The unrecovered solvent remaining in the drum and cleaned goods, whatever its amount, is discharged into the atmosphere by a blast of cool air discharged through the mass of clothes in the drum. This creates a number of difficulties. First, it usually makes it necessary for cleaning plants to erect a stack to a height greater than that of the surrounding buildings, usually an expensive measure. Moreover, even though the quantity of solvent vented to atmosphere may be not more than 5% of the quantity originally used, these amounts are quite high enough to cause a definite pollution of the atmosphere, resulting in frequent difficulties with the neighbourhood and public health authorities. In another connection, the clothes or other textile articles as withdrawn from the machine and impregnated with solvents give out an objectionable smell. Besides, the discharge of solvent to atmosphere and retention in the cleaned goods results in a substantial financial loss which increases the cost of cleaning operations.

The primary object of the present invention is to provide a recovery system which will achieve a substantially full recovery of the solvent including the fractions currently vented to atmosphere and retained in the cleaned articles. Another object is to accomplish such full recovery without substantially increasing the total time of the cleaning process.

The invention therefore provides a way of recovering volatile solvents applicable both to solvent present in an enclosure and that retained in a batch of textile and similar articles, which comprises discharging air into said enclosure and/or through said articles, then passing the solvent laden air over active carbon to absorb the solvent vapours from the air blast, and regenerating the active carbon, for example, with steam at 212–320° F., to recover the absorbed solvent.

Preferably, the air to be discharged is at an initial temperature lower than 100° F.

A solvent recovery operation using active carbon according to the invention as applied to the dry cleaning of clothes and other textile articles, may be performed according to any one of the following ways, as related to the conventional steps of a drying cleaning process:

1. It may be effected after a conventional hot drying operation of the dry-cleaned articles, which drying step is preferably combined with the usual solvent recovery by condensation;

2. It may be effected as in (1) after completion of a high temperature drying step with solvent condensation, but with said drying and condensing operations being stopped at a point at which only some 5 to 10% of the solvent initially used has been recovered, that is, after only about 40 to 80% of the maximum amount of solvent recoverable by said operations has actually been recovered. The advantage of such a limitation of the drying and condensing steps is a substantial gain of time and energy since, as already mentioned, the rate of solvent recovery achieved by those steps drops off rapidly with time; or

3. The preliminary hot air drying and condensing operations may be omitted altogether, especially in cases where such operations may be detrimental to the articles being cleaned. In all cases the air discharged, according to the invention, into the enclosure and/or over the articles being cleaned in order to carry away the solvent vapours preferably is cool, or relatively cool air, especially at ambient temperature, thereby saving expense in fuel or other heating energy.

A further object of the invention is to provide a device for recovering solvent in which the recovery is possible within a single compact apparatus and without transferring the absorbent material from one container to another.
A further object of the invention is to provide a system with a relatively thin-walled container, which requires no safety valve.

Still another object of the invention is to provide an arrangement in which a single coil serves a number of different applications.

An additional object of the invention is to provide an arrangement for cooling the solvent-vapor-laden air before it contacts the absorbent material so as to increase the efficiency of the apparatus.

Solvent recovery apparatus according to the invention may comprise a sealed enclosure containing the following component units:

- An absorption unit having one or more beds of activated carbon through which the solvent-laden air blast is passed.
- A regeneration unit for the activated carbon wherein the absorbed solvent is transferred with water vapour.
- A condenser for condensing said water vapour together with the solvent vapours entrained with it.
- A separator unit for separating the condensed water from the recovered solvent.

In preferred embodiments of such an apparatus, the enclosure is in the form of a vertical, preferably cylindrical, vessel having the absorption unit mounted within the upper part of it, and the solvent-charged air is made to flow upwardly through said absorption unit, the purified air being discharged through one or more outlets at the top of the vessel and means being provided for discharging steam at selected periods through the absorption unit in the reverse, downward direction. Means are provided for recovering the solvent in the bottom of the vessel after said solvent has successively passed through a condensation unit positioned below the absorption unit and a cooling and separating unit below the condenser.

If the apparatus is to be used in connection with a dry cleaning machine, the above described apparatus is preferably, directly and permanently connected with such machine.

Exemplary embodiments of apparatus according to the invention will now be described with reference to the accompanying drawings.

In the drawings:

FIG. 1 shows in cross-section one form of device embodying the invention;
FIG. 2 is a similar view of a modified form;
FIG. 3 is a cross-section on the line 3—3 of FIG. 2, with the plates omitted.
FIG. 4 is a perspective view of the baffle unit;
FIG. 5 shows in elevation a modified form of coil; and,
FIG. 6 is a plan view thereof.

The apparatus shown comprises an upstanding cylindrical vessel 1 made, for instance, from galvanized steel sheet about 3 to 4 mm. thick, and providing a sealed enclosure.

In the upper section of the enclosure is an absorption unit comprising a mass of active charcoal 2 arranged upon a wire mesh or perforated screen 3 and having another wire mesh 4 extending over its upper surface. Steam discharge and distributing piping 5 is mounted above the absorption unit for regeneration of the activated charcoal.

A condenser coil 6 is mounted beneath the absorption unit for condensing the steam and solvent vapours. Underlying the condenser 6 is a shallow receiver or tray for collecting the condensed products, and cooling them off somewhat. The receiver has a central downwardly extending outlet pipe plunging at its lower end into a separator 8.

The vessel 1 rests on a stable base 9.

The air blast laden with solvent vapours, which may be derived from the washing drum of a dry cleaning machine, is delivered into the vessel by a conduit 10 having a discharge fan 10a connected in it. The outlet of the fan 10a is connected at 13a with the enclosure 1, preferably below the absorption unit 2—3—4, so that the solvent-charged air will flow upwardly as indicated by the flow-path A through the bed 2 of active charcoal. The air stripped of its solvent content by absorption in the charcoal bed (said absorption being usually better as the stream temperature is lower) is then discharged through the outlet 14a of a conduit 14 and is sent through the conduit 11. It is found that the discharge air from apparatus according to the invention has a solvent concentration so low that the outlet conduit 11 can be vented directly to the surrounding atmosphere without requiring an elevated stack. The discharge air is quite odourless.

The inlet conduit 10 delivering the solvent-charged air and the outlet conduit 11 are each provided with one or more valves 13, 14, both of which are opened during the absorption stage of the process.

After the bed of active charcoal has become saturated with solvent, the bed is regenerated and the solvents absorbed therein are simultaneously recovered. This may be done at timed intervals. Moreover a side outlet 17 tapped from the outlet conduit 11 may serve to determine, by analysis of the discharge air or simply by the sense of smell, the fact that the charcoal bed is in need of regeneration.

At such times the valves 13 and 14 are closed and valve 5a is opened to connect the steam distributor 5 with a source of steam, not shown, at a pressure of say 3 kg. per sq. cm. The flow-path of the steam is shown at B. Also an inlet valve 15 is opened for delivering cooling water into the condenser coil 6. The water flows through the coil 6 and is discharged by way of pipe 16.

When the active charcoal bed is at a temperature of about 212° F., as indicated preferably by a thermometer probe 18, the condensed water and solvents flow along the path D into the tank 8 of a separator unit by way of the funnel-like receiver 7. Since the solvents are heavier than water, they settle to the bottom of the tank 8 while the water collects at the top. The water is discharged by way of water outlet 19 connected with the upper part of tank 8 to waste while the solvents are siphoned from the bottom of the tank through a syphon 20a into a solvent receiver tank.

No excessive pressure can arise in the system, even without the use of a safety valve, because an increase in pressure of the vapor-laden air or of the steam will cause any gaseous material which does not condense to pass downwardly through pipe 8, and then to bubble up through the condensate in the space below plate 7, and to escape through pipe 19. Since the liquid in this space is only about 20 cm., the highest pressure which can develop is only that of 20 cm. of water. Thus the tank 1 can be made with relatively thin walls.

In the modification of FIGS. 2 to 4, there is a shell or tank 21 formed of a vertical cylinder, a body 22 of absorptive material such as activated charcoal in one or more layers, a steam distributing pipe 25, a heat exchanger formed of one or more coils 26, a collector 27 and a separator-decanter 28 with outlet conduits 19 and 20. The apparatus is connected to a blower 10 by a pipe 29 in which is a valve 13. The intake of blower 10 is connected to a pipe 50 which, by valves 51, 51' can be connected either to the distributor of a dry cleaning device or to the atmosphere. Pipe 29 opens into the tank 21 at 30, at a point below at least a part of the heat exchanger 26 and preferably at or below the bottom thereof.

Heat exchanger 26 has an inlet pipe 31 with a drain valve 35 and an outlet pipe 32. Pipe 31 can be connected either to the steam supply of a dry cleaning device or to a pump and supply of cold water by opening valve 34.

Outlet pipe 32 can be connected by opening valves 36 or 37 to the steam or cold water respectively.

The heat exchanger is preferably composed of a plurality of concentric coils supported in holes in distributing plates 39 which are arranged upright in radial planes and are spaced apart at their inner edges. In the center, across the top edges of the inner parts of the plates, is
a disc 40 to block the central part of the interior of the drum. These plates as shown by the arrows in FIG. 3, act to cause the incoming vapor-laden air to be distributed through the cross-section of the casing, and to receive a swirling motion, after which the air will pass upwardly and make good contact with the coil 26, while disc 40 prevents escape of air upwardly through the center out of contact with the coils.

In the use of this mechanism, during a first stage of an operating cycle with valves 49 and 51 open and valve 51' closed, valve 13 is opened (along with valves 34 and 37, so as to feed a coolant to coil 26) and blower 10 is started. The incoming vapor-laden air passes upwardly through the heat exchange relation with the coils, so that it is cooled substantially and the efficiency of the absorptive material is thereby improved. With water at 20° C., air entering at 60° C. can be cooled to 30° C. by this arrangement.

After the air has been passed through sufficiently to saturate the carbon, a second stage of the operating cycle takes place. During this second stage, valves 13, 49 and 51 are closed and steam is admitted into diffuser 25. This steam passes downward through the charcoal and vaporizes the solvent. The steam and solvent are condensed by cooling of the heat exchanger 26, fall onto collector 27 and is heated thereto to a sufficient degree to dry the charcoal, which can be done in a few minutes, so that the cycle of operation is considerably shortened. Then the operating cycle is repeated.

It is apparent, therefore, that the solvent recovery apparatus of the invention includes the hollow casing 21 which is formed at a given elevation with the outlet means 49 which is capable of being opened and closed. The blower 10 together with the valve 13 and opening 30 for the inlet means communicating with the interior of casing 21 at an elevation substantially lower than the outlet means 49. The valve 51 and 51' form a pair of means both communicating with the inlet means 13, 30 through the conduit 50 and this pair of means is alternately operable for alternately introducing solvent-carrying air and pure air, respectively, into the casing 21 through the inlet means. The body 22 of activated charcoal is situated in the interior of casing 21 to define a flow path through which air must pass before reaching the outlet means 49. The heat exchanger means 26 is situated in the casing 21 beneath the body of charcoal 22. The valves 33 and 34 respectively form together with the valves 36 and 37 a pair of means which communicate with the heat exchanger means 26 for alternately circulating therethrough a heating fluid and a cooling fluid, respectively. The conduit 25 forms a steam conduit means for directing through the body of charcoal 22 steam which passes downwardly therethrough. Finally, elements 27 and 28 form together with the conduits 19 and 26 a separating means situated in the casing at an elevation lower than the heat exchanger means 26 to collect condensate therefrom and separate the condensate into its different liquid components.

FIGS. 5 and 6 show a heat exchanger formed of several S-shaped coils 4 with vanes 45 for improving the exchange of heat.

It would obviously be possible, in the form of FIGS. 2 to 4, to supply steam by valve 36 and to exhaust it by either valve 33 or valve 35, if desired.

It will be readily perceived that the solvent recovery apparatus of the invention has many important advantages especially in connection with dry-cleaning plants. The total cost of such a solvent recovery apparatus as described herein is lower than the cost of erecting a discharge stack 15 meters high or taller such as would be usually required in the absence of such apparatus.

The recovery of a considerable proportion of solvent that would otherwise be lost to the atmosphere reduces the cost of cleaning and degreasing operations. Thus, in one type of widely used automatic dry cleaning machine handling 240 kg. of clothes with 100 liters of initial solvent, experience has shown that the apparatus of the invention makes possible a recovery of at least 6 to 8 liters of solvent over and above the amount recoverable by conventional methods. The cost of the steam required for regeneration of the active carbon is an order of about one tenth of the cost of solvents recovered.

The total time required for the drying operation and recovery of solvents according to the invention may be made somewhat shorter, about from 3 to 8 minutes, than in the absence of the improved recovery plant, since the hot-drying and condensation stage of the conventional cleaning process may be considerably shortened. This constitutes an additional economic advantage to the invention.

Further, the clothes or other textile or the like goods are practically free from the smell of solvent present in conventionally cleaned clothes and their temperature on discharge from the cleaning plant is lower.

The dangers of air pollution and fire and explosion hazards inherent in the prior practice of discharging air with a high solvent concentration in the atmosphere, are completely eliminated.

Finally, the apparatus according to the invention is simple and inexpensive to manufacture, and not very space consuming, easy to transport, install and operate and can readily be combined into an integral unit with conventional automatic dry cleaning machines and/or known solvent recovery devices.

While we have described herein some embodiments of our invention, we wish it to be understood that we do not intend to limit ourselves thereby except within the scope of the claims hereto or hereinafter appended.

The fan 10 or 10a may as well be put on the top of the cylindrical vessel, and the air laden with solvent vapours be drawn into the vessel instead of blown into it. The entire vessel is then under a slight depression (less than atmospheric pressure), which has the consequence that there are no more losses of air laden with solvent occurring through small leaks which may exist in the apparatus.

The change of position of the fan 10 or 10a does not include any change of position of the inlets 13a or 39.

The hydraulic valve constituted by the separator-decantor 28 is constructed in such a way that it may function as well under pressure as under a depression.

What we claim is:

1. Solvent recovering apparatus comprising, in combination, a hollow casing provided at a given elevation with an outlet means capable of being opened and closed; an inlet means communicating with the interior of said casing at a second elevation substantially lower than said given elevation; a first pair of means both communicating with said inlet means and alternately operable for alternately introducing solvent-carrying air and pure air, respectively, into said casing through said inlet means; a body of activated charcoal situated in the interior of said casing to define a flow path through which air must pass before reaching said outlet means; a heat exchanger means situated in said casing beneath the body of charcoal; the valves 33 and 34 respectively form together with the valves 36 and 37 a pair of means which communicate with the heat exchanger means for alternately circulating therethrough a heating fluid and a cooling fluid, respectively; a steam conduit means for directing through the body of charcoal steam which passes downwardly therethrough; and a separating means situated in the casing at an elevation lower than said heat exchanger means to collect condensate therefrom and to separate the condensate into its different liquid components.

2. Solvent recovering apparatus comprising, in combination, a hollow casing provided at a given elevation with an outlet means capable of being opened and closed; an inlet means communicating with the interior of said casing at a second elevation substantially lower than said given elevation; a first pair of means both communicating with said inlet means and alternately operable for alternately introducing solvent-carrying air and pure air, respectively, into said casing through said inlet means; a body of activated charcoal situated in the interior of said casing at an elevation lower than said given elevation but higher than said second elevation and defining a flow path through which air must pass before reaching said outlet means; a heat exchanger means situated in said casing beneath said body of charcoal but at an elevation higher than said second elevation; a second pair of means communicating with said heat exchanger means for alternately circulating therethrough a heating fluid and a cooling fluid, respectively; steam conduit means communicating with the interior of said casing at an elevation higher than said body of charcoal for directing steam downwardly through the latter; valve means in said steam conduit means for opening and closing the latter; and separat-
ing means situated in said casing at an elevation lower than said second elevation for collecting condensate from said heat exchanger means and separating the condensate into different liquid components thereof, whereby during a first stage of an operating cycle with said outlet means open that one of said first pair of means for introducing solvent-carrying air through said inlet means into said casing and that one of said second pair of means for circulating cooling fluid through said heat exchanger means can be rendered operative so that the solvent-carrying air will have solvent condensed therefrom by said heat exchanger means before passing through said body of charcoal to have further solvent removed therefrom before the air flows out through said outlet means, during a second stage of said operating cycle with said outlet means closed both of said first pair of means can be rendered inoperative while said one of said second pair of means is still maintained operative and steam is directed through said body of charcoal from said steam conduit means to remove from said charcoal solvent to be condensed with steam by said heat exchanger means and received in said separator means, and during a final stage of said operating cycle with said outlet means open the other of said first pair of means can be rendered operative for introducing pure air through said inlet means into said casing while the other of said second pair of means can be simultaneously rendered operative for circulating heating fluid through said heat exchanger means to heat said pure air before it reaches said body of charcoal to dry the latter before reaching said outlet means.

2. Apparatus as recited in claim 1 and wherein a valve means communicates with said heat exchanger means for emptying heating fluid therefrom before cooling fluid is circulated therethrough and cooling fluid therefrom before heating fluid is circulated therethrough.

3. Apparatus as recited in claim 1 and wherein said heat exchanger means includes a plurality of concentric coils of tubing and a plurality of plates extending radially with respect to and distributed about the common axis of said coils of tubing and formed with openings through which said coils of tubing pass, said plates defining spaces in which air introduced in said inlet means into said casing is distributed across the interior of said casing while flowing upwardly past said heat exchanger means to said body of charcoal.

4. Apparatus as recited in claim 1 and wherein said heat exchanger means includes a plurality of banks of finned tubing respectively situated at different elevations between said body of charcoal and said second elevation.

5. Apparatus as recited in claim 1 and wherein said separating means is in permanent communication with the outer atmosphere and said outlet means when open also communicates with the outer atmosphere so that excessive pressures cannot build up in said casing.

6. Apparatus as recited in claim 6 and wherein said second pair of means circulate fluid through said heat exchanger means from a lower elevation to a higher elevation.

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