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[54] **LAMINAR FLOW RINSING AND DRYING VESSELS**
9 Claims, 4 Drawing Figs.

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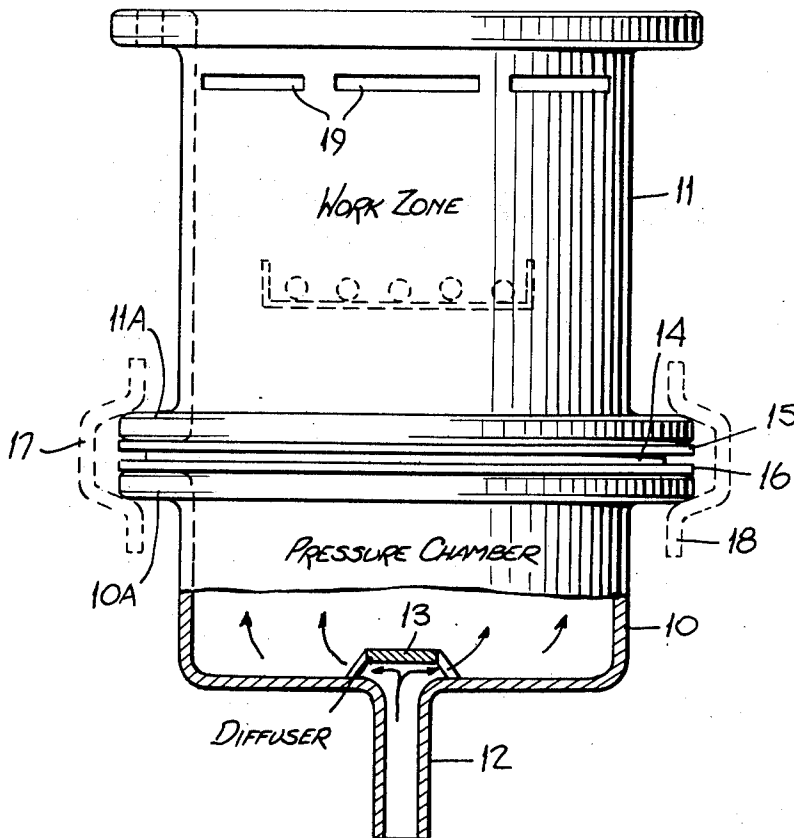
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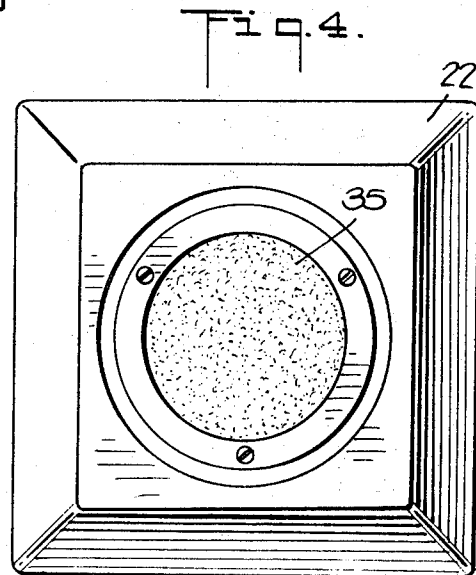
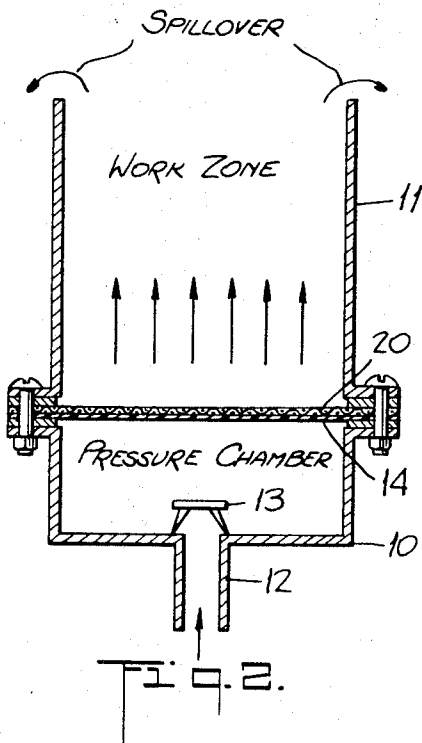
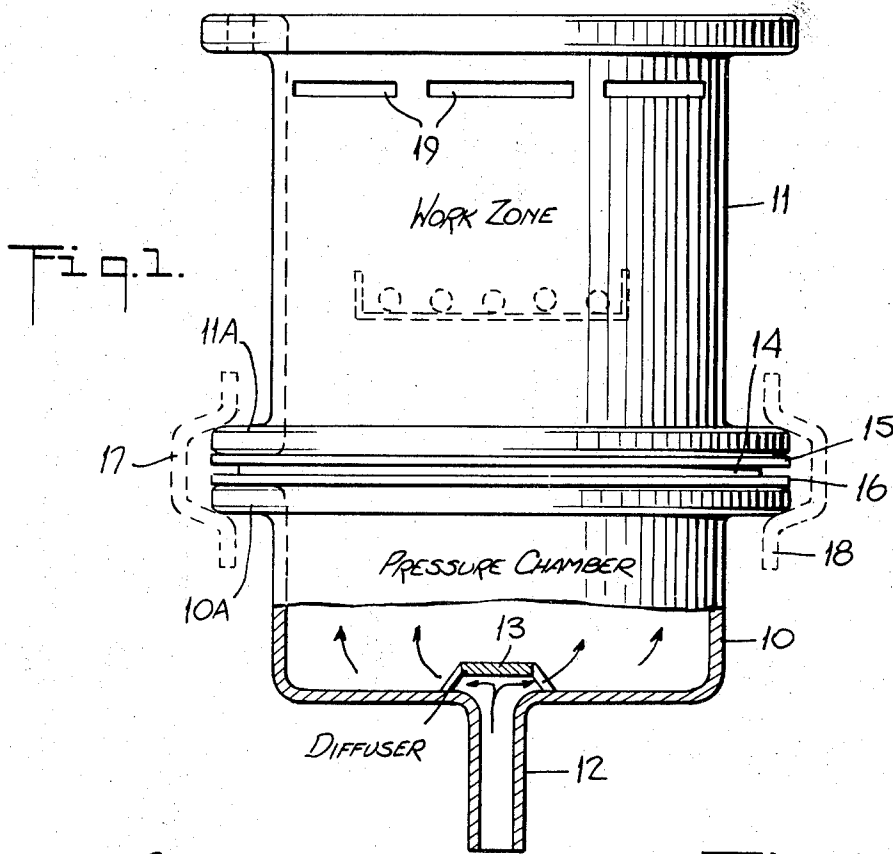
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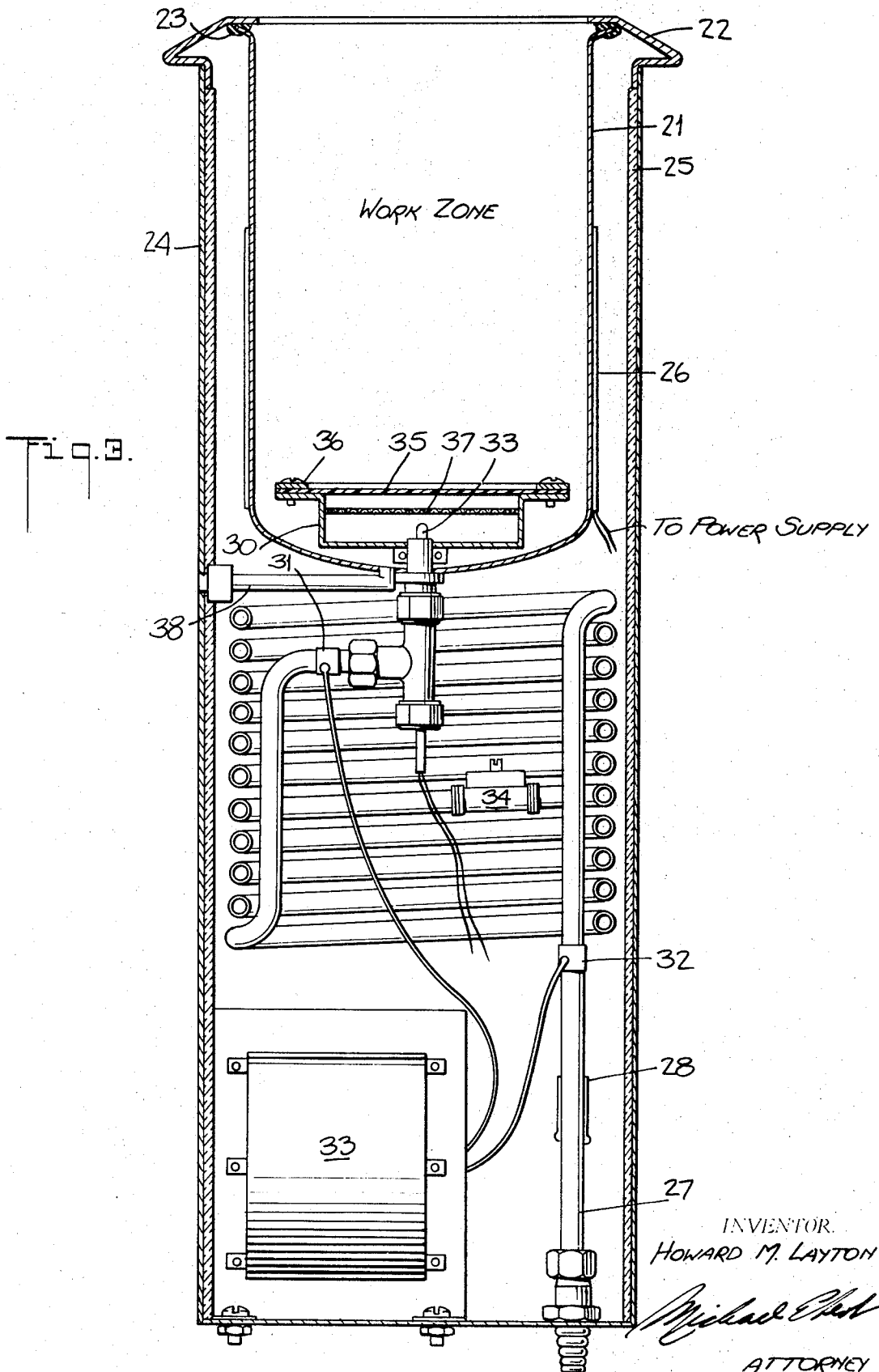
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ABSTRACT: A process vessel for rinsing or drying small parts, the vessel being formed by separable lower and upper sections and a porous membrane clamped therebetween to serve as a flow impedance. A rinsing or drying fluid is fed into the lower section which acts as a pressure chamber. The fluid passes through the impedance into the upper section to produce a laminar flow therein, the parts to be cleaned being carried into a work zone in said upper section.





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LAMINAR FLOW RINSING AND DRYING VESSELS

This invention relates generally to apparatus for rinsing or drying small parts, such as microcircuit and semiconductor elements, and more particularly to a process vessel adapted to subject these parts to a fluid flow which is uniform throughout the work zone.

The terms "microcircuitry" or "microelectronics" designate electronic circuits, subsystems and systems whose parts density exceeds by an order of magnitude or more, that which is attainable when utilizing conventional components. The integrated circuit is one in which a multiplicity of elements are brought together on a single substrate. Various techniques are used for this purpose, including vacuum processes in which metals are deposited to form conductive elements and sputtering processes for forming dielectrics. Both the active and the passive elements can be directly fabricated onto the substrate by such processes as diffusion, alloying, etching and evaporation.

The creation of such devices entails the preparation of perfectly clean metallic surfaces so that further metallic layers may be deposited or diffused into the substrate metal itself. Since a complex device may have to be discarded because of the failure of one element within the device, in order to obtain a high production yield, it is vital that preparatory cleaning procedures remove all dirt, grease and other foreign matter that might otherwise give rise to a defective element. Such critical cleaning steps are involved, for example, prior to etching of semiconductor substrates. If the cleaning process is carried out imperfectly, the etching will be impaired and the yield will be poorer.

To accomplish this purpose, elaborate washing, rinsing, and drying techniques have been developed. Associated with these processes are particle-filtration systems which serve to remove insoluble contaminants from the process fluid down to a fraction of a micron diameter. To ensure that the process itself receives the full benefit of fine filtration, it is the usual practice to locate the final filter assembly in the fluid supply line as close as possible physically to the process vessel itself. By this expedient, the risk of recontamination is minimized.

The term "process vessel", as used herein, designates a chamber into which one or more items, substrates, components, microcircuit or semiconductor elements, or other metal or plastic pieces are introduced for the purpose of having their surfaces treated in some manner by fluid contained in or passing through the chamber. This term encompasses tanks in which the work is rinsed by liquid as well as tunnels in which the work is dried by gas.

In water rinsing processes, care is usually taken to remove trace organics from the process water. Resin beds of various types are employed to extract mineral ions to a degree that the rinse water delivered to the point of use approaches the quality of theoretically pure water. The purity of water is generally determined by its electrical resistivity, a resistivity of 15 to 18 megohms per cm. at 20° C. being acceptable for rinsing microelectric parts. Similarly, one must carefully purify the gas required for use in hot drying vessels or tunnels. It is therefore the practice to pass the gas (usually nitrogen) through a submicron filter before admitting it into the gas drying chamber.

In order to derive maximum benefit from rinsing procedures carried out in process vessels, it is important that the process fluid flow continuously so that contaminants flushed from the surfaces of the part being treated are immediately withdrawn from its vicinity, thereby maintaining a clean fluid zone around the part. It is also essential to effect a uniform exchange of all fluid in the process vessel to prevent buildup of regions or pockets of contaminated fluid.

If no means are provided to govern or direct the flow of incoming fluid through the process vessel, the inflowing fluid tends to pass through the vessel in a direct line extending from the inlet point, thereby leaving relatively stagnant and contaminated pockets in other regions of the vessel. In order to produce more satisfactory flow patterns, various expedients

have heretofore been used in the microelectronics industry, generally in the form of flow diffusers such as multioutlet spray heads, perforated screens, deflectors, baffles, and other devices adapted to modify or split up the stream to create a desirable flow pattern.

One commonly used process vessel takes the form of an overflow tank having a single weir at the open top thereof, such that as influent water causes the water in the tank to rise, the fluid surface is skimmed off as it spills over the weir. An advantage of this arrangement is that contaminants floating toward the fluid surface are caused to pass over the weir. However, the placement of a single inlet at the bottom tends to cause fluid exchange to take place mainly in the midsection of the vessel, while relatively stagnant pockets are developed toward the lower corners thereof. This flow pattern can be modified somewhat by disposing a perforated screen above the inlet point, but its ability to achieve controlled deflection is limited because typical flow rates are not high enough to produce consistent deflection patterns.

Another widely used rinsing vessel commonly known as a cascade or step rinser, is constituted by a tank divided by baffles into a series of spaced stages whose right sides are of progressively reduced height, purified water being fed into the first stage through a long, narrow slot at the bottom on the left side thereof, which water rises to the top of the first stage and overflows the right side thereof into the space between the first and second stages, the water then entering the second stage through a long, narrow slot at the bottom thereof at the left side, and so on. A diffuser screen is disposed in each stage. Since the influent water is purest in the first stage, the succeeding stages are used as a prerinsing facility.

Because advances in the microelectronics art have imposed more stringent demands on process control, the use of vessels with deflectors, diffusers and baffles often proves inadequate and the effectiveness of the rinsing operation frequently depends on where the work is placed in the vessel; hence good results are not always repeatable. With overflow weir tanks and cascade rinsers, for example, conductivity monitoring of the water effluent reveals the existence of contaminated water pockets in an otherwise "cleaned-up" vessel. This becomes evident when readings fluctuate as the work carrier is moved about or withdrawn from the vessel.

In monitoring the performance of a process vessel, it is usually the practice to place a conductivity cell in the effluent line, the cell functioning to check the specific resistance of the water flowing out of the vessel. Before a given rinsing operation, an initial reading of, say, 12 to 18 megohms per cm. indicates a satisfactory level of water purity approaching the quality of theoretically pure water. As the rinsing cycle proceeds, the immersion of contaminated parts brings about a considerable deterioration in the quality of effluent. Thus a subsequent reading of 1 megohm per cm. or lower, indicates that contaminants are indeed being removed from the processed parts. Ordinarily, the rinsing cycle is considered complete when the quality of the effluent has regained some predetermined value close in quality to that of the influent.

With existing process vessels, the nonuniform flow-through and unstable fluid exchange, which is characteristic of such vessels, yields a rinsing action of the processed parts which is uneven. As a consequence, the cleanup cycle has poor repeatability, process monitoring is less meaningful, and the risk of recontamination of the parts is high, for in withdrawing the parts from the vessel, pockets of stagnant and contaminated water are disturbed and some contaminants return to the surface of the cleaned parts.

In view of the foregoing, it is the main object of this invention to provide a process vessel having a substantially uniform flow-through and fluid exchange pattern.

More specifically, it is an object of this invention to provide a process vessel which creates a uniform or laminar flow pattern by means of a controlled impedance extending across the entire influent plane of the work zone, the impedance being sealed into position to create a pressure differential between the front and back thereof to insure flow laminarity.

Also an object of the invention is to provide a process vessel of the above type, in which the impedance is in the form of a membrane disc which also filters out particulate matter from the influent, whereby the membrane performs a dual function. Thus an advantage of the invention is that it obviates the need for a particulate filter in the incoming fluid line.

Still another object of the invention is to provide a sectional process vessel assembly which may be readily dismantled to replace the filter.

Briefly stated, these objects are accomplished in a process vessel assembly comprising separable lower and upper sections between which is clamped a removable membrane which constitutes a fluid impedance whereby the lower section functions as a pressure chamber and the upper section functions as a work zone. Fluid is supplied to the lower section, and because of the impedance offered by the membrane, the fluid is dispersed uniformly across the surface thereof, the fluid passing through the membrane and filling the upper section into which the parts to be cleaned or dried are introduced, the impedance characteristic being such as to produce a laminar flow pattern therein.

For a better understanding of the invention as well as other objects and further features thereof, reference is made to the following detailed description to be read in conjunction with the accompanying drawing, wherein:

FIG. 1 is an elevational view, partly in section, of one embodiment of a process vessel in accordance with the invention;

FIG. 2 is a sectional view of another embodiment of a process vessel in accordance with the invention;

FIG. 3 is a sectional view of still another embodiment of a process vessel intended for gas; and

FIG. 4 is a plan view thereof.

Referring now to FIG. 1, there is shown a laminar flow process vessel in accordance with the invention, the vessel being constituted by a lower section 10 and an upper section 11, which sections are adapted to clamp a flow impedance therebetween. In practice, the vessel sections may be made of Pyrex glass or other material suitable for the intended purpose.

Rinse water of high purity is supplied to the vessel through an inlet tube 12 connected to the bottom wall of lower section 10 at the center thereof. Mounted above the mouth of inlet tube 12 within the bottom section is a diffuser disc 13, preferably also of Pyrex glass, and having a spiderlike support, whereby the incoming stream impinges on the disc, the stream being deflected thereby and entering the vessel laterally through the spaces between the supporting legs. This diffuser prevents the liquid stream from directly striking the back of the porous membrane and thereby obviates unnecessary strain thereon.

Interposed between the lower and upper sections of the vessel is a fluid impedance in the form of a permeable membrane or diaphragm 14, which is sandwiched between sealing rings 15 and 16, preferably made of Teflon or similar nonreactive resilient material. In practice, the membrane may be a standard KEL-F disc having an average pore size of 15 microns. The bottom and top sections with the membrane therebetween, are held together by suitable V-band clamps 17 and 18 or similar means, the sections having complementary flanges 10A and 11A to receive the clamps.

In operation, the influent water, after being spread somewhat by diffuser disc 13, fills the lower section 10 and then encounters the back surface of the porous membrane 14. Inasmuch as the membrane resists the flow of fluid (typically about 1 pound or so per square inch pressure drop), the lower section constituted a pressure chamber in which fluid is dispersed across the back surface of the membrane in a uniform manner. Thus a uniform flow-through is achieved.

The fluid passing through the membrane then fills the upper section 11 of the vessel, which constitutes the work zone, in which the parts to be cleaned are placed in a removable basket or other carrier. The fluid in the upper section overflows through a ring of circumferential slots 19. As a consequence, a flow-through of ultrapure water is achieved without leaving

pockets of unexchanged fluid in the lower peripheral regions of the work zone.

Depending on the particular application, the required flow rates, and the nature of the fluid, the necessary impedance to achieve laminar or nonturbulent flow may be in the form of a sintered, stainless steel or ceramic filter membrane, a finely perforated metal sheet or a pair of such sheets in superposed relation with the perforations so staggered as to form an irregular or sinuous flow path. Alternatively, the membrane may be of fibrous material or in the form of an enclosed volume of powder, granules or crystals, using such materials as sand, certain resins, or small plastic shapes and spheres, or other elements of sufficient unit size capable of being retained by a screen or barrier which is permeable to gas or liquid. In some applications, a combination of two or more of the above filter media may be used. In all instances, the fluid enters the work zone through myriad, minute openings distributed across the entire front surface of the membrane.

The process vessel, in some instances may be of limited dimensions, so that the walls thereof play a significant role in the flow profile and because of friction and drag, tend to distort the otherwise laminar flow produced by the membrane. This distortion may be compensated for by so grading the impedance of the membrane, whereby its resistance to flow is varied across the plane of the impedance to produce a velocity profile which corrects for the slowdown effect produced by the walls of the vessel. Alternatively, this correction may be effected by a special impedance configuration, such as a cone or inverted cone.

The use of a sealed impedance as described hereinabove, whether flat, shaped graded, or otherwise modified, affords the enforced control of flow and controlled fluid exchange which is of growing importance in modern microelectronic processing. While the invention is of particular value in the context of ultrapure water rinsing and nitrogen drying processes, it will be appreciated that the principles underlying the invention are also useful in connection with other solvents and in other situations calling for a controlled exchange of fluid in all areas of a process vessel.

The impedance not only serves to produce the desired flow pattern, but also functions to filter the influent. As pointed out previously, the current practice is to interpose a particle filtration device in the incoming line in close proximity to the process vessel to ensure an influent of high purity. With the present invention, particle filtration means are incorporated in the vessel itself, thereby affording point-of-use filtration in the strictest sense of this term.

In most cases, the filter pore size required for submicron particle retention is smaller than that necessary to achieve laminar flow control, which is the primary function of the membrane. Hence in using a membrane which performs the dual function of particle filtration and flow control, the resultant pressure drop will be greater than for a membrane intended only for laminar flow control. Because of the increased pressure drop, it may be necessary mechanically to support the membrane against the pressure imposed thereon. This may be accomplished by means of a perforated supporting screen 20, as shown in FIG. 2, which is placed close against the face of the filtration impedance and downstream with respect thereto, the large openings in the screen and the spacing therebetween being such as not to interfere materially with the dual function of the impedance.

While in some applications, an impedance may be permanently installed in the vessel, particularly where a separate particle filter is used in conjunction therewith, where the impedance performs the dual function of filtration and of laminar flow control, it is preferable that the assembly shown in FIG. 1, be of the type which facilitates dismantling thereof and replacement of the membrane when its useful life or particle retention capability has been exhausted and when consequently, the limit of convenient pressure differential across the impedance has been reached.

In practice, it has been found that the requirement for a uniform flow of ultrapure water filtered to 0.35 microns absolute, is effectively met through the use of a particle filter membrane of 0.35 microns absolute pore size, with a support screen placed against its surface on the downstream side. These two elements are clamped together between the upper and lower sections in the process vessel assembly. The influent water enters the work zone through this impedance to produce a laminar flow rinse thereabove, uniform flow and submicron filtration being concurrently achieved.

Referring now to FIGS. 3 and 4, there is shown a process vessel for drying parts with a heated inert gas, such as nitrogen, the arrangement being such that the gas flow is laminar in order to effect an efficient drying action. The cylindrical process vessel or open tank 21, which may, for example, be formed of stainless steel, is disposed below a top flange 22, a gasket 23 being provided for thermal insulation. Suspended from flange 22 is a rectangular framework 24 whose inner wall is lined with thermal insulation 25.

Surrounding vessel 21 is an electrical heater 26 to preheat the metal vessel. Heater 26 is in the form of a blanket which is vulcanized to the outer surface of the vessel to warm the surface thereof. Since the metal vessel acts as a heat sink, it interferes with the temperature uniformity of the heated gas flowing into the work zone of the vessel, for the gas which is relatively close to the vessel walls, tends to lose more thermal energy than gas which flows in the center of the vessel. This effect is avoided by preheating the vessel.

The incoming gas is fed by an inlet pipe 27 covered by a thermal and electrical insulating sleeve 28 through a tubular stainless steel gas heater coil 29 into a pressure chamber 30 mounted on the bottom of the process vessel. This coil, which is preferably of precleaned stainless steel tubing, is heated by passing current therethrough, this being accomplished by attaching electrodes 31 and 32 at the input and output ends of the coil. These electrodes are connected to the output of a transformer 33 mounted on the base of the framework 24.

The advantage of this arrangement is that it avoids any possibility of contaminating influent gas with oxides and scales from conventional high temperature heating elements. The coil through which the gas flows is made long enough so that it is not necessary to raise its temperature beyond 500° F. in order to provide a mean gas temperature of between 300° F. and 400° F.

To maintain the desired temperature level, a temperature sensor 33 is disposed within pressure chamber 30. Sensor 33 acts to sense the temperature of gas entering the chamber and to control the power supply so as to vary the current fed to the coil to govern the desired temperature level. Also included in the system is a limiting thermostat 34. Thus, the use of a separately heated and temperature controlled process vessel makes it possible to adequately regulate the gas temperature level and to maintain a uniform temperature within the work zone.

Mounted on top of pressure chamber 30 is a porous membrane 35 which is held thereon and sealed in position by a clamping ring 36. Disposed below membrane 35 within the

pressure chamber is a diffuser screen 37 which serves to break up the inflowing gas stream to prevent the gas from directly striking the membrane. Condensate collected in the bottom of the process vessel is discharged through a drain pipe 38.

Thus the incoming gas which fills the container, filters through the membrane into the work area thereabove, the membrane producing a pressure differential and hence laminar flow in the work area. In practice, membrane pore sizes, depending on the application, may range from 0.1 microns to 200 microns.

While there have been shown and described preferred embodiments of laminar flow rinsing and drying vessels in accordance with the invention, it will be appreciated that many changes and modifications may be made therein without, however, departing from the essential spirit of the invention as defined in the annexed claims.

I claim:

1. A process vessel for treating small parts with a continuously flowing fluid, said vessel comprising:
 - A. a tank having an opening to receive parts to be treated in a work zone, means to support said parts within said zone for treatment by said fluid, and outlet means disposed above said support means to permit the fluid after treating said parts to be discharged from said tank;
 - B. a porous membrane disposed in said tank to define a pressure chamber below said work zone; and
 - C. means to supply said fluid into said pressure chamber in directions displaced from said membrane to prevent the fluid from striking the member directly, said membrane having an impedance characteristic creating a pressure differential between said pressure chamber and said work zone to produce a substantially laminar flow in said work zone.
2. A vessel as set forth in claim 1, wherein said means to supply said fluid into said pressure chamber includes a diffuser placed in the pressure chamber in the path of the incoming fluid to break up the fluid stream to divert it from the membrane and to minimize strain on the membrane.
3. A vessel as set forth in claim 1, wherein said fluid is a liquid and said membrane has a pore size to filter submicron particles from the liquid passing therethrough.
4. A vessel as set forth in claim 3, wherein said membrane has a pore size of about 0.35 microns.
5. A vessel as set forth in claim 1, wherein said membrane has a pore size in the range of 0.1 microns to 200 microns.
6. A vessel as set forth in claim 1, wherein said tank is formed by separable upper and lower sections, with the membrane being clamped therebetween, the lower section defining the pressure chamber and the upper section the work zone.
7. A vessel as set forth in claim 6, wherein said sections are made of glass.
8. A vessel as set forth in claim 6, wherein said outlet means includes a series of circumferential overflow slots adjacent the upper end of the upper section.
9. A vessel as set forth in claim 1, further including a perforated supporting screen above said membrane to protect same.