

[54] **EXHAUSTLESS CLEAN ROOM WORK STATIONS**

[75] Inventor: **Howard M. Layton**, Pound Ridge, N.Y.

[73] Assignee: **Interlab, Inc.**, Pleasantville, N.Y.

[22] Filed: **July 8, 1971**

[21] Appl. No.: **160,664**

[52] U.S. Cl. **62/126, 62/78, 62/85,**
98/115, 98/36, 62/129, 34/73, 62/93

[51] Int. Cl. **F25b 49/00**

[58] Field of Search 34/72, 73, 79, 82,
34/27, 32, 130, 131, 132, 76, 77, 78; 62/78,
85, 93, 126, 129; 98/115 LH, 36

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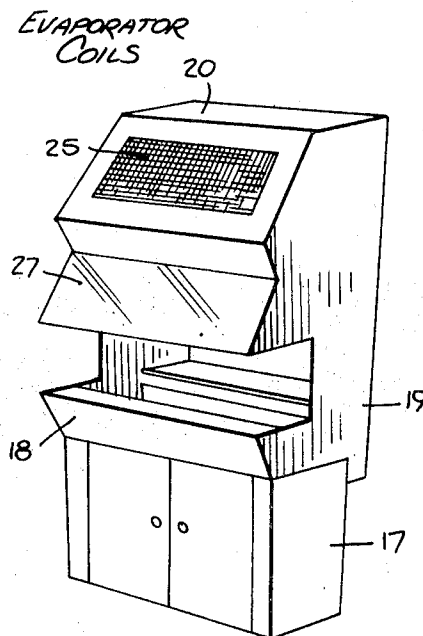
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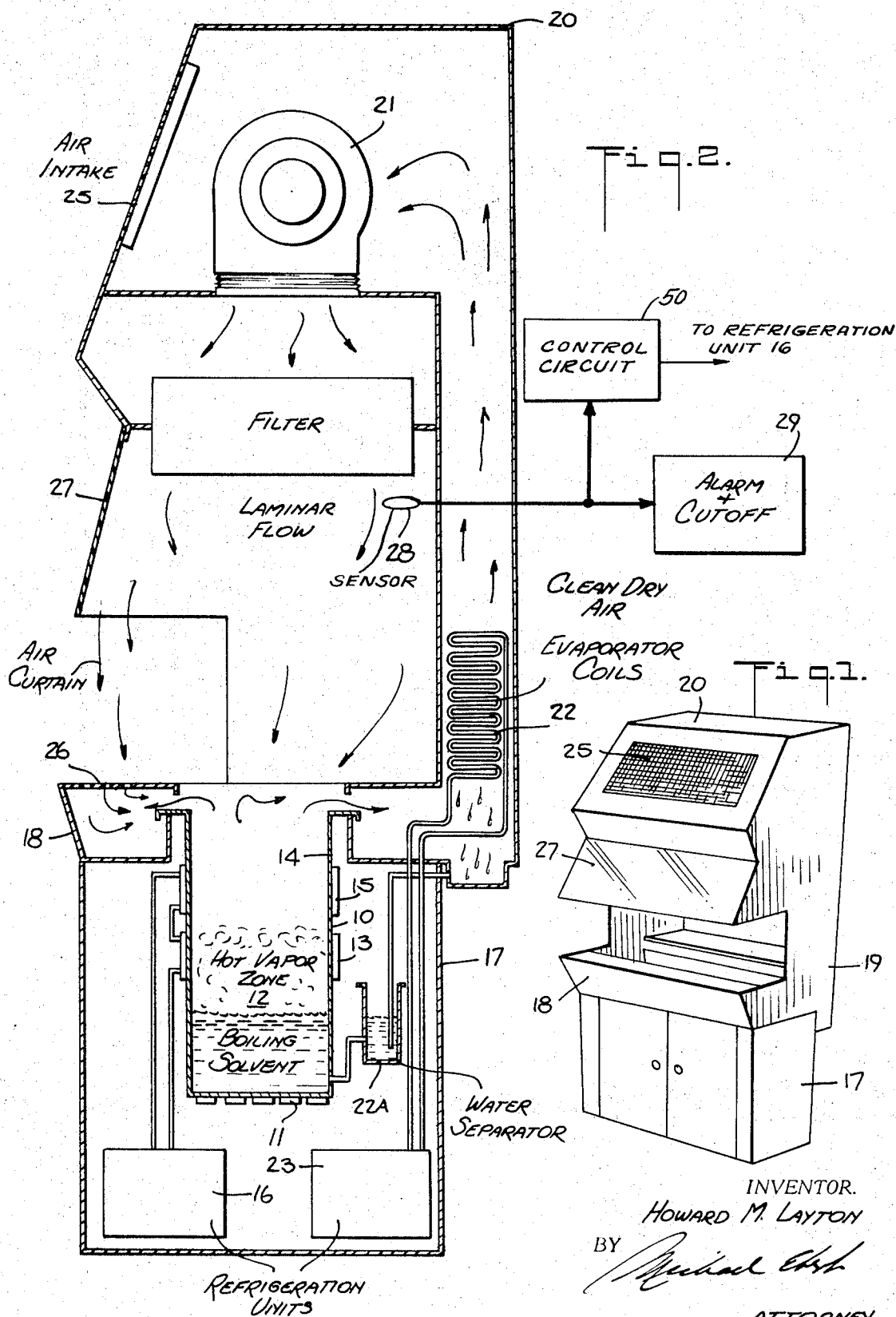
Primary Examiner—William J. Wye
Attorney—Michael Ebert

[57] **ABSTRACT**

An exhaustless clean room work station in which work to be treated is subjected to a vapor-generating wet process, which vapor contaminates the atmosphere. To maintain clean room standards, the vapor produced at the station is drawn through a chimney containing chilling coils or other means functioning to condense the vapor to form a liquid which is returned to the process, the resultant dry air being forced through a sub-micronic filter to remove particulate matter therefrom before the air is returned to the station.

10 Claims, 3 Drawing Figures





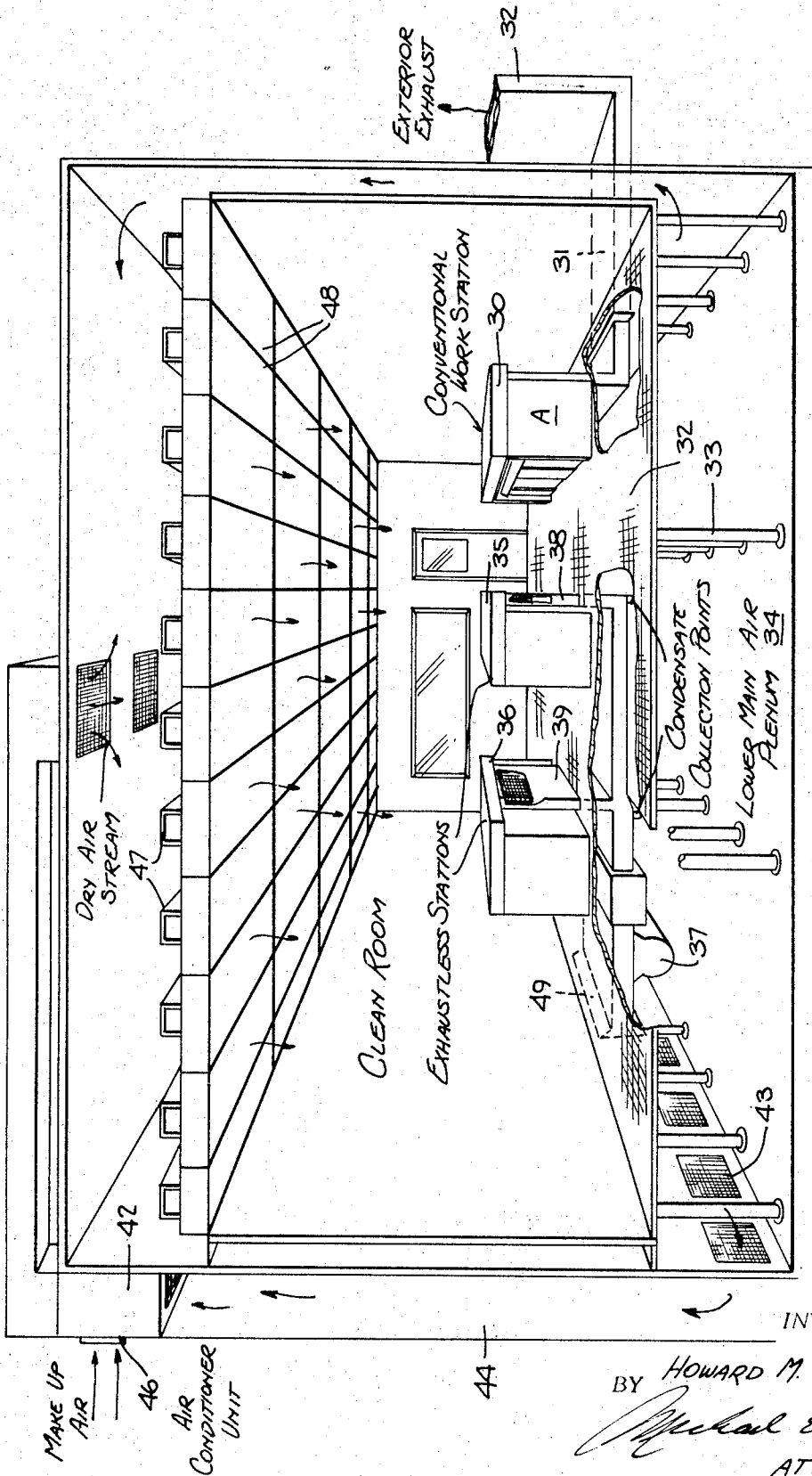
INVENTOR.

HOWARD M. LAYTON

BY

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ATTORNEY



EXHAUSTLESS CLEAN ROOM WORK STATIONS

BACKGROUND OF THE INVENTION

This invention relates generally to clean rooms, and more particularly to exhaustless work stations for critical applications in "Class 100" clean room environments.

Clean rooms serve as work areas wherein control is exercised over contaminating material subject to airborne transport. The degree of control depends on the particular operations performed in the clean room area. Clean room air is degraded by the presence of people in the area as well as by activities and material that generate particulate matter and fumes.

With the advent of micro-electronics, cleaning and wet processing standards have been rendered far more critical, so that ordinary air-conditioned environments suitable for less sophisticated applications have been deemed inadequate for most applications in the micro-electronics field.

The production of micro-electronic 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 any 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.

Critical cleaning steps are, therefore, entailed, as for example, cleaning prior to etching of semiconductor substrates. If the cleaning process is carried out imperfectly, the etching will be impaired and the yield will be poor. To ensure effective cleaning, use is made of elaborate washing, rinsing and drying machines including degreasing and other vapor-producing machines.

In order to provide a controlled environment for laboratory and manufacturing processes in the micro-electronics industry and for sophisticated aerospace technology applications, clean rooms have been developed which make use of heavy-duty, expensive air-conditioning systems that function not only to govern humidity and temperature conditions, but also incorporate means for eliminating dust, lint, fibers and other forms of particulate contamination so as to afford uniform contamination-free processing conditions for the highly critical work involved.

Government committees in collaboration with industrial groups have established certain standards for clean environments. Of these, the most critical now in general use as a clean-room specification, is Federal Standard No. 209A, Class 100, more simply known as a "Class 100" environment. The standard imposed by Class 100 is such that to comply therewith, the environment must not exhibit more than 100 particles larger than 0.5μ in size, per cubic foot of air.

In one typical clean room manufactured in compliance with this standard, the air stream flowing through the room first passes through a bank of particulate filters capable of removing all particles down to 0.3μ in size. In some of these arrangements, the filter banks are disposed across one end wall of the room. In another design which is becoming increasingly popular, the filter banks are overhead, whereas the air flows vertically downward through an open-mesh floor, to be

collected in a lower plenum from which it is returned to the starting point and re-used.

Individual work stations have also been developed to provide Class 100 environments for the processes housed therein. The use of banks of such work stations offers a feasible alternative to the use of a work room in which the entire atmosphere is subjected to continuous sub-micron filtration. Such self-contained Class 100 work stations are designed for critical applications in the electronics, instrumentation, chemical, pharmaceutical and other sophisticated industries.

The individual Class 100 work station, as above described, is also popularly referred to as a laminar flow hood or as a clean work station. Depending on the intended use, the flow of air into the work area of the station, is arranged to be vertically downward, horizontally forward from the rear of the work area. In another arrangement, a combination of both vertical and horizontal air flow patterns is used. To provide Class 100 conditions in the work area of the station, the air stream which is forced into the work area from above or from the rear, is caused to pass through a bank of sub-micron filters so that particulate matter is removed, and after leaving the work area, the air stream is then dispersed into the external room atmosphere.

In the case of the horizontal laminar flow hood, the air flow path is directed to the front of the work area and as this is open to the room environment, diffusion of the clean air stream into the environmental air is automatic. For the vertical laminar flow arrangement, the surface of the work bench is usually perforated so that the downflow clean air stream can pass directly through the work area to be dispersed through the understructure of the console and thence to the environment again.

The above-described Class 100 laminar flow consoles are only suitable for applications which do not introduce contamination into the air stream. These would include assembly, adjustment, inspection and test procedures, but would exclude most of the wet chemistry processes encountered in micro-circuit work.

Laminar flow consoles which provide a Class 100 environment for micro-circuit processes, such as etching, developing, stripping and critical cleaning, also incorporate means for collecting all of the air that has passed through the work area, and for transferring this air to a fume exhaust system so that it will not be re-mixed with the room environment. The same is true of wet chemistry processes installed in a Class 100 clean room, for again, the air which encounters the work area and becomes contaminated with vapors emanating from aqueous and solvent processes, is continuously drawn through openings in the work surface itself for subsequent transfer to a fume exhaust network.

It is important to note that the clean ambient air which flows through a Class 100 room is seldom discarded after leaving the room area. Bearing in mind that such air has been pre-conditioned and sub-micron filtered at relatively high cost, it is usually an economic necessity to recirculate the entire air volume and re-use it continuously. Since the room itself is maintained at a moderate positive air pressure, there is some loss through access doors as well as through the fume ex-

haust networks which are associated with the wet chemistry processes. Arrangements are made to supply makeup air through the air-conditioning system of the room, to offset these losses.

From the foregoing, it will be evident that chemical vapor contamination levels which would be acceptable in ordinary environments, cannot be tolerated at all in clean room applications. Chemical vapors lost to the room environment are not dispersed. They are, for the most part, trapped and recirculated with the main body of room air and the mean vapor concentration therefore builds up in the course of a working day to levels which would not be encountered in ordinary environments. Further, a stratification effect is sometimes experienced and this can result in some areas of a clean room harboring heavier concentrations of contaminating vapors than others.

To make matters worse, it has been reported that the health hazard is not the only criterion to be taken into account in the design of chemical vapor control systems for Class 100 applications. Many micro-circuit processes are themselves much more sensitive to vaporous contamination than are humans. For example, a very low concentration of vapors of certain halogenated hydro-carbons can, when impinging on hot surfaces such as baking ovens and hotplates, produce by-products harmful to metallic deposition work. Similarly, relatively low chemical vapor concentrations can, by cross-contamination, interfere with etching processes and with the efficacy of critical cleaning and drying procedures.

Hot solvent processing and vapor degreasing are widely used in cleaning procedures in micro-electronic applications, but for critical Class 100 processes, it becomes necessary to install these machines in vertical laminar flow consoles equipped with suitable fume exhaust facilities.

The conventional free-standing vapor degreaser has no place in such applications because a laminar flow of clean air moving continuously through the work area (at 50 to 100 feet per minute) would entrain more vaporous contamination than could safely be released into the environment. Whether the console is fitted with an individual clean hood for Class 100 filtration, or whether it is simply provided with an air collection plenum for use in a vertical flow Class 100 clean room, there is always a forced air exhaust chimney connected to the console to transfer the contaminated air to a factory exhaust system.

Thus with vapor-generating work stations in which the contaminated air is exhausted, there is a loss of conditioned air, the volume of which must be replaced and reconditioned. Where a clean room makes use of several stations of this type, the demand imposed on the air-conditioning system is very heavy, thereby considerably raising the cost of maintaining a clean room.

SUMMARY OF THE INVENTION

In view of the foregoing, it is the main object of this invention to provide a clean room having work stations therein which emit contaminating vapor and moisture into the work area, the contaminated air from the stations being re-purified, recirculated and reused in an exhaustless system.

More specifically, it is an object of this invention to provide an exhaustless work station in which work to be treated is subjected to a wet chemical process giving rise to residual vapors in the work area, which vapors are drawn through into a cooling chimney wherein the vapors are condensed and the resultant liquid removed, the dry air being filtered to extract particulate matter before being returned to the process work area for reuse.

Because of its "post-treatment" method for removing residual contaminants from the air stream, the system in accordance with the invention, is easier to control in that residual vapor removal is effected after variable factors such as work-basket movement and drag-out turbulence have taken place. Moreover, the forced air movement imparted to air withdrawn from the work station can, with appropriate design, result in an optimum dispersion of the exit stream into the ambient atmosphere, and hence afford a double safeguard against the build-up of hazardous vapor areas.

In addition, a system in accordance with the invention has the following practical advantages:

a. Since all residual vapors from the process work area must pass through the cooling and vapor removal chimney, reliable monitoring of the final contamination level of the effluent air stream and its continuous influence on the environment, is greatly facilitated.

b. Connection to a fixed plant exhaust-forced air system is avoided. This is of particular significance where an exhaust network does not already exist.

c. Independence from a fixed plant exhaust connection results in mobility of equipment — comparable with the mobility of free-standing vapor degreasers of the type used where exhaust and toxicity regulations are not stringent.

d. Whereas conventional exhaustless vapor degreasing machines are likely to produce ambient vapor concentrations in excess of 100 parts per million in the general environment around the work area, concentrations produced by a system designed in accordance with the present invention are easily limited to less than 20 parts per million (using trichlorethylene for reference purposes).

OUTLINE OF THE DRAWING

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 a perspective view of a preferred embodiment of an exhaustless work station in accordance with the invention;

FIG. 2 is a sectional view of the work station; and

FIG. 3 is a perspective view of a clean room including exhaustless work stations in accordance with the invention.

DESCRIPTION OF THE INVENTION

Referring now to FIGS. 1 and 2, there is shown a laminar flow, exhaustless work station in accordance with the invention, which station includes a tank 10 for vapor degreasing of work pieces placed therein.

Degreasing machines utilizing a volatile solvent are customarily employed for flushing grease, wax, dirt or other foreign matter from metal parts, in order to

produce a chemically-clean surface for the purpose of preparing the parts for subsequent fabrication, plating and other operations. Among the volatile solvents commonly used in degreasing machines are trichlorethylene, perchlorethylene and other chlorinated solvents. Trichlorethylene has a boiling point of about 188° - 190°F, the vapor of which is several times heavier than air. Also in use for degreasing are fluorocarbon solvents.

In order to prevent the escape of such vapor from the open tank in which the parts to be cleaned are admitted, the tank is usually provided with cooling coils in the upper region thereof. The cooling coils act to chill and condense the vapor, the condensate being returned to the liquid in the lower region of the tank where it is reheated. Thus, the distillation cycle is closed and solvent loss is minimized.

Various methods are currently in use with open-tank degreasers. In the vapor method used in micro-electronics, work is suspended in the vapor region above the boiling solvent, the solvent condensing on the cooler parts with impurities dripping away with the condensate. Particulate matter may be removed by a solvent spray in the vapor region.

In the two-stage degreasing method, vapors condensed by the cooling jacket or coils are collected in a trough in the form of fresh distillate and then transferred in a continuous stream to the "dip" tank which in turn, continuously overflows into the boil tank to complete the cycle. The work is first submerged in the overflowing distillate tank and then elevated in the vapor zone for rinsing off. The present invention, for reasons of simplicity, will describe a vapor method degreaser, but it is to be understood that the invention is applicable to all vapor-generating machines as well as to wet processing machines in general.

In the degreaser machine shown in FIG. 1, the solvent contained in the sump of tank 10, is heated by suitable heater elements 11, to create a vapor in a work zone 12 directly above the solvent pool. The parts to be cleaned are supported within the zone in a work basket or by other means appropriate to the work being treated.

The bulk of the solvent vapors is confined within the upper region of the tank by means of a set of cooling coils or a cooling jacket 13, located at the upper boundary of the hot vapor zone 12. Vapors which rise into this chilled region are immediately condensed back into heavier driplets, thereby being prevented from rising to the top of the vapor-degreasing vessel and escaping into the ambient air. The condensed vapors fall directly back into the boil sump for recycling.

In addition, a separating zone or freeboard 14 is established between the chilled vapor line and the open top of degreasing tank 10. This helps to minimize disturbance of the solvent vapor zone by atmospheric air movement and by the routine transposition of work baskets. The freeboard behaves as a buffer zone between the hot vapor region and the outside atmosphere and prevents excessive drag-out of vapor when work baskets are raised out of the vessel.

Condensation of vapors rising into the buffer zone is effected by a secondary coil or cooling jacket 15 surrounding the freeboard, the condensed vapors being collected in a suitable trough and returned to the sol-

vent pool. Cooling jackets 13 and 15 are supplied by a standard refrigeration unit 16. In practice, the secondary cooling jacket 15 is operated at a somewhat lower temperature than the primary jacket 13. This has the effect of further chilling the air in the freeboard zone, thereby trapping more of the residual low concentration vapors before they can reach the lip of the tank.

Notwithstanding the fact that the vapors are condensed by both primary and secondary jackets and that great care is exercised in modern vapor degreaser designs to prevent the escape of vapors into the atmosphere, the final ambient contamination level is still materially influenced by operating procedures and by the particular ambient air movement conditions of the work station location.

Vapors emanating from vapor degreasers or other vapor-producing machines, are considered somewhat toxic and hazardous to health unless their concentration is controlled and limited in accordance with certain established standards. Limit values for a few of the most common solvents are listed in the table below. The figures appearing in the table represent the maximum permissible vapor concentration to which human operators may be exposed on a continuous basis without ill effect. Laws governing solvent vapor control in industrial processes, vary from State to State, but the figures given are commonly used. (Ref. American Conference of Governmental Industrial Hygienists).

1968 THRESHOLD LIMIT VALUES
American Conference of Governmental Industrial Hygienists

Substance	Threshold limit value	
	Parts per million by volume	Milligrams per meter
Carbon dioxide.....	5,000	9,000
Freon TF.....	1,000	7,600
Ethyl alcohol.....	1,000	1,900
Methyl chloroform.....	350	1,900
Methylene chloride.....	500	1,740
Hexane.....	500	1,800
Perchloroethylene.....	100	670
Trichloroethylene.....	100	535
Chloroform (ceiling).....	50	240
Benzene (ceiling).....	25	80
Carbon tetrachloride (skin).....	10	65

Because of the possible health hazards involved, and the fact that the vapors entering the clean room atmosphere are contaminating, it has heretofore been the practice to couple vapor degreasers or other vapor-producing machines to a forced air, outside exhaust system. Since the air discharged from the room is conditioned air, this increases the demand imposed on the conditioning system and adds significantly to operating costs.

To avoid these drawbacks, and to provide an exhaustless system for the degreaser, a console is provided including a cabinet 17 for containing the degreaser machine and the associated refrigeration units. Tank 10 is vertically suspended from a plenum 18 mounted on top of cabinet 17, the plenum being coupled to a

rear chimney 19 leading to an overhead hood 20 having air blower 21 mounted therein.

Thus in operation, the vapors in the air above the open mouth of the tank 10 are not permitted to flow into the clean room, but are drawn by blower 21 up chimney 19, as shown by the flow-direction arrows. Placed within chimney 19 are evaporators or cooling coils 22 which are coupled to a second refrigeration unit 23 installed in cabinet 17 below the processing tank. In practice, the heat generated by refrigerator units 16 and 23 may be applied to the bottom of tank 10 to supplement the heat furnished by heater elements 11, rather than being wasted.

Thus residual vapors and moisture in the air drawn from the top of the tank are condensed by chimney coil 22, and the resultant liquid is conducted to a water separator 22A which is adapted to segregate the cleaning solvent from the water, the cleaning solvent being returned to tank 10 for recycling and the water being fed to a drain. Thus the upwardly flowing air stream at the output of evaporator coil 22 is dry, being free of solvent vapors and moisture.

The forced dry air at the output of blower 21 is directed toward a sub-micron or a so-called HEPA filter 24 having minute pores therein, which act to trap substantially all particulate matter in the air blown therethrough, and to render the pure, clean air emitted therefrom, laminar in nature. The console arrangement is made such as to facilitate replacement of the filter when it is clogged with dirt.

Also provided in the hood is an adjustable air-intake grill or louver 25 which permits intermixing of the air drawn up chimney 19 with conditioned air from the clean room. Since very little makeup air is required, grill 25 is provided with a suitable damper. On the upper surface of the plenum 18, adjacent the front thereof, are adjustable openings 26. Clean air flows downwardly from filter 24 through openings 25 into plenum 18 at relatively high velocity to define an air curtain that acts as a barrier to prevent contaminated air from entering the room atmosphere so that all fumes from the processing tank are compelled to enter the chimney for treatment. To minimize turbulence, the air collection plenum may incorporate suitable dampers for this purpose. The work area is made visible by means of a clear acrylic window 27.

In order to be sure that no toxic fumes succeed in escaping from the tank, a monitoring sensor 28 is provided which is set to provide a signal when the contamination level (parts per million) exceeds a predetermined safety point. This signal may be used to trigger an alarm 29 and to automatically cut off the degreaser heater. Or the safety signal may be used to control the refrigerator units 16 by means of a suitable control circuit 50 to increase their cooling effect and thereby reduce the amount of residual fumes present in the area above the degreaser tank.

Though the exhaustless console, in accordance with the invention, has been described in connection with a vapor degreaser, it is fully applicable to other wet chemistry processes, especially those operated at elevated temperatures and acting to release significant quantities of contaminating vapor into the incident air stream.

In many critical micro-electronic applications, it is even necessary to discard air which has become heavily laden with plain water vapor because failure to do so would place an excessively heavy burden on the air-conditioning system in use. Or the ambient humidity levels might reach an unacceptable level for the processing sequences involved. In this case, the invention provides a point-of-use de-humidifying service, permitting recirculation and re-use of the same air. Many other wet chemistry processes including acid etches, photo-resist stripping processes, etc. can be dealt with in the same way so as to eliminate the need for a permanent plant exhaust connection.

In clean rooms employing two or more wet processing stations, it may be more efficient to make use of a combined exhaustless purification system common to the several stations, rather than making each station a self-sufficient exhaustless system of the type illustrated in FIGS. 1 and 2.

FIG. 3 illustrates both a combined, exhaustless purification system for several work stations in a clean room as well as a conventional exhaust-type system typical of the prior art. In FIG. 3, work station A represents a conventional wet chemistry exhaust-type console having an air plenum 30 thereabove, which is coupled by a duct 31 to an exterior exhaust chimney 32 which discharges fumes into the atmosphere. The air volume exhausted by this arrangement must be replaced in the clean room by a freshly air-conditioned, filtered make-up air supply.

The wet-processing work stations B and C incorporate point-of-use vapor removal consoles in accordance with the present invention, thereby obviating the need for factory exhaust connections and also avoiding the imposition of an extra load on the main air-conditioning system.

The clean room is housed in a chamber having a raised open-grid floor 32, supported on posts 33 above the base of the structure to define a lower main air plenum 34. Work stations B and C are provided at their tops with individual plenums 35 and 36, respectively.

An air blower 37 is coupled by chimneys 38 and 39 to individual plenums 35 and 36 to provide negative pressure for work stations B and C. This blower acts to draw the contaminated air from these work stations through vapor-removing refrigerated coils 40 and 41, respectively.

The air in the clean room is properly conditioned by an air-conditioner unit 42 which draws air from the lower main air plenum 34 through grills 43, the air being forced upwardly through passage 44 and being passed into an upper main plenum 45 together with makeup air drawn from the exterior through inlet 46.

In the upper air plenum 45, a bank of blowers 47 forces the conditioned air through sub-micron filters 48 back into the clean room for recirculation. It will be seen that the output duct 49 of the suction blower 37 coupled to work stations B and C leads to passage 44, so that the air processed in chimneys 38 and 39 of these stations remixes with the main recirculating air stream at this point. Sensors may be placed at the remixing point to produce a signal when the contamination level is unacceptable. This signal is arranged to actuate a duct switching assembly (not shown) to cause the air exhausted from consoles B and C to be directed to an outside exhaust system.

Thus, in lieu of separate blowers and sub-micron filters for each wet processing work station, an exhaustless system is provided in the clean room in which the blowers and particulate filters are common to two (or more) work stations exuding vapors. The essential operating principles of this arrangement are no different from those involved in the self-contained, single-station system illustrated in FIGS. 1 and 2.

While there have been shown and described preferred embodiments of an exhaustless clean-room work stations, 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.

I claim:

1. In a clean room an exhaustless work station comprising:

- A. a wet-processing machine for treating parts with a liquid, said machine emitting residual vapors into the air in the vicinity of the machine,
 - B. means including a chimney coupled to said machine for drawing the air containing said residual vapors therefrom,
 - C. means in said chimney to condense said vapors and thereby produce a dry air stream in the output of said chimney, and
 - D. means to force said dry air stream through a filter to remove particulate matter therefrom to produce clean, dry air and to direct same to said clean room
2. An arrangement as set forth in claim 1, further including means to return the liquid derived from said cooling device to said machine for re-use therein.
3. An arrangement as set forth in claim 1, wherein said condensing means are constituted by refrigerated coils.

4. An arrangement as set forth in claim 3, wherein said machine is a degreasing machine including a tank for containing a volatile cleaning liquid, said tank having heating means to create a vapor zone and being provided with a cooling jacket at a point adjacent said zone to cool and condense said vapors, whereby the vapors emitted from the machine are residual vapors not condensed by said jacket.

5. An arrangement as set forth in claim 4, further including an air plenum mounted above said tank to collect said residual vapors, said chimney being coupled thereto.

6. An arrangement as set forth in claim 4, further including a freeboard secured to said tank above said zone and provided with a secondary cooling jacket to cool and condense vapors escaping beyond the first cooling jacket.

7. An arrangement as set forth in claim 6, further including a first refrigeration unit operatively coupled to said cooling jackets, and a second refrigeration unit operatively coupled to said refrigeration coils.

8. An arrangement as set forth in claim 5, further including apertures in said plenum to create an air curtain for effectively isolating said machine from the atmosphere in the clean room.

9. An arrangement as set forth in claim 5, further including a sensor disposed above said plenum to detect the level of vapor present and to increase the cooling effect of said cooling jacket when the level exceeds a predetermined safety point.

10. An arrangement as set forth in claim 1, further including additional wet-processing machines, each having said chimney and said condensing means, said means to force said dry air stream through a filter being common to all machines.

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