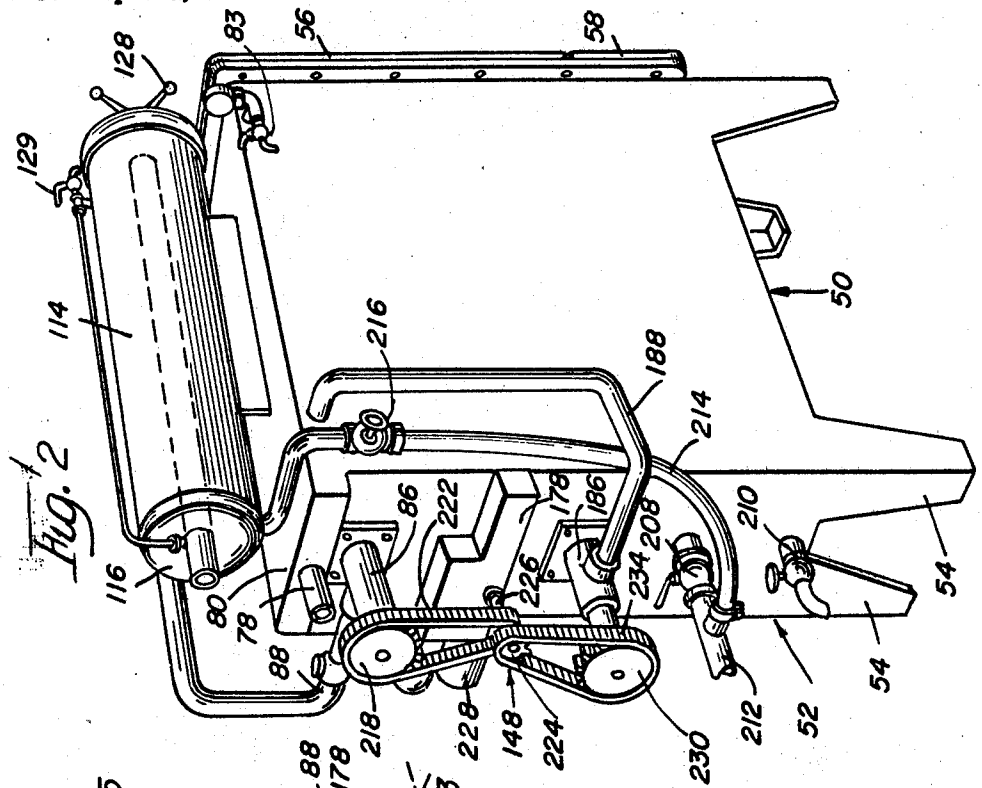
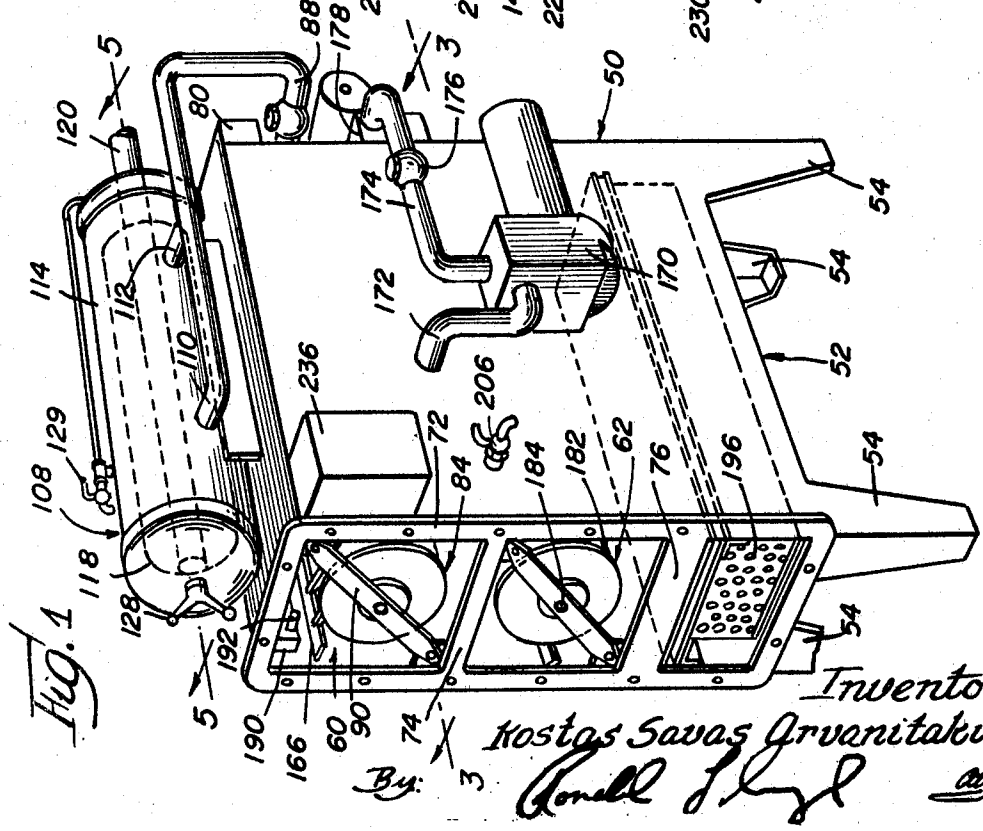
Feb. 24, 1970 K. S. ARVANITAKIS 3,497,452

METHOD AND APPARATUS FOR CLARIFYING A LIQUID

Filed Sept. 9, 1968 14 Sheets-Sheet 1





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METHOD AND APPARATUS FOR CLARIFYING A LIQUID

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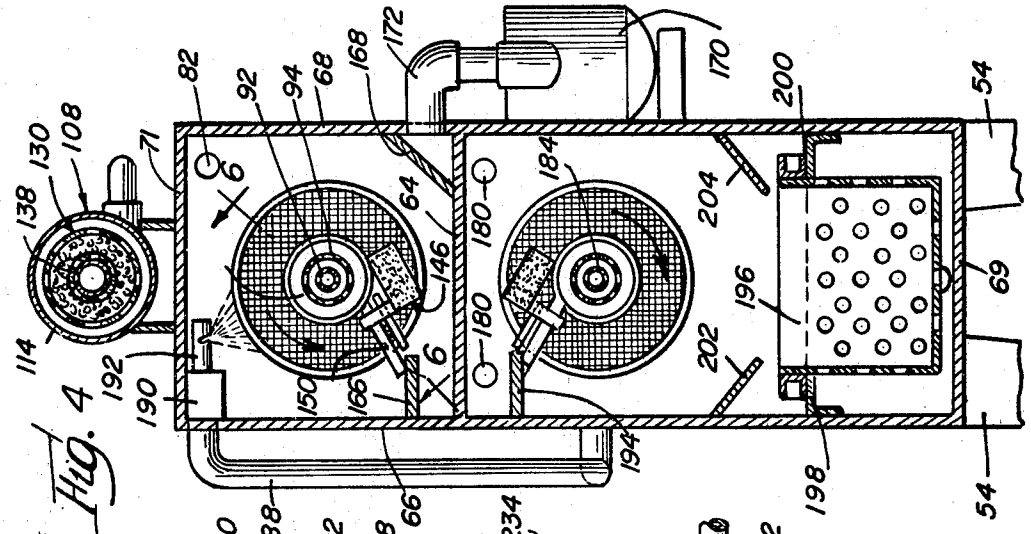

Fig. 4

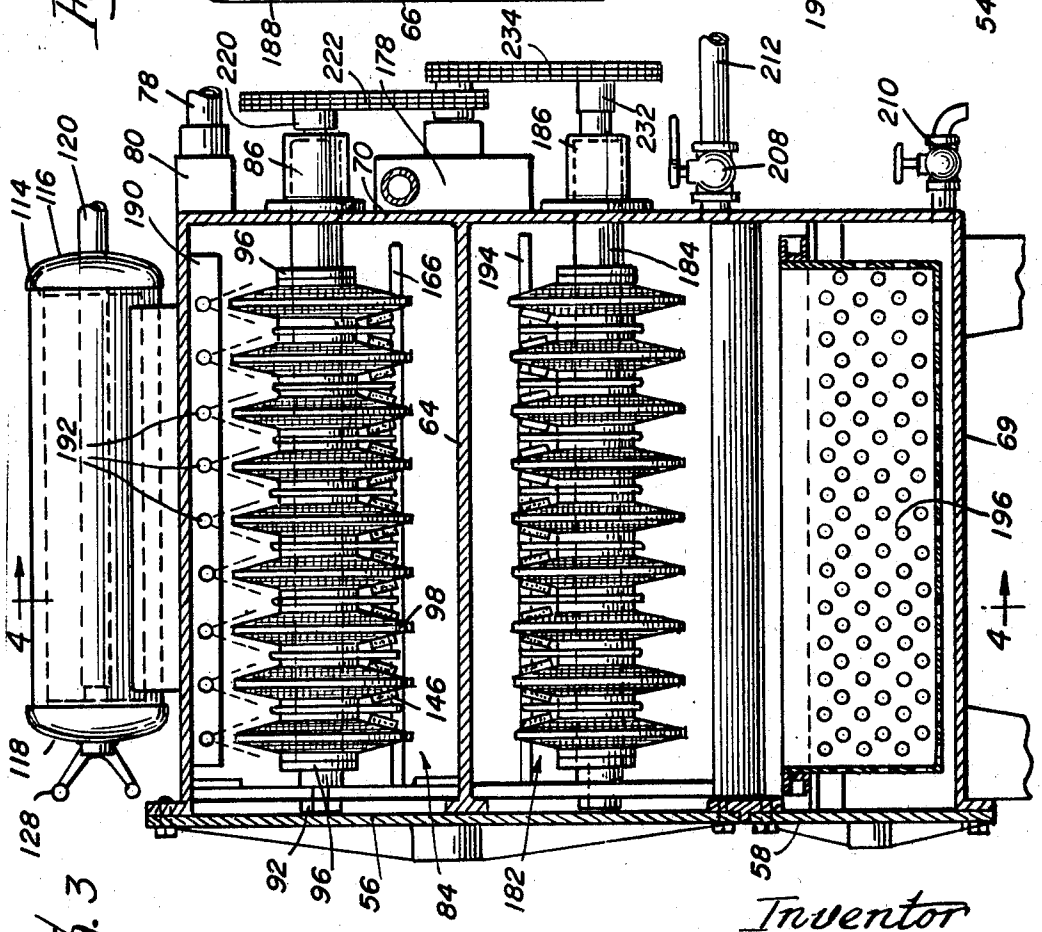

Fig. 3

Inventor
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By Ronald Flugel Atty

Feb. 24, 1970 K. S. ARVANITAKIS 3,497,452

METHOD AND APPARATUS FOR CLARIFYING A LIQUID

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Fig. 5

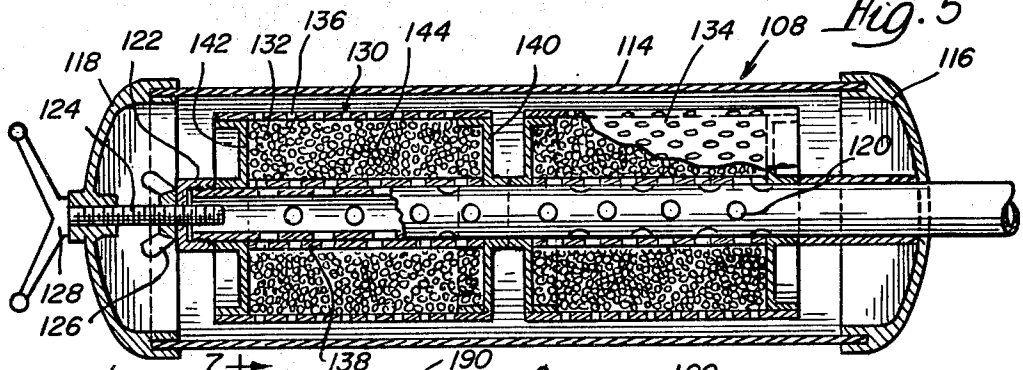


Fig. 6

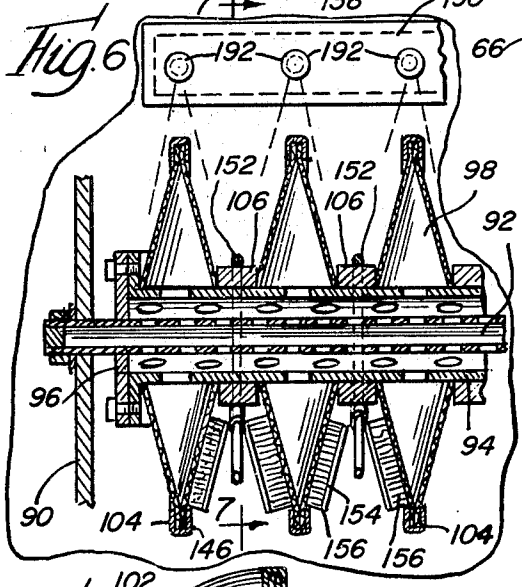


Fig. 7

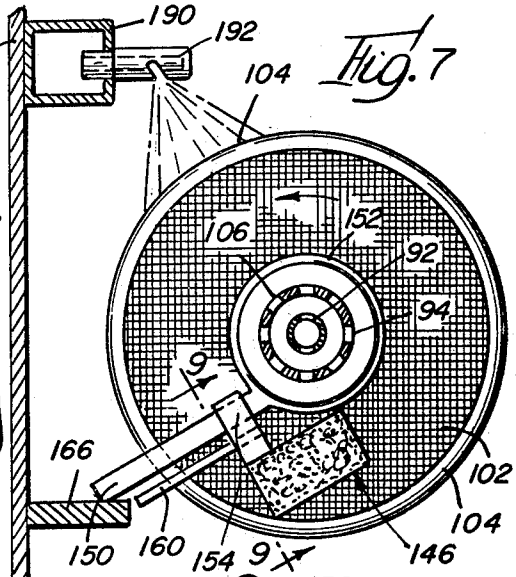


Fig. 8

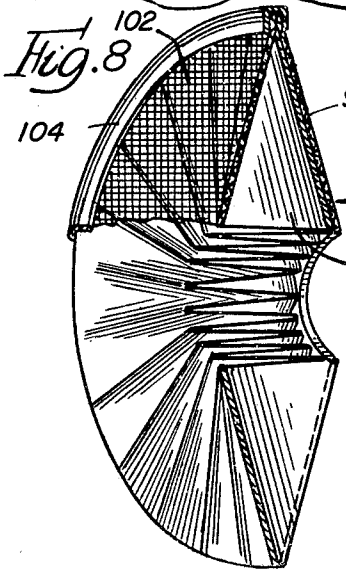


Fig. 9

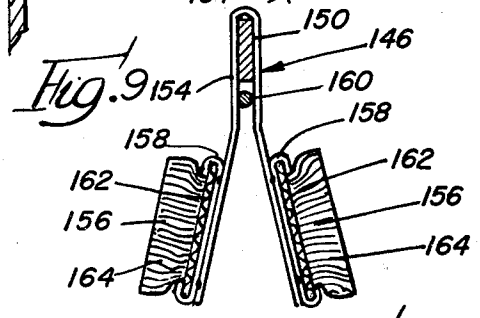
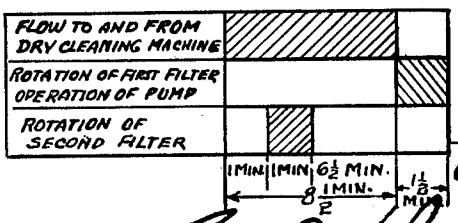


Fig. 10



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Feb. 24, 1970 K. S. ARVANITAKIS 3,497,452

METHOD AND APPARATUS FOR CLARIFYING A LIQUID

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Fig. 11

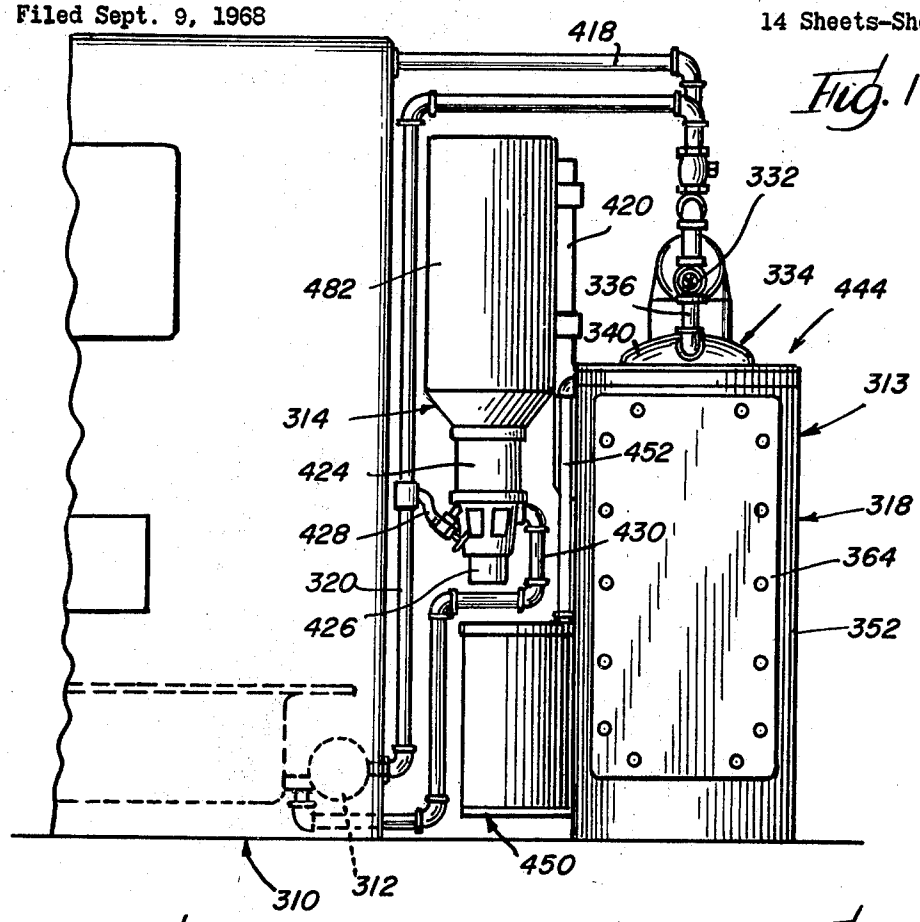


Fig. 12

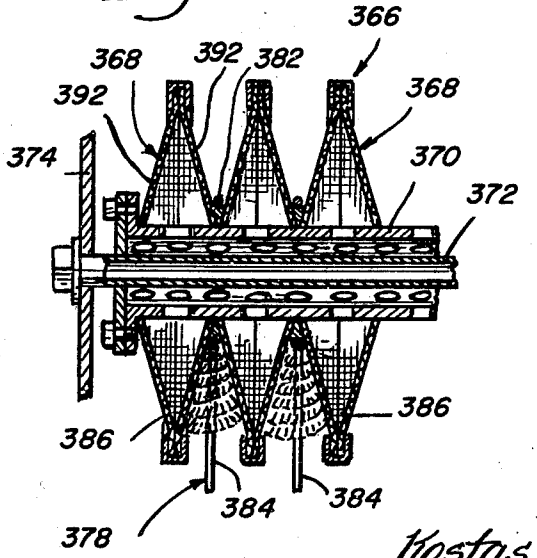
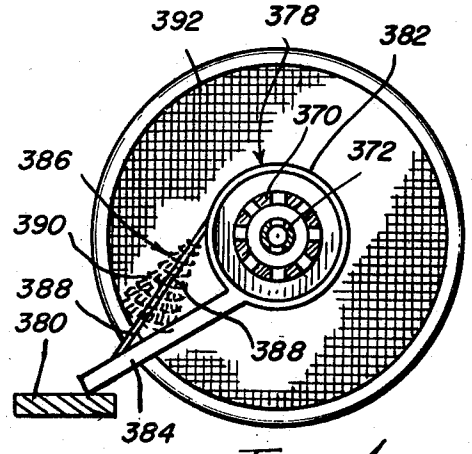


Fig. 13



Inventor

Kostas Savas Arvanitakis

By: Arnold J. Levi Atty

Feb. 24, 1970 K. S. ARVANITAKIS 3,497,452

METHOD AND APPARATUS FOR CLARIFYING A LIQUID

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Fig. 15

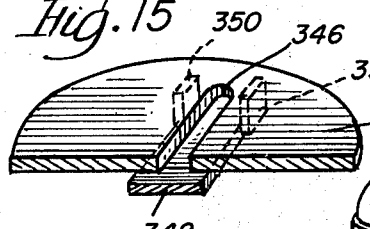

Fig. 14

Inventor

Kostas Savas Arvanitakis

By: Atty

Feb. 24, 1970 K. S. ARVANITAKIS 3,497,452

METHOD AND APPARATUS FOR CLARIFYING A LIQUID

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Fig. 16

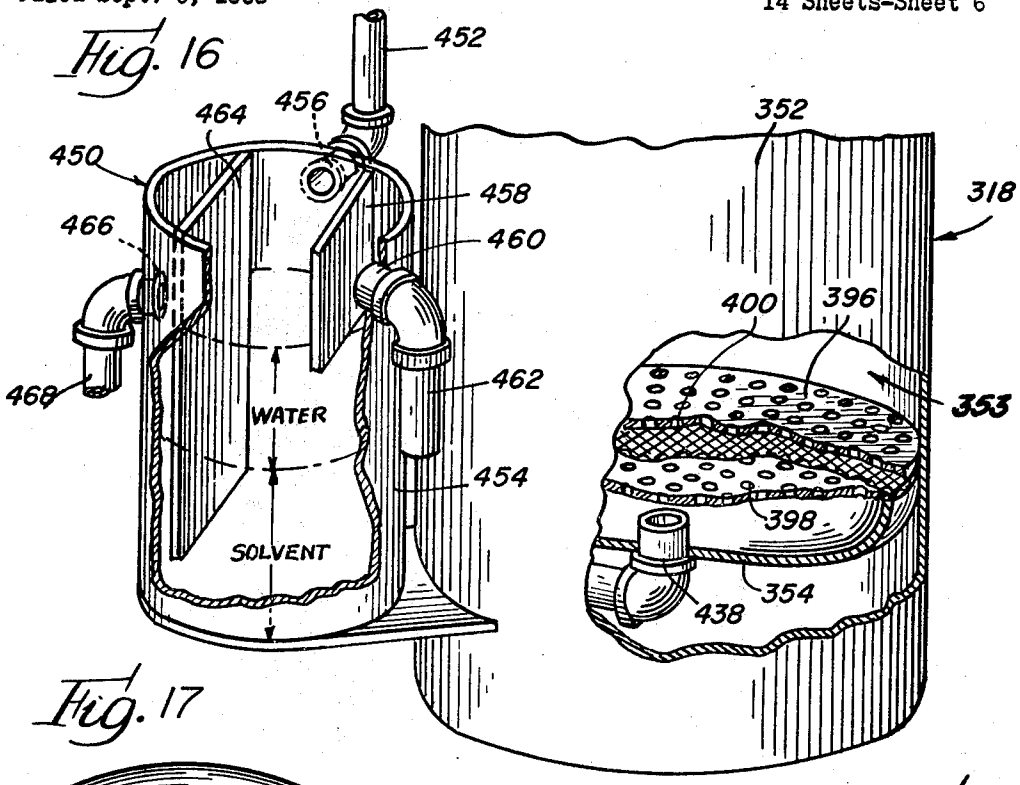


Fig. 17

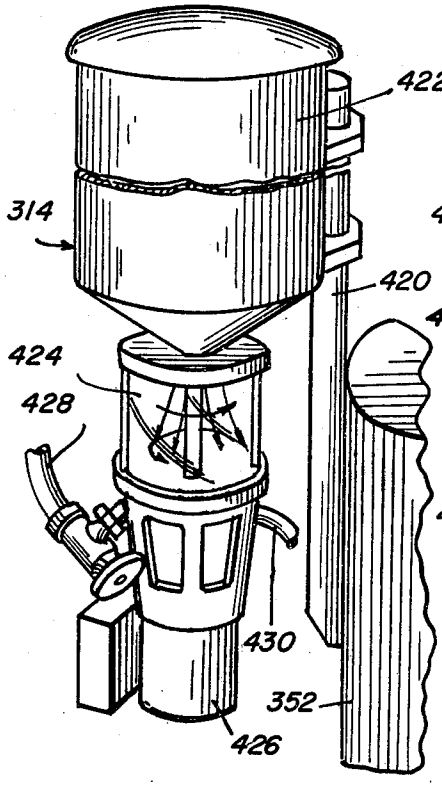
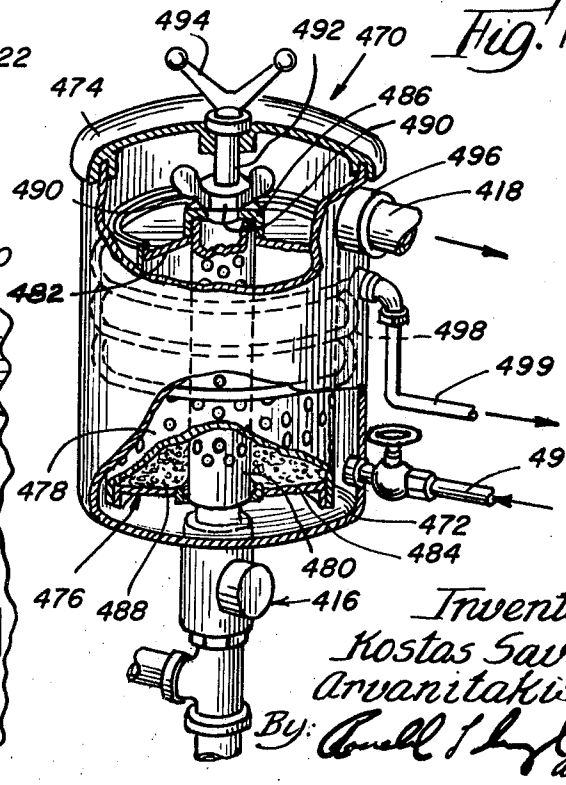


Fig. 18



Inventor
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Feb. 24, 1970 K. S. ARVANITAKIS 3,497,452

METHOD AND APPARATUS FOR CLARIFYING A LIQUID

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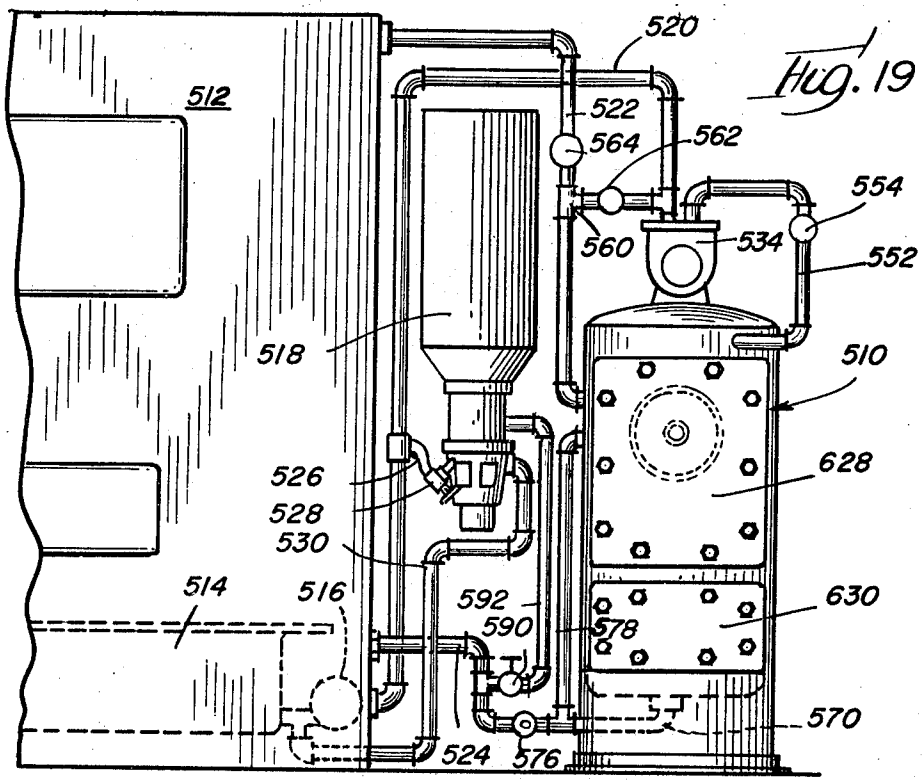

Fig. 19

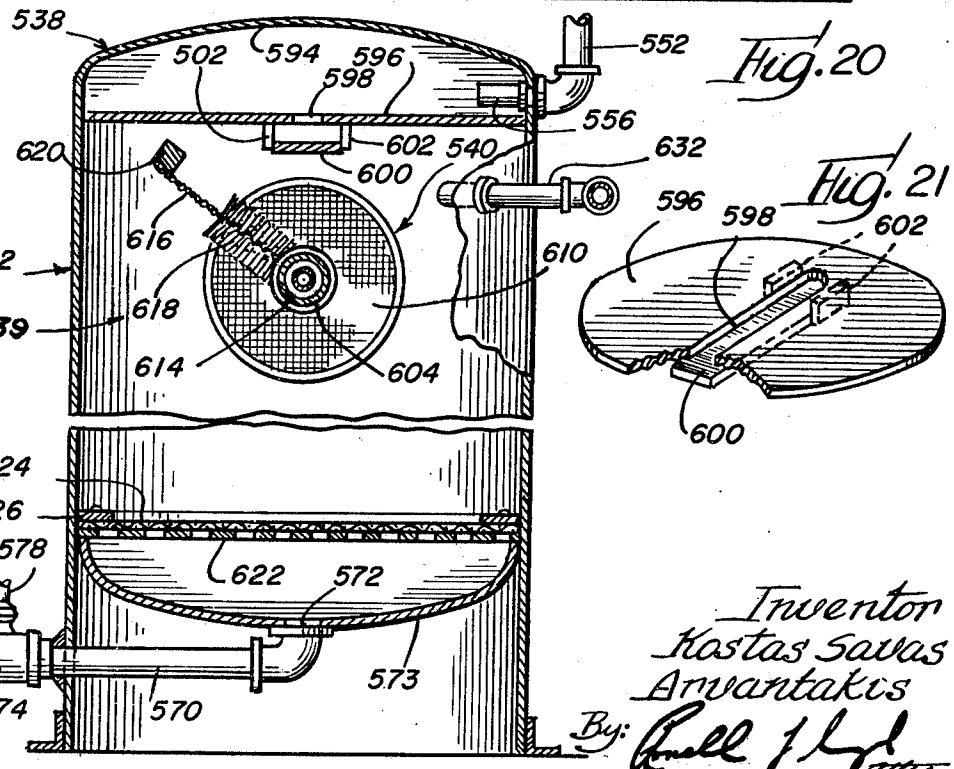

Fig. 20

Fig. 21

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Fig. 22

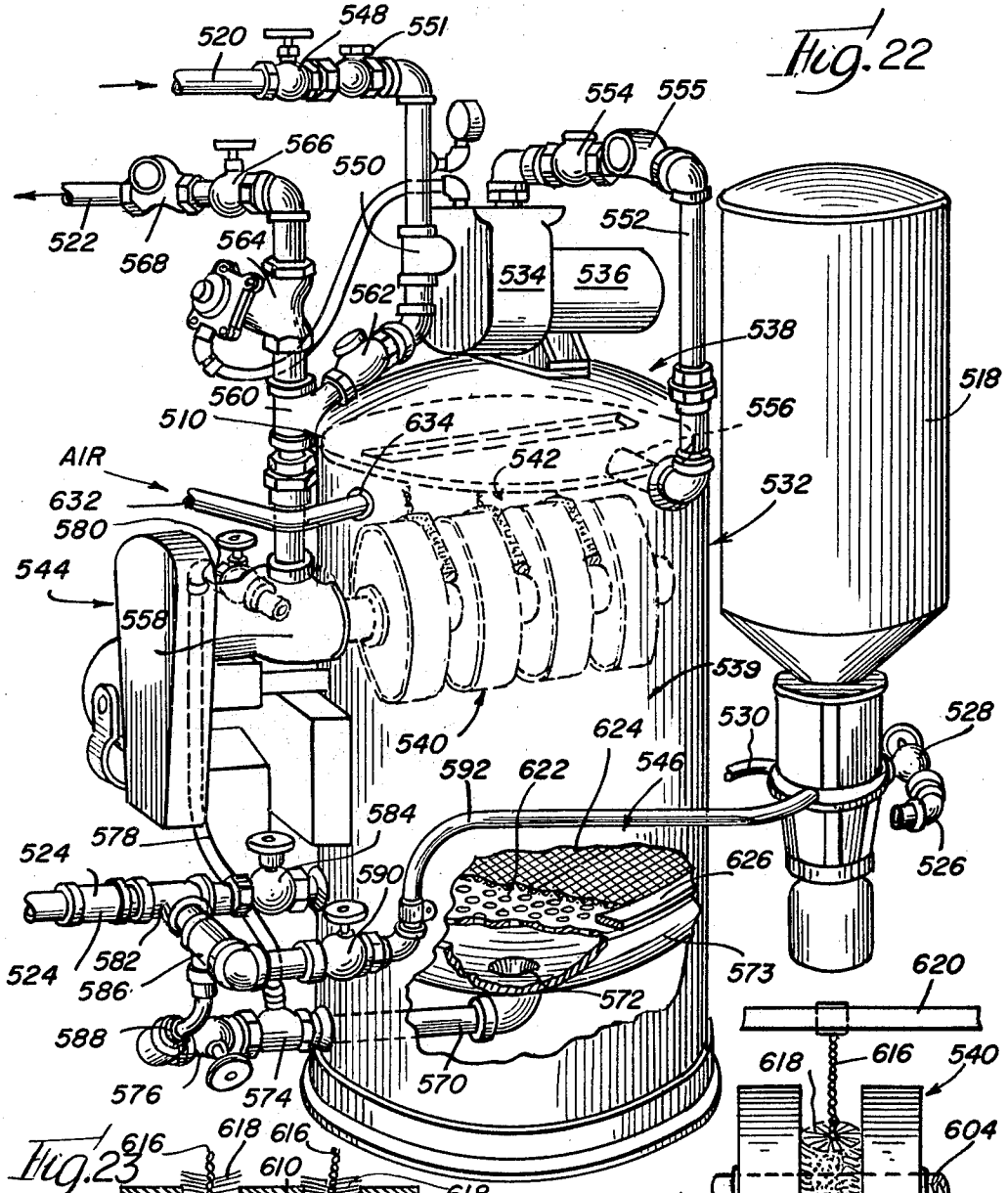

Fig. 23

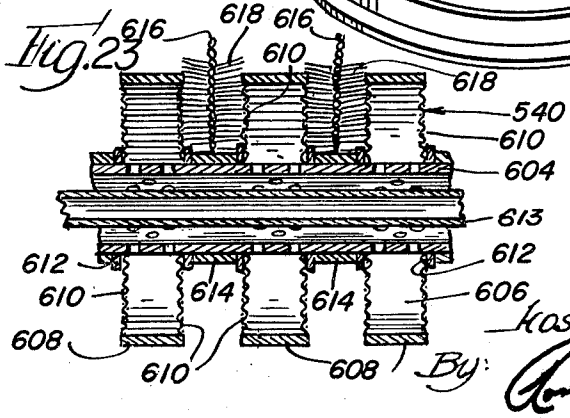

Fig. 24

Inventor
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Atty.

Feb. 24, 1970 K. S. ARVANITAKIS 3,497,452

METHOD AND APPARATUS FOR CLARIFYING A LIQUID

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Fig. 25

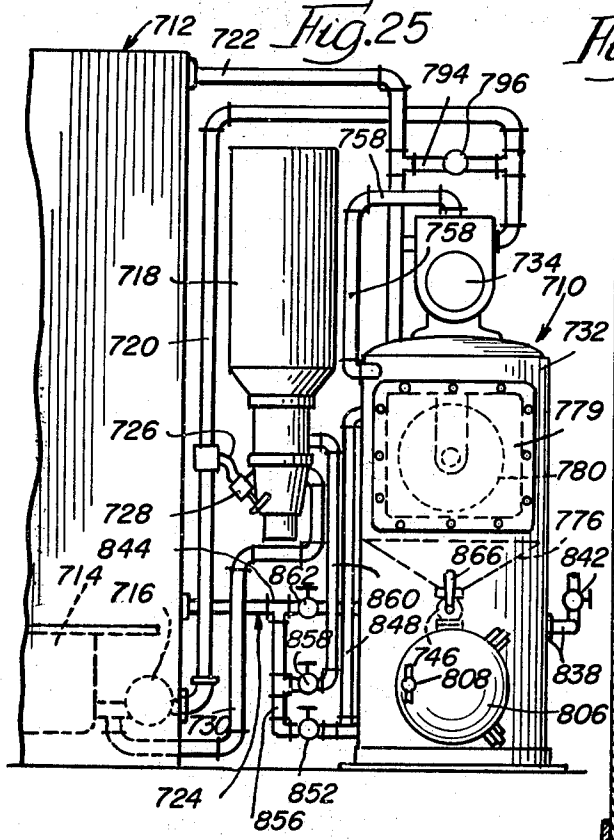


Fig. 26

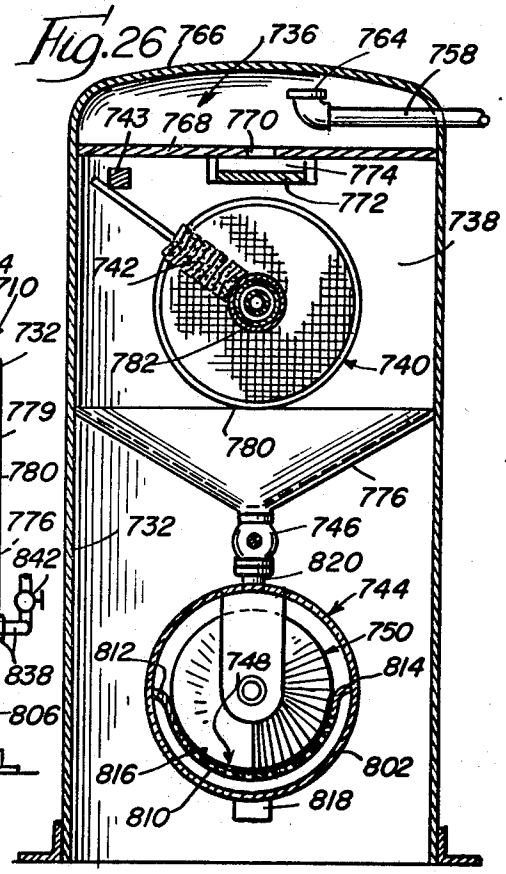
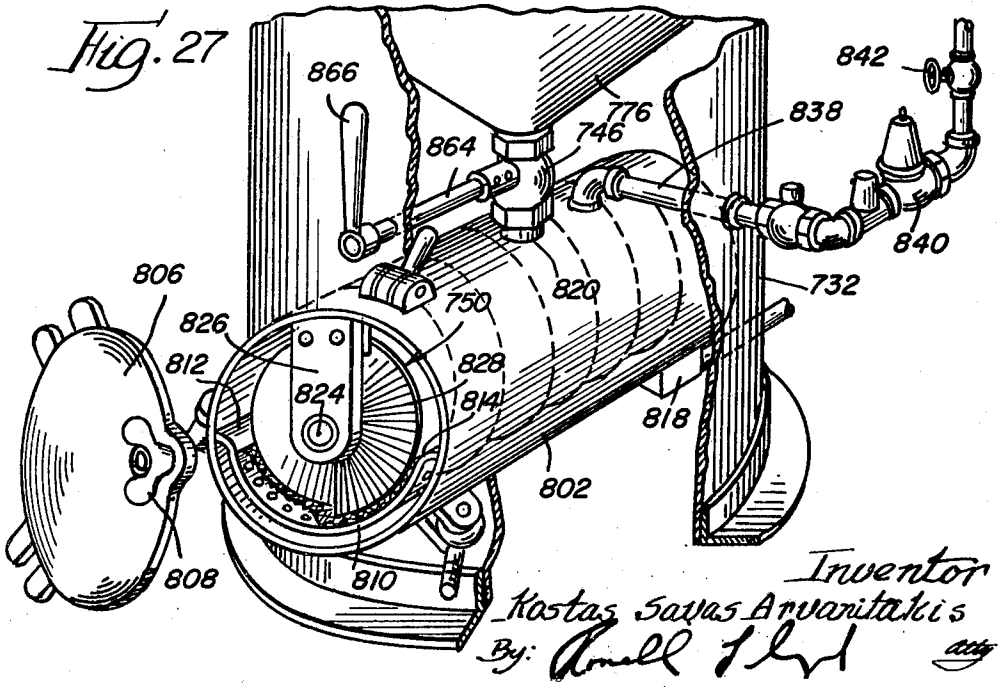


Fig. 27



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By: Arnold Lloyd
Atty

METHOD AND APPARATUS FOR CLARIFYING A LIQUID

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Fig. 28

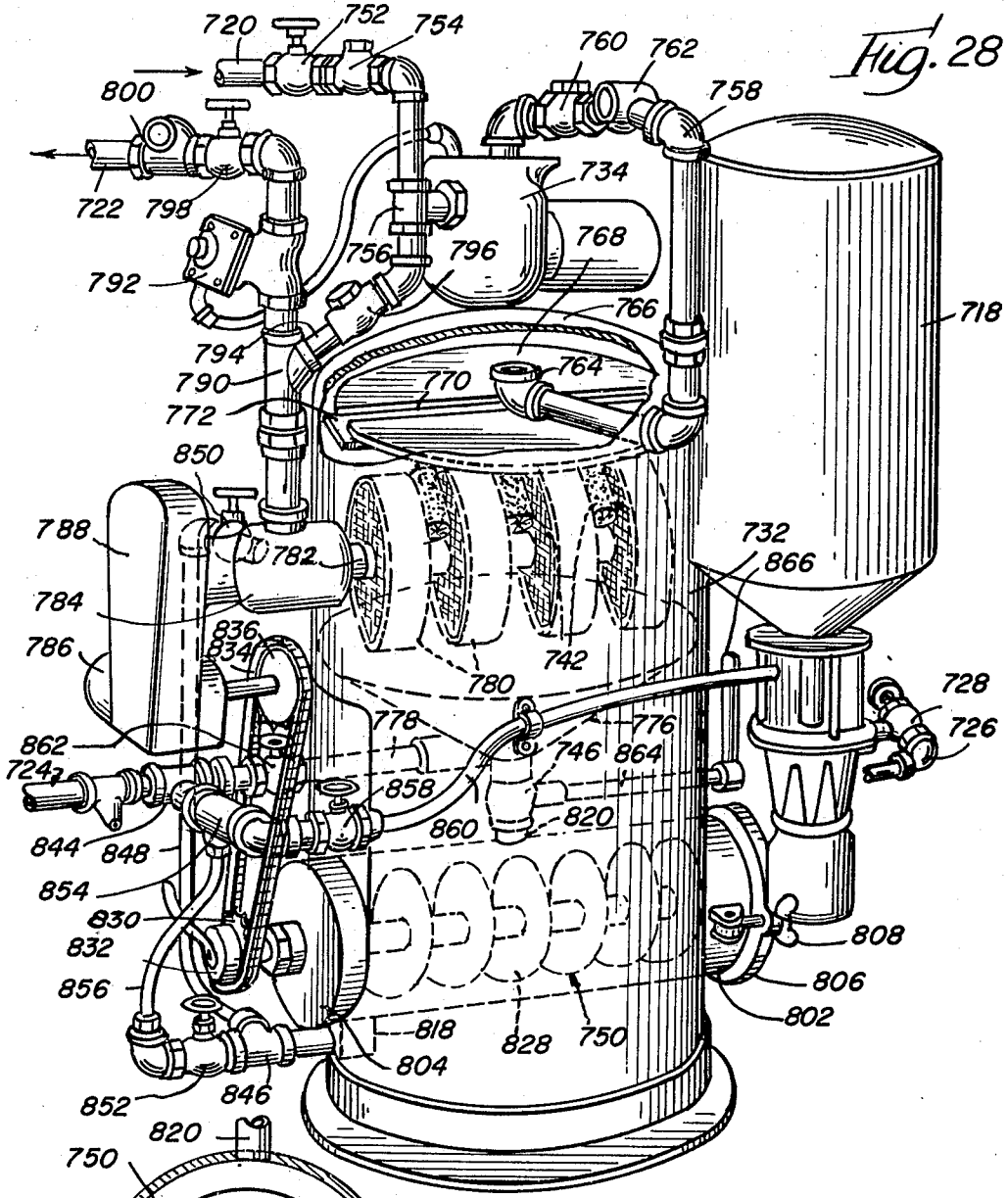

Fig. 29

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Feb. 24, 1970 K. S. ARVANITAKIS 3,497,452

METHOD AND APPARATUS FOR CLARIFYING A LIQUID

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Fig. 30

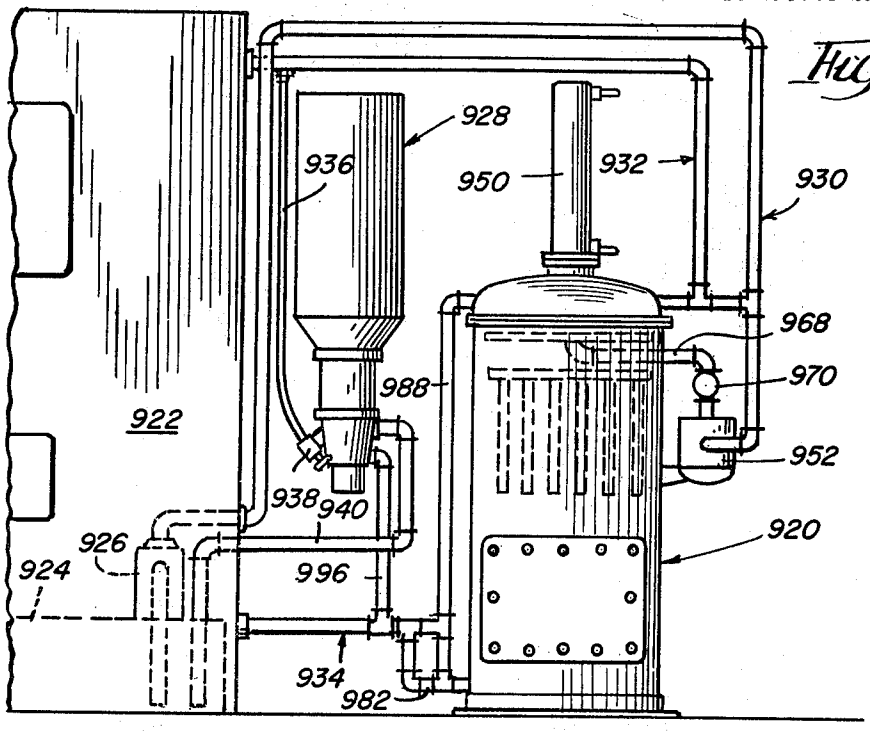
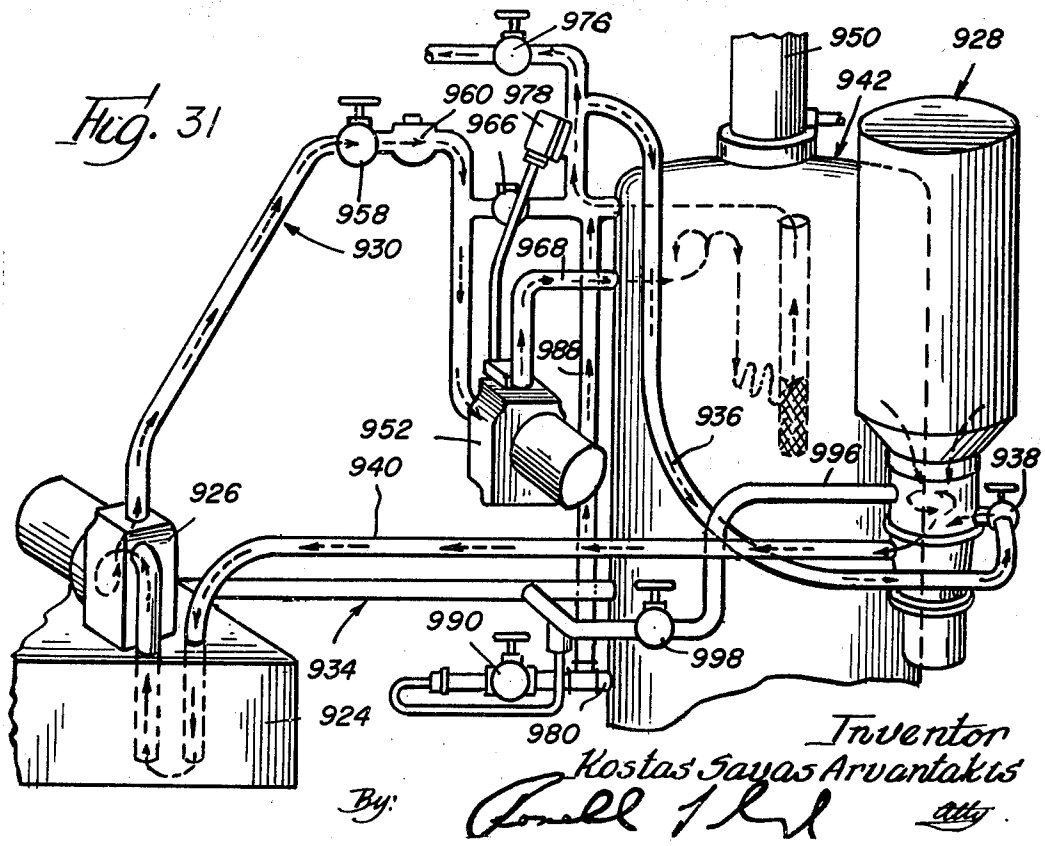


Fig. 31



Inventor
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Feb. 24, 1970 K. S. ARVANITAKIS 3,497,452

METHOD AND APPARATUS FOR CLARIFYING A LIQUID

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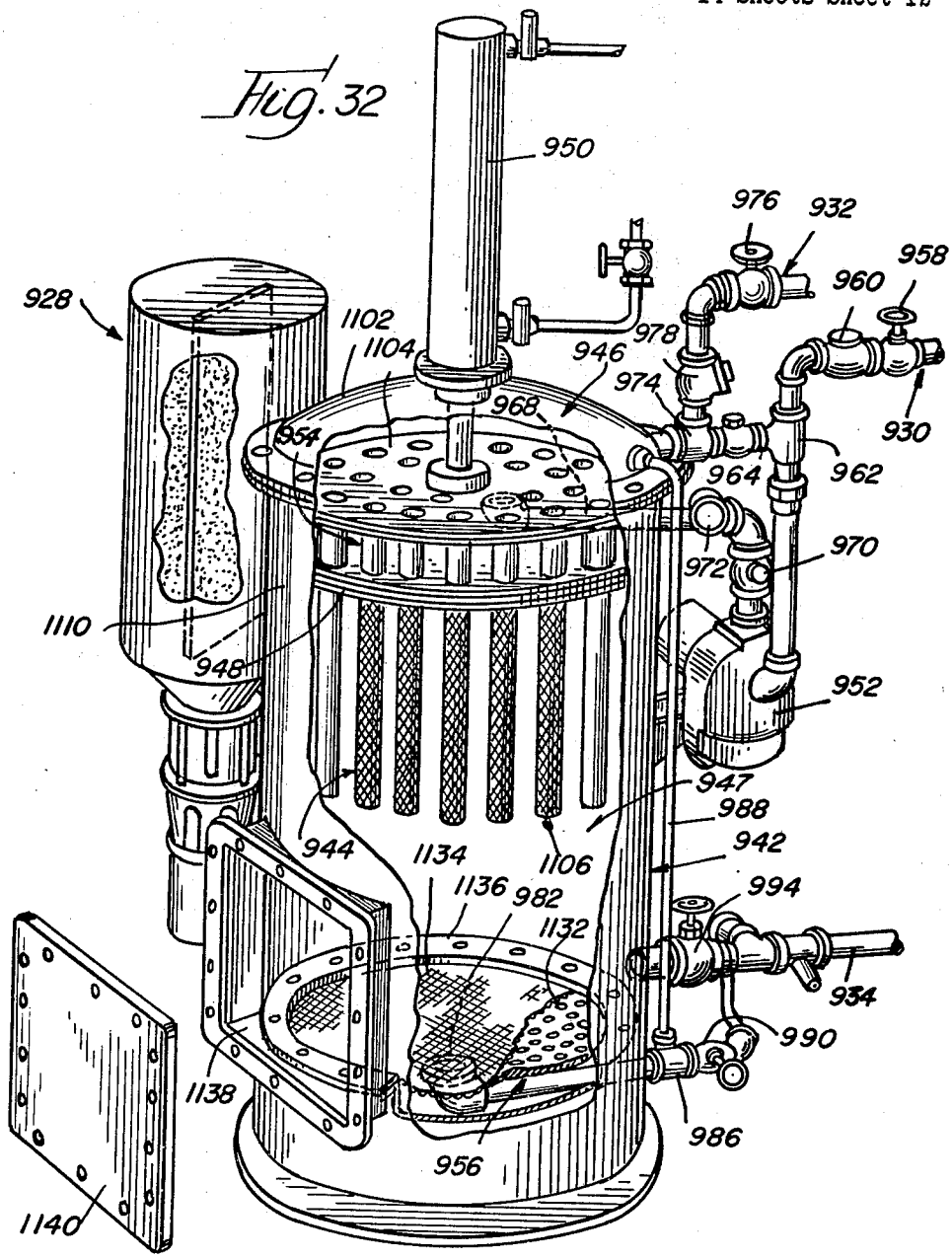
Fig. 32



Inventor
Kostas Savas Arvanitakis
By: Attorney

METHOD AND APPARATUS FOR CLARIFYING A LIQUID

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Fig. 33

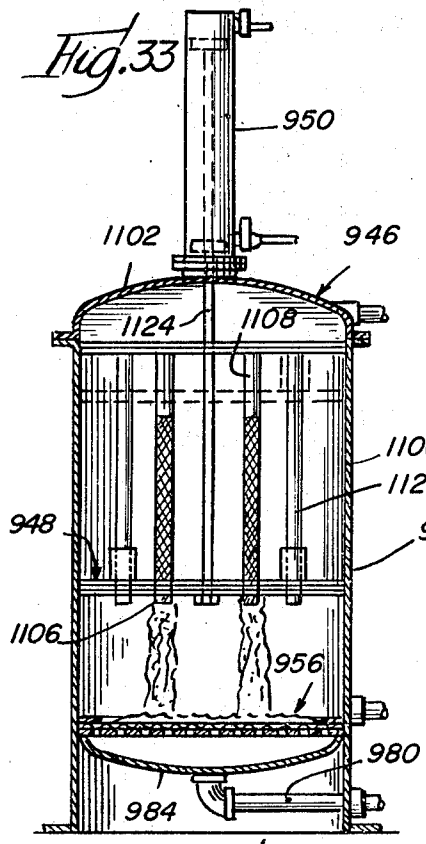


Fig. 34

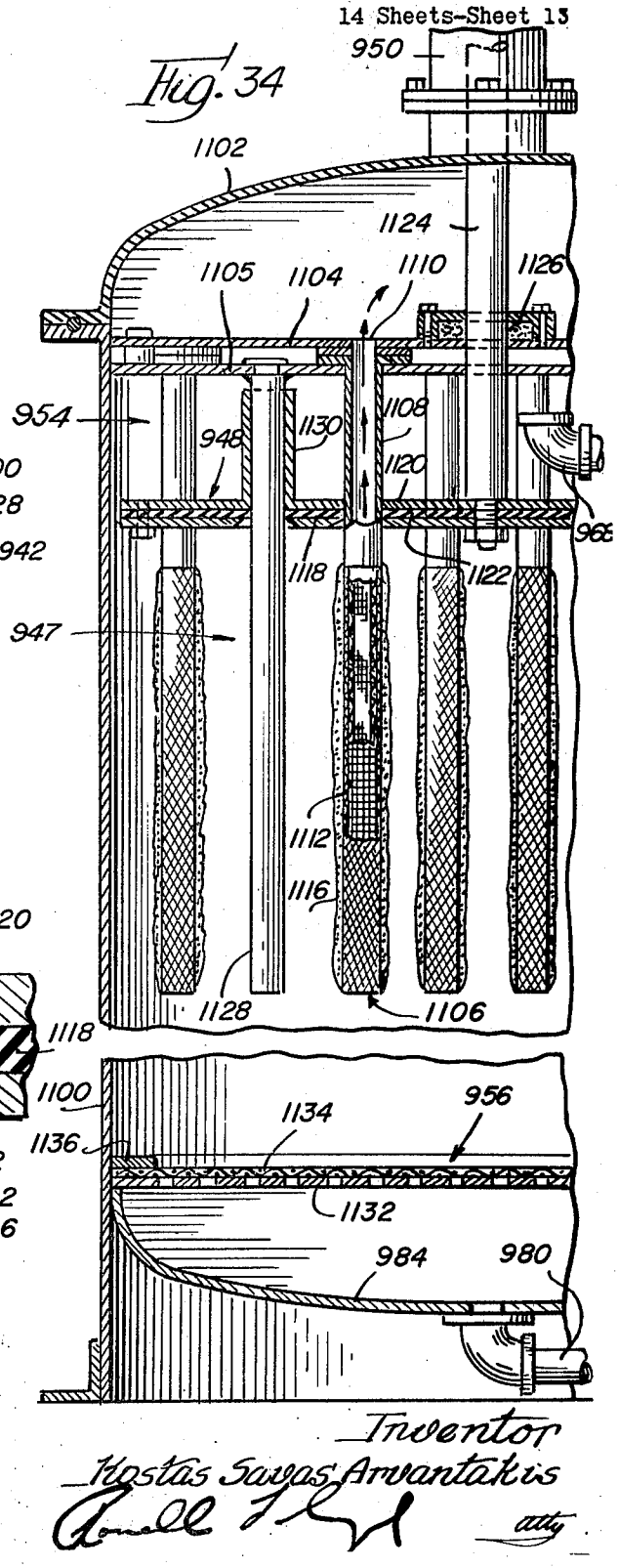
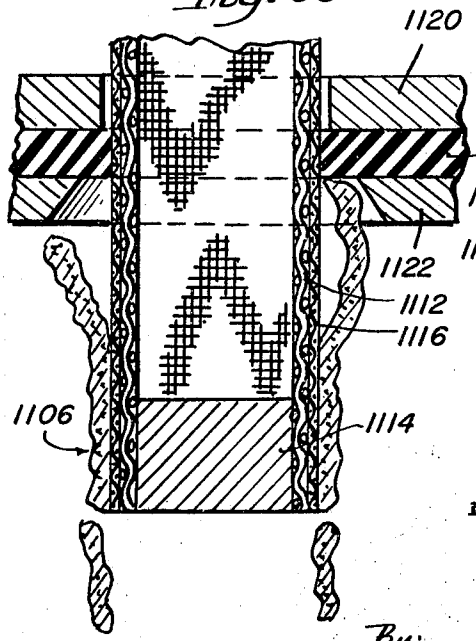


Fig. 35



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METHOD AND APPARATUS FOR CLARIFYING A LIQUID

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Fig. 36

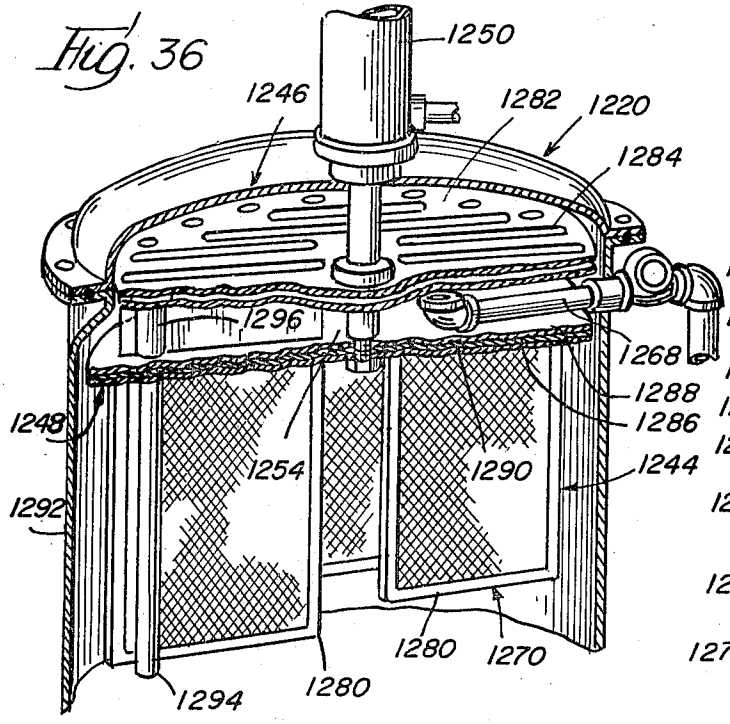


Fig. 37

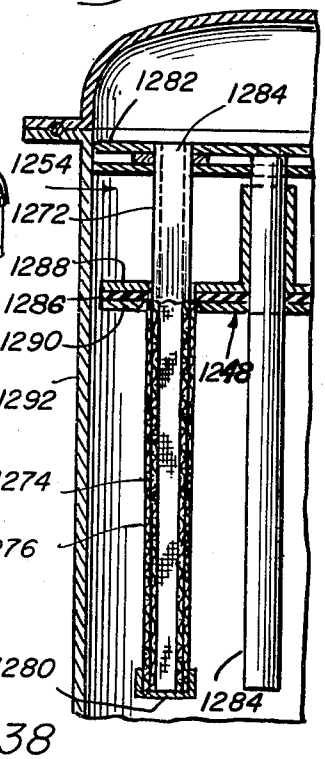


Fig. 39

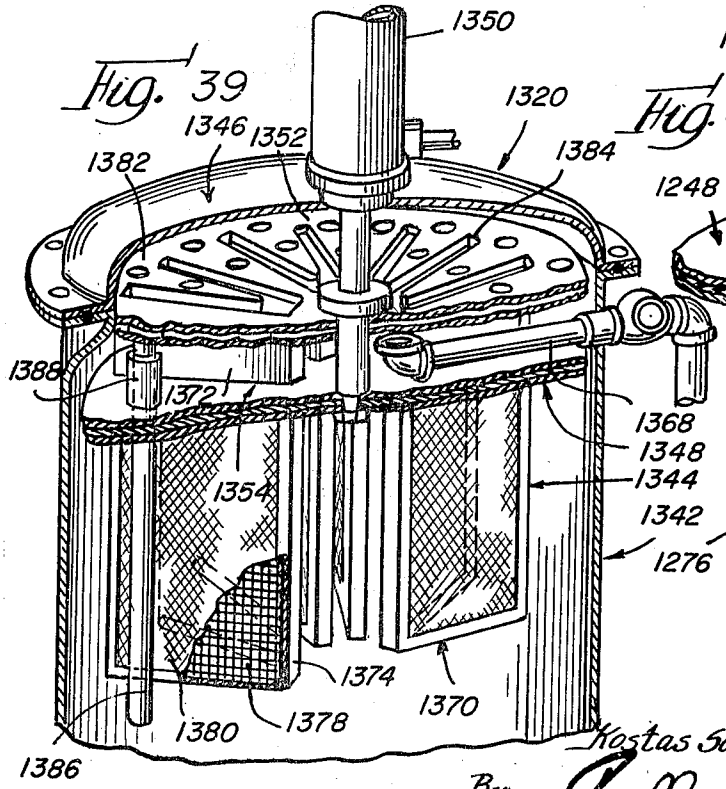
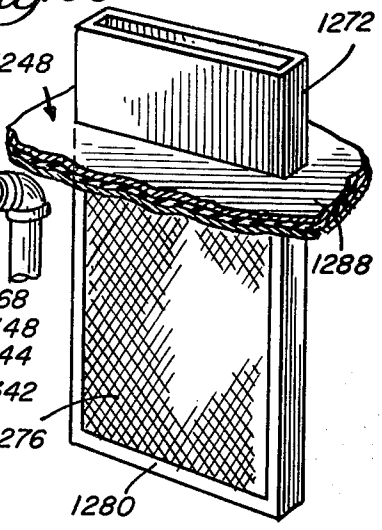


Fig. 38



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By: Donald Lloyd
Atty

United States Patent Office 3,497,452 Patented Feb. 24, 1970

3,497,452

METHOD AND APPARATUS FOR CLARIFYING A LIQUID

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Continuation-in-part of applications Ser. No. 459,588, May 28, 1965, Ser. No. 582,887, Sept. 29, 1966, Ser. No. 652,336, July 10, 1967, Ser. No. 664,536, Aug. 30, 1967, and Ser. No. 664,480, Aug. 30, 1967. This application Sept. 9, 1968, Ser. No. 758,442

Int. Cl. B01d 15/06, 37/02

U.S. Cl. 210—39 57 Claims

ABSTRACT OF THE DISCLOSURE

A method and apparatus for clarifying a liquid with a filter and for intermittently removing filter cake deposited on the surface of the filter automatically. The principal filtering operation is accomplished by pumping an unclarified liquid from a source through a primary filter, and then conveying the liquid clarified thereby to a receptacle, thus leaving an accumulation of filter cake on the surface of the filter. The automatic cleaning operation is accomplished by temporarily interrupting the filtering operation, dislodging the filter cake from the filter surface into unclarified liquid adjacent to the filter surface by means of a wiper moving at less than 1000 inches per minute relative to the surface of the filter, and removing dislodged filter cake from the unclarified liquid by recirculating the liquid within the filter apparatus through a secondary filter until the filter cake is deposited on the secondary filter.

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation-in-part of the following co-pending applications by the same applicant, now all abandoned:

Method and Device for Cleaning Dry Cleaning Solvent, Ser. No. 459,588, filed May 28, 1965.

Apparatus and Method for Clarifying a Dry Cleaning Solvent, Ser. No. 582,887, filed Sept. 29, 1966.

Apparatus and Method for Clarifying a Dry Cleaning Solvent, Ser. No. 652,336, filed July 10, 1967.

Apparatus and Method for Clarifying a Liquid, Ser. No. 664,536, filed Aug. 30, 1967.

Apparatus and Method for Clarifying a Dry Cleaning Solvent, Ser. No. 664,480, filed Aug. 30, 1967.

BACKGROUND OF THE INVENTION

Field of the invention

This invention relates to an improved method and apparatus for clarifying liquids with a filter, wherein filter cake deposited on the filter is intermittently dislodged from the filter and removed from the system automatically.

Description of the prior art

Many industrial operations utilize filter apparatus for clarifying liquids. In a dry cleaning operation, for example, an expensive solvent (e.g., perchloroethylene) is used in order to remove solid particles, such as lint and dirt, and chemical contaminants, such as higher fatty acids, from soiled clothing. Since this solvent is expensive, industrial dry cleaning operations utilize filter apparatus in conjunction with a dry cleaning machine for removing the solid and chemical impurities from the dry cleaning solvent so that the solvent may be re-used.

In order to remove both solid and chemical impurities from the solvent, one of two types of filter apparatus is generally used. One type of filter apparatus provides a

mechanical filter for removing solid particles (e.g., a fine mesh screen through which the liquid flows) in series with a chemical filter for removing chemical impurities (e.g., a filter composed of activated charcoal, diatomite, or some other material that is capable of adsorbing chemical impurities from the solvent). Another type of filter provides not only a mechanical filter but also provides a device for adding an adsorptive powder to the unclarified solvent before the liquid passes through the mechanical filter. As the solvent passes through the mechanical filter from the high-pressure side to the low-pressure side, the adsorptive material as well as the solid impurities form a filter cake deposit on the high-pressure side of the filter, thus creating a layer of adsorptive material on the surface of the filter. Thereafter, when unclarified liquid passes through the mechanical filter, it also undergoes chemical filtration as it passes through the layer of adsorptive material.

In a typical dry cleaning operation, a dry cleaning machine and filter apparatus are used cyclically. When a load of clothing is being washed, solvent is circulated continuously from the dry cleaning machine to the filter apparatus and then back to the dry cleaning machine, and the returned solvent is supposed to be free of solid and chemical impurities, so that it may be reused to remove additional solid and chemical impurities from the load of soiled clothing in process. When the clothes are clean, the dry cleaning machine and the circulation of solvent through the filter apparatus are stopped, and the dry cleaning machine is reloaded with another load of dirty wash.

One of the principal problems encountered in a dry cleaning operation (as well as in all other filtering operations in which a substantial quantity of filter cake is removed from a liquid) is that solid impurities and adsorptive materials removed from the liquid accumulate on the surface of the filter and clog the filter, thereby impairing the efficiency of the filter apparatus. Therefore, many attempts have been made to devise methods and apparatus for removing filter cake from a filter surface and from a filter apparatus. Unfortunately, until now, these attempts have not been successful in producing a filter that can be cleaned frequently without costly and time-consuming delays in the filtering operating and without injury to the filter.

One type of filter apparatus previously developed utilizes a replaceable filter. When this filter becomes clogged, the operator discontinues the filtering operation, disassembles the filter apparatus, and replaces the filter with a new one. This procedure, of course, requires a great deal of time and much effort, so this apparatus is not readily adaptable to an operation in which the filter requires frequent cleaning.

Several filters have been developed in which filter cake may be dislodged from a filter surface without disassembling the filter apparatus. Some of these employ filter cleaning means such as brushes, scrapers, or sprayers that operate on the filter cake from the high-pressure or upstream side of the filter, while others employ a backwashing action (i.e., reversing the flow of liquid through the filter) that operates on the filter cake from the low-pressure or downstream side of the filter.

A primary problem that has characterized wiping approaches in the prior art involves the possibility that the use of a rigid scraper to wipe filter cake from a delicate filter surface, often a fine mesh screen, might damage or puncture the screen. Another problem is that an improper wiping speed can cause a wiping member to force a filter cake into and through the fine mesh screen and into the clarified liquid on the low-pressure side of the filter (thereby clogging the filter and contaminating the clari-

fied liquid), and it can cause the remaining filter cake to break into particles that are so finely divided that the settling of the dislodged particles from the liquid occurs very slowly, if at all.

One type of prior art device employing a means for dislodging filter cake from a filter surface without disassembling the filter apparatus is a dual-chamber filter specifically designed for clarifying a dry cleaning solvent. In the operation of this apparatus, unclarified liquid from a dry cleaning machine is pumped to a primary filter chamber, through a primary filter mounted in the chamber, and then back to the dry cleaning machine, leaving a filter cake deposit on the primary filter. When the accumulation of filter cake on the primary filter impairs the passage of liquid through the filter, a mechanical scraping device dislodges the filter cake from the filter and permits it to settle to the bottom of the chamber. When the accumulation of filter cake on the bottom of the chamber reaches an undesirable level, the filtering operation is interrupted and the entire contents of the primary filter chamber (including the filter cake) are pumped to a secondary or sludge filter chamber, wherein the liquid is removed from the filter cake by a secondary or sludge filter and is returned to the dry cleaning machine for re-use.

There are several disadvantages in this type of apparatus. First of all, when the filter cake is dislodged from the primary filter, much of it remains in suspension in the surrounding solvent, so the operator must wait until the force of gravity causes the particles to settle to the bottom of the chamber, before resuming the filtering operation in order to prevent the filter cake from being re-deposited on the primary filter. This waiting period results in a long delay in the filtering operation.

Another disadvantage in this filtering system is that the entire primary filter chamber must be evacuated in order to remove the sludge from the bottom of the chamber, thus requiring that the chamber be completely refilled every time the filter cake is removed before filtering can resume. Refilling the primary filter chamber creates additional delay in resuming the dry cleaning operation, and thus makes it impractical to evacuate the chamber after every dry cleaning cycle.

Still another disadvantage with this prior art system is that evacuation of the chamber leaves deposits of filter cake (like a bathtub ring) on the filter and on the walls of the primary filter chamber as the liquid is drained from the chamber, so the removal of filter cake from the primary filter chamber is incomplete.

Another example of a filter apparatus heretofore known comprises a primary filter and a secondary filter mounted in the same filter chamber. In the normal operation of this device (which is also specifically designed for filtering dry cleaning solvents), used dry cleaning solvent is pumped from a dry cleaning machine, through the primary filter, and then back to the dry cleaning machine, thereby depositing a filter cake on the primary filter. The secondary filter, mounted at the bottom of the filter chamber, is inoperative during the normal dry cleaning cycle. The primary filter is cleaned by backwashing the filter (i.e., reversing the flow of the solvent through the filter) and, at the same time, actuating the secondary filter at the bottom of the tank. This causes the filter cake to break away from the primary filter and drift to the bottom of the tank. The secondary filter returns solvent directly back to the dry cleaning machine for re-use.

The principal disadvantage of this type of apparatus is that the primary filter must be cleaned by backwashing in order to create the flow of liquid and dislodged filter cake from the primary filter to the secondary filter, and backwashing is very hard on a filter and reduces its life considerably. Most types of filters are constructed of a fine mesh screen supported only on the low-pressure side by a support structure, and this fine mesh screen distends and disrupts easily like a balloon when subjected to pressure from its low-pressure side. Therefore, backwashing is not feasible with most types of filters.

Another disadvantage in the above-described device is that liquid passing through the secondary filter returns directly to the dry cleaning machine, so it must be pumped all the way back to the filter for backwashing. Consequently, it takes a long time for the liquid to flow from the secondary filter to the primary filter, and this may prolong the cleaning operation. Moreover, the dry cleaning machine must be operative during the filter cleaning operation in order to pump liquid back to the filter apparatus for backwashing, even though it is normally stopped at the end of the dry cleaning cycle. If this cleaning operation were to be performed regularly (once per cycle, for example), the dry cleaning machine would be pumping liquid continuously, and this would result in greater fatigue and greater wear on the dry cleaning machine than would result from a normal cyclical operation.

Still another disadvantage in this filter apparatus is that the apparatus is constructed so that the secondary filter is operative only during a cleaning cycle. During the normal filtering operation, the secondary filter is deactivated, so gravity is the only force operative on the suspended particles to cause them to settle from the liquid in the filter chamber. This natural settling operation occurs quite slowly, so most of these particles are removed from the liquid by the primary filter, thus resulting in a rapid accumulation of filter cake on the surface of the primary filter. Therefore, frequent cleaning and frequent and harmful backwashing of the filter is required.

Another disadvantage in both of the filter systems described above is that filter cake is removed from the primary filters only when the filter cake begins to clog the filter, and the systems are not designed for frequent cleaning. Consequently, the openings in the primary filter for the passage of liquid must be quite large in order to avoid frequent clogging of the filter. This, of course, reduces the effectiveness of the filtering operation.

SUMMARY OF THE INVENTION

Since the utilization of the prior art filtering devices described above involves either an incomplete and time-consuming cleaning process or entails the harmful backwashing of the filter, neither of these devices are completely satisfactory for use in a large scale industrial process, such as in the dry cleaning industry, where almost continuous operation of a filter apparatus working at peak efficiency is required. The present invention obviates these deficiencies of the prior art devices and provides several embodiments of filtering apparatus that are capable of functioning in a cyclical operation at peak efficiency at all times.

Briefly, in the normal filtering operation of the several embodiments of the subject invention described below, unclarified liquid pumped from a source, such as a dry cleaning machine, enters a filter chamber in the filter apparatus, flows through a primary filter mounted therein, and flows out of the filter chamber to a receptacle (e.g., back to the dry cleaning machine), leaving a filtrate deposit on the surface of the primary filter.

In several embodiments of the invention, a portion of the liquid is filtered by a secondary filter, which is disposed either in an auxiliary filter chamber or in the same filter chamber below the primary filter. The latter approach is especially preferred because the secondary filtering action that is achieved creates a slight downward flow of liquid within the chamber and enhances the settling of solid particles from the unclarified liquid.

Another modification shown in several embodiments of the subject invention is the use of a turbulence suppressor at the inlet of the primary filter chamber in order to ensure that the liquid in the chamber remains in a quiescent state. One embodiment includes a turbulence suppressor that also functions as a wiper for removing accumulated filter cake from the primary filter.

Intermittently, the normal filtering operation is interrupted for a short time while the filter cleans itself. The flow of liquid through the primary filter is stopped, and a wiper mounted in the primary filter chamber in contact with the primary filter wipes accumulated filter cake from the high-pressure side of the primary filter and dislodges it into unclarified liquid surrounding the primary filter in the primary filter chamber. In one embodiment, a sprayer is also used to assist the wiper in dislodging the filter cake.

For the most effective wiping action, the preferred approach of the subject invention teaches that the relative motion between the wiper and the high-pressure side of the primary filter should be less than about 1000 inches per minute, and, ideally, about 200 to about 400 inches per minute. This prevents the filter cake from being forced through the filter by the wiper and causes the filter cake to break-off in large chunks that settle rapidly.

In order to ensure that the dislodged filter cake is not re-deposited on the filter surface when the filtering operation is resumed, the unclarified liquid entraining the dislodged filter cake is recirculated within the filter apparatus through a secondary filter located either at the bottom of the primary filter chamber or in separate filter chamber. This action transfers the suspended filter cake to the secondary filter and returns clarified liquid to the area surrounding the high-pressure side of the primary filter. When the secondary filter is mounted at the bottom of the primary filter chamber, the transfer of filter cake to the secondary filter is enhanced by the natural settling action attributable to the force of gravity.

There are several advantages to the important recirculation feature of the subject invention. First of all, the transfer of filter cake from the vicinity of the primary filter to the secondary filter is much more rapid and more thorough than can be accomplished by merely allowing the filter cake to settle under the influence of gravity or by draining the tank. Recirculation produces a flushing action that is much more vigorous than the settling or draining processes employed in the prior art filters.

Another advantage to the recirculation approach is that the filter cake is transferred to the secondary filter while the filter chamber remains full of liquid, so the primary filter is ready to commence another filtering operation immediately after the filter cake is transferred to the secondary filter. As stated above, additional time to refill the filter chamber is required when the inefficient draining process is used.

Still another advantage of the recirculation approach of the instant invention is that the primary filter is cleaned and the filter cake is transferred to the secondary filter without requiring any harmful backwashing of the primary filter, as is required in certain prior art filters.

Still another advantage of the instant invention is that this flushing or recirculating of liquid within the filter chamber is accomplished independently of the source from which the unclarified liquid is obtained. Thus, in an industrial use, such as in a dry cleaning operation, the dry cleaning machine need operate only during the washing cycle. During reloading, the dry cleaning machine may be completely inactive while the filter apparatus cleans itself independently and automatically.

After the filter cake suspended in the unclarified liquid has been transferred to the secondary filter, the recirculating means is automatically deactivated, and the filter is ready to resume another cycle with a freshly cleaned primary filter.

An additional feature disclosed in connection with one of the embodiments of the subject invention described below is an automatic cleaning device for the secondary filter. After the filter cake has been dislodged from the high-pressure side of the primary filter and transferred to the high-pressure side of the secondary filter by recirculating the liquid within the filter apparatus (i.e., recirculating the liquid from the primary filter chamber to the secondary filter chamber, through the secondary filter, and back to the primary filter chamber), and after the normal filtering operation has resumed, a wiper mounted in the secondary filter chamber wipes the filter cake from the high-pressure side of the secondary filter and dislodges it into the liquid surrounding the secondary filter. This filter cake then settles from the liquid into a removable basket at the bottom of the secondary filter chamber, leaving the secondary filter clean for the next filter cleaning operation.

It will be recognized readily that the methods and apparatus for filtering liquid described herein are applicable to a variety of filtering operations and are especially applicable to a dry cleaning operation because the filter is able to operate in successive continuous cycles at peak efficiency. At the completion of a washing cycle of a dry cleaning machine, the filter will clean itself automatically while the operator is removing the cleaned wash and inserting another load of dirty wash into the dry cleaning machine. By the time the dry cleaning machine is ready to resume operation, the filtering apparatus is cleaned and ready to reclarify the dry cleaning solvent.

Since this apparatus permits frequent removal of filter cake from the primary filter, clogging of the primary filter will be less of a problem than in the prior art filters, so that smaller openings in the primary filter (i.e., a filter screen with a finer mesh) may be employed.

Accordingly, it is a primary object of this invention to provide methods and apparatus for clarifying a liquid that facilitate frequent cleaning of the filter without any action on the part of the operator and with a minimum of interruption in the filtering process.

Another object of the invention is to provide an effective wiper for thoroughly dislodging filter cake from a filter in a filter apparatus without damaging the filter.

Another object of this invention is to provide a wiper as described above that also functions as a turbulence suppressor to ensure that liquids entering the filter apparatus are in a quiescent state.

Still another object of this invention is to provide an effective speed for wiping filter cake from the surface of a filter in a filter chamber such that filter cake is not forced through the filter by the wiping action and filter cake is not broken into finely divided particles that are slow to settle away from the filter in the filter chamber.

A further object of this invention is to provide methods and apparatus for actively transferring filter cake from a primary filter mounted in a filter chamber to a secondary filter without draining the filter chamber and without backwashing the primary filter.

Another important object of this invention is to provide methods and apparatus for transferring filter cake entrained in a liquid surrounding a primary filter in a filter apparatus to a secondary filter in the filter apparatus by recirculating the liquid within the filter apparatus through the secondary filter, without any backwashing of the primary filter.

Still another object of this invention is to provide methods and apparatus for recirculating liquid within a filter apparatus as described above wherein the liquid flows from the high-pressure side of the primary filter through the secondary filter and returns to the high-pressure side of the primary filter through directing means (such as sprayers or nozzles) that direct the returning liquid against the filter cake on the primary filter and help the wiper to dislodge the filter cake from the primary filter.

A further object of this invention is to provide methods and apparatus for clarifying a liquid wherein, during normal filtering operation, most of the liquid is clarified by a primary filter mounted in the filter apparatus, but a small portion of the liquid is filtered by a secondary filter mounted below the primary filter in the filter apparatus, so that the settling of solid particles suspended in the

iquid will be aided by the downward flow of liquid with-n the filter apparatus.

Another object of this invention is to provide a device for cleaning the secondary filter described above without disassembling the filter apparatus.

Still another object of this invention is to provide a ilter apparatus having primary and secondary filters which are mounted in separate, communicating filter chambers, wherein the secondary filter chamber may be solated from the primary filter chamber and disassembled and the filter cake removed therefrom without draining he primary filter chamber and without disrupting the filtering operation of the primary filter.

These and other objects, advantages, and features of he subject invention will hereinafter appear, and, for purposes of illustration but not of limitation, several exemplary embodiments of the subject invention are described below and illustrated in the appended drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGURE 1 is a perspective view of one embodiment of the subject invention, with clean-out doors removed in order to show the interior construction of the device;

FIGURE 2 is a perspective view of the embodiment shown in FIGURE 1, showing the opposite side of the device;

FIGURE 3 is a cross-sectional view, taken along line 3—3 of FIGURE 1;

FIGURE 4 is a cross-sectional end view of the embodiment shown in FIGURE 1, taken along line 4—4 of FIGURE 3;

FIGURE 5 is a cross-sectional view, taken along line 5—5 of FIGURE 1, showing the construction of a chemical filter and a chamber for the chemical filter;

FIGURE 6 is a cross-sectional view of a portion of a mechanical filter shown in FIGURES 3 and 4, taken along line 6—6 of FIGURE 4, showing the relation of spray nozzle relative to screen disc components of the filter;

FIGURE 7 is a cross-sectional view, taken along line 7—7 of FIGURE 6, showing an end cross-sectional view of a mechanical filter element and a spray nozzle and header adjacent to the filter element;

FIGURE 8 is a perspective view with a portion broken away of one of the mechanical filter elements shown in FIGURE 6, showing the interior construction of the element;

FIGURE 9 is a cross-sectional view taken on line 9—9 of FIGURE 7 showing the construction of a wiper;

FIGURE 10 is a schematic timing chart for the embodiment shown in FIGURE 1;

FIGURE 11 is a side elevational view of a portion of a second embodiment of the subject invention, shown for exemplary purposes connected to a conventional dry cleaning machine;

FIGURE 12 is a cross-sectional view of several filter elements in a primary filter mounted within the filter apparatus shown in FIGURE 11;

FIGURE 13 is a cross-sectional end view of the filter elements shown in FIGURE 12;

FIGURE 14 is a perspective view of a portion of the embodiment shown in FIGURE 11 with a portion of the filter apparatus broken away to show the filter elements in FIGURES 12 and 13 as they are mounted in the tank, and to show the interior construction of the filter apparatus;

FIGURE 15 is a detailed fragmentary view of a portion of a turbulence suppressor shown in FIGURE 14;

FIGURE 16 is a perspective view of the embodiment shown in FIGURE 11, with portions broken away to show the construction of a separator and a lower portion of a tank shown in FIGURE 14;

FIGURE 17 is a perspective fragmentary view of an adsorptive powder injector used with the filter apparatus shown in FIGURE 11;

FIGURE 18 is a perspective view with portions broken away of a carbon cooling filter used with the filter apparatus shown in FIGURE 11;

FIGURE 19 is an elevational view of a third embodiment of the subject invention shown for exemplary purposes connected to an adsorptive powder injector and a conventional dry cleaning machine by piping (which for clarity is shown in simplified form with the omission of many of the valves and connectors);

FIGURE 20 is an enlarged fragmentary partial cross-sectional view of a portion of the filter apparatus shown in FIGURE 19, showing a primary filter, a wiper, and a secondary filter above an outlet at the bottom of the tank;

FIGURE 21 is a perspective view of a portion of a turbulence suppressor shown in FIGURE 20, with a portion broken away in order to show the construction of turbulence suppressor in detail;

FIGURE 22 is an enlarged perspective view of the filter shown in FIGURE 19, showing in detail the primary and secondary filters and various valves and connections, with portions broken away to show the construction of the interior of the apparatus.

FIGURE 23 is a cross-sectional view of a portion of the primary filter and wiper shown in FIGURE 22;

FIGURE 24 is an elevational view of a portion of the primary filter and wiper shown in FIGURE 22, showing the wiper (a brush) in engagement with the opposing surfaces of two filter elements, and further showing the brush in engagement with a stop to hold the brush against free rotation relative to the filter apparatus;

FIGURE 25 is an elevational view of a fourth embodiment of the subject invention, shown for exemplary purposes connected to an adsorptive powder injector and a conventional dry cleaning machine by piping (which for clarity is shown in simplified form, with the omission of many of the valves and connectors);

FIGURE 26 is a cross-sectional view of the filter apparatus shown in FIGURE 25, showing primary and secondary filter chambers with primary and secondary filters mounted therein;

FIGURE 27 is an enlarged fragmentary perspective view of the lower portion of the primary filter chamber and the secondary filter chamber shown in FIGURE 26, showing a secondary filter and an auger mounted in the secondary filter chamber;

FIGURE 28 is an enlarged perspective view of the filter apparatus shown in FIGURE 25 showing in detail the various pipe sections and connections, with portions broken away to illustrate the construction of the interior of the apparatus;

FIGURE 29 is a cross-sectional end view of the secondary filter chamber shown in FIGURE 25, showing in detail the secondary filter and the auger mounted in the secondary filter chamber;

FIGURE 30 is an elevational view of a fifth embodiment of the subject invention, shown for exemplary purposes connected to an adsorptive powder injector and a conventional dry cleaning machine by piping (which for clarity is shown in simplified form, with the omission of many of the valves and connectors);

FIGURE 31 is an enlarged pictorial diagrammatic view of the filter apparatus shown in FIGURE 30, showing flow lines that illustrate the liquid flow paths to, from, and through the filter apparatus;

FIGURE 32 is an enlarged fragmentary perspective view of the filter apparatus shown in FIGURE 30, with portions broken away in order to show in the internal construction thereof;

FIGURE 33 is a cross-sectional elevational view of the apparatus shown in FIGURE 30, showing a wiper in its furthermost extended position;

FIGURE 34 is an enlarged cross-sectional fragmentary view of the filter apparatus shown in FIGURE 30, showing the construction of primary and secondary filter elements;

FIGURE 35 is an enlarged fragmentary cross-sectional view of the filter apparatus shown in FIGURE 34, showing a portion of a primary filter element and a wiper in engagement therewith breaking-off chunks of filter cake;

FIGURE 36 is a fragmentary perspective view of the filter apparatus shown in FIGURE 30, with portions broken away, showing an alternative construction of primary filter elements in the form of plates;

FIGURE 37 is a fragmentary cross-sectional view of the filter apparatus shown in FIGURE 36, showing the interior construction of one of the plate elements;

FIGURE 38 is a perspective view of one of the plate elements shown in FIGURES 36 and 37; and

FIGURE 39 is a fragmentary perspective view of the filter apparatus shown in FIGURE 30, with parts broken away, showing an alternative form of primary filter elements wherein the filter elements are in a V-form.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Embodiment No. 1—Dual-chamber filter

With reference to the drawings, FIGURES 1–10 show a first embodiment of the subject invention, comprising a dual-chamber filter apparatus, generally indicated by reference numeral **50**. As shown in FIGURES 1 and 2, the filter apparatus **50** includes a frame or hollow rectanuglar casing **52** having legs **54** for supporting the casing and having upper and lower doors **56** and **58**, respectively, in one end wall of the casing to provide access into the interior of the casing.

The interior of casing **52** is divided into an upper or primary filter chamber **60** and a lower or secondary filter chamber **62** by horizontal divider **64** which is attached to side walls **66** and **68** and to end wall **70**.

Upper and lower doors **56** and **58** are mounted on flange **72**, which extends around the periphery of an open end of casing **52**. Flange **72** is provided with a sealing bar **74** (to separate the primary filter chamber **60** from the secondary filter chamber **62** when the upper door **56** is closed) and a cross bar **76** (to receive the lower edge of upper door **56** and the upper edge of lower door **58**).

Primary filter chamber **60** is connected to a source of unclarified liquid, such as a dry cleaning machine (not shown), which pumps unclarified liquid containing solid and chemical impurities through pipe **78** into inlet header **80** mounted on end wall **70** and then through inlet apertures **82** formed in end wall **70** into the primary filter chamber **60**. An air vent **83** is provided in the primary filter chamber to permit the expulsion of air from the chamber.

After the liquid fills primary chamber **60**, the pump forcing the liquid into the filter chamber forces the liquid through a first mechanical filter or primary filter **84** rotatably mounted in the primary filter chamber **60**, whereby solid particles are removed from the unclarified liquid. The liquid is then pumped out of the primary filter chamber through bearing seal housing **86** and into outlet pipe **88**.

The construction of the primary filter **84** is shown in FIGURES 1, 3, and 6. A hollow filter shaft **92** is rotatably mounted in a filter bracket **90** at one end of primary filter chamber **60** and in bearing seal housing **86** at the other end. As shown in FIGURE 6, filter shaft **92** has perforations through its walls and is closed at both ends.

A perforated filter tube **94** is mounted on shaft **92** for rotation therewith. The ends of tube **94** are fixed to plates **96**, which are in turn fixed to filter shaft **92** to close the ends of the tube. The interior of tube **94** communicates with the interior of filter shaft **92** through the perforations in the shaft wall so that liquid may flow through tube **94** into shaft **92**.

As shown in FIGURES 3, 6, and 8, the filtering operation is accomplished by a series of hollow disc-shaped filter elements **98** mounted in coaxial alignment on filter tube **94** and separated by spacers **106**, which cover the perforations in filter tube **94** between adjacent filter elements. Each filter element **98** includes a support structure or spacer **100** covered with a fine mesh screen **102**. The support structure **100** is a flat sheet of material folded in an accordian-like fold radiating outward from the center of the element and tapering to a point at the outer edge. The fine mesh screen **102** covering the support structure **100** has 325 by 325 openings per square inch (each opening being approximately 47 microns) so that all solid particles suspended in a liquid are retained on the screen when unclarified liquid is pumped through the filter. The outer periphery of each of the filter elements **98** has a metal rim **104** fixed thereon that slightly overlaps the screen and seals the outer periphery of the filter element.

In passing through the primary filter the unclarified liquid received in primary filter chamber **60** through inlet apertures **82** flows from the high-pressure side of the primary filter through the fine mesh screen **102**, along the pleats of the accordian-like support structure **100**, through filter tube **94**, and into filter shaft **92**. The liquid then flows along filter shaft **92** into bearing seal housing **86** and into outlet pipe **88**. At this stage, all solid particles should be removed from the unclarified liquid and deposited as filtrate on the fine mesh screens **102** on the high-pressure side of primary filter.

After leaving the primary filter chamber through outlet pipe **88**, the liquid then flows into chemical filter chamber **108** mounted on the top **71** of casing **52** and enters the chemical filter chamber through inlet pipes **110** and **112**.

Chemical filter chamber **108**, which is best seen in FIGURE 5, includes a tubular outer casing **114** with a fixed head **116** sealingly mounted on the right end (FIGURE 5 orientation) and a removable head **118** sealingly mounted on the other end. A perforated interior tube **120** is mounted inside the chemical filter chamber **108** and extends through head **116**. A closure **122** is threaded on the end of interior tube **120**, and a stud **124** is threaded into an opening in closure **122**. A wing nut **126** is threaded on the stud in engagement with the closure. The stud extends through removable head **118** and engages a threaded handle **128** which holds the removable head **118** in position. An air vent **129** is provided in the chemical filter chamber to permit the expulsion of air from the chamber.

A chemical filter **130** mounted within chemical filter chamber **108** includes two identical filter sections **132** and **134** that are mounted in series on interior tube **120**. Each section has an outer perforated tubular wall **136** and an inner perforated tubular wall **138** which are fastened together by end plates **140** and **142** to form a porous casing surrounding the perforated tube. Each casing is filled with granules of activated charcoal **144**.

When liquid received from the primary filter chamber enters the chemical filter chamber through inlet pipes **110** and **112**, the liquid flows through the outer perforated tubular wall **136** of the chemical filter, through the activated charcoal **144**, through the inner perforated tubular wall **138**, and into the interior of interior tube **120**. As the liquid passes through the activated charcoal, chemical impurities dissolved in the liquid are adsorbed by the activated charcoal and retained in the chemical filter. The clarified liquid then flows along interior tube **120** through fixed head **116** and to an appropriate receptacle for clean liquid (e.g., back to the dry cleaning machine).

As the filtering operation continues, filter cake removed from the unclarified liquid continues to build up on the high-pressure side of the primary filter, and this impedes the free flow of unclarified liquids through the primary filter. Accordingly, provision is made in the subject apparatus for the intermittent removal of accumulated filter cake from the surface of the primary filter.

Wipers **146** are rotatably mounted on each spacer **106** separating the individual filter elements of the primary filter so that each wiper is in contact with the opposing faces of two adjacent filter elements. A drive means **148** is provided for rotating primary filter **84** relative to

wipers 146. This relative motion between the wipers and the primary filter elements causes the filter cake to be dislodged from the surfaces of the filter elements into the unclarified liquid in primary filter chamber 60.

As shown in FIGURES 7 and 9, each wiper is slidably mounted on an arm 150 that is attached in a non-radial position to a ring 152, which is in turn rotatably mounted on spacer 106. Arm 150 is attached to ring 152 in the non-radial position shown (i.e., the filter rotates into an acute angle between the ring and the arm) so that the rotation of the filter relative to the wiper will automatically urge the wiper to slide along the arm toward the axis of the filter and thereby ensure a firm contact between the wiper and the surface of the filter.

Each wiper includes a resilient U-shaped band 159 slidably mounted over each arm 150 (FIGURE 9 orientation) and brushes 156 fastened on the outside of the legs of the U-shaped band 154 by clips 158. A rod 160 is soldered to the U-shaped band 154 below the arm 150 to maintain the band in its U-shape. Each brush 156 has a woven backing 162 with nylon fibers 164 lodged therein and engages the surface of one filter element in the manner shown in FIGURE 6. An arm stop 166 is mounted on wall 66 of the primary filter chamber to prevent wipers 146 from rotating in a counterclockwise direction (the direction of rotation of the primary filter 84) so that the wipers will remain stationary and brushes 156 will dislodge accumulated filter cake from the entire surface of the filter elements when drive means 148 rotates the primary filter.

It has been found that the speed at which the filter elements are rotated relative to the stationary wiper brushes is important to the efficient operation of the wiper 146. When the surface of the filter element is wiped at a speed greater than about 1000 inches per minute some of the filter cake is forced into and/or through the fine mesh screen 102, thereby clogging the filter and reducing the effectiveness of the filtering operation. Moreover, this rapid wiping breaks the rest of the filter cake into particles that are so finely divided that they do not settle readily from the liquid surrounding the primary filter. If, on the other hand, a wiper speed of less than 1000 inches per minute is employed, preferably between about 200 and about 400 inches per minute, the wiping action forces the filter cake away from the filter surface and causes it to break off in large chunks that settle readily from the surrounding liquid. Accordingly, drive means 148 should be adjusted to provide the proper wiping speed in this apparatus.

Since particles dislodged from the primary filter 84 are placed in suspension in the liquid in the primary filter chamber 60, immediate resumption of the filtering operation could cause these particles to be redeposited on the primary filter. Therefore, means are provided in the subject apparatus for removing dislodged filter cake from the primary filter chamber 60 by recirculating the liquid in the primary filter chamber through a secondary filter 182 in a secondary filter chamber 62 and returning the liquid directly back to the primary filter chamber 60 .

As shown in FIGURE 4, primary filter chamber 60 has a baffle 168 which extends most of the length of the entire chamber, leaving openings at the ends so that solvent may be drawn behind the baffle from primary filter chamber 60. A conventional pump 170 mounted on wall 68 draws liquid from behind baffle 168 through exhaust conduit 172 and delivers the liquid through delivery pipe 174 through one-way valve 176 and into header 178 mounted on end wall 70. The liquid then flows from header 178 through inlet aperture 180 into the secondary filter chamber 62.

Pump 170 then forces the liquid entraining the dislodged filter cake through a second mechanical filter or secondary filter 182 rotatably mounted in the secondary filter chamber in order to remove the dislodged filter from the liquid. After the liquid passes through secondary filter 182, it flows into hollow filter shaft 184 (corresponding to filter shaft 92 of primary filter 84), along the shaft 184 out of secondary filter chamber 62, and into bearing seal housing 186 mounted on the outside of end wall 70. From the bearing seal housing 186, the liquid flows into outlet pipe 188 and returns directly back to the primary filter chamber through header 190 on wall 66.

Header 190 has a plurality of spray nozzles 192 mounted therein which spray the liquid returning to the primary filter chamber against the high-pressure sides of primary filter elements 98, and thereby aid wipers 146 in dislodging filter cake from the filter elements.

The construction of the secondary filter 182 is identical to the construction of the primary filter 84, and the secondary filter 182 is also connected to drive means 148 for rotation within the filter chamber. The only difference in the drive arrangement is that drive means 148 rotates the secondary filter in the opposite direction from which it rotates the primary filter. In this case, the secondary filter rotates in a clockwise direction and the primary filter rotates in a counterclockwise direction.

Wipers identical to the wipers 146 employed in cleaning primary filter 84 are also provided for cleaning the secondary filter 182. The only structural dissimilarities between the wipers are that the wipers for the secondary filter are adapted to operate with filter elements that are rotated in a clockwise direction, as shown in FIGURE 4. Stop 194 attached to wall 66 prevents the rotation of the wiper in a clockwise direction.

Filtrate dislodged from the secondary filter 182 by the rotation of the secondary filter in a clockwise direction relative to the wiper settles within secondary filter chamber 62 into a perforated collector basket 196 slidably mounted on supporting flanges 198 and 200 just above the bottom 69 of the secondary filter chamber. Supporting flanges 198 and 200 are mounted on side walls 66 and 68, respectively. Baffles 202 and 204, also mounted on wall 66 and 68, respectively, guide the settling dislodged filter cake into the collector basket.

The secondary filter chamber is provided with an air bleed valve 206 (shown in FIGURE 1) and two liquid drain valves 208 and 210 which are attached to end wall 70 and communicate with the interior of secondary filter chamber 62 (shown in FIGURE 3). The upper drain valve 208 is positioned just above collector basket 196 in the secondary filter chamber and is connected to a drain pipe 212 which leads to an appropriate storage tank for unclarified solvent (not shown). Another outlet from drain pipe 212 is a conduit 214 leading through shut off valve 216 to an inlet in chemical filter chamber 108. The lower drain valve 210 is placed at the bottom of the secondary filter chamber for draining solvent from the portion of the chamber containing the collector basket 196 so that the lower door 58 may be taken off and the collector basket may be removed for cleaning.

As stated above, the primary and secondary filters are rotatably driven in opposite directions by a single drive means 148. This drive means (shown in FIGURES 1 and 3) is constructed as follows. Hollow filter shaft 92 of the primary filter extends through bearing seal housing 86 and is connected to sprocket 218 through one-way clutch 220, which effects driving engagement between shaft 92 and sprocket 218 when sprocket 218 is rotated in a counterclockwise direction. Drive chain 222 connects sprocket 218 to a drive sprocket 224, which is mounted on an output shaft 226 of a reversible electric motor 228. Similarly, hollow filter shaft 184 of the secondary filter extends through its bearing seal housing 186 and is attached to a second sprocket 230 through one-way clutch 232 which effects driving engagement between the sprocket and shaft when the sprocket is rotated in a clockwise direction. A second drive chain 234 connects sprocket 230 with drive sprocket 224.

With the drive arrangement set up in this manner, when reversible electric motor 228 operates in a counterclock-

wise direction, primary filter **84** is rotated in a counterclockwise direction and is cleaned by wipers **146**, while second sprocket **230** free wheels and secondary filter remains stationary. When the direction of the motor is reversed to a clockwise direction, secondary filter **182** is rotated in a clockwise direction and is cleaned by the wipers mounted in the secondary filter chamber, while sprocket **218** free wheels and primary filter **84** remains stationary.

The operation of this filter apparatus is controlled by a conventional control device, including a timer and other conventional components, mounted in control box **236** on side wall **68** (shown in FIGURE 1). The control device controls the operation of pump **170** and drive means **148** and controls the flow of liquid through the filter apparatus.

An example of the sequential operation of the subject apparatus in a typical dry cleaning operation is as follows. In the normal washing cycle of a dry cleaning machine there is a continuous circulation of dry cleaning solvent from the dry cleaning machine through the filter apparatus and back to the dry cleaning machine for a period of eight and one-half minutes (as shown in the time chart in FIGURE 10). A sump pump in the dry cleaning machine forces dirty solvent from the washing machine through inlet pipe **78** into the primary filter chamber **60** wherein solid particles suspended in the dry cleaning machine are removed by primary filter **84**. The liquid passes through fine mesh screens **102** of primary filter elements **98** and flows into hollow filter shaft **92** and out of the primary filter chamber through bearing seal housing **86**. The dry cleaning solvent, still containing dissolved chemical impurities, then flows into chemical filter chamber **108** through inlet pipes **110** and **112**, wherein chemical impurities are removed from the solvent by chemical filter **130**. The clarified liquid then leaves the chemical filter through interior tube **120** and returns to the dry cleaning machine for reuse.

At the end of the washing cycle, the dry cleaning machine is stopped and the operator removes the cleaned wash and reloads the dry cleaning machine with dirty clothing. During that time the primary filter **84** is automatically cleaned and filter cake dislodged therefrom is flushed from primary filter chamber **60**. Control device **236** interrupts the flow of solvent to and from the filtering apparatus and simultaneously activates reversible electric motor **228** in a counterclockwise direction to clean the primary filter and activates pump **170** to recirculate the liquid within the filter apparatus through the secondary filter. The counterclockwise operation of the the reversible electric motor **228** causes primary filter **84** to rotate in a counterclockwise direction relative to wiper **146** (preferably at a speed less than 1000 inches per minute), and this causes the filter cake accumulations on the primary filter to become dislodged from the primary filter and pass into suspension in the unclarified liquid in primary filter chamber **60**. The simultaneous recirculation of the liquid within the filter apparatus from primary filter chamber **60** through secondary filter **182** transfers the dislodged filter cake from the primary filter chamber to the high-pressure side of secondary filter **182** and returns clarified liquid back to the primary filter chamber while leaving both the primary and secondary chambers full of liquid at all times. The returning liquid enters primary filter chamber **60** through spray nozzles **192** which spray the incoming liquid against the high-pressure side of primary filter elements **98** and assist wipers **146** in dislodging filter cake from the surfaces of the primary filter elements.

This simultaneous wiping and spraying of the primary filter elements and the recirculating of liquid within the filter apparatus continues for a period of one and one-half minutes, when control device **236** deactivates pump **170** and reversible electric motor **228** so that another washing cycle may be commenced with a clean primary filter and a clean primary filter chamber.

One minute after the normal washing cycle has been resumed, control device **236** activates reversible electric motor **228** in a clockwise direction so that secondary filter **182** is rotated in a clockwise direction relative to stationary brushes mounted in the secondary filter chamber **62**. This effects the removal of accumulated filter cake from the surface of secondary filter **182** and dislodges this filter cake into the liquid in secondary filter chamber **62**. One-way valve **176** ensures that the liquid remains in the secondary filter chamber while the secondary filter is being cleaned, and thus prevents the liquid from contaminating the liquid in the primary filter chamber. After one minute of operation, the control device **176** deactivates reversible electric motor **228** so that both the primary and secondary filters are stationary. Particles dislodged from the surface of secondary filter **182** settle to the bottom of the secondary filter chamber and collect in the perforated collector basket **196** for the remainder of the washing cycle (i.e., 6½ minutes), leaving the secondary filter clean for the next filter cleaning cycle.

Filter cake accumulated in collector basket **196** may be removed from filter apparatus **50** periodically without disrupting the normal dry cleaning cycle by draining secondary filter chamber **62** through drain valves **208** and **210**, removing lower door **59**, and sliding perforated collector basket **196** from the machine on supporting flanges **198** and **200**.

Chemical filter **130** also may be replaced easily by removing threaded handle **128**, removable head **118**, and closure **122**. Chemical filter sections **132** and **134** may then be withdrawn from the chamber by sliding them from the chamber axially along interior tube **120**.

Embodiment No. 2—Unitary-chamber filter

A second embodiment of the subject invention, a filter apparatus having primary and secondary filters mounted in a single filter chamber, is shown in FIGURES 11–18 in conjunction with a conventional dry cleaning machine. Although this apparatus may be used in any large scale filtering operation, one of the principal applications foreseen for this invention is in the dry cleaning industry, so for exemplary purposes, this apparatus is shown and described in that context.

Referring now to the drawings and especially to FIGURE 11, a second filter apparatus embodying the subject invention, generally indicated by reference numeral **313**, is shown connected to a conventional dry cleaning machine **310** having a sump pump **312** for circulating used dry cleaning solvent through the filter apparatus. Sump pump **312** pumps the used dry cleaning solvent to a filter pump **316** which raises the pressure of the dry cleaning solvent and discharges it into clarifying tank **318**. An adsorptive power injector **314** is employed with this filter apparatus to inject an adsorptive powder into the unclarified liquid before it reaches the clarifying tank **318**. Tank **318** has an outlet for returning clarified solvent to the dry cleaning machine for reuse.

The outlet of sump pump **312** is connected to a pipe **320** that conveys used dry cleaning solvent from the dry cleaning machine to the inlet of filter pump **316** through check valve **322** and inlet T **324**. The filter pump, which is driven by a conventional electric motor **328**, pumps the solvent through check valve **330** and control valve **332** and discharges it through conduit **336** into turbulence suppressor **334** in tank **318**.

The turbulence suppressor includes a splash dome **340**, which constitutes the upper portion of the tank, and a floor **344** with an elongated slot **346** formed therein. An elongated plate **348** is secured to the bottom of the floor by a plurality of blocks **350** and is spaced from the floor **344** below the slot **346** so that any fluid flowing through the slot **346** must pass between the plate **348** and floor **344** to enter the tank **318**. Solvent entering the turbulence suppressor through conduit **336** is directed upward against the splash dome **340** by elbow **342** on the end of

conduit 336, and then it flows to slot 346 and passes between floor 344 and plate 348 into filter chamber 353 below.

The tank 318 includes a generally cylindrical upright shell 352 having a bottom 354 and a head 356, with the turbulence suppressor 334 mounted in the head. An open frame 358 fixed on the side of shell 352 defines an aperture 360. A door 364 is mounted on a plurality of stud bolts 62 in frame 58 for convenient access to the interior of the tank. The interior portion of the tank below the turbulence suppressor constitutes filter chamber 353.

A primary filter, generally indicated by numeral 366, is rotatably mounted in the upper portion of filter chamber 353. This filter is identical to primary filter 84 employed in the first embodiment of the subject invention (described above) and includes a plurality of filter elements or discs 368 mounted on a perforated tube 370. As in the Embodiment No. 1, each of the filter elements or discs includes a support structure covered with a 325 by 325 mesh screen 392 made from wire having a diameter of 0.0014 inch using a plain weave. This particular screen has openings of approximately 47 microns, and these openings are small enough so that filter aids and lint will be retained on the screen, but the openings are not so small that water will not pass through the filter screen.

The tube 370 is fixed to a perforated hollow filter shaft 372, one end of which is rotatably supported in support bar 374. The other end of shaft 372 is supported by and communicates with a junction 376, so that a fluid may flow from the interior of the filter chamber through the filter elements 363, through tube 370, into shaft 372, and then to junction 376 to be returned to the dry cleaning machine.

Wipers 378 that are less complex than the wipers 146 employed in Embodiment No. 1 are positioned between each pair of adjacent filter elements 368. Each of the wipers includes a ring 382, which is freely rotatable relative to tube 370, and an arm 384 which is fixed to the ring and engageable with a stop 380 mounted on shell 352 to limit rotation of the wipers. Fixed to each arm 384 and its corresponding ring 382 is a tapered brush 386. Each brush 386 includes a conventional wire stem 388 with a plurality of nylon bristles 390 conventionally secured to the wire stem. It should be noted that each tapered brush 386 fits between and is in engagement with the opposing surfaces of two adjacent filter elements.

The filter elements of the primary filter are rotatable in the filter chamber 353 through shaft 372. Shaft 372 extends through the junction 376 and has a wheel 383 fixed thereon, which wheel is driven by a belt 385. The belt 385 is mounted in driving engagement with pulley 387 mounted on the outlet shaft of a speed reducer 389. The speed reducer 389 receives its source of power from a conventional electric motor (not shown). Thus, when the electric motor is activated, the primary filter is rotated relative to brushes 386, and this action causes filter cake to be wiped from the filter elements and placed in suspension in the liquid surrounding the primary filter in the filter chamber.

A secondary filter 394 is mounted within the filter chamber 353 below the primary filter at a slight distance above the bottom of the filter chamber. The secondary filter includes a pair of perforated plates 396 and 398 and a screen 400 sandwiched between the plates. Screen 400 is of the same construction as the screens 392 in the primary filter.

A solvent outlet 402 for secondary filter 394 is placed at the bottom 354 of filter chamber 353. The outlet 402 is connected to the junction 376 by means of piping 404 through a one-way check valve 406 that allows solvent to flow only toward the junction 376. An outlet in junction 376 leads to an outlet T 408 through piping 410 and manual outlet control valve 412. One branch of T 408 is connected to the filter pump inlet T 324 through a one-way check valve 414 that allows fluid to flow only from T 408 toward T 324. The other branch of T 408 is connected to a return pipe 418 leading back to the dry cleaning machine 310 through solenoid valve 416.

Solenoid valve 416 is a conventional component that may be selectively activated to block the flow of clarified solvent from the filter to the dry cleaning machine, in which case filter pump 316 forces the solvent to flow through check valve 414 and recirculate through the filter apparatus. When solenoid valve 416 is open, the pressure differential across check valve 414 is such that no liquid flows through the check valve, so it all returns to the dry cleaning machine. Consequently, dry cleaning solvent clarified by the primary and secondary filters may be pumped back to the dry cleaning machine or it may be recirculated through the filter apparatus simply by opening or closing solenoid valve 416.

An adsorptive powder injector 314 of the type described in applicant's copending U.S. application, Ser. No. 698,451, filed Jan. 17, 1968 provides a convenient means for introducing adsorptive powder into the dry cleaning solvent. The injector is supported on post 420 which is in turn fixed to shell 352, as may be best seen in FIGURE 17. The adsorptive powder injector 314 may include a storage container 422 connected to a mixer chamber 424. An electric motor 426 is connected to a dispenser between the mixer chamber and the storage container to dispense a prescribed amount of adsorptive powder from the storage container into the mixer chamber. An additive inlet pipe 428 leads from pipe 320 to the inlet of the mixer chamber to deliver solvent to the mixer chamber and an additive outlet pipe 430 leads from the outlet of the mixer chamber 424 to the inlet to the sump pump in the dry cleaning machine to return solvent bearing adsorptive powder in suspension to the system.

Although the wipers 378 are a satisfactory means for removing filtrate from the primary filter, this filtrate settles to the secondary filter at the bottom of the filter chamber and must be removed from the filter occasionally (e.g., every four to eight weeks). Accordingly, the subject apparatus provides for the occasional removal of filtrate from the filter chamber with a minimum loss of dry cleaning solvent.

A steam inlet 432 in tank 318 in connected to a conventional source of steam through a steam pipe 434 which has a gauge 436 connected thereto. When steam is introduced into the filter chamber, steam and solvent are forced through outlet 438 mounted in the bottom of the filter chamber and flow through piping 440 and manual control valve 442 to a condenser 444, wherein the solvent and steam are condensed. Condenser 444 includes cooling coils 448 mounted within condenser shell 446 in the upper portion of tank 318 surrounding the turbulence suppressor. Cooling coils 448 are connected to a conventional source of cold water to condense the evaporated liquids.

In order to separate the condensed solvent from the condensed steam (i.e., water), the condenser shell is connected to a separator 450 by means of conventional piping 452. The separator 450 (shown in FIGURE 16) includes a vessel 454 which has an inlet 456 positioned in the upper portion of the vessel that is connected to piping 452. A flat, vertically positioned water baffle 458 is mounted within the vessel and has vertical sides sealingly fixed to the vessel so that fluid may enter only at the bottom of the baffle. The baffle extends down into the vessel a distance less than half of the height of the vessel so that only the lighter liquid (i.e., the water) will flow behind the baffle. A water outlet 460 is positioned in the upper portion of vessel 454 behind water baffle 458 and this outlet is connected to a conventional drain by means of piping 462. A solvent baffle 464 mounted parallel to water baffle 458 in vessel 454 also has vertical sides sealingly fixed to the vessel 454, but this baffle extends further toward the bottom of the vessel 454 so that only the heavier liquid (i.e., the solvent) will flow behind the baffle. The space between the bottom of baffle 464 and

the bottom of vessel **454** is approximately one-fourth the overall height of the vessel **454**. A solvent outlet **466** is positioned in the upper portion of the vessel **454** behind the solvent baffle **464** and is connected to dry cleaning machine **310** by means of piping **468** to return dry cleaning solvent to the dry cleaning machine from the separator.

The dry cleaning machine **310** operates in a conventional manner. While clothes are being cleaned, a dry cleaning solvent such as perchlorethylene is pumped through a container holding clothes, and used solvent is delivered to sump pump **312**. The sump pump forces the dry cleaning solvent along pipe **320** through the check valve **322** and into the filter pump **316**. The filter pump **316** forces the dry cleaning solvent through check valve **330** and elbow **342**, splashing the dry cleaning solvent up against dome **340**. The solvent flows along the dome and along floor **344** through elongated slot **346**. As the solvent flows through elongated slot **346**, it engages the elongated plate **348** and flows outward into filter chamber **353**.

It may be appreciated that the turbulence suppressor causes the dry cleaning solvent to assume a steady flow along the upper portion of the filter chamber so that there is a minimum of turbulence within the filter chamber. The quiescent state within the filter chamber enhances the settling of solid particles from the liquid and prevents the disruption of the layer of filter aid on the filter elements.

Most of the dry cleaning solvent is filtered by the primary filter **366**, so most of the dry cleaning solvent flows toward the primary filter. However, a minor portion of the dry cleaning solvent is filtered by the secondary filter **394**, so a minor portion of the solvent flows downward toward secondary filter. This constant flow of dry cleaning solvent downward toward the secondary filter causes the solid particles to drift toward the bottom of the filter chamber, thus complementing the natural settling effects due to gravity.

The dry cleaning solvent filtered by the primary filter flows through fine mesh screens **392**, leaving all additive, lint, and other foreign particles trapped on the outer or high-pressure surfaces of the screens, and then it flows through perforated tube **370** and hollow shaft **372** into junction **376**. The minor portion of the dry cleaning solvent filtered by the secondary filter flows through perforated plates **396** and **398** and screen **400**, leaving foreign particles, lint, and additive on screen **400**. The solvent then flows through outlet **402** and along piping **404** through check valve **406** and into junction **376**.

The dry cleaning solvent from the primary and secondary filters then flows from junction **376** back to the dry cleaning machine through piping **410**, T **408**, solenoid valve **416**, and piping **418**. During the washing cycle, solvent does not flow from T **408** through the check valve **414** because the pressure drop through the primary filter and the secondary filter is sufficiently great so that the pressure at T **408** is less than the pressure at T **324**. Therefore, all of the filtered dry cleaning solvent is returned to the dry cleaning machine.

At the end of each washing cycle of the dry cleaning machine, the filter apparatus automatically cleans itself while the dry cleaning machine is shut off for unloading and loading clothes. Thus, the subject apparatus does not allow its primary filter to become unduly clogged and lose efficiency. After the dry cleaning machine stops, both the sump pump and the filter pump operate for 23 seconds and then they are stopped simultaneously. The tank remains filled with dry cleaning solvent when the two pumps stop. For the next 20 seconds there is no movement of the mechanical parts of the apparatus so that the dry cleaning solvent may attain a quiet attitude.

At the end of the 20 second period the disc drive motor is activated and wheel **383** is driven to rotate the filter elements **368** relative to the respective brushes **386**. This causes all filtrate (i.e., foreign particles, lint, and adsorptive powder) to be dislodged from the surface of the discs into the liquid in the filter chamber. As in the first embodiment, the effectiveness of the wiper is greately improved if the relative speed between the surface of the filter elements and the wiper is less than 1000 inches per minute, preferably between 200 and 400 inches per minute. The disc drive motor operates for one minute and 22 seconds, during which time there is no flow of solvent through the tank.

After the disc motor is stopped, the filter cake that has been dislodged from the filter elements is allowed to settle in the tank toward the secondary filter for five seconds, so that the dislodged filtrate will settle below the primary filter.

After this settling period, solenoid valve **416** is closed and filter pump **316** is placed into operation. The filter pump forces dry cleaning solvent to flow through the turbulence suppressor into the filter chamber and then out of the filter chamber through the primary and secondary filters into junction **376**. From the junction **376** the solvent flows through piping **410** to T **408**. Since the valve **416** is closed, the solvent passes through check valve **414** and is returned to the filter pump **316** to be recirculated through the filter apparatus. As this recirculation continues, the force of gravity and the constant downward flow of solvent to the secondary filter cause all of the dislodged filter cake to drift to the secondary filter at the bottom of the filter chamber. Moreover, the rapid recirculation of solvent within the filter apparatus tends to flush the tank and remove solid material that may have adhered to the walls of the filter apparatus.

After two minutes of operation of the filter pump with the solenoid valve **416** closed, the filter cake that has been removed from the filter elements will have been transferred to the secondary filter, so the solenoid valve **416** is opened and the sump pump **312** is activated, thus resuming the flow of dry cleaning solvent through the filter apparatus. After 40 seconds of operation of the sump pump, the adsorptive powder injector **314** is activated for one minute and 15 seconds in order to add adsorptive powder (in this instance, activated carbon) to the solvent and deliver it to the inlet of the sump pump. From there the activated carbon is carried to the filter pump and into the tank. As the solvent passes through the primary and secondary filters, the activated carbon is retained on the fine mesh screens like all other solid particles and coats the outer surface of the filter elements. When the screens are thoroughly coated with a layer of adsorptive material, the apparatus is in condition to start another washing cycle. It should be noted that as the dry cleaning solvent passes through the screens during the normal filtering, it is first subjected to chemical filtration as it passes through the layer of activated carbon on the filter surface and then it is mechanically filtered by the fine mesh screen covering the primary and secondary filters.

The above-described operation provides a convenient means for cleaning the primary filter after each load of dry cleaning, in preparation for the next load of clothing. Consequently, the primary filter is operating at peak efficiency during each washing cycle and there is always a fresh layer of activated carbon on the screens for removing chemical impurities from the dry cleaning solvent.

In addition to the removal of filter cake from the primary filter, on occasion it is necessary to remove accumulated filter cake from the surface of the secondary filter. Because the secondary filter handles only a minor portion of the normal filtering, the subject apparatus need only be cleaned every four to eight weeks, depending upon the volume of clothing cleaned by the dry cleaning machine. In order to conserve the dry cleaning solvent, the subject device utilizes live steam to force the dry cleaning solvent out of the tank and to distill dry cleaning solvent from the filter cake which is deposited on the secondary filter.

After the dry cleaning machine is shut down, the subject filter apparatus is shut down by deactivating the filter pump **316**, closing manual outlet valve **412** and control valve **332**, and opening steam control valve **442**. Live steam is introduced into steam pipe **434** from a convenient source of steam in a dry cleaning establishment (not shown), and the pressure of the steam forces the dry cleaning solvent to flow through the secondary filter and into steam and solvent outlet **438**. The dry cleaning solvent flows along piping **440** to the condenser shell **446**, and from the condenser shell to the separator **450**. It may be noted that by closing valves **332** and **412** there is no opportunity for the solvent and steam to be forced into the dry cleaning machine. Rather, all of the solvent, steam and steam condensate is carried to the condenser **444** and then to the separator **450**. After the initial amount of dry cleaning solvent is forced out of the tank, some of the solvent is vaporized, so both steam and vaporized solvent flow into the condenser **444**. The steam also distills the solvent from the accumulated filter cake, so very little dry cleaning solvent is lost when the filter cake is removed from the filter apparatus and discarded. In condenser **444**, the cooling coils cause the vaporized solvent and steam to condense so that a mixture of water and liquid dry cleaning solvent is delivered to the separator **450**.

Separator **450** utilizes the differences in specific gravity of solvent and water to separate the solvent from the water. The mixture of dry cleaning solvent and water enters the separator **450** through inlet **456**. Since the water is lighter than the solvent, the mixture separates with the water floating above the solvent. The water flows behind baffle **458** and is drained off through water outlet **460**, and the solvent flows between baffle **464** and the wall of vessel **454** and is drained from the separator through outlet **466** and returned to the dry cleaning machine.

After substantially all of the solvent has been recovered from the tank, the steam inlet is shut off and the tank is allowed to cool. Next, the door **364** is removed from the frame **358** and the accumulated filter cake comprising a mixture of foreign particles and adsorptive powder is removed from the surface of the secondary filter. After the tank is thoroughly cleaned, the door is remounted on the frame **358** and the tank is closed. Valve **442** is then closed and valves **332** and **412** are opened, and the tank is filled with dry cleaning solvent from the dry cleaning machine and the apparatus is ready for use.

The subject apparatus readily adapts itself to a modified construction wherein a carbon-cooling filter for providing additional chemical filtration and for cooling the solvent may be mounted on the outlet of solenoid valve **416**. As shown in FIGURE 18, carbon-cooling filter **470** includes a jacket **472** and a cover **474** sealingly mounted thereon. Positioned in the jacket is a carbon granule canister **476** formed by a perforated tubular outer wall **478**, a perforated central tube **480**, and sealed ends **482** and **484**. The canister is filled with conventional activated carbon granules **488**.

The lower end of tube **480** (FIGURE 18 orientation) is connected to the outlet of valve **416**, and the other end is closed by cap **486**. A wing nut **490** is mounted in cap **486**, and a threaded stud **492** is mounted in the wing nut and extends through the cover **474**. A handle **494** is threaded on stud **492** for holding cover **474** in place. Jacket **472** has an outlet **496** which is connected to the return pipe **418** leading to the dry cleaning machine.

A cooling coil **498** is positioned between the canister **476** and the interior wall of jacket **472**. A coolant inlet **497** is connected to a convenient source of cold water (not shown) and a coolant drain **499** is connected to a convenient water drain (not shown).

With the carbon cooling filter **470** mounted on the subject apparatus, the clarified dry cleaning solvent leaving solenoid valve **416** enters the tube **480** and passes through the carbon granule canister **476** into the space between the canister and the jacket **472**, thereby undergoing an additional chemical filtration step. The dry cleaning solvent then is cooled by cooling coil **498** and is delivered to the outlet **496**, from which it is carried by return pipe **418** to the dry cleaning machine.

Embodiment No. 3—Unitary-chamber filter with annular filter elements

A third embodiment of the subject invention is shown in FIGURES 19–24. As in Embodiment No. 2, for exemplary purposes this filter apparatus is shown connected to a conventional dry cleaning machine.

Embodiment No. 3 is quite similar in structure and in operation to Embodiment No. 2, with the exception of the method for occasionally removing filter cake from the filter tank, and with the exception of a number of dissimilar features (e.g., a different type of filter element and wiper; a compressed air purge for the filter chamber instead of a steam purge; a Teflon-coated turbulence suppressor; two doors in the filter chamber; observation junctions in the lines; and, a different structure for the secondary filter).

Referring now to the drawings and especially to FIGURE 19, a third filter apparatus embodying the subject invention, generally indicated by reference numeral **510**, is shown connected to a conventional dry cleaning machine **512** having a sump tank **514** and a sump pump **516** for pumping used dry cleaning solvent through inlet piping **520** to a filter pump **534**. Filter pump **534** then raises the pressure of the dry cleaning solvent and discharges it into a clarifying tank **432**. The filter apparatus **510** is provided with primary outlet piping **522** for returning clarified solvent to the dry cleaning machine for reuse and with secondary outlet piping **524** for draining solvent from the filter apparatus and returning it to sump tank **514** for refiltering.

An adsorptive powder additive injector **518** of the type used in Embodiment No. 2 is employed with this filter apparatus in order to inject an adsorptive powder into the unclarified liquid before it reaches the filter apparatus **510**. The inlet to the additive injector is connected to inlet piping **520** through injector inlet pipe **526** and inlet valve **528**, and the outlet from the additive injector is connected to the inlet of sump pump **516** through injector outlet pipe **530**, so that solvent flowing along inlet piping **520** is partially diverted through the adsorptive powder injector (where it picks up a charge of adsorptive powder) and is returned to the sump pump, which pumps it through inlet piping **520** to the filter apparatus. The additive injector is also provided with a drain pipe **592** that leads to secondary outlet piping **524** through a manual control valve **590** so that the additive injector may be drained before removal, repair, or cleaning.

Looking now to FIGURE 22, as in Embodiment No. 2, the filter apparatus **510** includes a cylindrical tank **532** which has a filter pump **534** mounted on the top thereof, with a motor **536** drivingly connected to the filter pump. A turbulence suppressor, generally indicated by number **538**, is formed in the upper portion of the tank, and a filter chamber **539** is formed in the lower portion of the tank. A primary filter **540** is rotatably mounted in the upper part of filter chamber **539**, and a secondary filter **546** is mounted at the bottom of filter chamber **539**. Wiper means **542** for cleaning the primary filter **540** are mounted in the filter chamber in engagement with the primary filter, and a drive means **544** is mounted on the outside of the tank and is drivingly connected to the primary filter **540** to rotate the primary filter relative to the wiper means.

Unclarified dry cleaning solvent entering the filter apparatus through inlet piping **520** passes through an inlet control valve **548** and a check valve **551** and enters filter pump **534** through inlet T **550**. The outlet of the filter pump is connected to turbulence suppressor piping **552** through a filter pump check valve **554** and an inlet observation junction **555**. The turbulence suppressor piping terminates in an interior section **556**, which is positioned in the turbulence suppressor within the tank **532**. Unclari-

fied solvent received by filter pump **534** is pumped through this piping into the turbulence suppressor.

The turbulence suppressor **538** (shown in FIGURES 20 and 21) is formed by a dome-shaped upper end **594** of tank **532** and a flat floor **596** sealingly fixed to the interior walls of tank **532**. The floor **596** includes an elongated slot **598** having its center on a diameter of the floor and an elongated suppressor plate **600** spaced below the slot but connected to the floor by a plurality of blocks **602**. The underside of the floor **596** is covered with a slippery material such as Teflon so that particles entrained in the solvent pumped into the turbulence suppressor from filter pump **534** will not stick to the floor as the solvent flows out of the turbulence suppressor through slot **598** and into the filter chamber.

Primary filter **540** is similar to the primary filter **366** employed in Embodiment No. 2 in that it includes a series of disc-shaped filter elements or filter discs **606** mounted on a perforated tube **604**. However, the construction of the filter elements in Embodiment No. 3 is different from the construction of the filter elements used in Embodiments No. 1 and No. 2. In those embodiments, the filter elements take the shape of two opposed saucers, with the portions mounted on the tube being relatively wide and with those portions tapering gradually to a common point at the outer periphery of the filter elements, while the subject filter elements **606** are cylindrical in shape and have parallel filtering surfaces. As shown in detail in FIGURES 23 and 24, each of the filter elements includes a spacer ring **608** and a pair of circular filter screen discs **610**. Each of the circular filter screen discs is made from 325 by 325 mesh filter screen which is made from wire having a diameter of 0.0014 inch using a plain weave (as in Embodiments No. 1 and No. 2). This particular screen has openings of approximately 47 microns, and these openings are small enough so that filter aids, adsorptive powder, dirt and lint are retained on the screen, but the openings are not so small that water will not pass through the screen. The outer periphery of each of the filter screens is fixed to its respective spacer ring **608**, and the inner periphery of each of the filter screens is fixed to a washer ring **612**, which is fixed to tube **604**. Tube **604** is mounted on drive shaft **613**, which is rotatably mounted in the filter chamber in the same manner employed in Embodiment No. 2.

Tube **604** communicates with an outlet head **558** mounted on the outside of filter chamber **539** at the end of primary filter **540** (as in Embodiment No. 2). Head **558** is connetced to outlet T **560** (corresponding to T **408** in Embodiment No. 2), one branch of which is connected to inlet T **550** through check valve **562** (corresponding to one-way check valve **414** in Embodiment No. 2), and the other branch of which is connected to the primary outlet piping through a control valve **564** (corresponding to solenoid valve **416** in Embodiment No. 2). A manual shut-off valve **566** and an observation junction **568** are also included in outlet piping **522**.

The wiper means **542** for removing filter cake from the primary filter are also different from the wipers employed in Embodiments No. 1 and No. 2. Each of the wiper means **542** includes a wiper ring **614** rotatably mounted on the perforated tube **604** in engagement with adjacent washer rings **612** of adjacent filter elements. A wiper rod **616** has one end fixed to the respective wiper ring **614**, and a plurality of nylon bristles **618** is mounted on the rod to provide a brush for removing particles from the filter screen discs. The bristles are positioned in engagement with adjacent filter discs. Mounted in the filter chamber **539** is a stop bar **620**, which is engageable with the free end of the wiper rods **516** to hold the brushes as the filter elements rotate in the tank.

The drive means **544** mounted on the side of tank **532** for the rotation of primary filter **540** is identical to the driver means employed in Embodiment No. 2.

As in Embodiment No. 2, a minor portion of the solvent entering filter chamber **539** is filtered by a secondary filter **546** mounted at the bottom of the filter chamber, but a modified form of construction for the secondary filter is employed. The secondary filter **546** includes a lower perforated filter plate **622** (corresponding to plate **398** in Embodiment No. 2), which has its outer periphery sealingly fixed to the interior of the tank, and a secondary filter screen **624** (corresponding to filter screen **400** in Embodiment No. 2) mounted thereon. However, an annular locking ring **626** is mounted on the screen in engagement with the outer periphery of the screen to hold the screen in place instead of the upper perforated plate **396** used in Embodiment No. 2.

A solvent outlet **572** for secondary filter **546** is placed at the bottom of filter chamber **539**. The outlet **572** leads through pipe **570** into T **574**. One arm of T **574** is connected to head **558** through return piping **578** and a manual secondary outlet valve **580** for returning clarified solvent to the dry cleaning machine or for recirculating dry cleaning solvent within the filter apparatus. The other arm of T **574** is connected to secondary outlet piping **524** through manual drain valve **576**, pipe **588**, T **586**, and T **582** for draining the filter chamber. A drain outlet in the side of the filter chamber is also connected to secondary outlet piping **524** through a manual control valve **584** for the same purpose. Likewise, a drain outlet in the additive injector **518** is connected to the secondary outlet piping **524** through a conduit **592** and a manual control valve **590** for draining the additive injector.

As in Embodiment No. 2, the subject filter apparatus provides a means for occasionally removing accumulated filter cake from the filter chamber **539**, but the means employed in this embodiment are much less complex than the means used in Embodiment No. 2. Instead of using the steam purge of Embodiment No. 2, the subject filter employs a compressed air purge, so that no water contaminates the dry cleaning solvent. Consequently, there is no need for the condenser **444** and separator **450** used in Embodiment No. 2. The compressed air is supplied by a conventional source and is connected to the tank **532** through an air pipe **632** and an air inlet **634** positioned in the side of the tank immediately below the turbulence suppressor **538**.

The tank **532** includes a removable upper door **628** (which provides a convenient access to the primary filter), and a removable lower door **630** (which provides a convenient access to the secondary filter) for cleaning the filter chamber and/or repairing or replacing the filters once the air purge has evacuated the tank.

The operation of the subject filter apparatus in conjunction with a conventional dry cleaning machine **512** is the same as described for Embodiment No. 2. During the normal washing cycle, most of the solvent is filtered by the primary filter **540**, but a small portion of the solvent is filtered by the secondary filter **546**, so that there is a constant downward flow of solvent in the tank to enhance the settling of solid particles from the solvent and to prevent them from being deposited on the primary filter.

Cleaning of the primary filter is accomplished by rotating the primary filter relative to the wiper **542** at a speed of less than about 1000 inches per minute. In the specific construction of the subject filter apparatus, the filter elements have an outside diameter of 10 inches and are rotated at 10 revolutions per minute, so that the speed of the outer periphery of the filter elements is approximately 314 inches per minute. This particular rate of relative movement has been found to be very efficient in the removal of filter cake.

Filtrate dislodged from the primary filter is transferred to the secondary filter by closing the control valve **564** and recirculating the solvent within the filter chamber through both the primary and secondary filters until the constant downward flow of solvent toward the secondary filter and the force of gravity cause all dis-

lodged filter cake to drift to the secondary filter at the bottom of the tank.

During any phase of the operation of the instant apparatus, an operator may observe the color of the solvent entering the tank by observing the solvent in the observation junction **555**. An operator may also observe the color of the solvent being delivered to the dry cleaning machine by noting the solvent in observation junction **568**. An operator may thereby note a malfunction of the instant device before any serious consequences occur.

As in Embodiment No. 2, it is occasionally necessary to evacuate tank **532** and remove the accumulated filtrate from the filter chamber **539**. This operation is performed when the dry cleaning machine is shut down. First, valves **548** and **566** are closed, and valve **576** is opened. Next compressed air is delivered to the air inlet **634** so that all of the dry cleaning solvent in the tank is forced out through the secondary filter **546**. The compressed air also tends to squeeze the dry cleaning solvent out of the filter cake on screen **624**. The dry cleaning solvent leaves the tank through outlet **572** and flows through secondary outlet piping **524** back to the dry cleaning machine.

Once the dry cleaning solvent is forced out of the tank, door **630** is removed and all of the filter cake (i.e., lint, foreign particles and additives) in the tank is removed from the secondary filter. The primary filter **540** and wipers **542** may be inspected, repaired, or replaced by removing door **628**.

After the tank has been cleaned, the doors **628** and **630** are replaced, valves **548** and **566** are opened, valve **576** is closed, and the tank is filled with dry cleaning solvent. The additive injector **518** is then placed into operation in order to coat the annular screen discs with adsorptive powder, and the apparatus is ready for use.

Embodiment No. 4—Dual-chamber filter with auger

A fourth embodiment of the subject invention is shown in FIGURES 25–29. As in Embodiments No. 2 and No. 3, for exemplary purposes this filter apparatus is shown connected to a conventional dry cleaning machine.

Embodiment No. 4 is similar to Embodiment No. 3, but it includes a novel secondary filter arrangement that makes it possible to remove accumulated filter cake from the filter apparatus very quickly and without discontinuing the filtering operation.

Referring now to the drawings, and especially to FIGURE 25, a fourth filter apparatus for clarifying a liquid embodying the subject invention is generally indicated by numeral **710**. In this instance, the filter apparatus **710** is connected to a conventional dry cleaning machine **712** having a sump tank **714** and a sump pump **716** for delivering used dry cleaning solvent to the filter apparatus **710**. A conventional adsorptive powder additive injector **718** is connected to the filter apparatus **710**.

As may be seen in the diagrammatic representation of the piping in FIGURE 25, the sump pump **716** has its outlet connected to the filter apparatus **710** through inlet piping **720**. The filter apparatus **710** has its outlet connected to the dry cleaning machine **712** by primary outlet piping **722**. The filter apparatus **710** also has a secondary outlet piping **724** connected to the dry cleaning machine. The additive injector **718** is connected to piping **720** by an injector inlet **726** through an injector inlet valve **728**. The outlet of the additive injector is connected to the inlet of sump pump **716** through injector outlet piping **730**, so that a portion of the dry cleaning solvent from the sump pump is diverted through additive injector **718**, where it picks up a charge of adsorptive powder, and that portion of the dry cleaning solvent is returned to the inlet of the sump pump and is pumped to the filter apparatus **710**.

The filter apparatus **710** includes a cylindrical housing **732** with a filter pump **734** mounted on top of the housing **732**. As may be seen in FIGURE 26, a turbulence suppressor **736** is mounted within the housing, and a primary filter chamber **738** is mounted below the turbulence suppressor **736** in communication with the turbulence suppressor. A primary filter **740** is rotatably mounted in the primary filter chamber **738**, and the primary filter has a plurality of wipers **742** in engagement therewith, which wipers engage a stop **743**. A secondary filter chamber **744** is mounted below the primary filter chamber **738** and is connected to the primary tank through a valve **746**. The secondary filter chamber has a secondary filter **748** positioned in the lower portion thereof with an auger assembly **750** mounted adjacent to the secondary filter.

Looking now to FIGURE 28, it may be seen that the inlet piping **720** includes an inlet control valve **752**, which has mounted in series therewith a one-way inlet check valve **754**. The inlet piping **720** is connected to an inlet T **756** which has one arm connected to pump **734**. The pump has its outlet connected to piping **758**, which piping **758** includes a one-way check valve **760** and an observation junction **762**. The piping **758** terminates within suppressor **736** in an upwardly directed elbow **764**.

The turbulence suppressor **736** includes a dome-shaped head **766** which is a part of the housing **732**. A circular floor **768** is positioned below the dome **766**, and the floor has its outer periphery sealingly fixed to the housing **732**. Both the upper and lower surfaces of floor **768** are coated with tetrafluoroethylene so that materials will not cling to the surfaces and disrupt the flow of liquid. The floor **768** has an elongated slot **770** positioned on a diameter and an elongated suppressor plate **772** mounted below the slot and fastened to the bottom of floor **768** by a plurality of blocks **774**.

Primary filter chamber **738** is bounded on the top by floor **768** of the turbulence suppressor, on the sides by housing **732**, and on the bottom by conical bottom **776**, which opens into valve **746**. The conical bottom **776** also communicates with a drain outlet pipe **778** to provide a means for draining the primary filter chamber. An inspection door **779** is mounted on the housing to provide easy access to the interior of the primary filter chamber for maintenance of the primary filter and the wipers.

The primary filter **740** is identical in construction to the primary filter employed in Embodiment No. 3 and includes a plurality of filter elements or filter discs **780** which are mounted on a disc shaft **782**. The disc shaft **782** communicates with a head **784**, and the shaft is driven by a motor **786** through a drive **788**, as in Embodiments No. 2 and No. 3. The head **784** is connected to the outlet piping **722** through a T **790**, one arm of which is connected to the outlet piping through an outlet control valve **792** (corresponding to solenoid valve **416** in Embodiment No. 2), and the other arm of which is connected to a cross-over pipe **794**, which leads through check valve **796** (corresponding to valve **414** in Embodiment No. 2) to inlet T **756**. The outlet piping **722** also includes a manual outlet shut-off valve **798** and an outlet observation junction **800**.

Wipers **742** identical to the wipers **542** employed in Embodiment No. 3 are rotatably mounted on primary filter **740** and engage stops **743**, which prevents the wipers from rotating with the primary filter.

The secondary filter chamber includes a cylindrical tubular shell **802**, which has its axis perpendicular to the axis of housing **732** and extends beyond the housing, as may be best seen in FIGURE 28. The shell has an end plate **804** sealingly fixed on one end and a door **806** releasably secured to the other end by a conventional fastener **808**.

The secondary filter **748** is mounted entirely within the shell **802**. The secondary filter includes a perforated filter support plate **810**, which has ears **812** and **814** formed integrally with the plate and fixed sealingly to the interior of shell **802**. One end of support plate **810** sealingly engages the end plate **804**, and the other end of the plate is sealingly engageable with door **806**. A secondary filter screen **816** of the type employed in the embodiments described above is mounted on top of plate **810**.

In order to allow liquid passing through secondary filter **748** to leave shell **802**, an aperture is provided at the bottom of the shell with a junction box **818** mounted thereon to collect liquid that passes through the secondary filter. Shell **802** also contains an inlet port in its upper portion that is connected to valve **746** through inlet pipe **820**.

An auger assembly **750** is mounted in the secondary filter chamber for moving residue toward the open end of the shell **802**. As shown in FIGURE 27, the auger assembly includes an auger shaft **824** having one end rotatably and sealingly mounted in end plate **804** and the other end rotatably mounted in a shaft support **826**, which is fixed to shell **802** adjacent to door **806**. An auger blade **828** is fixed to shaft **824**, with its outer edge positioned adjacent to screen **816** of the secondary filter for moving residue along the screen. The auger assembly is connected to a sprocket **830** mounted on shaft **824** through a clutch **832**. The sprocket is driven by a chain **834** through a drive sprocket **836** connected to drive **788**, which is driven by motor **786**.

As may be seen in FIGURE 27, the secondary filter chamber **744** is connected to a source of compressed air (not shown) through piping **838**, trap **840**, and an air control valve **842**. The junction box **818** of the secondary filter has its outlet connected to an outlet T **846**, one arm of which is connected to secondary return piping **848** and head **784** through a secondary outlet valve **850**, and the other arm of which is connected to drain piping **724** through secondary filter chamber drain valve **852**, piping **856**, T **854**, and T **844**. The other arm of T **854** leads to the additive injector **718** through a manual control valve **858** and piping **860** and provides a means for draining the additive injector through drain piping **724**. The drain piping **724** also is connected to the drain outlet piping **778** of the primary filter chamber **738** through a T **844** and a drain outlet control valve **862** and provides a means for draining the primary filter chamber through drain piping **724**.

Valve **746** between the primary and secondary filter chambers is a conventional ball valve with an elongated stem **864** extending out through the housing **732**. A handle **866** is connected to the stem **864** so that the valve may be conveniently operated exteriorly of the housing.

During the normal operation of the dry cleaning machine, valve **746** remains open and the subject apparatus operates in the same manner and according to the same time schedule as Embodiments No. 2 and No. 3. During the washing cycle, the primary filter **740** handles the major portion of the filtering operation, but a small portion of the unclarified solvent is drawn through valve **746** from the primary filter chamber **738** and is filtered by the secondary filter **748** and returned to the dry cleaning machine. This gradual and steady flow of solvent in a downward direction enhances the settling of particles from the solvent during the washing cycle.

When the washing cycle is completed, outlet control valve **792** is closed and accumulated filter cake is dislodged from the primary filter by rotating primary filter discs relative to stationary wipers **742** in the same manner employed in Embodiments No. 2 and No. 3.

Dislodged filter cake is then transferred to the secondary filter by recirculating the solvent within the filter apparatus (i.e., through the primary and secondary filters and then back to the primary filter chamber through check valve **796** and pump **734**) until the downward flow of solvent through the secondary filter and the settling action of gravity cause all of the dislodged filter cake to drift through valve **746** to the secondary filter at the bottom of secondary filter chamber **744**.

The principal difference between the operation of the subject apparatus and the operation of the embodiments described previously is in the method for removing accumulated filter cake from the secondary filter. With this apparatus it is not necessary to interrupt the filtering operation and drain the primary filter tank in order to remove accumulated filter cake from the filter apparatus. Rather, while the dry cleaning machine is operating in its normal washing cycle and the primary filter is operating to clarify the dry cleaning solvent, the operator simply turns handle **866**, which closes the valve **746** between the primary and secondary filter chambers, and closes valve **850** and opens valve **852**. He then opens air control valve **842** and introduces compressed air into the secondary filter chamber, so that the dry cleaning solvent is drained from the secondary filter chamber through drain piping **844**. This leaves only the filter residue in the dry cleaning tank. The door **806** is then opened by loosening the fastener **808**, and the drive means is placed into operation, so that sprocket **836** operates the chain **834**, and the clutch **832** is placed into engagement to drive the auger shaft **824**. The rotation of the auger shaft causes the auger blade to carry all of the residue which has collected on the screen **816** of the secondary filter toward the open end of shell **802**. After all of the residue has been expelled by the auger, the auger is stopped and the door **806** is again placed into sealing engagement with shell **802**. Valve **852** is closed and valve **746** is opened so that the dry cleaning solvent fills the secondary tank. Finally, valve **850** is opened so that the subject apparatus resumes the cycles described above.

Because of the ease with which this filter may be cleaned, the instant apparatus may be operated continuously in a dry cleaning establishment without requiring any interruptions for periodic cleaning or replacement of filters or adsorptive materials.

Embodiment No. 5.—Unitary-chamber filter with elongated filter elements

A fifth embodiment of the subject invention is shown in FIGURES 30–39. As in Embodiments Nos. 2, 3, and 4, for exemplary purposes this filter apparatus is shown connected to a conventional dry cleaning machine.

Embodiment No. 5 is quite similar to Embodiment No. 3 of the subject invention, with the principal differences being that vertically disposed, elongated rod, plate, or V-shaped filter elements are employed as the primary filter instead of the coaxially stacked disc-shaped filter elements utilized in Embodiment No. 3, and a novel, combination turbulence suppressor and resilient wiper is employed instead of the separate turbulence suppressor and rotatably mounted wipers utilized in Embodiment No. 3.

Referring now to the drawings, and especially to FIGURE 30, a fifth filter apparatus embodying the subject invention, generally indicated by reference numeral **920**, is shown connected to a conventional dry cleaning machine **922** having a sump tank **924** and a sump pump **926** for circulating used dry cleaning solvent through inlet pipe **930** to a filter pump **952**. Filter pump **952** raises the pressure of the dry cleaning solvent received from sump pump **926** and discharges it into a clarifying tank **942**. The filter apparatus **920** is provided with primary outlet piping **932** for returning clarified solvent to the dry cleaning machine for reuse and with secondary outlet piping **934** for draining solvent from the filter apparatus and returning it to sump tank **924** for refiltering.

An adsorptive powder additive injector **928** of the type used in Embodiments Nos. 2, 3, and 4 is employed with this filter apparatus in order to inject an adsorptive powder (in this instance activated carbon and diatomite) into the unclarified solvent before it reaches the filter apparatus **920**. One difference from Embodiment No. 3 is that the inlet to the additive injector is connected to outlet piping **932** returning clarified solvent to the dry cleaning machine instead of to the inlet piping **930** (as in Embodiment No. 3). The inlet to the additive injector is connected to outlet pipe **932** through injector inlet pipe **936** and inlet valve **938**, and the outlet from the additive injector is connected to the inlet of sump

pump 926 through pipe 940, so that solvent returning to the dry cleaning machine from the filter apparatus along outlet pipe 932 is partially diverted through the adsorptive powder injector (where it picks up a charge of adsorptive powder) and is returned to the sump pump 926, which then pumps it through inlet piping 930 to the filter apparatus. The adsorptive powder injector is also provided with a drain pipe 996 that leads to secondary outlet piping 934 through a manual control valve 998 so that the additive injector may be drained before removal, repair, or cleaning.

As shown in FIGURES 32, 33, and 34, the filter apparatus 920 includes a cylindrical tank 942 having cylindrical side wall 1100 with a top of 1102 and a bottom 984 sealingly secured thereto. A filter pump 952 is mounted on the side wall 1100. A filter head 946 is formed in the upper portion of the tank, and a filter chamber 947 is formed in the lower portion of the tank. A primary filter 944 is mounted in the upper portion of the filter chamber and is attached to the under side of head 946 so that the outlet or low-pressure side of the primary filter communicates with the interior portion of filter head 946. A secondary filter 956 is mounted at the bottom of the filter chamber 947. A horizontal wiper 948 for cleaning the primary filter 944 is movably mounted in the tank below filter head 946 in engagement with the primary filter. A conventional double-acting hydraulic cylinder 950 mounted on the top 1102 of tank 942 is connected to the wiper 948 for moving the wiper vertically relative to the primary filter. The hydraulic cylinder 950 is connected to any convenient source of hydraulic fluid through conventional valving. The space between the wiper 948 and the filter head 946 constitutes a turbulence suppressor 954.

Filter head 946 (shown in FIGURE 34) is formed by the top 1102 of the tank and by a pair of parallel head plates 1104 and 1105 sealingly mounted in tank 942. Upper head plate 1104 has a plurality of apertures 1110 that register with the outlet or low-pressure side of the primary filter 944, so that solvent clarified by the primary filter may flow into filter head 946. Filter head 946 has an outlet that leads to a T 974, one arm of which leads to outlet piping 932 for returning clarified solvent to the dry cleaning machine and the other arm of which leads back to the inlet of the filter pump 952 through check valve 964 for recirculating solvent within the filter apparatus. Lower head plate 1105 positioned below the upper head plate 1104 and fastened thereto has apertures that are in alignment with the apertures in upper head plate 1104. The purpose of the two head plates is to provide a means for suspending the primary filter in the filter chamber while maintaining a tight seal between the primary filter and the apertures in filter head and while permitting the occasional removal of individual elements of the primary filter from the head plate and from filter apparatus. The lower surface of lower head plate 1105 is coated with Teflon to prevent solid particles from accumulating on the surface.

Primary filter 944 includes a plurality of vertically disposed, hollow, rod-shaped filter elements 1106 that fit through the apertures in lower head plate 1105 and are suspended from the lower head plate 1105 by hollow cylindrical collars 1108 that are in sealing communication with the apertures in upper head plate 1104 (as shown in FIGURE 34). These elements extend from the filter head 946 down into the filter chamber through openings in wiper 948. The lower portion of each filter element comprises a cylindrical heavy wire base 1112 attached to the bottom of collar 1108 in alignment with the collar, with a plug 1114 closing the bottom end of the filter element. A fine mesh filter screen 1116 of the type used in Embodiments Nos. 1–4 is mounted over the heavy wired base in order to provide a suitable filtering surface.

Horizontal wiper 948 includes a sheet of rubber 1118 or some other resilent material that engages filter screens 1116 of each of the filter elements. This sheet of rubber is sandwiched between an upper wiper plate 1120 and a lower wiper plate 1122. Apertures are provided in the rubber and in the wiper plates so that the filter elements 1106 may fit through the wiper. The apertures in the sheet of rubber 1118 are formed so that the rubber is in engagement with the filter elements, but the apertures in the wiper plate are larger than the filter elements so that the rigid plates do not contact and damage the fine filter screen. As shown in FIGURE 35, the opening in the lower wiper plate 1122 is slightly larger than the opening in the upper wiper plate 1120, and the opening is beveled so that filter cake dislodged from the filter elements will be bowed away from the surface of the filter and will not be forced into the pores of the filter screen.

The wiper 948 is spaced from the walls of filter chamber 947 and is suspended in the filter chamber by a cylinder rod 1124 of the cylinder 950 that is vertically movable along the entire length of the filter elements (as shown in FIGURE 33). The cylinder rod passes through a seal 1126 which is mounted on filter head plate 1104 to insure that there is no contamination of the filtered dry cleaning solvent with the unfiltered dry cleaning solvent.

In order to maintain the wiper in alignment with the filter elements, three rigid guide rods 1128 are secured to lower head plate 1105 (as shown in FIGURE 34), and these guide rods are slideably engaged by rod bearings 1130 fixed to upper plate 1120 of the wiper. Thus, as the wiper travels along the length of the filter elements, the guide rods maintain perfect alignment between the wiper and the filter elements.

As stated above, turbulence suppressor 954 is formed by the bottom of the filter head 946 and upper portion of the wiper 948. Since the wiper is spaced slightly from tank wall 1100, dry cleaning solvent entering the filter chamber in the space between the filter head and the wiper through piping 968 flows upward toward lower head plate 1105 and along the bottom of the filter head to the outer periphery of the wiper and then into that portion of the tank below the wiper where the filter screens of the filter elements are exposed. Both the bottom of the filter head 946 and the top of the wiper 948 are coated with Teflon in order to prevent the solid particles entrained in the solvent from collecting on these surfaces.

Most of the solvent entering the filter chamber from the turbulence suppressor is filtered by the primary filter, but a minor portion of the solvent is filtered by the secondary filter 956 mounted at the bottom of the filter chamber 947. Secondary filter 956 is identical to the secondary filter employed in Embodiment No. 3.

The outlet piping provided for the secondary filter is very similar to the corresponding outlet piping in Embodiment No. 3 and includes solvent outlet pipe 980 at the bottom of filter chamber 947 that leads to T 986. One arm of T 986 is connected to filter head 946 through return piping 988 for returning clarified solvent to the dry cleaning machine or for recirculating dry cleaning solvent within the filter apparatus. The other arm of T 986 is connected to secondary outlet piping 934 through manual control valve 990. A drain outlet in the side of the filter chamber is also connected to secondary outlet piping 934 through a manual control valve 994 for the same purpose. Likewise, a drain outlet in the additive injector 928 is ronnected to the secondary outlet piping 934 through a drain pipe 996 and a manual control valve 998 for draining the additive injector.

During the normal operation of the filter apparatus, solvent filtered by the secondary filter passes through the arm of the T 986 that leads to filter head 946, where the solvent joins the solvent clarified by the primary filter. The solvent leaving filter head 946 may be returned to theh dry cleaning machine through T 974, outlet control valve 978, manual control valve 976, and primary outlet pipe 932, or, by closing outlet control valve 978, the solvent can be returned to the inlet of filter pump 952 through check valve 964, T 962, and pipe 970 and recirculated through the filter apparatus. This is the same type of outlet piping utilized in Embodiments Nos. 2, 3, and 4.

As in Embodiment No. 3, the subject apparatus provides for the occasional removal of filter cake from the filter chamber by purging the tank with compressed air and then removing a door and withdrawing accumulated filter cake. The air inlet is not shown in the drawings, but removable door **1140** mounted on aperture **1138** is shown in FIGURE 32.

The dry cleaning machine **922** operates in a conventional manner. While clothes are being cleaned, dry cleaning solvent is pumped through a container holding the clothes, and the used dry cleaning solvent is then delivered by sump pump **926**. The sump pump forces the dry cleaning solvent along piping **930** to the filter pump **952** through inlet control valve **958**, check valve **960**, T **962**, and pipe **970**. The filter pump **952** then forces the used dry cleaning solvent along pipe **968** into turbulence suppressor **954**.

Inside turbulence suppressor **954**, the used dry cleaning solvent flows along the bottom of the filter head toward the wall **1100** of the tank. Since the adjacent surfaces of plates **1105** and **1120** are coated with Teflon, there is no opportunity for foreign particles to adhere to those surfaces and impair the operation of the wiper. When the dry cleaning solvent reaches the wall **1100**, it passes between the wiper and the wall **1100** and into filter chamber **947** in a steady downward flow so that there is no turbulence in the filter chamber.

It should be noted that in addition to the absence of turbulence caused by the turbulence suppressor, there are other advantages to the flow patterns created within the filter chamber by the turbulence suppressor **954**. First of all, the solvent is forced to flow along the walls of the filter chamber, and this provides a cleansing action that prevents solid particles from clinging to the walls. Another advantage to the flow pattern produced is that the solvent flows in a downward direction along the walls toward the secondary filter, thus causing the solid particles to drift toward the bottom of the filter chamber away from the primary filter.

Most of the solvent entering the filter chamber is filtered by the primary filter. The solvent flows through the filter screens **1116** into the interior of the filter elements and upward through collars **1108** into the head **946**, leaving filter cake deposited on the outside of the filter elements. The dry cleaning solvent then leaves the head **946** and enters the primary outlet piping **932** through T **974** to be returned to the dry cleaning machine for reuse.

As in Embodiments Nos. 2, 3, and 4, a minor portion of the dry cleaning solvent flows downward toward secondary filter **956**, thereby setting up a state of steady downward flow within the tank (complementing the downward flow caused by the turbulence suppressor) that causes large foreign particles to drift to the bottom of the filter chamber. The natural force of gravity also enhances this settling effect. The dry cleaning solvent clarified by the secondary filter leaves the filter chamber through solvent outlet pipe **980**, T **986**, and secondary return pipe **988** to head **946**. There it joins the major portion of the clarified dry cleaning solvent and is returned to the dry cleaning machine for reuse.

At the end of each washing cycle of the dry cleaning machine, the filter apparatus **920** automatically cleans itself while the dry cleaning machine is shut off for the unloading and loading of clothes. Thus, the instant apparatus does not allow its primary filter to become clogged and lose efficiency. After the dry cleaning machine stops, both the sump pump **926** and filter pump **952** operate for 23 seconds and then are stopped simultaneously. The tank **942** remains filled with dry cleaning solvent when the two pumps stop. For 20 seconds, there is no movement of the mechanical parts of the apparatus so that the dry cleaning solvent may attain a quiet attitude. During this period, the valve **978** is closed and any foreign particles in the dry cleaning solvent start to settle out due to gravity.

At the end of the 20 second settling period, cylinder **950** is activated through a convenient source of hydraulic fluid so that the rod **1124** is moved downward, thereby pushing wiper **948** downward in a straight line along primary filter elements **1106**. This action scrapes the filter cake from the surface of the primary filter elements and dislodges it into the solvent at the bottom of the filter elements.

As in the other embodiments, it is important that the speed of the wiper **948** be carefully controlled so that the relative movement between the wiper and the filter screens is less than 1,000 inches per minute in order to thoroughly remove the filter cake (i.e., absorptive powder, dirt and other foreign particles) from the filter screens. As shown in FIGURE 35, by the use of a relatively low speed, the resilient wiper element **1118** of the wiper causes the foreign particles on the filter screens to be bowed away from the filter screens so that the foreign particles form large chunks which are broken away and readily settle out of the dry cleaning solvent to the bottom of the tank. With this type of wiper and filter arrangement (as well as with the disc-shaped filters), when the speed of the relative movement between the wiper and the primary filter elements is greater than 1,000 inches per minute, the collection of foreign particles on the surface of the filter screens will not be bowed away and broken up into large chunks but will be fragmented into fine particles so that the wiping action of the wiper will force some material into the openings of the screen discs, thereby clogging the primary filter elements. Once the primary filter is clogged with foreign particles, dry cleaning solvent may not flow into the filter, and the primary filter loses its efficiency. Further, the fragmentation of material will place fine particles of foreign material into suspension in the tank so that the material will not settle out readily.

When the wiper **948** reaches the end of its stroke to the attitude shown in FIGURE 33, the operation of the cylinder **950** is reversed in a conventional and well-known manner so that the wiper **948** moves upward relative to the filter elements. During the retraction of the wiper, the dry cleaning solvent between wiper **948** and the cylinder head is compressed, and a lower pressure is created in the portion of the tank between the wiper and the secondary filter so that a small portion of the dry cleaning solvent will pass through that portion of the primary filter elements above the wiper and out into the tank below the wipers, thereby creating a gentle reverse flow of solvent through the dry cleaning elements to further clean the filter elements. During the operation of the cylinder, the rod bearings **1130** slide relative to guide rods **1128** so that there is always perfect alignment between the wiper element and the filter screens.

Five seconds after the wiper is positioned in its up position (as shown in FIGURE 34) filter pump **352** is placed into operation. The filter pump forces dry cleaning solvent to flow through the turbulence suppressor into the filter chamber and then out of the filter chamber through the primary and secondary filters into filter head **946**. From the filter head **946** the solvent flows into T **974**. Since the valve **978** is closed, the dry cleaning solvent flows through the check valve **966** back to filter pump **952** to be recirculated through the filter apparatus. As this recirculation continues, the downward flow of solvent through the secondary filter, and the force of gravity causes all of the dislodged filter cake to settle to the bottom of the filter chamber.

The filter pump is allowed to operate for two minutes with the valve **978** closed so that all foreign particles settle away from the primary filter. Then, the valve **978** is opened and sump pump **926** is energized so that dry cleaning solvent from the dry cleaning machine is passed through the filter apparatus. After 40 seconds of opera-

tion of the sump pump, the additive injector is activated so that additives (in this instance, powdered activated charcoal and diatomite) are added to the solvent and carried to the filter pump and into the filter. As the solvent is filtered by the primary and secondary filters, the additive is retained on the filter screens and coats the outer surface of the filter screens with a fresh layer of absorptive powder. The additives are added for one minute and 15 seconds, then the additive injector is deactivated and the filter apparatus is in condition to start another cycle.

During any phase of the operation of the instant apparatus, an operator may observe the color of the solvent entering the tank by observing the solvent at an observation junction (not shown) in pipe **930**. An operator may thereby note any malfunction of the instant device before any serious consequences occur.

As mentioned above, the materials trapped by the instant apparatus may be periodically removed from within the tank **942**. The tank is cleaned when the dry cleaning machine is shut down and after all the solvent has been removed from the tank. The dry cleaning solvent is removed from the tank by first closing valves **958** and **976** and opening valve **994**. The solvent in the tank is forced through the secondary filter and out of the tank through secondary outlet piping **934** by compressed air. Once the dry cleaning solvent has been evacuated from the tank, the compressed air is relieved, door **1140** is removed, and all of the filtrate (i.e., lint, foreign particles and additives) on the secondary filter are removed. After the tank has been cleaned, the door **1140** is replaced and the tank is refilled with dry cleaning solvent. After the additive injector **928** is placed into operation in order to coat the screens with additives, the apparatus is ready for use.

In the above-described filter apparatus **920**, the primary filter elements of primary filter **944** have been described as being in the form of cylindrical rods. A second form of primary filter element is shown in FIGURES 36, 37, and 38, wherein plate-shaped filter elements **1270** are utilized in the same type of filter apparatus instead of the rod-shaped filter elements **1106** described above. FIGURES 36, 37, and 38 depict a filter apparatus **1220** that is identical in construction to apparatus **920**, except for changes made to accommodate a plate-shaped primary filter **1244**. The filter apparatus **1220** includes a cylindrical tank **1292**, a filter head **1246**, a turbulence suppressor **1254**, and a wiper **1248**, which engages the primary filter. The filter apparatus **1220** is provided with a used solvent inlet pipe **1268** for introducing solvent into turbulence suppressor **1254**.

The primary filter **1244** includes a plurality of plate-like primary filter elements **1270**. Each of the primary filter elements is identical in construction to each other primary filter elements and includes a collar **1272** of rectangular cross section. A pair of wire screen bases **1274** is connected to the lower portion of each of the collars and a filter screen **1276** is mounted on the outside of each of the wire screen bases. The filter screen **1276** is made of the same material as filter screens **1116**. A solid frame **1280** surrounds the outer periphery of the screens to provide a box-like structure, as shown in FIGURE 38.

The filter head includes a filter head plate **1282**, which has a plurality of rectangular slots **1284** formed therein that register with the upper ends of collars **1272**. The collars **1272** are fixed to the filter head plate **1282** in the same manner that collars **1108** are fixed to plate **1104**.

As in wiper **948**, the wiper **1248** includes a sheet of rubber **1286** supported by upper and lower wiper plates **1288** and **1290**, respectively, and this wiper resiliently engages the filter screens **1276**. The wiper **1248** is suspended from a cylinder rod **1298** that extends down from cylinder **1250** and is spaced slightly from the wall of tank **1292** in order to allow used dry cleaning solvent to pass between the wall and the wiper to eliminate turbulence in the filter chamber.

The filter apparatus **1220** includes three guide rods **1294** which are fixed to the filter head plate **1282**. A rod bearing **1296** is mounted in sliding engagement with each guide rod **1294**, and each bearing **1296** is fixed to the upper plate **1288** of wiper **1248**.

The operation of the filter apparatus **1220** is identical to the above-described operation of filter apparatus **920**, the only differences between the two filters being that plate-shaped filter elements are employed instead of rod-shaped filter elements and the head and wiper are altered to accommodate the plate-shaped filter elements.

Still another form of primary filter element (a V-shaped filter element) is shown in FIGURE 39 in filter apparatus **1320**, which is the same as filter apparatus **920** and **1220** except that it is adapted to accommodate V-shaped filter elements. The filter apparatus **1320** includes a tank **1342** with a filter head **1346** mounted in the upper portion hereof, a primary filter **1344** mounted within the tank below the filter head, and a wiper **1348** mounted within the tank and engageable with the primary filter **1344**.

The construction of wiper **1348** is identical to the construction of wipers **948** and **1248** described in detail above, but the wiper **1348** is adapted to receive and engage V-shaped filter elements **1370** of primary filter **1344**. The wiper **1348** co-operates with the filter head and the tank **1342** to form a turbulence suppressor **1354** immediately below the filter head. The wiper **1348** is suspended in the tank by means of a rod **1352**, which is connected to a double-acting conventional hydraulic cylinder **1350** mounted on top of the tank **1342**.

The used dry cleaning solvent is introduced into the tank **1342** at the turbulence suppressor **1354** through piping **1368**, which is identical to piping **968** described in detail above.

The primary filter **1344** includes a plurality of V-plate filter elements **1370**. Each of the primary filter elements is identical in construction to each other primary filter element and includes a collar **1372** having a V-shaped cross section and a solid frame **1374** connected to the collar. Each filter includes four flat filtering areas consisting of a heavy wire screen base **1378** covered by a filter screen **1380**. The material used in filter screens **1380** is identical to the material used in filter screens **1116**.

The filter head **1348** includes a filter head plate **1382** that has a plurality of radially disposed V-shaped slots **1384** formed therein that register with the collars **1372**. The collars **1372** are secured to the plate **1382** in the same manner that collars **1108** are secured to plate **1104**.

The wiper **1348** is guided by three guide rods **1386** which also are secured to the filter head **1382**. A rod bearing **1388** is slideably engageable with each guide rod **1386**, and each rod bearing **1388** is mounted on the wiper **1348**, so that the wiper is held in perfect alignment with the primary filter elements.

The operation of the apparatus **1320** is identical to the operation of apparatus **920**. The only differences between apparatus **1320** and apparatus **920** are that the filter elements are V-shaped rather than rod-shaped, and the head and wiper are altered to accommodate the V-shaped filter elements. The timing cycles and the operation of the various parts are the same.

It should be understood that the embodiments described are merely exemplary of the preferred practices of the present invention and that various changes, modifications, and variations may be made in the arrangements, operations, and details of construction of the elements disclosed herein, without departing from the spirit and scope of the present invention, as defined in the appended claims.

I claim:

1. A filter apparatus for clarifying a liquid comprising:
primary filtering means;
secondary filtering means;
inlet means in fluid communication with the high-pressure side of the primary filtering means and adapted to feed unclarified liquid thereto;

outlet means in fluid communication with the low-pressure side of the primary filtering means and adapted to convey liquid clarified by the filter apparatus away from the filter apparatus;

filter cake dislodging means adapted to dislodge filter cake accumulated on the high-pressure side of the primary filtering means, thereby placing the dislodged filter cake into suspension in liquid on the high-pressure side of the primary filtering means;

recirculating means adapted to recirculate liquid bearing suspended filter cake within the filter apparatus from the high-pressure side of the primary filtering means, through the secondary filtering means, and back to the high-pressure side of the primary filtering means, thereby relocating the filter cake for accumulation on the high-pressure side of the secondary filtering means; and

control means adapted to intermittently activate the recirculating means,

whereby activation of the control means serves to transfer filter cake accumulated on the high-pressure side of the primary filtering means to the high-pressure side of the secondary filtering means.

2. A filter apparatus as claimed in claim **1**, wherein the recirculating means interconnect the low-pressure side of the secondary filtering means to the high-pressure side of the primary filtering means, such that liquid clarified by the secondary filtering means is transferred directly to the high-pressure side of the primary filtering means without passing through the primary filtering means.

3. A filter apparatus as claimed in claim **1**, wherein the control means are adapted to intermittently block fluid passage through the outlet means and to activate the recirculating means only when the outlet means are so blocked.

4. A filter apparatus as claimed in claim **3**, wherein the control means are adapted to activate the filter cake dislodging means only when the outlet means are so blocked.

5. A filter apparatus as claimed in claim **1**, wherein the filter cake dislodging means comprises a wiper member that is adapted for movement relative to the primary filtering means at a speed of less than 1,000 inches per minute.

6. A filter apparatus as claimed in claim **1**, wherein the filter cake dislodging means comprises a wiper member that is adapted for movement relative to the primary filtering means at a speed of between about 200 and about 400 inches per minute.

7. A filter apparatus as claimed in claim **1**, and further comprising filter cake removal means adapted to dislodge and remove from the filter apparatus filter cake accumulated on the high-pressure side of the secondary filter means.

8. A filter apparatus as claimed in claim **7**, wherein the control means are adapted to intermittently block fluid passage through the secondary filtering means and to activate the filter cake removal means only when the secondary filtering means is so blocked.

9. A filter apparatus as claimed in claim **1**, wherein the primary filtering means and the secondary filtering means are located in separate filter chambers.

10. A filter apparatus as claimed in claim **9**, wherein the secondary filtering means is disposed beneath the primary filtering means, such that filter cake is induced to gravitate towards the secondary filtering means.

11. A filter apparatus as claimed in claim **9**, and further comprising means for sealing-off the filter chambers from each other, whereby accumulated filter cake may be removed from the secondary filtering means without affecting the filtering action of the primary filtering means.

12. A filter apparatus as claimed in claim **11**, and further comprising valved means for expelling liquid from the secondary filtering means filter chamber.

13. A filter apparatus as claimed in claim **12**, wherein the filter cake removal means comprises an auger mounted in the secondary filtering means filter chamber.

14. A filter apparatus as claimed in claim **9**, and further comprising a third filter chamber, chemical filtering means disposed in the third filter chamber, and conduit means adapted to transfer liquid from the low-pressure side of the primary filtering means to the high-pressure side of the chemical filtering means.

15. A filter apparatus as claimed in claim **1**, wherein the primary filtering means and the secondary filtering means are located in the same filter chamber.

16. A filter apparatus as claimed in claim **15**, wherein the secondary filtering means is disposed beneath the primary filtering means, such that filter cake is induced to gravitate towards the secondary filtering means.

17. A filter apparatus as claimed in claim **15**, and further comprising chemical filtering means in the form of an adsorptive powder that is periodically introduced to the high-pressure side of the primary filtering means and that is removed therefrom as accumulated filter cake.

18. A filter apparatus as claimed in claim **15**, and further comprising turbulence suppressor means associated with the inlet means, whereby liquid introduced into the filter apparatus is rendered relatively quiescent to enhance the filtering operation.

19. A filter apparatus as claimed in claim **1**, wherein the filter cake dislodging means comprises a mechanical scraper disposed to contact filter cake accumulated on the primary filtering means.

20. A filter apparatus as claimed in claim **1**, wherein the filter cake dislodging means comprises a sprayer adapted to direct a spray of liquid against the filter cake accumulated on the primary filtering means.

21. A filter apparatus as claimed in claim **1**, wherein the filter cake dislodging means comprises a mechanical scraper disposed to contact filter cake accumulated on the primary filtering means and a sprayer adapted to direct a spray of liquid against the said filter cake simultaneously with the mechanical scraping action thereof.

22. A filter apparatus as claimed in claim **21**, wherein the spray of liquid is provided by the recirculating means.

23. A filter apparatus as claimed in claim **1**, wherein the primary filtering means comprises a series of co-axially stacked, wire meshed rotary filter elements.

24. A filter apparatus as claimed in claim **1**, wherein the primary filtering means comprises a series of filter elements and the filter cake dislodging means comprises a resilient wiping mechanism adapted for movement relative to the filter elements so as to remove accumulated filter cake therefrom.

25. A filter apparatus as claimed in claim **24**, wherein the wiping mechanism comprises a series of brush elements disposed between adjacent filter elements.

26. A filter apparatus as claimed in claim **24**, wherein the filter elements comprise parallely disposed, generally cylindrical rods.

27. A filter apparatus as claimed in claim **26**, wherein a filter head is provided in the filter apparatus and wherein each of the rods has an end thereof opening into the filter head to allow clarified liquid to pass through the rod and to collect in the filter head.

28. A filter apparatus as claimed in claim **24**, wherein the filter elements comprise parallelly disposed plates.

29. A filter apparatus as claimed in claim **24**, wherein the filter elements comprise a radially disposed series of generally V-shaped plates.

30. A filter apparatus as claimed in claim **24**, wherein the resilient wiping mechanism comprises a turbulence suppressor.

31. A filter apparatus as claimed in claim **30**, wherein the surface of the resilient wiping mechanism closest to the inlet means is provided with a polytetrafluoroethylene surface in order to minimize the adherence of any solid particles thereto.

32. A filter apparatus as claimed in claim 1, and further comprising purging means adapted to evacuate liquid from the filter apparatus and to facilitate recovery of clarified liquid from filter cake accumulated in the filter apparatus.

33. A filter apparatus as claimed in claim 32, wherein the purging means comprises a steam rinser adapted to direct a steam jet into the interior of the filter apparatus so as to force liquid therefrom and to volatize liquid entrained in filter cake accumulated in the filter apparatus, and a solvent recovery still adapted to separate condensed steam and liquid.

34. A filter apparatus as claimed in claim 32, wherein the purging means comprises a compressed air purger adapted to be directed against liquid contained within the filter apparatus.

35. A method for clarifying a liquid comprising the steps of:

filtering at least the major portion of the unclarified liquid by passing the liquid from an inlet, through a primary filter, and to an outlet;

intermittently dislodging filter cake accumulated on the high-pressure side of the primary filter into suspension in liquid on the high-pressure side of the primary filter; and

recirculating liquid bearing the suspended filter cake from the high-pressure side of the primary filter, through a secondary filter, and directly back to the high-pressure side of the primary filter, thereby relocating the filter cake for accumulation on the high-pressure side of the secondary filter.

36. A method for clarifying a liquid as claimed in claim 35, and further comprising the step of intermittently interrupting the filtering of unclarified liquid prior to and during the removal of filter cake from the primary filter by intemittently dislodging filter cake accumulated on the high-pressure side of the primary filter into suspension in liquid on the high-pressure side of the primary filter, and the recirculation of the liquid bearing the suspended filter cake within the filter apparatus from the high-pressure side of the primary filter, through a secondary filter, and directly back to the high-pressure side of the primary filter, thereby relocating the filter cake for accumulation on the high-pressure side of the secondary filter.

37. A method as claimed in claim 35, wherein the recirculating step is effected only when the filtering of unclarified liquid through the primary filter is interrupted.

38. A method as claimed in claim 37, wherein the filter cake is dislodged from the primary filter only when the filtering of unclarified liquid through the primary filter is interrupted.

39. A method as claimed in claim 35, wherein the filter cake is dislodged from the primary filter by movement of a wiping member relative to the primary filter at a speed of less than 1,000 inches per minute.

40. A method as claimed in claim 35, wherein the filter cake is dislodged from the primary filter by movement of a wiping member relative to the primary filter at a speed of between about 200 to about 400 inches per minute.

41. A method as claimed in claim 35, and further comprising the step of dislodging and removing from the filter apparatus filter cake accumulated on the high-pressure side of the secondary filter.

42. A method as claimed in claim 41, wherein passage of liquid through the secondary filter is intermittently blocked and wherein the dislodging and removing of filter cake from the secondary filter is effected only when the passage of liquid through the secondary filter is so blocked.

43. A method as claimed in claim 35, and further comprising the steps of: periodically adding an adsorptive powder to the high-pressure side of the primary filter; and periodically removing the said powder therefrom as accumulated filter cake.

44. A method as claimed in claim 35, and further comprising the step of passing the liquid through a turbulence suppressor at the inlet, whereby liquid introduced to the primary filter is rendered relatively quiescent to enhance the filtering operation.

45. A method as claimed in claim 35, wherein the filter cake is dislodged from the primary filter by mechanically scraping filter cake accumulated on the high-pressure side of the primary filter.

46. A method as claimed in claim 35, wherein the filter cake is dislodged from the primary filter by spraying liquid against the filter cake accumulated on the high-pressure side of the primary filter.

47. A method as claimed in claim 35, wherein the filter cake is dislodged from the primary filter by simultaneously mechanically scraping and spraying liquid against filter cake accumulated on the high-pressure side of the primary filter.

48. A method as claimed in claim 47, wherein the liquid sprayed against the filter cake is recirculated liquid.

49. A method as claimed in claim 36, and further comprising the step of purging liquid from the filter apparatus.

50. A method as claimed in claim 49, wherein the purging is effected by a steam spray.

51. A method as claimed in claim 49, wherein the purging is effected by compressed air.

52. A method of clarifying a liquid comprising the steps of:

passing the liquid from a source into a filtering tank;

dividing the liquid so as to divert a major portion of the liquid to a primary filter within the tank and a minor portion of the liquid to a secondary filter positioned within the tank below the primary filter;

passing the major portion of the liquid through the primary filter and returning the liquid filtered thereby to the source while simultaneously passing the minor portion of the liquid through the secondary filter and returning the liquid filtered thereby to the source;

interrupting the flow of liquid from the source to the tank;

removing filter cake from the primary filter; and

circulating liquid through the tank,

such that the action of gravity and the constant downward flow of a minor portion of the liquid away from the primary filter facilitates settling away of foreign particles from the primary filter.

53. A method as claimed in claim 52, and further comprising the step of injecting an adsorptive powder into the unclarified liquid on the high-pressure surface of the primary filter, thereby to facilitate the clarification operation.

54. A method as claimed in claim 53, wherein the recited steps are cyclicly repeated and wherein the injected adsorptive powder is removed as filter cake from the primary filter during the course of each cyclic operation.

55. A method as claimed in claim 52, wherein the liquid is passed through a turbulence suppressor upon entry into the filtering tank.

56. A method as claimed in claim 53, wherein the step of removing filter cake from the primary filter is substantially completed and the filter cake is allowed to settle away from the primary filter prior to initiation of the circulating step.

57. A method as claimed in claim 54, wherein the step of removing filter cake from the primary filter is substantially completed and the filter cake is allowed to settle away from the primary filter prior to initiation of the circulating step.

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