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APPARATUS AND METHOD FOR REMOVAL OF OIL ENTRAINED IN AIR

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FIG. 1

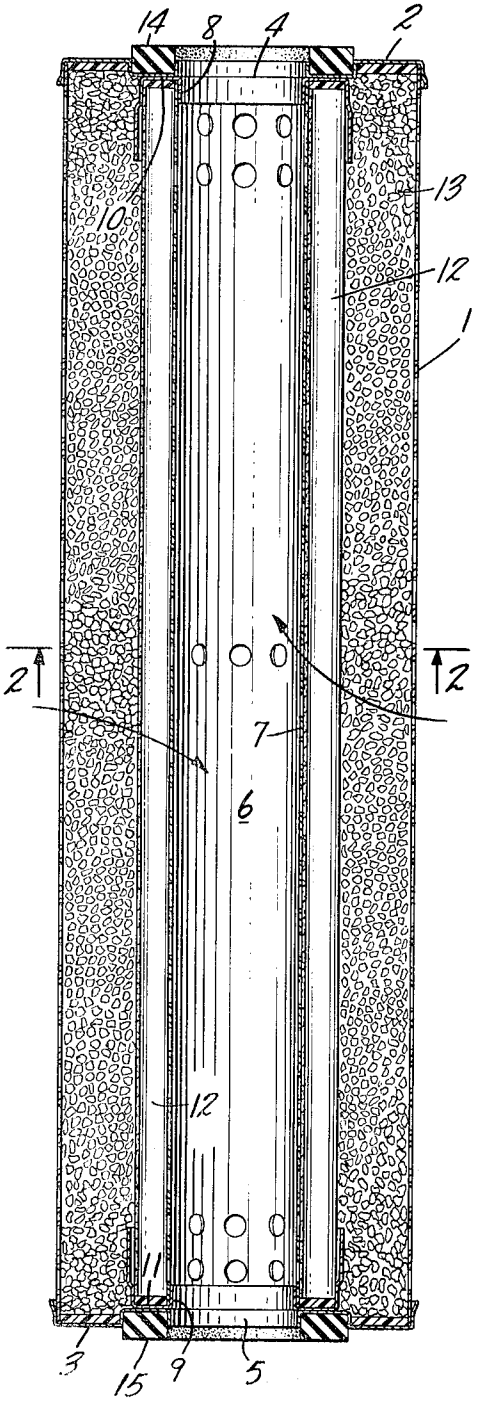
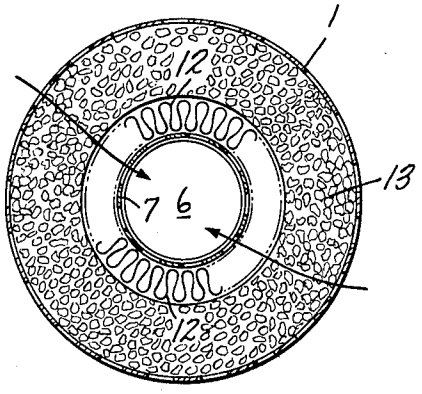


FIG. 2



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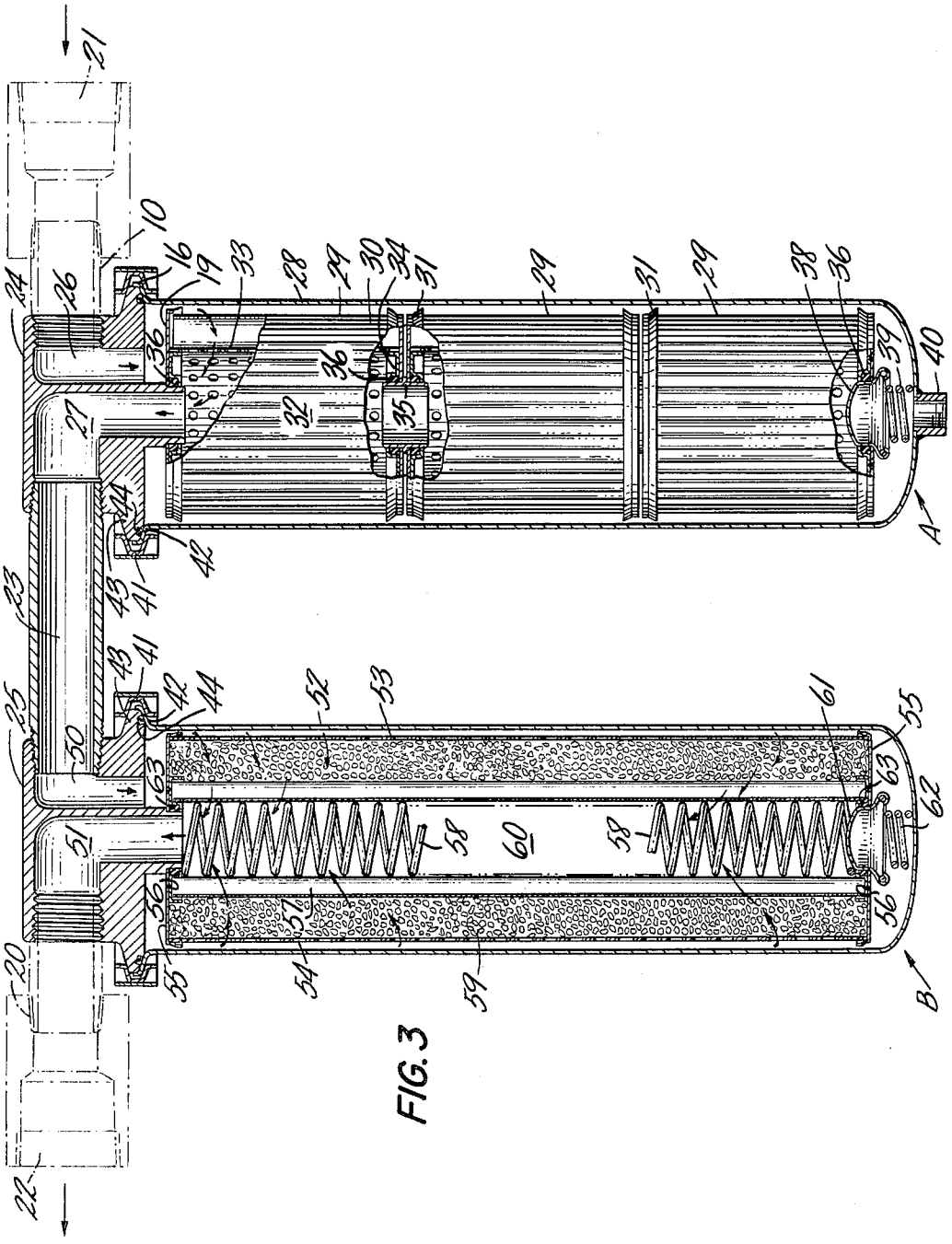


FIG. 3

United States Patent Office 3,252,270 Patented May 24, 1966

3,252,270

APPARATUS AND METHOD FOR REMOVAL OF OIL ENTRAINED IN AIR

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Filed Oct. 1, 1962, Ser. No. 227,380
19 Claims. (Cl. 55—74)

This application is a continuation-in-part of application Serial No. 74,130, filed December 6, 1960, now Patent No. 3,158,532 issued November 24, 1964, and copending applications Serial Nos. 98,595, filed March 27, 1961, and 215,151, filed August 6, 1962.

This invention relates to apparatus and to a method for removing oil entrained in air, and particularly, oil entrained in compressed air.

Compressed air is utilized in a great many industrial applications, and many types of equipment for compressing air are in use, such as compressors of the reciprocating piston type, rotary compressors, turbines, and the like. Such compressors are lubricated with petroleum hydrocarbon lubricants. During compression, air temperature is raised, generally in the range of 400° to 700° F. or higher for air compressed by a factor of more than four in a single stage. At these high temperatures, some of the lubricating oil vaporizes, and many of the components of the vapor react with each other and with air to form a wide range of organic products including oxygenated and partially oxygenated compounds, nitrogen compounds, and hydrocarbons in the low to intermediate molecular weight range. Such vapor phase contaminants are in addition to liquid phase lubricants that are mechanically entrained in the air.

As a result, air compressed in conventional fashion generally contains from about 5 to 25 parts per million parts of air by weight of lubricating oil-derived contaminants, varying from non-condensible hydrocarbon gases to droplets of lubricant 25 microns or more in diameter. In many industrial applications, the presence of even trace quantities of such contaminants is extremely objectionable. For example, the presence of such contaminants in air used in pneumatic instrument control systems causes orifices and moving parts to become covered with oil, thereby leading to dust collection and consequent instrument malfunction. Flow meters of some types will offer false data if coated with oil. As little as 3 parts per million of hydrocarbons entrained in air at high pressures, for example 3000 p.s.i., can form an explosive mixture. It is particularly essential that air or other inert gases used for compressing oxidizing agents such as liquid oxygen, nitric acid, or hydrocarbon peroxide, be free of hydrocarbons to avoid possibility of explosion. Compressed air intended for human breathing, as, for example, in underwater diving equipment, should be free of all potentially harmful contaminants. In chemical processes, oil in compressed air added to a reactor can introduce impurities or change the course of the reaction. Sewage disposal units require compressed air free from entrained oil in order to prevent buildup of sludge.

Different approaches are in use to obtain substantially oil-free compressed air. A compressor which does not need oil lubrication can be used, such as a liquid-packed ring type rotary compressor. This type of compressor, however, gives a much lower maximum pressure than a piston type compressor. Diaphragm type and carbon ring compressors are generally considered to involve overly great expenditures, both in initial cost and for maintenance.

It has been proposed to filter oil from compressed air. However, oil entrained in air is composed of a plurality

of droplets having varying sizes, ranging from a diameter of more than 25 microns down to molecular dimensions. While filtration is adequate to remove larger sized droplets, droplets of the order of magnitude of about 0.3 micron and higher, no filter has been available which has been capable of removing smaller sized droplets without at the same time causing an unduly large pressure drop in the air being treated. The pressure drop problem is particularly noticeable when air at a pressure greater than about 25 p.s.i.g. is being treated since conventional low pore size-high voids content filter media are generally incapable of resisting such high pressures, necessitating resort to more rigid, much less porous filter media such as ceramic filters. Ceramic filters, while capable of withstanding high pressures, cause extremely high pressure drops in the air being treated. Despite this, such filters have not been capable of removing vaporized impurities in the air or even liquid droplets in the size range of 0.05 micron and smaller.

Activated carbon beds or beds of other sorbents remove entrained vapors and droplets smaller than about 10 to 20 Angstrom units (.001 to .002 micron), but have no effect on larger droplet sizes. Conventional filters having a sufficiently high degree of porosity to minimize pressure drop and suitable for use in treating compressed air can remove only droplets larger than about .3 to 3 microns in diameter, depending upon the pore size of the filter. Hence, a combination of an active carbon bed and a conventional filter removes droplets of 0.3 to 3 microns in diameter and larger, and droplets of less than .001 to .002 micron in diameter but has substantially no effect on droplets which are larger than about .001 to .002 micron but smaller than about .3 to 3 microns.

The proportion of oil droplets entrained in compressed air having diameters within the range of .0015 to 1.5 microns has been found generally to range from 5 to 30% by weight of the total oil content entrained in the air. Accordingly, if the original oil content of the compressed air were 20 parts per million by weight, the use of a conventional filter plus an activated carbon bed would fail to remove from 1 to 6 parts per million of entrained oil, a residual oil content much too large for many applications.

By means of the apparatus and method of this invention, substantially all of the oil and hydrocarbons higher than methane in molecular weight entrained in compressed air can be removed. This invention is particularly applicable to compressed air having a pressure greater than 25 p.s.i.g.

The method of this invention comprises two essential treatment steps: passing the compressed air through a pleated high area microporous filter element of the fibrous depth type having an average pore size of less than 1 micron and a voids volume of at least 75 percent and contacting the compressed air with a sorbent capable of sorbing hydrocarbon vapors. The two steps can be carried out in either sequence. The air can be first contacted with the sorbent and then passed through the microporous filter element or vice versa. Each sequence has certain advantages as will be seen from the following description. Optionally, the two essential steps can be preceded by an additional filtration step in which a conventional filter is employed.

The microporous filter should have an average pore size of less than about 1 micron and preferably an average pore size of less than about 0.5 micron. Microporous filters having average pore sizes greater than about 1 micron are not satisfactory for removing oil entrained in compressed air, since they permit the passage of oil droplets which are not ordinarily removed either by the conventional filter, if one is employed, or by the sorbent. There is no effective lower limit on the pore size of the

microporous filter, except that imposed by an excessive pressure drop of the air in passing through the filter. This, of course, depends upon the quantity of air, the thickness of the filter, and the oil content and particle size distribution thereof in the air. It has been found, in practical applications, that microporous filters having an average pore size as low as .02 micron and even lower are effective.

It is preferred that the microporous filter element be flexible. Flexible materials exhibit a surprisingly low tendency toward clogging as compared to unflexible filters, such as rigid metallic filters. This may be due to a tendency of the microporous filter to flex under the force of the compressed air, thus expelling ultrafine droplets that might otherwise tend to clog the filter.

The depth or thickness of the microporous fibrous filter is not critical. A thick filter operates efficiently, but it should not create an undue pressure drop.

A preferred microporous filter for use in this invention is made of a porous base, such as paper, having relatively large pores, within or on the surface of which is deposited particulate material in an amount to diminish the average diameter thereof to less than 1 micron while retaining a voids volume in the microporous portion in excess of 75%, as disclosed in copending applications Serial No. 98,595, filed March 27, 1961, and Serial No. 215,151 filed August 6, 1962, the disclosures of which are herein incorporated by reference. The particulate material, which can be in the form, for example, of fibers or fine structured granules, is suspended in a fluid and deposited therefrom upon the surface of the porous base material. The particulate material can all be of the same size and type, or of two or more sizes and types, all suspended in the fluid system. The desired reduction in pore diameter of the base is obtained by varying the size and amount of the particulate material deposited, blending different sizes at different points, if desired. A particularly preferred microporous filter is one of the type described in application Serial No. 215,151, filed August 6, 1962, which comprises a porous base having superimposed thereon and adherent thereto a microporous layer comprising a fibrous material of which a proportion of fibers extend outwardly from the porous base at an angle greater than 30°, the microporous layer having an average pore diameter of less than 1 micron and a voids volume of at least 75 percent. The fiber spacing and angular disposition to the base throughout the entire microporous layer is noted by cross-sectional examination, upon sufficient magnification through an optical or electron microscope. The angular disposition of the fibers is in large measure responsible for the high voids volume and low pore size characteristic of the microporous filters preferred for use in this invention.

When fibers are laid down on a base in a conventional manner, they tend to lie almost entirely in planes parallel to the base. Such conventional fiber layers can be permeable to fluids, and can have a fairly low pore size, but they are universally characterized by low voids volumes, so that their use as filter media is not feasible. The proportion of angularly extending fibers, and the wide spacing of the fibers, both of which are characteristic of the preferred filters, serve to hold the fibers in the layer generally farther from the base, thereby increasing substantially the voids volume of the microporous layer. Since the fibers are relatively small, the interstices between them at their points of crossing will be very small, but since they are held farther apart, their interstices are fewer in number per unit volume. In consequence, the preferred filters have a very small pore size, and a high voids volume.

In order to insure good adhesion between the deposited layer and the base, an anchoring layer can be applied to the base prior to the application of the main layer. Such an anchoring layer is applied by treating the base with an anchoring dispersion comprising a liquid or liquefiable binding agent and a particulate fibrous material which is wetted by the binding agent.

Fibrous material is preferred as the particulate material to be deposited because of its versatility, and because of the greater ease of deposition as a film. A great variety of diameters of fibers are available, thus making it possible to achieve a very large assortment of mixtures of different diameter fibers for making fibrous material of any porosity, and such fibers can be made of any length, so as to take advantage of the greater cohesiveness of a layer of long fibers, as compared to granular material layers. Generally, fibers having diameters of 2 microns or less are preferred. Typical fibrous materials include glass, asbestos, potassium titanate, aluminum silicate, mineral wool, regenerated cellulose, polystyrene, polyvinyl chloride, polyvinylidene chloride, polyacrylonitrile, polyethylene, polypropylene, rubber, polymers of terephthalic acid and ethylene glycol, polyamides, casein fibers, zein fibers, cellulose acetate, viscose rayon, hemp, jute, linen, cotton, silk, wool, mohair, paper, and metallic fibers such as iron, copper, aluminum, stainless steel, brass, Monel, silver, and titanium.

Nonfibrous particulate materials can be used in admixture with fibrous materials. However, in order to achieve the requisite microporosity and voids volume, it is essential to employ at least one part by weight of fibrous material for every three parts of nonfibrous materials. When nonfibrous particles are employed, they should have an average diameter not exceeding 10 microns. Those nonfibrous materials containing a fine internal structure or porosity are preferred.

Typical nonfibrous particulate materials are diatomaceous earth, magnesia, silica, talc, silica gel, alumina, quartz, carbon, activated carbon, clays, synthetic resins and cellulose derivatives, such as polyethylene, polyvinyl chloride, polystyrene, polypropylene, ureaformaldehyde, phenol-formaldehyde, polytetrafluoroethylene, polytrifluorochloroethylene, polymers of terephthalic acid and ethylene glycol, polyacrylonitrile, ethyl cellulose, polyamides, and cellulose acetate-propionate, and metal particles such as aluminum, silver, platinum, iron, copper, nickel, chrominum and titanium and metal alloys of all kinds, such as Monel, brass, stainless steel, bronze, Inconel, cupronickel, Hastelloy, beryllium, and copper. Combinations of diatomaceous earth and glass fibers give excellent results.

Any porous material whose pores extend from surface to surface can be used as a base upon or within which the microporous layer is deposited. One or several layers of the same or varying porosity can be employed and can be composed of cellulose or other fibers. Paper, which can, if desired, be resin impregnated, is a preferred base material since it yields an effective, versatile and inexpensive microporous fluid-permeable medium. Where desired, other base materials can be used, such as porous sintered powders or forms of metals and of natural or synthetic plastic materials, such as aluminum, and synthetic resins and cellulose derivatives, in the form of spongy layers of any desired thickness, such as polyurethane (see Patent No. 2,961,710), polyvinyl chloride, polyethylene and polypropylene sponges and foams, woven wire products, sintered or unsintered, textile fabrics and woven and nonwoven fibrous layers of all kinds, such as felts, mats and bats, made of fibrous materials of any of the types listed below in connection with the particulate material. The porous base material will have an average pore diameter of not less than about 2.5 microns. Such materials will of course have pores as large as 20 to 25 microns, or more.

The fluid medium used for the dispersion is preferably inert to the particulate material and the base material. It should not dissolve a substantial amount thereof, although if the fluid is reused, the fact that some material is in solution is not a disadvantage, since a saturated solution is quickly formed ab initio. The fluid should be volatile at a reasonably elevated temperature below the melting point of the material to facilitate removal after the dispersion is deposited. However, nonvolatile fluids

may be desirable under certain conditions, and those can be removed, by washing out with a volatile solvent that is a solvent for the fluid but not for the particulate material.

Typical fluids are water, alcohols, polyalkylene glycols, such as polyethylene glycols, poly 1,2-propylene glycols, and mono and di alkyl ethers thereof, such as the methyl, ethyl, butyl and propyl mono and di ethers, dialkyl esters of aliphatic dicarboxylic acids, such as, di-2-ethylhexyl adipate and glutarate, mineral lubricating oils, hydraulic fluids, vegetable oils, and hydrocarbon solvents such as xylene and petroleum ether, silicone fluids, chloro, bromo and fluoro hydrocarbons, such as the Freons. Since the final product is permeable to any liquid, depending upon the choice of particulate material, obviously a wide selection of fluids is available, and such would be known to one skilled in this art.

The sorbent with which the compressed air is to be contacted can be of any type known to the art for use in sorbing hydrocarbon contaminants from air. The term "sorption" is inclusive of the processes known as "adsorption" and "absorption," the distinction being that molecules are said to be "absorbed" when they enter the inside of a solid material, i.e., the absorbent, and are said to be adsorbed when the molecules remain attached to the surface of the solid adsorbent.

Activated carbon is the preferred sorbent for use in this invention, since it is capable of efficiently sorbing hydrocarbon contaminants such as oil from air without being affected by an moisture contained in the air. Activated carbon can be employed alone, or it can be catalyzed with from about 0.2 to 5% of palladium, platinum, rhodium, cesium, rubidium or cuprous oxide. Activated carbon is also increased in activity by the addition of from about 5 to 20% by weight of the mixture of the oxides of copper, cobalt, manganese and silver, commercially known as "Hopcolite."

A number of other materials also have activity as sorbents, such as, for example, various crystalline substances and such other materials as chabicite, pumice, either alone or catalyzed with up to 10% nickel, silica gel, chromic oxide gel, lithopone, powdered porous glass, glass wool, activated alumina, quartz crystals, fuller's earth, Cecil soil, Barnes soil and glaucosil, which is useful particularly in removing oil from air of low water vapor content.

It is preferable that the sorbent employed have a large surface area exposed to the passage of compressed air. Accordingly, it is preferred that the solid sorbents be in particulate form, and not be compressed.

The sorbent should be located within a confined area which is permeable to the free passage of the compressed air, so that the air is passed through or over the sorbent. For example, the sorbent can be located within a chamber in the path of the compressed air. At least two walls of the chamber are comprised of a porous material which has pores large enough so as not to restrict the passage of compressed air, but small enough to prevent the loss and consequent contamination of the air by particles of the sorbent.

The quantity of sorbent required is proportional to the volume of air to be treated per unit time, and the amount of oil entrained. The greater the volume of air containing a given oil content, per unit time, the greater will be the amount of sorbent necessary to operate effectively. For most applications, the quantity of sorbent employed should be at least 25 grams per cubic foot of air passing through the apparatus per minute, calculated on the basis of standard temperature and pressure.

A preliminary filtration using a conventional filter is frequently, albeit not necessarily, desirable. Such preliminary filtration, which can be accomplished with any conventional filter media, preferably having a pore size of between 25 and 100 microns to avoid any undue pressure drops, serves to remove any very large oil droplets which might tend to clog the pores of the sorbent or the microporous filter. Exemplary of such conventional filters are filter paper and perforated metal sheets.

The microporous filter used in this invention is preferably in pleated or corrugated form to expose maximum surface are to the passage of compressed air within the limits of a confined unit. Where the filter employed is not in corrugated form but instead is of the smooth cylindrical type, even if made of the preferred fibrous depth variety of filter, a greater resistance to the passage of air will be developed unless a much larger size filter is employed, thus making the unit very large and inconvenient for use. Where, of course, size or space limitations are not a problem or where only negligible quantities of entrained oil are to be removed, smooth filters can be resorted to if the pleated or corrugated variety is not available. The length of the corrugated filter element as well as the depth and number of the corrugations will depend upon actual service requirements. Generally, elements having a length of from 2 to 30 inches, internal diameters (measured at the base of the corrugations) of from 0.5 to 10 inches, external diameters of from 0.8 to 25 inches and from about 10 to 100 pleats give good results. However, elements having different dimensions are useful under particular operating conditions.

In operation, the method of this invention can be carried out by employing a separate filter unit in which the filter element is made of a microporous flexible material as above described and a porous canister containing a quantity of the sorbent material such as activated charcoal. These two separate units can be placed at any point downstream of the air compressor and upstream of the ultimate end use for the air and the results of this invention can thereby be achieved. Optionally, the initial conventional filtration step can also be employed at any point prior to either of the other operations.

A preferred oil removal unit of this invention is shown in FIGURE 1, and is composed of three concentric layers, the outer layer being a perforated metal cylinder, the intermediate layer being a sorbent, such as activated carbon, and the inner layer being a microporous flexible filter. This treating unit can be placed downstream of a compressor and the air forced to pass through, in sequence, firstly the perforated metal cylinder, secondly the sorbent and thirdly the microporous filter, the air exiting from the composite unit in a condition substantially free from entrained oil, and suitable for applications in which the presence of even trace amounts of oil would be undesirable.

An alternative type of oil removal unit of this invention is shown in FIGURE 3, and can be connected to a compressed air line between any two points thereof, so that the compressed air passes in sequence through the microporous flexible filter and the sorbent, but in either order, as desired.

Further details of the apparatus of this invention can be had by reference to the drawings, in which—

FIGURE 1 illustrates a cartridge for an oil removal unit comprising two concentric filter layers and one sorbent layer;

FIGURE 2 is a cross section of the cartridge of FIGURE 1, taken through the line 2—2 of FIGURE 1; and

FIGURE 3 illustrates an oil removal unit for connection to a compressed air line so that air passes, in sequence, through a microporous flexible filter and then through a sorbent.

The oil removal cartridge of FIGURE 1 is in the form of a hollow cylindrical shell **1** of a perforated metal, having relatively large holes of an average diameter of 0.025 inch. The open ends are closed off by nonporous outer end caps **2** and **3** having central apertures **4** and **5** opening into the interior **6** of a perforated steel core **7** held by inturned portions **8** and **9** of the inner end caps **10** and **11**. The inner end caps **10** and **11** in turn hold

the ends of a concentric axially corrugated cylinder **12** of a microporous flexible fibrous depth type filter made in accordance with the procedure of application Serial No. 215,151 filed August 6, 1962, and having an average pore size of less than 1 micron, a voids volume of about 90%, an internal diameter of about 1 inch, and external diameter of about 1½ inches and about 30 corrugations. Disposed in the space intermediate the inner cylinder **12** and the outer cylinder **1** is a sorbent layer **13**, made up of approximately 350 grams of particulate activated carbon having an average particle size of 4 to 6 mesh, held in place by the cylinders and outer end caps **2** and **3**. Flat gaskets **14** and **15** are fitted in grooves in the end caps **2** and **3**, so as to seal the oil removal cartridge in an oil removal unit, and prevent intermingling of treated air with untreated air.

In operation, the cartridge and oil removal unit are put, for example, downstream of the compressor in a compressed air system, and air containing entrained oil and other hydrocarbon impurities is caused to enter the cartridge through perforated cylinder **1** which serves as a preliminary filter. The air then passes through sorbent **13** and the microporous filter **12**, during which passage entrained oil is removed, so that oil-free air enters interior passage **6**. Interior passage **6** is connected to the feed of oil-free compressed air. The apparatus illustrated in FIGURES 1 and 2 was found to be capable of removing oil from compressed air at air flow rates of up to 15 cubic feet per minute and pressures of up 75 p.s.i.g.

The oil removal unit shown in FIGURE 3 is connected at each end to a compressed air line **20**. Oil-entrained air enters the unit at inlet **21**, and emerges oil-free at outlet **22**.

The unit is composed of two parts, designated A and B, each comprising a bowl-supporting head, **24** and **25**, respectively.

The head **24** comprises an inlet **26** and a concentric outlet **27** opening into the bowl **28** and communicating, respectively, with the outside and inside of a plurality, in this case, three, of oil-removal cartridges **29**. However, one cartridge may be used, or more than three, depending on the system requirements. Each cartridge is composed of an outer shell **30** of a corrugated microporous depth type filter of the type used in the FIGURE 1 apparatus, having an average pore size of less than 1 micron. The open ends of these shells are closed off by end caps **31** having central apertures opening into the central passage **32** of a perforated metal core **33**, of plated or stainless steel. Beneath each end cap adjacent the aperture and webbed thereto for support is a V-shaped inner cap **34** which engages a matching connector **35** to communicate the central passage **32** of one cartridge with the next adjacent cartridge. The O-ring gaskets **36** prevent leakage between the cartridges **29**.

The bottommost cartridge **29** receives in its adjustor **34** a cap **38** which is biased by spring **39** upwardly, to hold the cartridge assembly firmly against the projecting end of outlet **27**. Leakage is prevented at both points by gaskets **36**. Oil separated by the cartridge collects at the bottom of the bowl **28**, and is removed via outlet **40**.

The bowl **28** is removably attached to the head **24** by clamps **41**, which engage the upper lip **42** of the bowl and hold it firmly against the corresponding lip **43** of the head. Leakage at the point therebetween is prevented by gasket **44**.

The second unit is attached to head **25**, which has an inlet **50** and an outlet **51** opening into bowl **52** on the outside and inside, respectively, of cartridge **53**. The cartridge is composed of a perforated metal cylinder **54** of plated steel or stainless steel, the open ends of which are closed off by end caps **55**, each of which has a central aperture. Beneath each cap, adjacent the aperture and welded thereto for support, is a V-shaped inner cap **56**, which holds the ends of a corrugated paper filter

shell **57**, the interior of which is provided with a supporting spring **58**. The space intermediate the shell **57** and cylinder **54** is filled with a sorbent **59** such as activated carbon. The interior of shell **57** is open, the central passage **60** thereby defined communicating directly with outlet **51**.

The bottom of cartridge **53** receives in the aperture of the end cap a cap **61** which is biased by spring **62** upwardly to hold the cartridge firmly against the projecting end of outlet **51**. Leakage is prevented at both points by gaskets **63**.

The bowl **52** is removably attached to head **25** in exactly the same manner as bowl **28**.

In operation, the oil removal unit of FIGURE 3 is connected to a compressor, from which oil-entrained air enters inlet **26**, filter bowl **28**, one of cartridges **29**, through filter shell **30** into passage **32**. Oil separated by the filter at the surface of the cartridge drops into the sump of the bowl, and is removed at **40** from time to time. Air still containing oil droplets too fine to be removed by filter **30** leaves the bowl **28** via outlet **27**, and enters the second unit at inlet **50**, passing into bowl **52**, and then through the sorbent **59** and paper filter **57** into passage **60**. Now, the air is oil-free, and returns to the line **20** through outlet **51**.

It will be readily understood that if desired, the apparatus can be constructed so as to have the air contact the sorbent prior to contacting the microporous filter or vice versa.

We claim:

1. A process for separating hydrocarbon vapors and droplets from compressed air which comprises the steps, taken in any order, of (1) passing the air over a sorbent for hydrocarbons and (2) passing the air through a microporous fibrous depth filter having an average pore size of less than one micron and a voids volume of at least 75%.

2. A process in accordance with claim **1** in which the order of steps is such that the air is first passed over the sorbent and then passed through the microporous filter.

3. A process in accordance with claim **1** wherein the order of steps is such that the air is first passed through the microporous filter and then is passed over the sorbent.

4. A process in accordance with claim **1** wherein the compressed air is subjected to a preliminary filtration by passing the air through a filter having a pore size of between about 25 and about 100 microns.

5. Apparatus for separating hydrocarbon vapors and droplets from compressed air comprising, in combination, a housing having an inlet and an outlet for flow of compressed air therethrough, and disposed across the line of air flow between the inlet and outlet so that all air flows therethrough, a microporous fibrous depth type filter having an average pore size of less than one micron and a voids volume of at least 75%, and a bed of particulate sorbent capable of sorbing hydrocarbons.

6. Apparatus in accordance with claim **5** wherein the microporous filter and sorbent are so arranged in the line of air flow that the filter is contacted first by the compressed air.

7. Apparatus in accordance with claim **5** wherein the microporous filter and sorbent are so arranged in the line of air flow that the sorbent is contacted first by the compressed air.

8. Apparatus in accordance with claim **5** including, first in the line of fluid flow, a filter having an average pore size of between about 25 and about 100 microns.

9. Apparatus in accordance with claim **5** wherein the microporous filter comprises a porous base having superimposed thereon and adherent thereto a microporous layer comprising a fibrous material.

10. Apparatus in accordance with claim **5** wherein the microporous filter is in corrugated form.

11. Apparatus in accordance with claim **5** wherein the

microporous filter and the sorbent bed are disposed concentrically within the housing.

12. Apparatus in accordance with claim **5** wherein the sorbent is activated carbon.

13. Apparatus for removing hydrocarbon vapors and droplets from compressed air comprising, in combination, a cylindrical cannister having a side wall provided with openings for passage therethrough of compressed air and having at least one open end closed by an end cap having a passage therethrough for flow of compressed air, a microporous tubular fibrous depth filter having an average pore size less than one micron and a voids volume of at least 75% disposed within the cylindrical cannister, a tubular core support disposed concentrically and internally of the microporous filter, and a layer of particulate sorbent disposed between the core and the container side wall on one side of the microporous tubular filter in a manner such that compressed air entering the container must pass through the sorbent layer and the microporous filter before emerging from the container.

14. Apparatus in accordance with claim **13** in which the microporous filter is in corrugated tubular form.

15. Apparatus in accordance with claim **13** wherein the sorbent layer is disposed internally of the filter.

16. Apparatus in accordance with claim **13** wherein the sorbent layer is disposed externally of the filter.

17. Apparatus in accordance with claim **13** wherein the microporous filter comprises a porous base having superimposed thereon and adherent thereto a microporous layer comprising a fibrous material.

18. Apparatus for removing hydrocarbon vapors and droplets from compressed air comprising, in combination, a head having air inlet and air outlet passages therethrough, a bowl attached to the head in a manner to receive air from the air inlet and to deliver air to the air outlet, and disposed in the bowl across the line of air flow from the inlet to the outlet a tubular microporous depth type filter having an average pore size of less than one micron and a voids volume of at least 75%, and a layer of sorbent for hydrocarbon vapors and droplets.

19. Apparatus in accordance with claim **18** wherein the microporous filter comprises a paper layer having relatively large pores and having deposited thereon a layer of fibrous material in an amount to reduce the average pore diameter thereof to less than one micron.

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