66. Solids-forming reactions between the process gas exiting delivery tube 70 and water vapor from weir 11 are, therefore, dramatically minimized until a point sufficiently downstream such that the action of weir 11 can flush any solids into the downstream abatement device.

In order to determine the anti-clogging efficiency of a given inlet design within the scope of the present invention, a suitable assessment technique is to monitor the solids build-up quantity and location of the specific inlet structure after several minutes at a flow rate of 1-5 slpm of trichlorosilane at an average flow rate of nitrogen carrier gas, to determine the suitability of the design and the effects of any inlet structure parameter change. A longer observation period may be desired to monitor the nature of the solids growth. It may also be advantageous, depending upon the gas stream, process use, and conditions, to maintain laminar axial gas stream flow in the gas delivery tube and in the annular section between the gas delivery tube exterior and the porous wall interior to ensure adequate shrouding of the effluent stream and containing walls of the inlet.

Delivery tube 70 may also be heated to reduce condensation gases. Solids are formed on the walls of tube 70 by condensation of gases flowing through the tube. Suitable means for heating tube 70 may include an electrical resistance heater, stream tracing lines, heating jackets, etc., with such heating system being constructed and arranged for transferring thermal energy to the internal passages of the delivery tube 70 to combat condensation. For purposes of illustration, the heating means are shown as comprising heating coils 76. A thermal jacket may also cooperate with the heating means to raise the internal temperature of delivery tube 70. A thermal jacket may be employed to raise the side wall temperature to prevent condensable process gases from condensing in the tube.

At its lower end, the lower annular section 30 may be suitably joined to the housing of the water scrubber 13. The water scrubber may be constructed in a conventional manner for conducting scrubbing abatement of particulates and solubilizable components of the process stream. Alternatively, the inlet structure 60

may be coupled to any other processing equipment for treatment or processing of the gas stream passed through the inlet structure, from the inlet end to the discharge end thereof.

Thus, there is provided by the inlet structure 60 a gas flow path 66 through which influent gas may flow in the direction indicated by arrow "1" in FIGURE 1 to the discharge end in the direction indicated by arrow "2" in FIGURE 1.

In operation, particulate solids-containing gas is introduced from an upstream source, such as a semiconductor manufacturing tool (not shown) by means of suitable connecting piping, which as mentioned hereinabove may be heat-traced to suppress deleterious sublimation or condensation of gas stream components in the inlet structure. The stream enters the inlet structure 60 in the flow direction indicated by arrow "1" and passes through the inlet section 7 (or delivery tube 70, if installed) and enters the upper annular section 8. Gas, such as nitrogen, or other gas, is flowed from source 4 through gas feed line 24 connected to port 22, and enters the annular interior volume 20. From the annular interior volume 20 the introduced gas flows through the gas-permeable wall 6, into the interior gas flow passage 66. The particulate-containing or particulate forming gas thus flows through the interior gas flow passage 66 and into the water scrubber 13, as the gas from gas feed line 24 flows into the annular interior volume 20 and through the gas-permeable wall 6.

In this manner, the annular interior volume 20 is pressurized with the gas from the source 4. Such pressure ensures a steady flow of the gas through the porous wall into the interior gas flow passage 66. Such low flow rate, steady flow of the gas through the gas-permeable wall maintains the particulates in the gas stream flowing through the interior gas flow passage 66 away from the interior wall surfaces of the

inlet structure. Further, any gases present with the gas flow stream in the interior flow passage 66 are likewise kept away from the interior wall surfaces of the inlet structure.

The gas feed line 24 can if desired be heat traced. Such heat tracing may be desirable if the gas stream flowing through the inlet structure contains species that may condense or sublimate and deposit on the walls of the inlet structure.

Concurrently, high pressure gas from high pressure gas supply 5 may be periodically flowed through high pressure gas feed line 52 through high pressure gas injection port 50 to the annular interior volume 20. For this purpose, the line 52 may have a flow control valve (not shown) therein, to accommodate the pulsed introduction of the high pressure gas. In this manner, the high pressure gas is injected into the annular interior volume at specified or predetermined intervals, in order to break away any particle buildup on the inner surface of the gas permeable wall 6. The duration and time sequencing of the pulsed introduction of the high pressure gas may be readily determined without undue experimentation within the skill of the art, to achieve the desired wall scouring effect which will prevent solids accumulation on the gas permeable wall surfaces. If required, when the inlet structure is employed in connection with a water scrubber servicing a semiconductor manufacturing tool, such high pressure injections may be interrupted during the tool batch cycle in order to eliminate pressure fluctuations at the tool exhaust port by suitable integration of control means operatively linked to the tool control system. For this purpose, a control valve such as a solenoid valve may be appropriately coupled with control means of the tool assembly.

In the inlet structure embodiment shown, the flanges 26 and 28 may be clamped to one another to permit quick disconnection of the upper annular section 8 from the lower annular section 30. For such purpose, a quick-disconnect clamp may be employed. The sealing gasket 10 between flanges 26 and 28 may be formed of a suitable material such as a corrosion resistant, high temperature elastomer material. This elastomeric gasket additionally functions as a thermal barrier to minimize heat transfer from the upper annular section to the lower annular section of the inlet structure, a feature which is particularly important in heat traced embodiments of the invention.

The gas permeable wall 6 of the upper annular section of the inlet structure may be formed of any suitable gas-permeable material, e.g., ceramics, metals and metal alloys, and plastics. As a specific example, the wall may be formed of a Hastelloy 276 material. The outer wall 9 of the upper annular section may likewise be formed of any suitable material, and may for example be a thin walled stainless steel pipe.

The lower annular section 30 of the inlet structure may be formed of any suitable material such as a polyvinylchloride plastic. Water is injected into the annular interior volume 32 between the outer wall 12 and the inner weir wall 11 through line 50 from water supply 3. Preferably, the water is injected tangentially, to allow the angular momentum of the water in the annular interior volume 32 to cause the water to spiral over the top end 46 of the weir wall 11 and down the interior surface of the weir wall in the interior flow passage 66 of the inlet structure. Such water flow down the interior surface of the weir wall 11 is employed to wash any particulates down the flow passage 66 to the water scrubber 14 below the inlet structure. As mentioned, the lower annular section 30 is an optional structural

feature which may be omitted, e.g., when the downstream process unit is a combustion scrubber.

The pressure drop through the inlet structure can be readily determined by pressure tapping the exhaust pipe from the upstream process unit and the scrubber unit downstream of the inlet structure. The pressure drop can be sensed with a Photohelic gauge or other suitable pressure sensing gauge and such pressure drop reading can be sent to suitable monitoring and control equipment to monitor clogging in the scrubber inlet.

By the use of the inlet structure in accordance with the present invention, an interface may be provided between the water scrubber and the tool exhaust stream from a semiconductor manufacturing operation, that does not clog repeatedly in normal process operation. The inlet structure of the present invention provides an interface with two ancillary process streams, a steady low flow purge stream and a high pressure pulse stream. The low flow purge stream creates a net flux of inert gas, e.g., nitrogen, away from the inner surface of the upper annular section toward the centerline of the central flow passage 66. The high pressure gas flow stream provides a self-cleaning capability against solids clogging. The high pressure gas flow is employed to eliminate any particle buildup on the inlet structure upper annular section interior surfaces of the central flow passage 66.

Gases, entrained particles, and previously deposited particles are then directed into the overflow stream at the inner wall surface in the lower annular section of the inlet structure, to be flushed down into the water scrubber downstream of the inlet structure. In this manner a direct interface between the gas permeable wall of the upper annular section and the weir wall of the lower annular section of the inlet

structure, providing a highly efficient inlet conformation which effectively minimizes the buildup of particulate solids in operation.

The inlet structure of the invention has a number of advantages. In application to a semiconductor manufacturing facility and water scrubber treatment system for processing of waste gas effluents from a tool in the semiconductor process facility, the exhaust gas from the semiconductor tool can be heated continuously all the way from the tool exhaust port to the water interface in the water scrubber inlet structure. Heat tracing on the inlet lines can be used to heat the lines by conducting energy into the piping, which transfers energy to the flowing gas stream by forced convection. Process gas may be heated all the way down to the overflow weir wall of the lower annular section of the inlet structure by heat tracing the gas flow line which flows gas to the upper annular section, as well as by heat tracing the high pressure gas flow line feeding pulsed high pressure gas to the interior annular volume of the upper annular section of the inlet structure. Such flow of heated gas will maintain the process gas flowing through the central flow passage of the inlet structure at a temperature which is determined by the vapor pressure of any particulate forming gas in the gas stream flowing to the inlet structure from the upstream process unit that would otherwise condense or sublimate and deposit on the walls of the inlet structure.

Another advantage of the inlet structure of the present invention is that such structure may be readily disassembled. In the event that the inlet structure does clog in operation, the structure is easily taken apart by simply removing the clamps or other securement elements holding the flanges of the inlet structure to one another. The upper annular section may thus be replaced by removing the clamps holding the respective flanges in position, and by disconnecting the respective gas feed lines that feed the upper annular section.

A still further advantage of the inlet structure of the present invention is that it is self-cleaning in character. Particles that have been entrained in the gas stream flowing to the inlet structure from the upstream process unit or that have been formed by chemical reaction in the inlet structure can be readily cleaned from the gas-permeable wall of the inlet structure by the pulsed high pressure gas injection into the interior annular volume in the upper annular section of the inlet structure. The particles that are then dislodged from the interior wall surfaces of the upper annular section of the inlet structure then are directed to the overflow portion of the weir wall where such particulate solids are flushed to the downstream scrubber. The pressure, duration and periodicity of the high pressure gas pressure pulses can be easily set to accommodate the prevailing system particulate concentration conditions and character of such solids. The effectiveness of the pulsed high pressure gas injection will depend on the character of the particulate solids. The inlet structure of the present invention therefore is self-cleaning in nature, without the use of scraper or plunger devices typical of the so-called self-cleaning apparatus of prior art fluid treatment systems.

The material specification of the porous wall element of the upper annular section of the inlet structure is dependent on the incoming process gas from the upstream process unit. If the gas stream includes acid gas components, such gases will be absorbed in the water scrubber and will be present in water which is recirculated to the overflow weir wall in the lower annular section of the inlet structure. It is possible that some of the overflow weir wall water will splash up on the porous inner wall of the upper annular section of the inlet structure. The porous wall in such instance is desirably selected from corrosion-resistant materials of construction. A preferred metal material for such purpose is Hastelloy 276 steel,

which exhibits excellent corrosion resistance under low temperature hydrous acid conditions.

Another advantage of the inlet structure of the present invention is that it minimizes the backflow of water vapor from the top of the water scrubber into the process piping when the inlet structure is employed upstream of a water scrubber as illustratively described herein. By way of explanation of this advantage, it is to be appreciated that particulates may be present in the exhaust streams of some semiconductor tools as either entrained particulates from the process tool, or as the reactants of a chemical reaction within the gas stream's flow path.

The present invention minimizes or eliminates the previously described Richardson annular effect. Due to the steady outflow of gas at the inner surface of the porous wall of the upper annular section of the inlet structure, the static boundary layer condition at the inner wall surface of the upper annular section cannot develop. There is a net flux of flowing gas from the gas-permeable wall which acts to "push" the process gas flow away from the wall bounding the central flow passage of the inlet structure, and avoids the presence of a static boundary condition, thereby avoiding the Richardson annular effect. Accordingly, if particles are formed as a result of chemical reaction in the flow stream, the thus-formed particles do not find a wall on which to agglomerate. The particles instead will flow with the gas stream into the water scrubber. The same is true for entrained particles. Once the particles reach the top of the inlet, they will become entrained in the gas flow stream because they will not have a wall on which to collect.

By opposing the conditions which give rise to the Richardson annular effect, the porous wall in the upper annular section of the inlet structure of the present

invention serves as an effective barrier to the back migration of water vapor to the exhaust lines of the process system. Any back migration will be exceedingly slow due to the aforementioned interdiffusion mechanism. This factor will greatly increase the mean time to failure for the scrubber, since the scrubber entry and exhaust lines will not clog as often with the inlet structure of the present invention. When the delivery tube 70 is used, the backflow of water vapor is minimized or eliminated due to the annular gas blanket formed by the action of gas flowing through porous wall 6.

Although the porous wall member of the upper annular section of the inlet structure of the invention has been described herein as being constructed of a metal material, it will be appreciated that such gas-permeable wall may be formed of any suitable material of construction. For example, the porous wall may be formed of a porous ceramic, plastic (e.g., porous polyethylene, polypropylene, polytetrafluoroethylene, etc.), or other material having the capability to withstand the corrosive atmospheres, temperature extremes, and input pressures that may be present in the use of the inlet structure of the present invention.

While the invention has been described herein in the embodiment shown illustratively in FIGURE 1 as comprising respective discrete upper and lower annular sections which are coupled to one another, as for example by flanges and associated quick-disconnect clamps or other interconnection means, it will be appreciated that such inlet structure may be formed as a unitary or integral structure, as may be desired or necessary in a given end use application of the present invention, and that the lower annular section is an optional section to the upper annular section, and may be unnecessary in some instances.

Referring now to FIGURE 2, another embodiment of a clogging-resistant inlet structure is shown. Inlet 100 may alternatively include conical skirt 105 circumscribed by solid outer wall 110. The exterior surface of delivery tube 112 and the interior surface of conical skirt 105 define therebetween an annular gas flow passage 115. The conical skirt annularly surrounds the particulate solids-containing and/or solids-forming gas stream with an inert gas and/or liquid. An inert gas enters the inlet structure through feed line 120. The downwardly and outwardly flaring conical skirt has a progressively decreasing cross-sectional area which causes the velocity of the inert gas to increase and the pressure to decrease. Conical skirt 105 is designed to produce an inert gas velocity equal to the velocity of the gas stream exhausting from delivery tube 112. The matching of flow velocities between the gas stream and the inert gas advantageously creates co-laminar flow to prevent turbulence in the gas stream and to prevent intermixing at an interface between the two flow streams. Efficiency of the inlet is, therefore, enhanced by minimizing the buildup of particulate solids during operation.

The downwardly and outwardly flaring conical skirt could also be used to advantageously introduce a liquid into the inlet structure. The outer wall 110 and the lower end (bottom periphery) of the conical skirt are in transversely spaced-apart relationship to one another to define a liquid flow passage 135 therebetween. Spray nozzles 125 could be circumferentially spaced apart in relation to each other within the inlet to disperse the liquid. The conical skirt directs the liquid toward wall surface 130. If the liquid is, for example, water, a thin film of water will be formed on wall surface 130 to flush particulate solids to the downstream scrubber. The material specification of the conical skirt is dependent on the inert gas and the gas stream flowing through delivery tube 112. If the gas stream includes acid gas components, such gases will be present in the water recirculated to spray nozzles 125. The conical

skirt in such instance is desirably fabricated from corrosion-resistant materials. As discussed in reference to the FIGURE 1 embodiment, the delivery tube, inert gas, and/or water may be heated to reduce condensation.

FIGURE 3 illustrates another embodiment of a clogging-resistant inlet structure 200. Outer solid wall 205 and porous inner wall 210 define an annular interior volume therebetween. Extended gas stream delivery tube 212 may be used to introduce the particulate solids-containing and/or particulate solids-forming gas stream at a specific desired location of the inlet structure. Delivery tube 212 is coupled in gas-flow receiving relationship with an upstream source and directs and exhausts the gas stream to a suitable location within the inlet structure. The interior facing surface of inner porous wall 210 circumscribes the exterior facing surface of delivery tube 212. Outer wall 205 is enclosed at its upper end by end cap 215.

The outer wall is provided with a water inlet port 225 which may be joined to a water supply. End cap 215 is provided with a gas inlet port 230 to axially introduce a shrouding inert gas into the inlet structure. End cap 215 may alternatively include a porous disperser structure to axially disperse the inert gas into the inlet structure. A gas cavity or reservoir may optionally contain the inert gas, e.g., nitrogen, for introduction into the inlet. Water is extruded, in this embodiment, through porous inner wall 210 to form a thin liquid film to flush particulates through the inlet structure. Porous wall 210 may be formed of any suitable material, e.g., ceramic, metal, metal alloy, or a plastic such as polyvinylchloride. As discussed hereinabove, the delivery tube, inert gas, and/or water may be heated to reduce or eliminate condensation.

As a further alternative to the specific structure shown in FIGURE 3, the porous inner wall 210 could be replaced with a weir of the type shown with reference to FIGURE 1. A weir wall could, for example, be constructed having an upper end in spaced relation to upper end cap 215 so as to form a gap therebetween defining an overflow weir.

FIGURE 4 shows another embodiment of a clogging-resistant inlet structure 300. The upper annular section 305 includes upper inner porous wall 310 and outer upper solid wall 315, defining an upper annular interior chamber 320 therebetween. Extended gas stream delivery tube 322 is circumscribed by upper porous wall 310 and is shown as being positioned coaxially with respect to porous wall 310. An exterior surface of the gas delivery tube and interior surface of upper porous wall define an annular volume therebetween. Delivery tube 322 is coupled in gas flow receiving relationship with an upstream gas source. Upper solid wall 315 includes an inlet port 325 to introduce a suitable fluid into the upper interior chamber 320.

Lower annular section 330 includes lower inner porous wall 335 and outer lower solid wall 340 defining a lower annular interior chamber 345 therebetween. Lower solid wall includes an inlet port 350 to introduce a fluid into lower chamber 345. In operation, the inlet structure of FIGURE 4 allows inert gas to permeate through upper porous wall 310 and water to extrude through lower porous wall 335. The flow of inert gas keeps the particulates in the gas stream away from the interior wall surfaces of the inlet structure. The thin film of water on the interior surface of lower inner porous wall 335 washes any particulates from the inlet structure.

FIGURE 4 shows delivery tube 322 exhausting the gas stream above a transition region 355 between the upper section 305 and lower section 330.

Transition region 355 may be a region abuttingly joining upper annular section 305 and lower annular section 330. Transition region 355 may also include a region separating upper section 305 from lower section 330 and circumscribing gas delivery tube 322. It is to be understood that the delivery tube may alternatively extend below transition region 355 and into the lower section. Whether delivery tube 322 exhausts the gas stream within the upper section, exhausts within the transition region, or exhausts within the lower section will depend upon the gas stream, process use, and conditions. As discussed hereinabove, the delivery tube, inert gas, and/or water may be heated to reduce or eliminate condensation.

FIGURE 5 is a schematic cross-sectional elevation view of a gas/liquid interface structure 410 according to one embodiment of the present invention.

The gas/liquid interface structure 410 includes a first vertically extending inlet flow passage member 412 defined by a cylindrical elongate wall 414. The cylindrical wall 414 circumscribes an enclosed flow passage 418 within the inlet flow passage member 412. At an upper end of cylindrical wall 414 there is provided a radially outwardly extending flange 416 for joining the gas/liquid interface structure to associated process flow piping, conduits, instrumentation, etc.

The first inlet flow passage member 412 thus has an inlet 420 at its upper end, and a corresponding outlet 422 at its lower end, so that the open inlet and outlet ends define with the interior volume a flow path including flow passage 418, through which gas from an upstream process unit 458 may be flowed, as in line 460 illustratively shown in Figure 5.

The length of the first inlet flow passage member 412 may be significantly shorter than is illustrated in Figure 5, and the outlet 422 extremity of such flow passage member may terminate just below the top end wall 438 in the interior annular volume 430 of the structure. Alternatively, the outlet 422 extremity of such flow passage member may terminate at a lower vertical point within the second flow passage member 424 than is illustratively shown in Figure 5.

The vertical downward extent of the first inlet flow passage member 412 may therefore be varied in the practice of the invention, and the specific length and dimensional characteristics may readily be determined without undue experimentation to select a conformation and arrangement which achieves a desired operating character in the specific application of use of the inlet structure of the invention.

The upstream process unit 458 may for example comprise a semiconductor manufacturing tool and associated effluent gas treatment apparatus. Such effluent treatment apparatus may in turn comprise an oxidizer for oxidation of oxidizable components in the effluent gas. Suitable oxidizers are of widely varying type, and may for example be constituted by a thermal oxidation unit, an electrothermal oxidizer, etc.

When the upstream process unit 458 comprises gas generating means and gas treatment means for semiconductor manufacturing operations, the gas stream introduced to inlet 420 of the first inlet flow passage member 412 may be at elevated temperature and may contain substantial concentration of particulate solids, e.g., in the form of sub-micron size particles.

The interface structure 410 further comprises a second flow passage member 424 which circumscribes the first flow passage member 412 and is in spaced relationship thereto, as shown, to define an annular volume 430 therebetween. The second flow passage member 424 extends downwardly to a lower end 468 below the lower end of the first flow passage member 412, so that the open outlet 422 of the first flow passage member is in vertically spaced relationship to the open lower end 468 of the second flow passage 424. As discussed, the position of the outlet 422 of the first flow passage member may be widely vertically varied in the broad practice of the present invention.

The second flow passage member 424 comprises an upper liquid-permeable portion 426 and a remaining liquid-impermeable portion 428, extending downwardly from the liquid-permeable portion 426, as illustrated. The upper liquid-permeable portion 426 and lower liquid-impermeable portion 428 may be formed in any suitable manner, as for example by joining of an upper porous cylindrical segment 426 to an initially separate lower solid-walled cylindrical segment 428, with the respective portions being joined to one another by brazing, soldering, welding, mechanical fastener securement, or in any other suitable manner with appropriate joining means and method.

Alternatively, the second flow passage member 424 may be formed from a unitary cylindrical tubular member, an upper part of which is rendered liquid-permeable in character by processing, such as water-jet machining, etching, sintering, micro-electromachining, or any other suitable technique by which porosity or permeability characteristics can be imparted to the upper portion of such tubular member. Preferably, the second flow passage member is formed of initially separate upper and lower portions which are joined together and wherein the upper portion is

constituted by a porous sintered metal material, a porous plastic material, a porous ceramic material, or other porous material, wherein the porosity is of sufficient dimensional character to allow liquid permeation therethrough, as described hereafter in greater detail.

The gas/liquid interface structure 410 further comprises an outer wall member 434 enclosingly circumscribing the second flow passage member and defining therewith an enclosed interior annular volume 470. The outer wall member 434 comprises a cylindrical side wall 36, a top end wall 438 and a bottom end wall 440, which corporately enclose the interior annular volume 470. The side wall 436 is provided with a liquid introduction port 442. The port may be provided in any suitable manner, but in the embodiment shown is constituted by tubular port extension 444. Alternatively, the port may simply be an orifice or opening in the side wall, or other liquid inlet structure, whereby liquid can be introduced into the interior annular volume 470 from an external liquid supply.

In the Figure 5 embodiment, the liquid inlet port 442 is coupled with liquid introduction line 446 containing flow control valve 448 therein. The liquid inlet line 446 is connected to liquid supply reservoir 450.

Figure 6 is a top plan view of the apparatus of Figure 5, showing the tangential feed arrangement for the liquid passed to the enclosed interior annular volume 470 of the interface structure shown in Figure 6. Figure 6 shows the tubular port extension 444 arranged to tangentially intersect and join with the cylindrical side wall of the outer wall member. In such manner the introduced liquid is highly evenly circumferentially distributed around the upper porous cylindrical segment (liquid-permeable upper portion 426), so that the liquid film produced by weepage through

the porous cylindrical segment is correspondingly circumferentially uniform to shroud the inner wall surface 472 as hereinafter more fully described.

The liquid flow control valve 448 in line 446 may be coupled to suitable controller/timer means, including a central processing unit (CPU), microprocessor, flow control console, and/or ancillary monitoring and control means, for providing a predetermined or otherwise selected flow of liquid from reservoir 450 through line 446 to liquid inlet port 442. The thus-introduced liquid fills the interior annular volume 470, and such liquid may be introduced at any suitable process conditions.

For processing of gas streams such as hot particulate-laden effluent gas streams from semiconductor manufacturing operations, the liquid in interior annular volume 470 may be water or other aqueous media.

By virtue of the liquid-permeable character of the upper liquid permeable portion 426 of the second flow passage member 424, liquid from interior annular volume 470 permeates through the upper portion 426 of the second flow passage member and is expressed at the inner wall surface 432 of such upper portion as liquid droplets 454.

Such issuing liquid droplets, as a result of gravitational effect, fall and coalesce with other liquid droplets and aggregate to form a downwardly flowing liquid film 456 on the inner wall surface 472 of the lower liquid-impermeable portion of the second flow passage member. The liquid in the liquid film discharging from the lower open end 68 of the second flow passage member may be directed to suitable collection and processing means (not shown), e.g., for co-processing thereof in a downstream

process unit 464 to which the gas stream is flowed from gas flow passage 452 of the second flow passage member in line462.

The downstream process unit 464 may be a water scrubber, reaction chamber, or other processing apparatus or treatment zone, in which the gas stream flowed from passage 452 in line 462 is subjected to further process operations, with discharge of final effluent gas from the downstream process unit in line 466.

The gas/liquid interface structure 410 thus is constructed to provide an interior annular volume 430 between the first and second flow passage members, with an upper liquid-permeable portion 426 of the second flow passage member, so that liquid weeping through the liquid-permeable upper portion can coalesce and develop the falling liquid film 456. By this arrangement, the gas flowed from flow passage 418 to flow passage 452 encounters an interior wall surface 472 of the lower portion of the second flow passage member, which is blanketed with a protective liquid film 456. Accordingly, any corrosive species in the gas discharged from the lower open end 422 of the first flow passage member will be "buffered" in relation to the inner wall surface, to minimize corrosion and adverse reaction effects on such interior wall surface of the second flow passage member.

Further, by introduction of liquid to the interior annular volume 470 between the second flow passage member and the outer wall member 434, there is provided a liquid reservoir "jacket" structure. Liquid thereby is provided to the porous upper portion of the second flow passage member, for permeation therethrough, and downward "weeping" of liquid to form a protective film on the interior wall surface of the second flow passage member.

Such falling film on interior surface 472 of the second flow passage member also serves to entrain and to carry away any particulates from the gas stream which in the absence of such liquid film might deposit on and aggregate on the interior wall surface of the second flow passage member.

Accordingly, the falling liquid film affords a protective function with respect to the interior wall surface of the second flow passage member, as well as provides an entrainment medium which carries away particulate solids and any other gas phase components, which otherwise would be deleterious in accumulation on the interior wall surface of the flow passage member.

As a further advantage of this structure illustratively shown in Figure 5, the use of an upper liquid permeable portion 426 serves to minimize liquid usage, relative to the provision of a structure such as a liquid overflow weir, in which liquid from the interior annular volume 470 would simply overflow an upper end of wall 426 and flow downwardly in a film on the wall, over the full interior surface length of the second flow passage member. The liquid required for operation is maintained at a very low level by the weeping weir structure of the present invention.

Another advantage of the weeping weir structure of the present invention over simple liquid overflow weir structures is that the latter require precise alignment to vertical in order for the weir to work efficiently as designed, whereas the weeping weir structure is tolerant of deviations from normal (vertical) orientation, without loss or impairment of operational design efficiency.

In other words, the weeping weir structure of the present invention is characterized by decoupling of overflow weir water addition rate from the levelness of

the structure, as well as from minimum wetting rate by the liquid permeable weir wall (since there is no threshold liquid inventory to be established and maintained for initiating liquid issuance from the weir, as in conventional overflow structures).

As an illustrative example of the gas/liquid interface structure of the type illustratively shown in Figure 5, such structure may be employed downstream of a thermal oxidizer unit processing effluent gases from semiconductor manufacturing operations, so that the gas stream in line 460 entering the interface structure 410 is at elevated temperature and laden with particulates, such as silica, particulate metals, and the like, as sub-micron size particles or even larger solids, as well as corrosive solids.

In such embodiment, the upper portion 426 of the second flow passage member may be constituted by a sintered metal wall having a thickness on the order of 1/16th inch, with an average pore size of about 2 microns. The length of the first flow passage member 412 may be on the order of 448 inches, with a diameter on the order of 2.5 inches. The corresponding second flow passage member 424 may correspondingly have a length on the order of 13.5 inches, with a diameter on the order of 4.5 inches. The outer wall member 434 may have a vertical length on the order of 5.5 inches, with a diameter on the order of 6 inches.

In such system, water may be employed as the liquid medium from reservoir 450 which is introduced into interior annular volume 470 for weep-through of such liquid onto the interior surface 432 of the upper liquid permeable portion 426 of the second flow passage member. The usage of water in such system may be on the order of 0.1-0.3 gallon per minute of operation.

FIGURE 7 is a schematic representation of system 510 including an upstream system 512 producing an effluent gas, an exit line 514, a manifold duct line 516, first and second inlet lines 518 and 520; and a downstream scrubber unit 550. As depicted, the upstream system, which may for example comprise a semiconductor manufacturing facility or semiconductor process tool, is in closed gas flow communication with the scrubber unit via the manifold and inlet lines. The exit line, manifold line and inlet lines may have any suitable diameter, e.g., a diameter ranging from 1.5 to 3 inches.

FIGURE 8 is a schematic representation of an illustrative embodiment of the present invention. The upstream system 612, e.g. semiconductor manufacturing tool, is connected to an exit line 614. Exit line 614 has walls defining an elongated tubular shape with an internal flow passage and a first end upstream from a second end. The internal flow passage of exit line 614 is connected at its first end to the upstream system 612 to receive effluent gas from the upstream system. The second end of exit line 614 is connected at an approximate midpoint of intake manifold line 616. Intake manifold line 616 has walls defining an elongated body with an internal flow passage, and first and second ends. The first and second ends of intake manifold line 616 are downstream from the approximate midpoint connection with exit line 614. The connection of exit line 614 and manifold 616 facilitates the effective passage of effluent gas from the interior flow passage of line 614 to the interior flow passage of manifold line 616.

First and second intake lines 618 and 620 have walls defining internal passages, and first and second ends. The respective first ends of intake lines 618 and 620 are connected to the first and second ends of manifold line 616 thereby facilitating passage of the effluent gas from the internal flow passage of manifold line 616 to the

internal flow passages of intake lines 618 and 620. The second ends of intake lines are downstream from the first ends. The respective second ends of the intake lines 618 and 620 are connected to scrubber unit 650.

Scrubber 650 is connected as shown to a scrubber water line 652. The connection facilitates passage of water, from scrubber water line 652 into scrubber 650. The scrubber 650 is also connected to a vent gas discharge line 654, to provide for passage of gas from scrubber 650 through line 654 to a discharge location. The scrubber 650 is also connected to a fluid waste line 656, to provide uninterrupted passage of liquid waste from scrubber 650 to a liquid waste discharge location. The scrubber water line 652, vent gas discharge line 654, fluid waste line 656, exit line 614, manifold intake line 616 and first and second intake lines 618 and 660, may be of any suitable diameter, appropriate to the specific gas flow rates and processing unit operations involved in the facility.

The connection between the manifold intake line and the first and second intake lines is angled between 45 and 90 degrees so that the internal passage of the manifold line serves as a water baffle retarding back migration of water from within the internal passages of the first and second intake lines.

Connected proximate to the upstream ends of the first and second intake ducts are first and second intake valves 622 and 624. The intake valves are two-way valves, each having an open and closed position. When in a closed position, the intake valve prevents the flow of effluent gas from the manifold line 616 into the intake lines.

Positioned proximate to the second, downstream ends of the intake lines are first and second heating means 646 and 648. Although depicted as heater coils, the

heating means may comprise any heating systems known to the skilled artisan for transferring thermal energy to the internal passages of the first and second inlet lines. For purposes of illustration, the heating means will be referred to as heating coils.

A gas delivery system for delivering gas from a gas source into the interior passages of the first and second intake lines will now be described. The gas delivery system of the present invention includes a gas source 626, first and second gas delivery lines 628 and 632 having internal passages, first and second ends, and first and second gas flow control valves 630 and 634 therein.

Its in understood the gas delivery system described herein may include more than one gas source. Multiple gas sources would be connected in gas flow communication to a gas source manifold. The gas source manifold may include an gas source isolation valve for each gas source and a gas source flow control valve for each gas source. The gas source manifold would then be connected in gas flow communication to the gas delivery system.

Gas source 626 is positioned proximate to the first and second intake lines. Gas source 626 furnishes gas, such as nitrogen, for delivery at rate of 2 to 100 standard cubic feet per hour, into the internal passages of the first and second intake lines 618 and 620. Effective gas delivery into the intake lines is facilitated by the connection (by any suitable connection means, such as couplings, connectors, etc.) of the first and second gas delivery lines to the first and second intake lines.

Gas source 626 is connected to the first gas delivery line 628 at the first end of line 628. The first end of a second gas delivery line 632 is connected at an approximate midpoint along the length of first gas delivery line 628. The connection

between said first gas line 628 and second gas line6 32 is such that gas contained in line 628 passes without obstruction or leakage into the interior passage of line 632. Second gas delivery line 632 is connected to line 628 at a point along the length of line 28 downstream from the connection between line 628 and gas source 626.

A downstream end of first gas delivery line 628 is connected to a length of second intake line 620 downstream from second valve 624. The connection between gas line 628 and intake line 620 provides an unobstructed passageway for gas contained in the internal passage of gas line 628 to pass freely and without leakage into the interior passage of intake line 620. A second end of second gas delivery line 632, downstream from the first end of line 632 is connected to first intake line 618. The connection between gas line 632 and intake line 618 provides an unobstructed passageway for gas in line 632 to pass freely and without leakage into the interior of intake line 618.

Positioned along first gas delivery line 628, upstream from the connection with second intake line 620 and downstream from the connection with second gas delivery line 632, is first gas valve 630. First gas valve 630 is a two way valve equivalent to the first and second intake valves discussed above. First gas valve 630 regulates the passage of gas along the interior of first gas delivery line 628 into second intake line 620. Positioned on the second gas delivery line, upstream from the connection with the first gas line, is second gas valve 634. Second gas valve 634 facilitates the passage of gas therethrough from the second gas line into the first intake line.

A pressurized water delivery system will now be described. The water delivery system includes a water source 636, first and second water lines 638 and 642

having first and second ends and internal passages, and first and second water valves 640 and 644.

Positioned proximate to the first and second intake lines is pressurized water source 636. Pressurized water source 636 produces a stream of water at a pressure ranging from 0.5 to 5 gallons per minute. Water source 636 is connected to the internal passage of the first water line 638 at the first end of line 638. The connection facilitates the effective passage of pressurized water from the source into the internal passage of line 638. The second end of first water line 638, downstream from said first end, is connected to second intake line 620 for the delivery of the pressurized water from the internal passage of first water line 638 into the internal passage of second intake line 620. Positioned on first water line 638, upstream from the connection with second intake line 620, is a first water valve 640 for facilitating the selective passage of pressurized water therethrough and into intake line 620. First water valve 640 is a two way valve.

A first end of second water delivery line 642 is connected to first water delivery line 638 at a location upstream from first water valve 640 and downstream from water source 636. The second end of second water delivery line 642, downstream from the first end, is connected to first intake line 618 for the delivery of pressurized water from the internal passage of line 638 into the internal passage of intake line 618. Positioned on the second water line, upstream from the connection to the first intake line 618, is second water valve 644 for selectively controlling the passage of pressurized water therethrough. Second water valve 644 is a two way valve.

A first thermal jacket 658 accommodates a length of first intake line 618, first intake valve 622, the connection between line 618 and second gas delivery line 634, the connection between line 618 and second water delivery line 642, and first heating means 648. The first thermal jacket provides insulating properties to the elements accommodated therein and cooperates with the heating means to raise an internal thermal temperature of first intake duct line 618. Thermal jacket 658 raises side wall temperature while N_2 is flowing to evaporate water deposited on the side wall, and thermal jacket 658 raises the side wall temperature to prevent condensable process gases from condensing in the line. In the metal etch example BCl_3 from the process will form boric acid upon hydrolysis reaction at the entry to the scrubber, yet, the process line must be heated to prevent $AlCl_3$ from condensing along the line as well. The line may, then, be heated from the process source as is the case for metal etch or WCVD.

A second thermal jacket 660 accommodates a length of second intake line 620, second intake valve 624, the connection between line 620 and first gas line 628, the connection between line 620 and first water line 638, and second heating means 646. The second thermal jacket provides insulating properties to the elements accommodated therein and cooperates with the heating means to raise an internal thermal temperature of second intake line 620.

The valves mentioned above are two way valves each having an open position and a closed position. For purposes of discussion hereafter, it will be assumed that the valves are pneumatic valves with an air open and spring close mode of operation (the valves may, though be air to close, spring to open depending upon the system requirements, performance, and objectives). Such pneumatic valves may include KF-50 connections, electro-pneumatic with integral air solenoid valve, and proof of

closure and proof of open switches leads. Such valves are available from HPS Division of MKS Instruments as model 190. Electrical connections between the above mentioned and below cited valves are maintained to a control panel (not shown). The control panel includes a programmable logic controller (PLC) in electrical connection with the system valves. The PLC maintains electrical connections with the valves to monitor valve position and actuate valve position (open or close). In addition, a timer is associated with the PLC to facilitate PLC timing of valve positions. However, it will be understood by the skilled artisan that other valves and control embodiments may be substituted without departing from the spirit or scope of the present invention. For example, the valves may be electrical, mechanical, electromechanical, magnetic, or other type valves, of any of various commercially available types. The valves may, in particular, include limit switches electrically coupled to the cycle timer control means or an alternate control means. The limit switches would provide valve position verification and control interlock to ensure the process gas flow is not deadheaded and to assist in preventing water from being introduced into an on-line (on-stream) gas flow line.

The method of operation of the above-described embodiment of FIGURE 8 of the present invention is described below with reference to the flowchart of FIGURE 9. Such description identifies the apparatus with respect to the reference numerals of FIGURE 8.

A first step (block 701 in the FIGURE 9 flowchart) in the operation of the present invention is to close all valves: 622, 624, 630, 634, 640, and 644. The programmable logic controller (PLC) controls the opening and closing of the valves by regulating the flow of pneumatic air thereto (not shown). The cessation of pneumatic air to a valve causes a spring to move a valve baffle to an obstructing position, thereby

preventing the flow of gas stream material from a position upstream of the valve to a position downstream of the valve. The first step prevents the flow of any effluent gas, pressurized water, or other gas, through any of the duct lines set out above. This initial step is a safety precaution prior to use of the apparatus of the present invention, to ensure that an operator is always aware of which intake duct lines are being occupied by a stream of effluent gas from the upstream system 612. The initial step ensures that the flow of effluent gas (along with pressurized water and gas from gas source 636) has not yet begun.

A second step (block 702 in the FIGURE 93 flowchart) in the operation of the present invention involves querying whether all the valves are shut. This query is executed by the PLC housed in the control panel. As set out above, the PLC is in electrical communication with electrical position indicator means housed within the aforementioned valves. This query is carried out by the PLC detecting signals from the positioned indicator means and associating same with predetermined valves indicative of a closed position. When it is determined that the aforementioned valves are in the closed position, the third step is initiated. When it is determined that the aforementioned valves are in an open position, an alarm is sounded and the prior step is repeated.

A third step (block 703 in the FIGURE 9 flowchart) entails opening second intake valve 624. The opening of valve 624 may be accomplished by allowing the flow of pneumatic air into the valve, thereby causing an internal spring to adjust the position of a valve baffle into one which allows the passage of effluent gas from manifold 616, through second intake valve 624 and into second intake line 620. The opening of second intake valve 624 is activated by the PLC. First intake valve 622 is held in a closed position thereby sealing off the first intake line from the flow of

effluent and off gas causing same to flow exclusively through the second intake line 620.

A fourth step (block 704 in the FIGURE 9 flowchart) entails querying whether the second intake valve 624 has been opened. The query into the valve position is carried out by the PLC in the same manner as the valve position query set out in step two. If the PLC determines that the second intake valve is closed, an alarm is sounded and the prior step is repeated. If the PLC detects the intake valve to be open, the next step in the operating procedure is implemented.

A fifth step (block 705 in the FIGURE 9 flowchart) entails opening second water valve 644. The opening of valve 644 is performed by the PLC in a similar manner as described above. The opening of valve 644 creates an outlet for the flow of pressurized water from water source 636, through first water delivery line 638 and second water delivery line 642, into first intake line 618. First water valve 640 is maintained in a closed position to ensure that no water from water source 636 passes therethrough and into second intake line 620. Valve 644 is held open by the PLC for a first duration of time set and monitored by a timer associated with the PLC. Second water valve 644 is held open for a time in the range of one to ten minutes. The flow of pressurized water into first intake line 618 flushes out and scours the internal passage of line 618, as well as dissolving soluble particulate, thereby causing particulates and the like to exit through the first intake line second end into scrubber unit 650.

A sixth step (block 706A in the FIGURE 9 flowchart) entails closing water valve 644 after the first duration of time has passed. After second water valve 664 has been closed, second gas valve 634 is opened (block 706B in the FIGURE 3

flowchart) and, if not already activated, the first heating means is activated (block 706C in the FIGURE 3 flowchart). The closing and opening of the valves is carried out by the PLC in a manner as described above. The first heating element is activated by generating a current flow therethrough, controlled by the PLC. The current flow encounters the natural resistance of the heating means and generates heat due to the ensuing electrical resistance. Second gas valve 664 is kept open for a second duration of time as set and monitored by the timer associated with the PLC. A preferred range of time for leaving second gas valve open and activation of the heating means is from thirty minutes to eight hours. First gas valve is maintained in a closed position so that the flow of gas from gas source 626 is directed along first gas delivery line 628 to second gas delivery line 632 and first intake line 618. The gas, in cooperation with heat delivered by first heating means 648, dries the interior walls of the first inlet line.

A seventh step (block 707 in the FIGURE 9 flowchart) entails disengaging the first heating means and opening first intake valve 622. The opening of the valve 622 is carried out by a similar manner as described above. The heating means is disengaged by the cessation of current thereto as controlled by the PLC.

An eighth step (block 708 in the FIGURE 9 flowchart) entails querying whether first intake valve 622 is open. The query is carried out by the PLC in a similar querying manner as set out above. If the PLC determines that the first intake valve is not open, an alarm is activated and step seven is repeated. Only when the PLC confirms the newly cleaned inlet is open will the PLC close the other inlet for cleaning; otherwise the flow of process gas could be blocked. If the PLC determines that the first intake valve is open, the next step in the operating procedure is implemented.

A ninth step (block 709 in the FIGURE 9 flowchart) entails closing second intake valve 624. First intake valve 622 is maintained in an open position. The closing of the second intake valve 624 causes the flow of effluent to become diverted from a now closed off second inlet line to a now open first inlet line.

A tenth step (block 710 in the FIGURE 9 flowchart) entails querying whether second intake valve 624 is closed. The query is carried out by the PLC in electrical connection with the second intake valve as set out above. If the PLC determines that the second intake valve is not closed, an alarm is activated and the ninth step is repeated. If the second intake valve is determined to be closed the next step in the operating procedure is implemented.

An eleventh step (block 711 in the FIGURE 9 flowchart) entails opening first water valve 640. The second water valve 644 is maintained in a closed position. The opening of the first water valve (and the closed second water valve 644) opens a passage for pressurized water to flow from the water source 36 through first water delivery line 638 and first water valve 640 and into second intake line 620. Second water valve 644 is maintained in a closed position to ensure that no water passes therethrough and into first inlet line 618. The pressurized water flows through second intake line 620 performing scouring and cleaning actions as set out above with regard to the first intake line. The pressurized water exits the second intake line through a second end connected to scrubber 650. The pressurized water is allowed to flush out the second intake line for a preselected time ranging from one to ten minutes. An adjustable timer, in electrical connection with the PLC, cooperates with same to time the discharge of the pressurized water.

A twelfth step (block 712 in the FIGURE 9 flowchart) entails closing first water valve 640, a thirteenth step entails opening first gas valve 630 (block 713 in the FIGURE 9 flowchart), and a fourteenth step (block 714 in the FIGURE 9 flowchart) entails activating second heating means 646. The opening and closing of the valves is carried out by the PLC in a similar manner as described above. The second gas valve 634 is maintained in a closed position to ensure that no gas passes therethrough and into first inlet duct line 618. The opening of first gas valve 630 opens a passage for gas to flow from gas source 626, through first gas delivery line 628 and first gas valve 630, and into second inlet line 660. The activation of the second heating means causes, in cooperation with the second thermal jacket 660, the internal temperature of the second inlet line to rise. The gas and heat generated from the second heating means, dries the interior passage of the second inlet line 620. The gas flows through the second inlet line and into the scrubber 650 via the line's second end. The first gas valve is held open and the second heating means is activated for a time duration ranging from thirty minutes to height hours. The time duration is monitored by a timer associated with the PLC as described above.

A fifteenth step (block 715 in the FIGURE 9 flowchart) entails closing first gas valve 630 and disengaging second heating means 646 after the time duration has been reached. In a sixteenth step (block 716 in the FIGURE 9 flowchart), the PLC queries the first intake valve 622 to ensure the valve remains in an open condition. The operation of the valves is performed in a manner as set out above.

A seventeenth step (block 717 in the FIGURE 9 flowchart) entails opening second intake valve 624 and querying (block 718 in the FIGURE 9 flowchart) by the PLC as to whether the second intake valve 624 is open. If it is determined that the

second intake valve is not open, an alarm is activated and the previous step is repeated. The PLC performs the querying process in a manner as set out above.

A nineteenth step (block 719 in the FIGURE 9 flowchart) entails closing first intake valve 622 and querying (block 720 in the FIGURE 9 flowchart) to ensure first intake valve is closed. If valve 622 is not closed, an alarm is sounded and the previous step is repeated. If first intake valve 622 is closed, the operational procedure queries the operator as below..

Finally the operator is queried (block 721 in the FIGURE 9 flowchart) as to whether to repeat the cleaning steps set out above, returning the to fifth step, or ending the cleaning cycle.

Industrial Applicability Paragraph

The inlet structures of the invention are usefully employed in connection with downstream process units such as gas stream scrubbers, purifiers, filters, neutralization units, extraction systems for recovery of stream constituents, reaction systems for further processing of gas relative to the composition obtaining at an upstream locus, etc. The inlet structures are constructed, arranged and operated to minimize the occurrence of occlusion from deposition of particulates, film formation from gas stream components and adverse hydrodynamic effects.

THE CLAIMS

1. An inlet structure for passage of a gas stream from an upstream source to a downstream locus, said inlet structure being selected from the group consisting of inlet structures (A), (B) and (C):

(A) an inlet structure comprising:

a gas-permeable wall enclosing a gas flow path, and an outer annular jacket circumscribing the gas-permeable wall to define an annular gas reservoir therebetween; and

means for introducing a gas into the annular gas reservoir during the flow of the particulate solids-containing and/or solids-forming gas stream to a gas processing system through such inlet structure at a pressure sufficient to cause the gas to permeate through the gas-permeable wall to combat the deposition or formation of solids on the interior surface of the gas-permeable wall;

(B) an inlet structure comprising:

a first vertically extending inlet flow passage member having an upper entrance for introduction of said gas stream and a lower end for discharge of said gas stream;

a second flow passage member circumscribing the first flow passage member and in spaced relationship thereto, to define an annular volume therebetween, said second flow passage member extending downwardly to a lower end below the lower

end of the first flow passage member, and said second flow passage member having an upper liquid-permeable portion and a lower liquid-impermeable portion below said upper liquid-permeable portion;

an outer wall member enclosingly circumscribing the second flow passage member and defining therewith an enclosed interior annular volume; and

a liquid flow inlet port in the outer wall member for introducing liquid into the enclosed interior annular volume between the second flow passage member and the outer wall member; and

(C) an inlet structure comprising:

a manifold receiving gas from the upstream source, including first and second inlet lines which are alternatingly employed to flow gas to a downstream process, each of said inlet lines at their first ends being joined to a manifold conduit, and each of the first and second inlet lines at their second ends being joined in flow communication with the downstream process unit;

each of the first and second inlet lines including a valve therein which is selectively openable or closeable to establish or discontinue flow of gas therethrough, respectively;

the manifold being arranged to receive gas from the upstream source and to flow the gas through the manifold and either the first or second inlet line, so that one of such lines is actively flowing gas from the upstream source to the downstream

process, while the other is blocked by closure of the respective valve therein to flow of the gas therethrough;

a pressurized water source coupled with the manifold, by water flow lines to each of the first and second inlet lines, with each of said water flow lines containing a valve which is selectively openable or closeable to establish or discontinue flow of pressurized water therethrough, respectively; and

cycle timer control means constructed and arranged to control the operation of the manifold and valves so that in operation,

gas from the upstream process flows into the manifold, with the valve in one of the first and second inlet lines being open, while the valve in the other of the first and second inlet lines is closed, so that the gas entering the manifold is flowed through a specific one of the inlet lines containing the opened valve, so that the gas flows through the specific one of the inlet lines containing the open valve and constituting an on-stream line, and passes to the downstream process, while the other inlet line of the manifold constitutes an off-stream line in which the valve is closed to prevent flow of gas therethrough;

the off-stream line, while not flowing gas therethrough, is cleaned to regenerate same for further processing so that the valves in the respective inlet lines are controlled with one of such valves being open at any given time, while the other is closed for off-stream cleaning of the line and renewal of the line for subsequent on-stream operation;

the off-stream line is cleaned by admission of pressurized water from the pressurized water source to the off-stream line by opening of the valve in the water flow line communicating the pressurized water source with the off-stream line, while in the other water flow line, the water flow line valve is closed, to prevent the flow of the pressurized water from the water source to the on-stream line, and after pressurized water has been flowed through the on-stream line for cleaning thereof, the inlet line valves in the respective inlet lines are switched to an opposite open/closed state;

with the gas flow being alternatingly, and sequentially directed through each of the inlet lines, so that during the off-stream period of a specific inlet line, the off-stream line is being flushed with pressurized water, to renew the inlet line for subsequent flow of gas therethrough.

2. A clog-resistant inlet structure for introducing a particulate solids-containing and/or solids-forming gas stream processing system, said inlet structure comprising:

a gas-permeable wall enclosing a gas flow path, and an outer annular jacket circumscribing the gas-permeable wall to define an annular gas reservoir therebetween; and

means for introducing a gas into the annular gas reservoir during the flow of the particulate solids-containing and/or solids-forming gas stream to a gas processing system through such inlet structure at a pressure sufficient to cause the gas to permeate through the gas-permeable wall to combat the deposition or formation of solids on the interior surface of the gas-permeable wall.

3. An inlet structure according to claim 2, further comprising a port for introducing a pulsed high pressure gas into the annular reservoir, wherein the port is coupled with a source of high pressure gas and means for pulsed delivery thereof from the source to the annular reservoir, to exert additional anti-clogging action on the gas-permeable wall.

4 An inlet structure according to claim 2, wherein the gas-permeable wall and outer annular jacket are coupled to a downstream flow path section including a wall enclosing a corresponding further section of the gas flow path and forming with the gas permeable wall a slot therebetween, with the wall of the downstream flow path section being circumscribed by an outer annular jacket to define an annular liquid reservoir therebetween in liquid overflow relationship with the slot so that when the annular liquid reservoir is filled with liquid beyond a certain point determined by the height of the wall, the liquid flows over the wall and down the interior surface of the wall, as a falling liquid film thereon, whereby the falling liquid film provides a barrier medium on the wall interior surface, to resist solids deposition or formation on such interior surface, and to wash away any solids which nonetheless are deposited or formed on the interior surface of the wall.

5 An inlet structure according to claim 4, wherein the outer annular jacket of the downstream flow path section of the inlet structure is provided with a port coupled to a supply of liquid therefor.

6. An inlet structure according to claim 2, wherein a first end of the gas flow path is coupled in gas flow relationship with a semiconductor manufacturing tool.

7. An inlet structure according to claim 6, wherein a second end of the gas flow path is coupled in gas flow relationship with a water scrubber unit.

8. An inlet structure according to claim 6, wherein a second end of the gas flow path is coupled in gas flow relationship with a combustion scrubber unit.

9. An inlet structure according to claim 2, wherein the inlet structure further comprises a gas stream delivery tube circumscribed by the outer annular jacket for delivering the particulate solids-containing and/or solids-forming gas stream to the inlet structure.

10 An inlet structure according to claim 9, further comprising means for heating the gas stream delivery tube to combat condensation of the particulate solids-containing and/or solids-forming gas stream flowing therethrough.

11. An inlet structure according to claim 4, wherein the inlet structure further comprises a gas stream delivery tube circumscribed by the gas permeable wall for delivering the particulate solids-containing and/or solids-forming gas stream to the inlet structure.

12. An inlet structure according to claim 11, further comprising means for heating the gas stream delivery tube to combat condensation of the particulate solids-containing and/or solids-forming gas stream flowing therethrough.

13. An inlet structure according to claim 11, wherein the gas stream delivery tube exhausts the particulate solids-containing and/or solids-forming gas stream below an upper end of the wall of the downstream flow path section.

14. An inlet structure according to claim 2, wherein the inlet structure further comprises a means for heating the gas permeating through the gas-permeable wall.

15. A clog-resistant inlet structure for introducing a particulate solids-containing and/or solids-forming gas stream to a gas processing system, said inlet structure comprising:

first and second generally vertically arranged flow passage sections in serial coupled relationship to one another, defining in such serial coupled relationship a generally vertical flow passage through which the particulate solids-containing and/or solids-forming gas stream may be flowed, from an upstream source of the particulate solids-containing and/or solids-forming gas stream to a downstream gas processing system arranged in gas stream-receiving relationship to the inlet structure;

said first flow passage section comprising an upper section of the inlet structure and including an inner gas-permeable wall having an interior surface bounding an upper part of the flow passage, and an outer wall enclosingly surrounding the gas-permeable wall to define an interior annular volume therebetween;

a gas flow port in the outer wall of the first flow passage section, said gas flow port being culpable to a source of gas for flowing of gas at a predetermined flow rate

into the interior annular volume, for subsequent flow of gas from the interior annular volume into the flow passage of the inlet structure;

the second flow passage section being serially coupled to the first flow passage section, for flowing of particulate solids-containing fluid downwardly into the second flow passage section from the first flow passage section, said second flow passage including an outer wall having a liquid injection port therein, said second flow passage section outer wall being coupled with the first flow passage section, and an inner weir wall in spaced apart relationship to the outer wall to define an interior annular volume therebetween, with the inner weir wall extending toward but terminating short of the gas-permeable wall of the first flow passage section, to provide a gap therebetween defining a weir, and with said weir wall having an interior surface bounding the flow passage in the second flow passage section;

whereby when liquid is flowed into the interior annular volume between the outer wall of the second flow passage section and the inner weir wall thereof, the introduced liquid overflows the weir and flows down the interior surface of the inner wall of the second flow passage section to wash any particulate solids from the wall and to suppress the deposition or formation of solids on the interior surface of the inner weir wall, as the particulate solids-containing gas stream is flowed through the flow passage of the inlet structure.

16. An inlet structure according to claim 15, further comprising a high pressure gas flow port in the outer wall of the first flow passage section, said high pressure gas flow port being coupleable to a source of high pressure gas for flowing of high pressure gas into the interior annular volume, to clean the gas-permeable wall of particulates depositing or forming thereon.

17. An inlet structure according to claim 15, wherein a source of gas is coupled to the gas port in the outer wall of the first flow passage section.

18. An inlet structure according to claim 16, wherein a source of high pressure gas is coupled to the high pressure gas port in the outer wall of the first flow passage section.

19. An inlet structure according to claim 15, wherein a lower end of the second flow passage section is joined to a water scrubber for scrubbing of the particulate solids-containing gas stream flowed through the flow passage of the inlet structure.

20. An inlet structure according to claim 15, wherein the first and second flow passage sections are quick disconnectably coupled with one another.

21. An inlet structure according to claim 15, wherein the first flow passage section and second flow passage section are coaxially aligned with one another.

22. An inlet structure according to claim 15, wherein the gas permeable wall is formed of a porous metal.

23. An inlet structure according to claim 15, wherein the gas permeable wall is formed of a porous ceramic.

24. An inlet structure according to claim 15, wherein the gas permeable wall is formed of a porous plastic.

25. An inlet structure according to claim 15, wherein the gas permeable wall and outer annular jacket are of circular cross-section.

26. An inlet structure according to claim 15, wherein the outer wall and inner weir wall of the second flow passage section are of circular cross-section.

27. An inlet structure according to claim 15, wherein the first flow passage section is joined to an upstream semiconductor manufacturing tool.

28. An inlet structure according to claim 15, further comprising a gas stream delivery tube circumscribed by the interior surface of the gas permeable wall, with the gas stream delivery tube being in gas-flow receiving relationship with the upstream source, and with the gas stream delivery tube exhausting the particulate solids-containing and/or solids-forming gas stream within the generally vertical flow passage.

29. An inlet structure according to claim 28, wherein the gas stream delivery tube exhausts the particulate solids-containing and/or solids-forming gas stream within the second flow passage section.

30. An inlet structure according to claim 28, wherein the gas stream delivery tube exhausts the particulate solids-containing and/or solids-forming gas stream below the gap defining the weir.

31. An inlet structure according to claim 28, wherein the gas stream delivery tube exhausts the particulate solids-containing and/or solids-forming gas stream above the gap defining the weir.

32. An inlet structure according to claim 15, further comprising means for heating the gas stream delivery tube to combat condensation of the particulate solids-containing and/or solids-forming gas stream flowing therethrough.

33. An inlet structure according to claim 15, further comprising means for heating the gas permeating through the gas-permeable wall.

34. A clog-resistant inlet structure for introducing a particulate solids-containing and/or solids-forming gas stream to a gas processing system, said inlet structure comprising an upper section having an upper porous wall and a lower section having a lower porous wall, said upper and said lower porous walls enclosing a gas flow path, with each said porous wall receiving a shrouding fluid.

35. An inlet structure according to claim 34, further comprising a gas stream delivery tube circumscribed by said upper porous wall, for exhausting the particulate solids-containing and/or solids-forming gas stream within the upper section.

36. An inlet structure according to claim 34, further comprising a gas stream delivery tube circumscribed by said upper porous wall, for exhausting the particulate solids-containing and/or solids-forming gas stream within the lower section.

37. An inlet structure according to claim 34, further comprising a transition region between said upper section and said lower section, and a gas stream delivery tube, said gas stream delivery tube exhausting the particulate solids-containing and/or solids-forming gas stream within the transition region.

38. An inlet structure according to claim 34, further comprising an axially disposed porous structure to introduce a fluid into the inlet structure.

39. A gas/liquid interface structure for transport of a gas stream from an upstream source of same to a downstream processing unit, said gas/liquid interface structure comprising:

a first vertically extending inlet flow passage member having an upper entrance for introduction of said gas stream and a lower end for discharge of said gas stream;

a second flow passage member circumscribing the first flow passage member and in spaced relationship thereto, to define an annular volume therebetween, said second flow passage member extending downwardly to a lower end below the lower end of the first flow passage member, and said second flow passage member having an upper liquid-permeable portion and a lower liquid-impermeable portion below said upper liquid-permeable portion;

an outer wall member enclosingly circumscribing the second flow passage member and defining therewith an enclosed interior annular volume; and

a liquid flow inlet port in the outer wall member for introducing liquid into the enclosed interior annular volume between the second flow passage member and the outer wall member.

40. A gas/liquid interface structure according to claim 39, wherein the upper liquid-permeable portion of the second flow passage member comprises a porous cylindrical wall member.

41. A gas/liquid interface structure according to claim 40, wherein the porous cylindrical wall member is formed of a material selected from the group consisting of sintered metal materials, porous ceramic materials, and porous plastic materials.

42. A gas/liquid interface structure according to claim 40, wherein the upper liquid-permeable portion of the second flow passage member is formed of a porous sintered metal material.

43. A gas/liquid interface structure according to claim 40, wherein the liquid-permeable portion is constituted by a porous wall having an average pore size in the range of from about 0.5 to about 30 microns.

44. A gas/liquid interface structure according to claim 39, wherein the first and second flow passage members are each cylindrical in character and coaxial with one another.

45. A gas/liquid interface structure according to claim 39, wherein the outer wall member enclosingly circumscribing the second flow passage member comprises a

cylindrical side wall in radially spaced relationship to the second flow passage member, a top end wall through which the first liquid flow passage member extends, and a bottom end wall between the second flow passage member and the side wall of the outer wall member.

46. A gas/liquid interface structure according to claim 39, wherein the liquid flow inlet port in the outer wall member for introducing liquid into the enclosed interior annular volume between the second flow passage member and the outer wall member is constructed and arranged for tangential feeding of the liquid into the enclosed interior annular volume, for circumferential distribution of the introduced liquid around the upper liquid-permeable portion of the second flow passage member.

47. A gas/liquid interface structure according to claim 39, constructed and arranged so that the weir liquid rate is decoupled from levelness of the structure.

48. A gas/liquid interface structure according to claim 39, constructed and arranged so that the weir liquid rate is decoupled from minimum wetting rate.

49. A gas/liquid interface structure for transport of a gas stream from an upstream source of same to a downstream processing unit, comprising first and second flow passage members defining an annular volume therebetween, with the second flow passage member extending downwardly to a lower elevation than the lower end of the first flow passage member, with an outer wall member enclosingly circumscribing the second flow passage member and defining therewith an enclosed interior annular volume, and with a liquid flow port in the outer wall member for introducing liquid into the enclosed interior annular volume, wherein the second flow passage member includes an upper liquid-permeable portion in liquid flow

communication with the enclosed interior annular volume, whereby liquid from such volume can weep through the permeable portion and form a falling liquid film on interior surface portions of the second flow passage member, as a protective liquid interface for the second flow passage member.

50. A gas/liquid interface structure according to claim 49, wherein the upper liquid-permeable portion of the second flow passage member comprises a porous cylindrical wall member.

51. A gas/liquid interface structure according to claim 50, wherein the porous cylindrical wall member is formed of a material selected from the group consisting of sintered metal materials, porous ceramic materials, and porous plastic materials.

52. A gas/liquid interface structure according to claim 50, wherein the upper liquid-permeable portion of the second flow passage member is formed of a porous sintered metal material.

53. A gas/liquid interface structure according to claim 50, wherein the liquid-permeable portion is constituted by a porous wall having an average pore size in the range of from about 0.5 to about 30 microns.

54. A gas/liquid interface structure according to claim 49, wherein the first and second flow passage members are each cylindrical in character and coaxial with one another.

55. A gas/liquid interface structure according to claim 49, wherein the outer wall member enclosingly circumscribing the second flow passage member comprises a cylindrical side wall in radially spaced relationship to the second flow passage member, a top end wall through which the first liquid flow passage member extends, and a bottom end wall between the second flow passage member and the side wall of the outer wall member.

56. A gas/liquid interface structure according to claim 49, wherein the liquid flow inlet port in the outer wall member for introducing liquid into the enclosed interior annular volume between the second flow passage member and the outer wall member is constructed and arranged for tangential feeding of the liquid into the enclosed interior annular volume, for circumferential distribution of the introduced liquid around the upper liquid-permeable portion of the second flow passage member.

57. A gas/liquid interface structure according to claim 49, constructed and arranged so that the weir liquid rate is decoupled from levelness of the structure and minimum wetting rate.

58. A system for processing of semiconductor manufacturing effluent gas, comprising:

a semiconductor manufacturing unit generating an effluent gas stream;

an oxidation unit for oxidatively treating the effluent gas stream;

a gas/liquid interface structure for transport of the gas stream form the oxidation unit to a downstream processing unit, said gas/liquid interface structure comprising:

a first vertically extending inlet flow passage member having an upper entrance for introduction of said gas stream and a lower end for discharge of said gas stream;

a second flow passage member circumscribing the first flow passage member and in spaced relationship thereto, to define an annular volume therebetween, said second flow passage member extending downwardly to a lower end below the lower end of the first flow passage member, and said second flow passage member having an upper liquid-permeable portion and a lower liquid-impermeable portion below said upper liquid-permeable portion;

an outer wall member enclosingly circumscribing the second flow passage member and defining therewith an enclosed interior annular volume;

a liquid flow inlet port in the outer wall member for introducing liquid into the enclosed interior annular volume between the second flow passage member and the outer wall member; and

a downstream process until receiving the effluent gas stream from the gas/liquid interface structure.

59. An apparatus for conveying a process gas stream from an upstream source to a downstream treatment unit, comprising:

a manifold receiving gas from the upstream source, including first and second inlet lines which are alternatingly employed to flow gas to a downstream process, each of said inlet lines at their first ends being joined to a manifold conduit, and each of the first and second inlet lines at their second ends being joined in flow communication with the downstream process unit;

each of the first and second inlet lines including a valve therein which is selectively openable or closeable to establish or discontinue flow of gas therethrough, respectively;

the manifold being arranged to receive gas from the upstream source and to flow the gas through the manifold and either the first or second inlet line, so that one of such lines is actively flowing gas from the upstream source to the downstream process, while the other is blocked by closure of the respective valve therein to flow of the gas therethrough;

a pressurized water source coupled with the manifold, by water flow lines to each of the first and second inlet lines, with each of said water flow lines containing a valve which is selectively openable or closeable to establish or discontinue flow of pressurized water therethrough, respectively; and

cycle timer control means constructed and arranged to control the operation of the manifold and valves so that in operation,

gas from the upstream process flows into the manifold, with the valve in one of the first and second inlet lines being open, while the valve in the other of the first and second inlet lines is closed, so that the gas entering the manifold is flowed through

a specific one of the inlet lines containing the opened valve, so that the gas flows through the specific one of the inlet lines containing the open valve and constituting an on-stream line, and passes to the downstream process, while the other inlet line of the manifold constitutes an off-stream line in which the valve is closed to prevent flow of gas therethrough;

the off-stream line, while not flowing gas therethrough, is cleaned to regenerate same for further processing so that the valves in the respective inlet lines are controlled with one of such valves being open at any given time, while the other is closed for off-stream cleaning of the line and renewal of the line for subsequent on-stream operation;

the off-stream line is cleaned by admission of pressurized water from the pressurized water source to the off-stream line by opening of the valve in the water flow line communicating the pressurized water source with the off-stream line, while in the other water flow line, the water flow line valve is closed, to prevent the flow of the pressurized water from the water source to the on-stream line, and after pressurized water has been flowed through the on-stream line for cleaning thereof, the inlet line valves in the respective inlet lines are switched to an opposite open/closed state;

with the gas flow being alternatingly, and sequentially directed through each of the inlet lines, so that during the off-stream period of a specific inlet line, the off-stream line is being flushed with pressurized water, to renew the inlet line for subsequent flow of gas therethrough.

60. An apparatus according to claim 59, further comprising means for drying the off-stream line subsequent to water washing thereof.

61. An apparatus according to claim 60, wherein the drying means include a source of drying gas, dry gas lines interconnecting each of the inlet lines to the drying gas source, and valves in the dry gas lines for selectively flowing or preventing flow of drying gas therethrough, wherein the valves are controlling coupled with the cycle timer control means.

62. An apparatus according to claim 59, further comprising means for heating the off-stream line, to enhance drying thereof.

63. An apparatus according to claim 62, wherein the heating means comprise a resistance heating element.

64. An apparatus according to claim 59, wherein each of said valves is a pneumatic valve.

65. An apparatus according to claim 59, wherein the water from the pressurized water source after flow through the off-stream inlet line is discharged into the downstream process.

66. An apparatus according to claim 59, wherein the upstream source is a semiconductor manufacturing tool.

67. An apparatus according to claim 59, wherein the downstream process is a water scrubbing process.

68. An apparatus according to claim 59, wherein the cycle timer control means includes at least one limit switch to determine a position of a valve.

69. An apparatus according to claim 59, wherein the cycle timer control means operates to prevent the first and second inlet lines from being simultaneously closed.

70. An apparatus according to claim 59, wherein the cycle timer control means operates to prevent pressurized water from flowing into an on-stream line flowing the process gas stream.

71. A method of flowing a gas from an upstream source to a downstream process through a manifold including two inlet lines through which the gas is flowable, by the steps of:

(a) flowing the gas through one of the inlet lines as an on-stream inlet line, while the other inlet line is isolated to flow of gas from the upstream source to the downstream process;

(b) flushing the isolated inlet line with pressurized water to remove particulate solids, water soluble solids, and the like from interior surfaces of the isolated inlet line;

(c) discontinuing the flow of pressurized water through the isolated inlet line;

(d) flowing pressurized drying gas through the isolated inlet line to dry said interior surfaces of said isolated inlet line;

(e) discontinuing the flow of the pressurized drying gas through the isolated inlet line;

(f) de-isolating the isolated inlet line, to constitute same an on-stream inlet line;

(g) discontinuing the flow of gas through the on-stream inlet line, and isolating the on-stream inlet line to constitute same an isolated off-stream inlet line;

(h) redirecting the flow of said gas from the upstream source to the downstream process through the de-isolated on-stream inlet line;

and cyclically, alternatingly and repetitively conducting steps (a) - (h), so that during flow of gas from the upstream source to the downstream process, one of the inlet lines has the gas from the upstream source flowed therethrough, and the other of the inlet lines is off-stream, and undergoes high-pressure water flushing.

72. A method according to claim 71, further comprising flowing pressurized drying gas through the off-stream line subsequent to said high-pressure water flushing.

73. A method according to claim 71, wherein the off-stream line is heated.

74. A method according to claim 71, wherein the upstream source is a semiconductor manufacturing tool.

75. A method according to claim 71, wherein the gas comprises semiconductor manufacturing effluent gas.

76. A method according to claim 71, wherein the downstream process comprises water scrubbing of the gas.

77. A method according to claim 71, wherein the method further comprises controlling steps (a) - (h) to maintain an uninterrupted flow of gas from the upstream source to the downstream process.

78. A method according to claim 71, the method further comprising controlling steps (a) - (h) to prevent flushing an on-stream line with pressurized water, and controlling steps (a) - (h) to prevent simultaneously isolating each inlet line and interrupting the flow of gas from the upstream source to the downstream process.

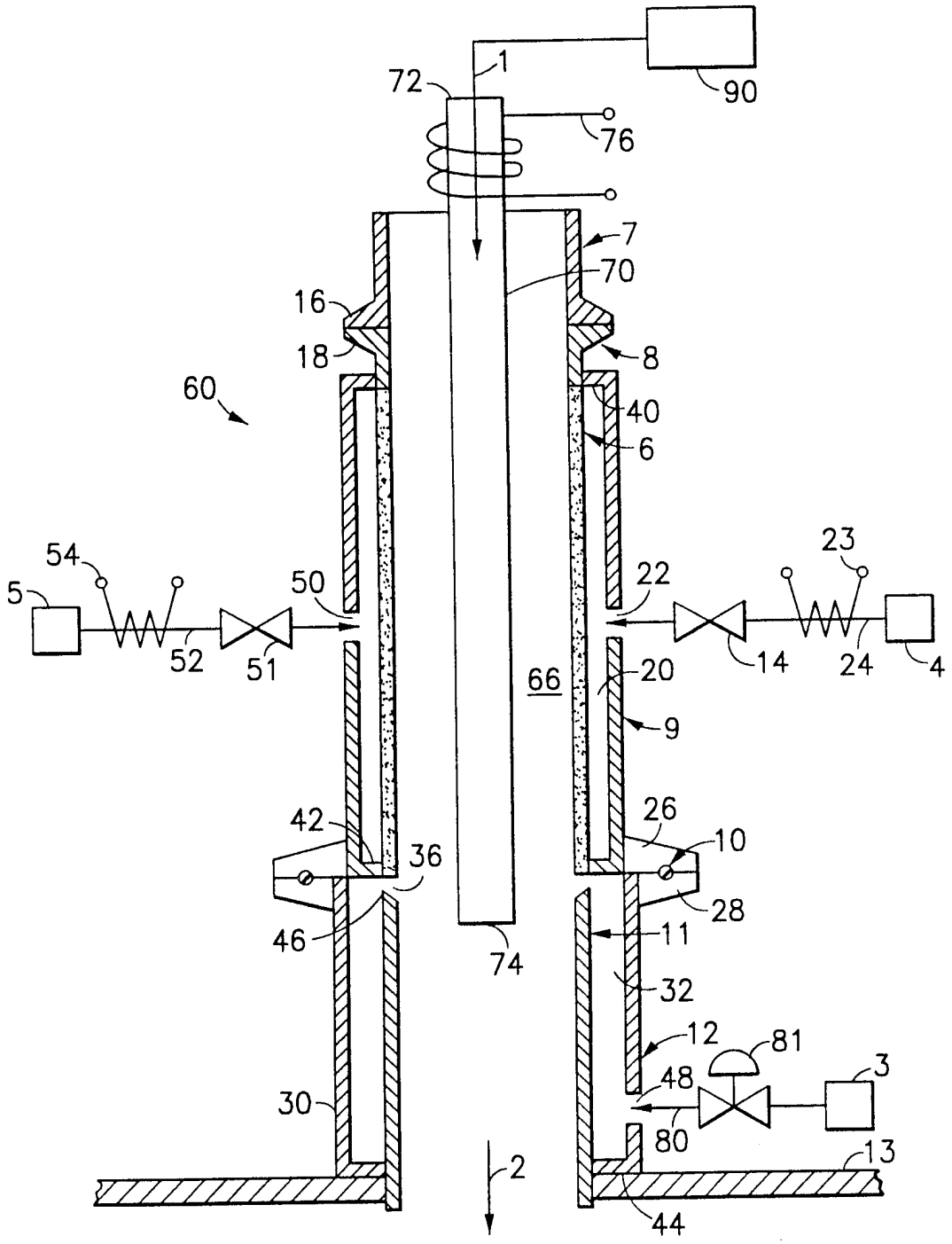

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FIG. 1

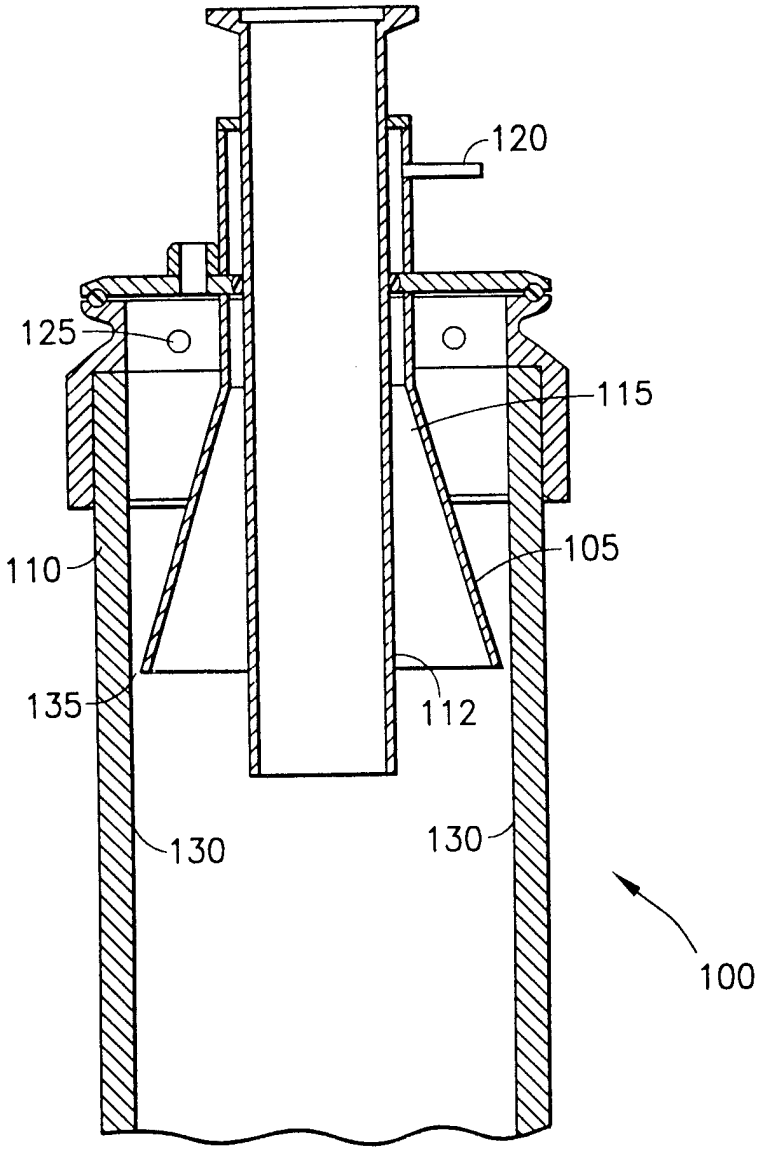


FIG.2

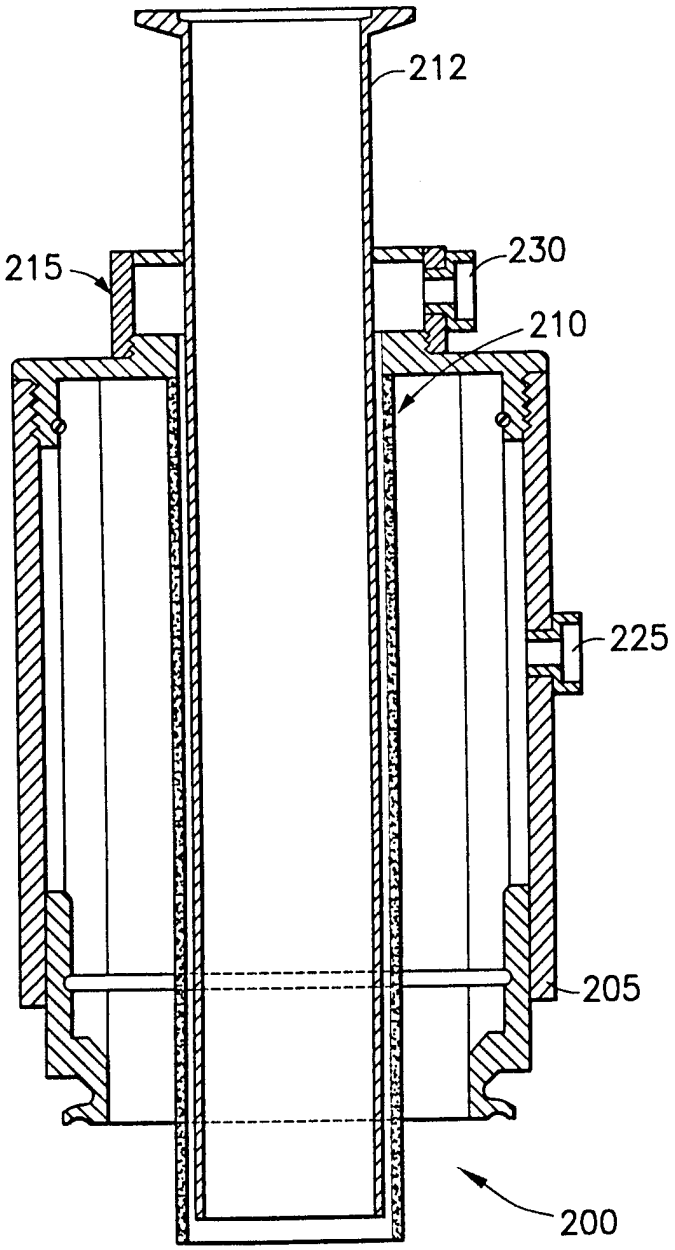


FIG.3

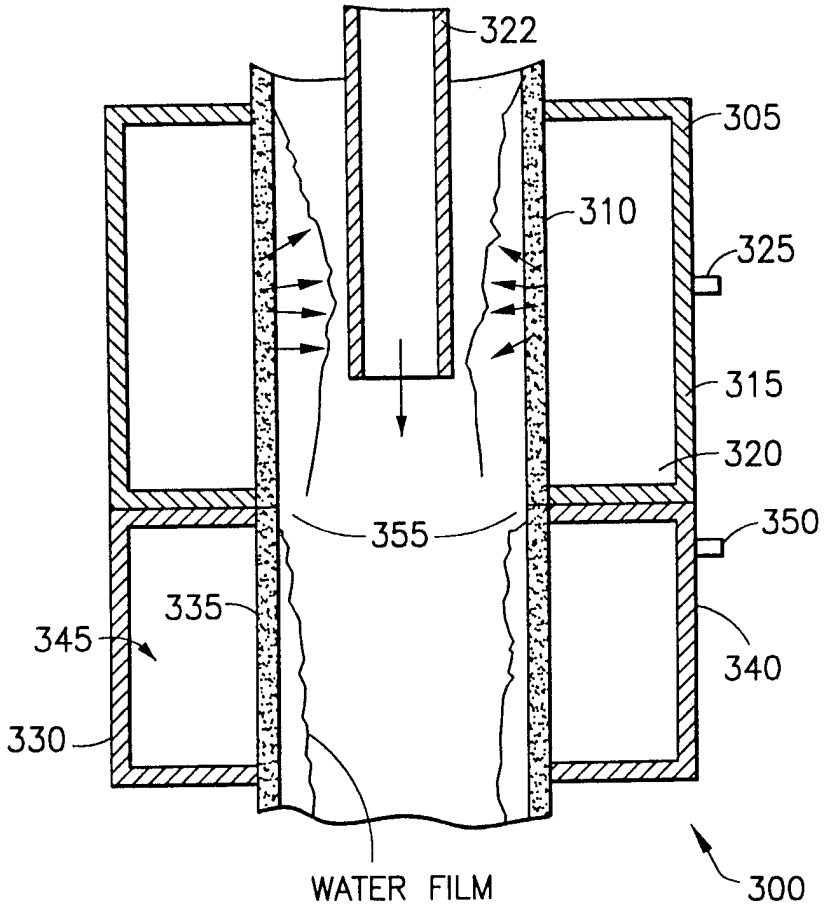


FIG.4

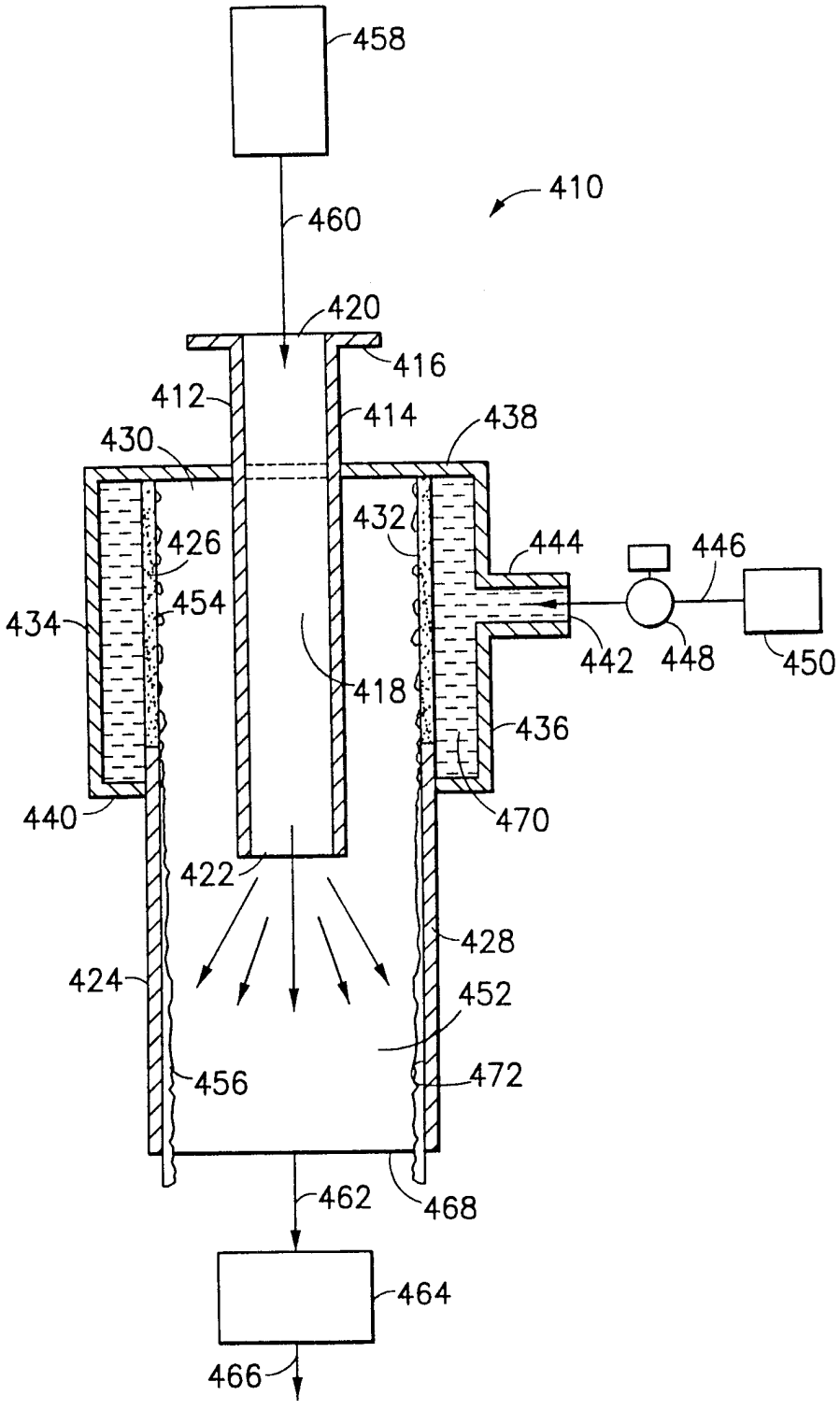

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FIG.5

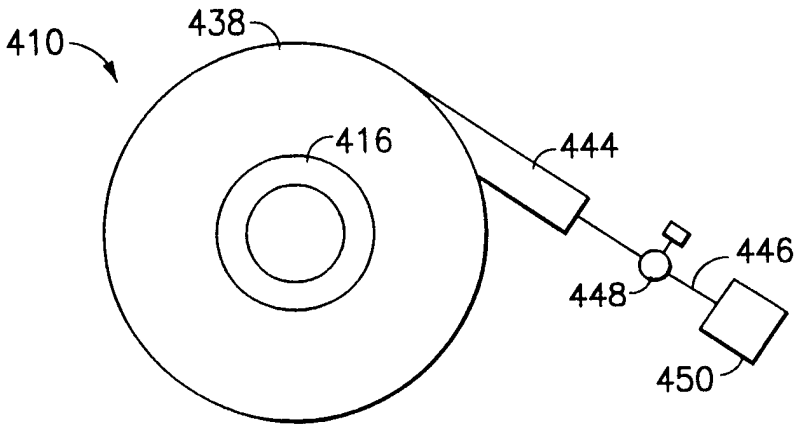


FIG.6

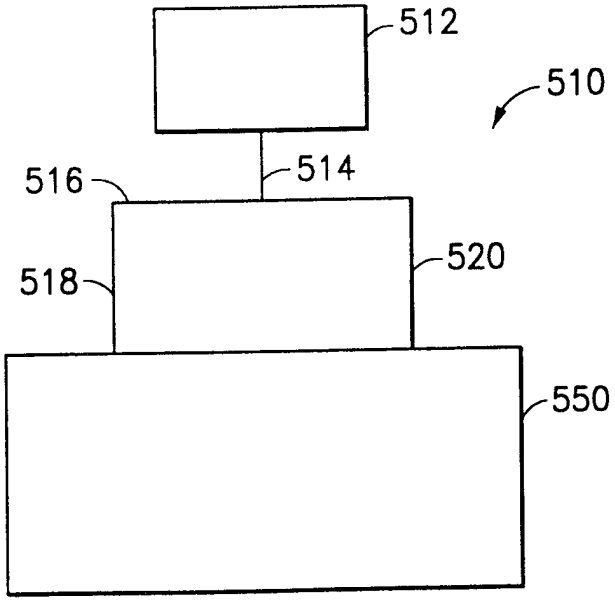


FIG.7

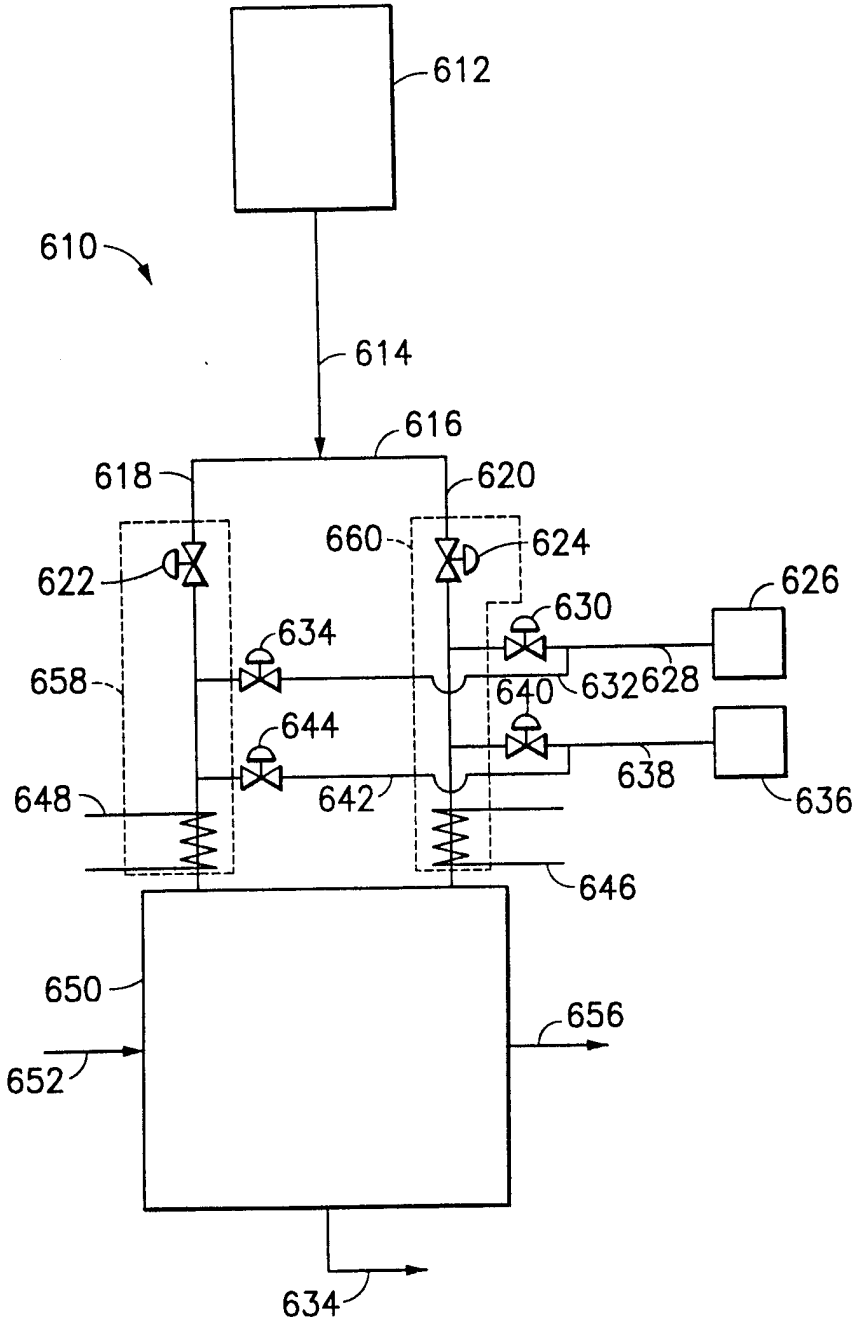

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FIG.8

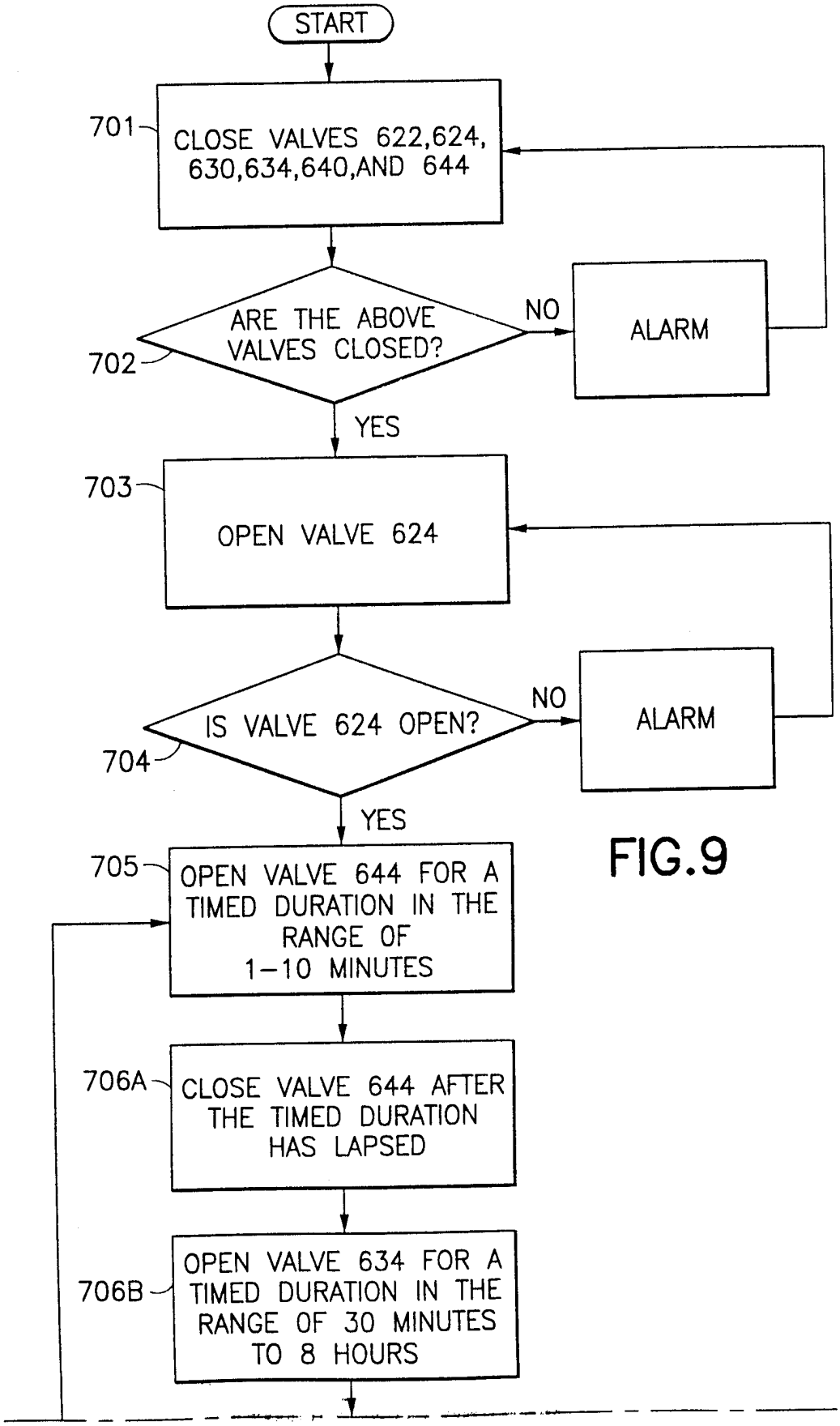

START
701
CLOSE VALVES 622,624, 630,634,640,AND 644
ARE THE ABOVE VALVES CLOSED?
702
NO
ALARM
YES
703
OPEN VALVE 624
IS VALVE 624 OPEN?
704
NO
ALARM
YES
705
OPEN VALVE 644 FOR A TIMED DURATION IN THE RANGE OF 1–10 MINUTES
706A
CLOSE VALVE 644 AFTER THE TIMED DURATION HAS LAPSED
706B
OPEN VALVE 634 FOR A TIMED DURATION IN THE RANGE OF 30 MINUTES TO 8 HOURS

FIG.9

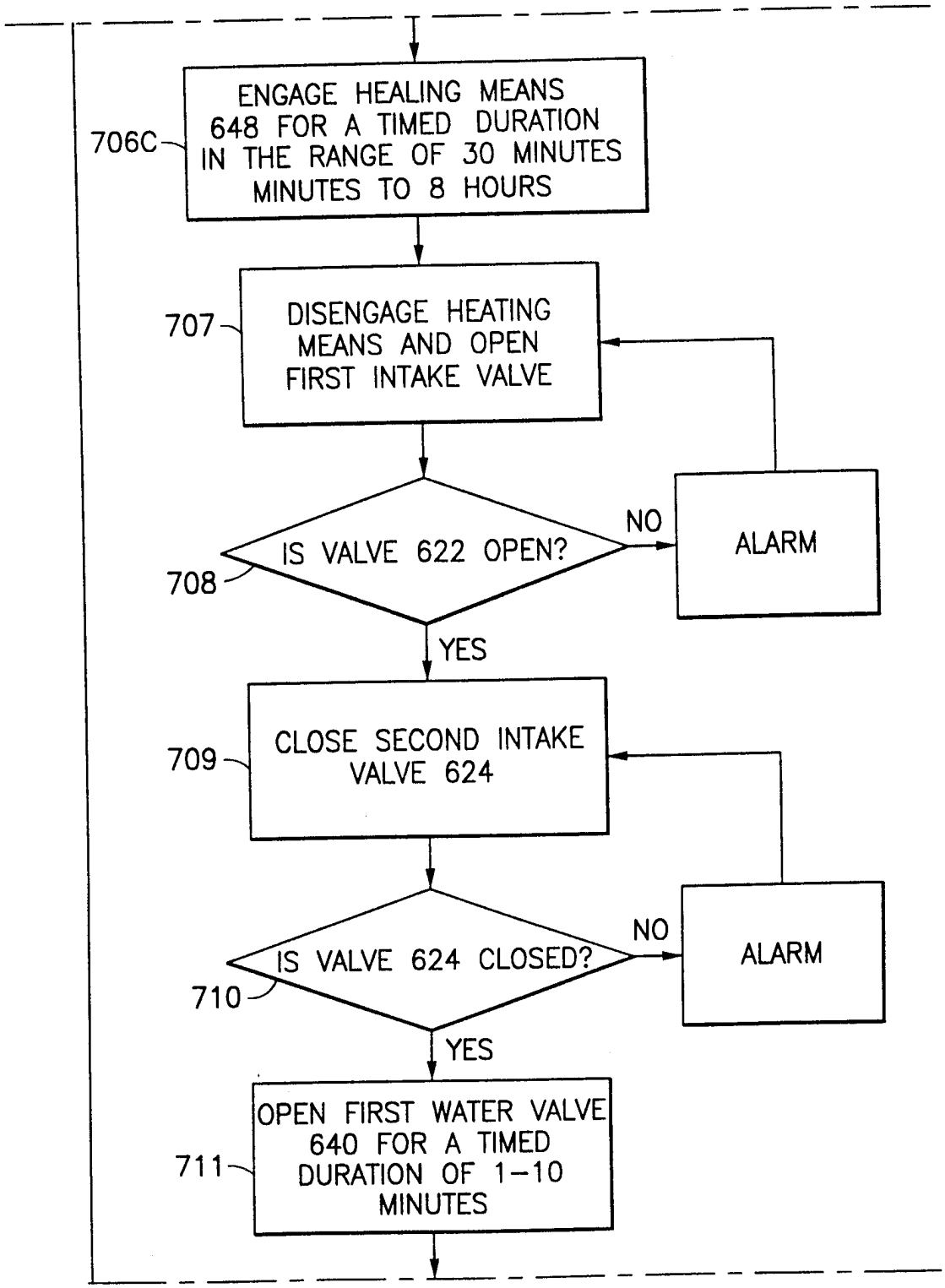

ENGAGE HEALING MEANS 648 FOR A TIMED DURATION IN THE RANGE OF 30 MINUTES MINUTES TO 8 HOURS
706C
DISENGAGE HEATING MEANS AND OPEN FIRST INTAKE VALVE
707
IS VALVE 622 OPEN?
708
NO
ALARM
YES
CLOSE SECOND INTAKE VALVE 624
709
IS VALVE 624 CLOSED?
710
NO
ALARM
YES
OPEN FIRST WATER VALVE 640 FOR A TIMED DURATION OF 1–10 MINUTES
711

FIG.9(Cont.)

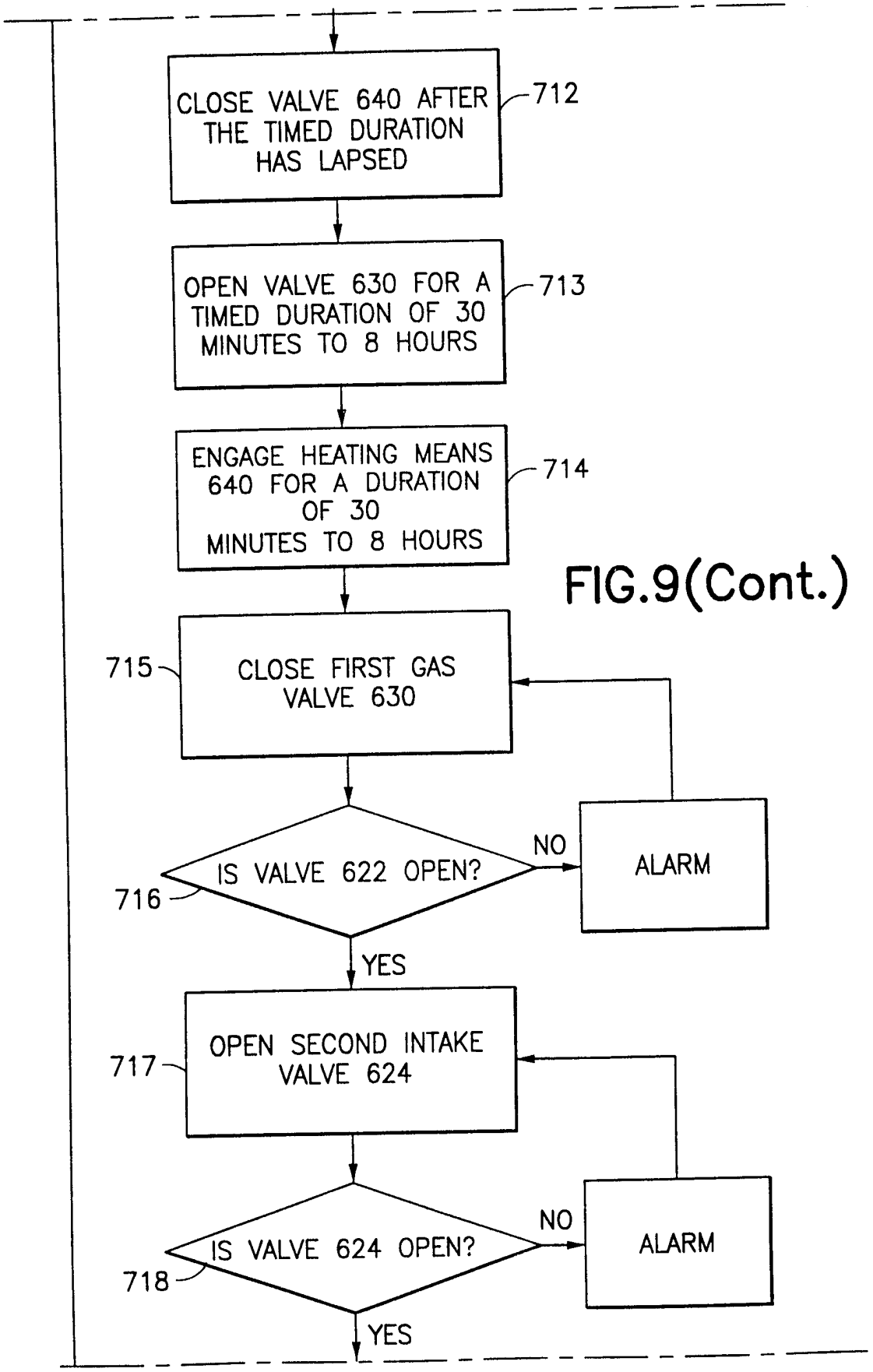

CLOSE VALVE 640 AFTER THE TIMED DURATION HAS LAPSED
712
OPEN VALVE 630 FOR A TIMED DURATION OF 30 MINUTES TO 8 HOURS
713
ENGAGE HEATING MEANS 640 FOR A DURATION OF 30 MINUTES TO 8 HOURS
714
715
CLOSE FIRST GAS VALVE 630
IS VALVE 622 OPEN?
716
NO
ALARM
YES
717
OPEN SECOND INTAKE VALVE 624
IS VALVE 624 OPEN?
718
NO
ALARM
YES

FIG.9(Cont.)

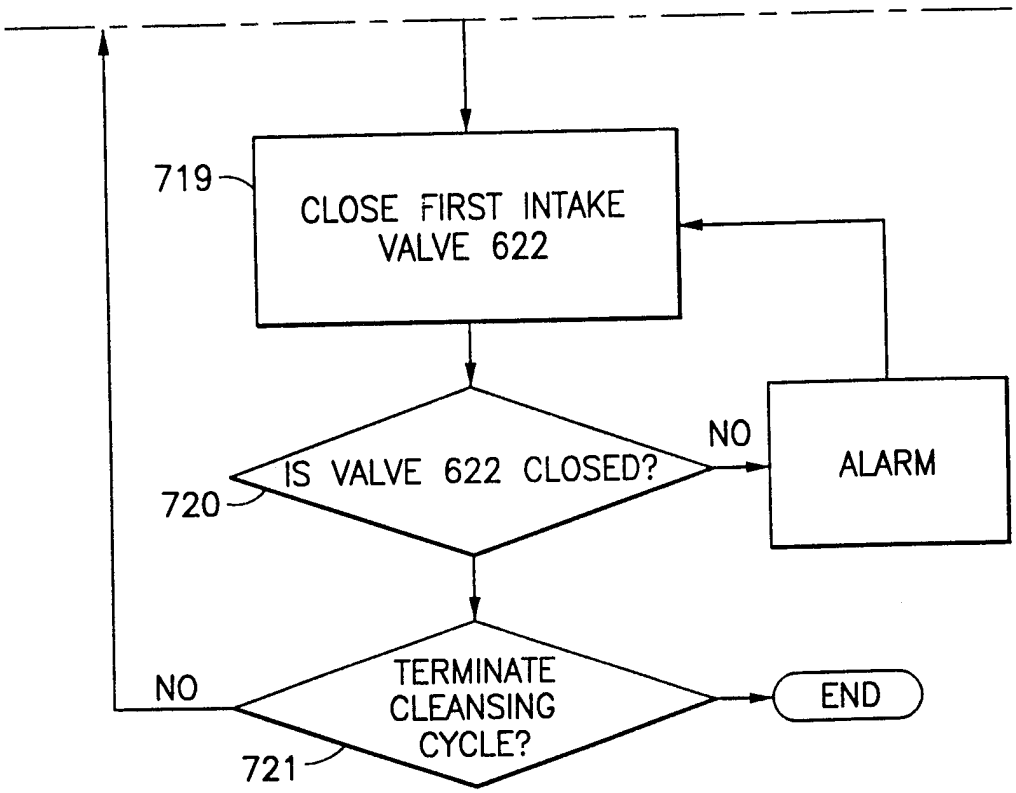

719
CLOSE FIRST INTAKE VALVE 622
IS VALVE 622 CLOSED?
720
NO
ALARM
TERMINATE CLEANSING CYCLE?
721
NO
END

FIG.9(Cont.)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US97/24275

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :B01D 41/00; B65G 45/00
US CL :Please See Extra Sheet.
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : Please See Extra Sheet.

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

NONE

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

NONE

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2,545,028 A (HALDEMAN) 13 March 1951, figs. 1 and 2.	46,56
Y	US 2,551,114 A (GODDARD) 01 May 1951, fig. 1.	39-57
A	US 2,857,979 A (VAN DIJCK) 28 October 1958.	
A	US 3,097,936 A (LINCOLN) 16 July 1963.	
Y	US 3,871,305 A (WATANABE et al) 18 March 1975, fig. 2.	39-57
X	US 3,888,955 A (MARUKO) 10 June 1975, fig. 2.	34-38

[X] Further documents are listed in the continuation of Box C. [ ] See patent family annex.

*	Special categories of cited documents:	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A"	document defining the general state of the art which is not considered to be of particular relevance	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"E"	earlier document published on or after the international filing date	"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"&"	document member of the same patent family
"O"	document referring to an oral disclosure, use, exhibition or other means		
"P"	document published prior to the international filing date but later than the priority date claimed		

Date of the actual completion of the international search 25 FEBRUARY 1998	Date of mailing of the international search report 16 MAR 1998
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703) 305-3230	Authorized officer A. SCOTT BUSHEY Telephone No. (703) 308-0651

Form PCT/ISA/210 (second sheet)(July 1992)★

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US97/24275

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X --- Y	US 3,918,917 A (ASHINA et al) 11 November 1975, fig. 1.	39,40,44,45,47-50,54,55,57 ---------- 41-43,46,51-53,56
X --- Y	US 4,083,607 A (MOTT) 11 April 1978, fig. 1.	1-3,9,25 -------- 6-8,10,14,22-24
X --- Y	US 4,172,708 A (WU et al) 30 October 1979, the figure.	1,22,23,25 -------- 6-8,22-24
X --- Y	US 4,479,809 A (JOHNSON et al) 30 October 1984, figs. 2 and 3.	1,25 ------ 6-8,22-24
A	US 4,986,838 A (JOHNSGARD) 22 January 1991.	
X --- Y	US 5,252,007 A (KLINZING et al) 12 October 1993, fig. 2.	1-3,9,25 -------- 6-8,10,14,22-24

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US97/24275

A. CLASSIFICATION OF SUBJECT MATTER:
US CL :

55/242, 257.1, 266, 273, 431, 523; 95/26, 280, 281; 134/26, 30, 166C; 137/238; 261/104, 112.1; 406/46, 48, 193; 422/168

B. FIELDS SEARCHED
Minimum documentation searched
Classification System: U.S.

55/227, 241, 242, 257.1, 261, 266, 271, 273, 431, 466, 522, 523, DIG 32; 95/26, 279, 280, 281; 134/22.12, 26, 30, 166C; 137/238, 240, 861; 261/104, 112.1; 406/46, 47, 48, 89, 172, 193; 422/168