Abstract: An improved dry cleaning system and process capable of producing satisfactory fabric cleaning results through multiple fabric laundering cycles without the need to replace or dispose of the solvent and other components in the system. The present system and process employ a novel solvent usage and reclamation regimen.
For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

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FIELD OF THE INVENTION

The present invention relates to a dry cleaning system and process that employs a novel solvent usage and reclamation regimen such that the system can operate through multiple laundering cycles without the need to replace or dispose of the solvent and other components in the system.

This improved system and process are particularly suitable for in-home dry cleaning applications where minimal contact between the user and the dry cleaning solvent is highly desirable.

BACKGROUND OF THE INVENTION

It is well known that the laundering process fall into two general categories: the conventional aqueous washing process and the dry cleaning or non-aqueous washing process. A major difference between the two processes is the extent of handling required of the wash medium in the waste stream. The waste stream from the aqueous laundering process can be disposed into the municipal sewer system without further treatment. The waste stream from the dry cleaning process cannot be disposed of in a similar manner because the waste stream from the dry cleaning process contains solvents and other laundry wastes (such as laundry soils, particulate matters, detergent ingredients, and water). As such, the dry cleaning waste disposal, especially solvent disposal, needs special handling to minimize environmental impact. Moreover, since the dry cleaning solvents are more expensive than water, it is desirable to recycle/reuse the dry cleaning solvents.

Commercial dry cleaning operations typically use distillation to separate the dry cleaning solvents from other components in the waste stream. However, the required equipment and conditions to run a distillation operation method are quite burdensome, energy consuming, and not practical for use in a consumer's home. Additionally, for in-home dry cleaning applications, it is desirable to minimize user exposure to the solvent for reasons of safety as well as convenience. Accordingly, non-distillative solvent purification methods have been developed. Representative systems using the non-

While these systems and methods are generally safe and satisfactory for recycling solvent within the system, minimizing consumer exposure, and minimizing environmental impact, there is still a need for improvement. For example, it is burdensome and time consuming to produce high purity dry cleaning solvents after every laundry cycle for re-use in the subsequent cycle. In addition, purification after each cycle increases the frequency at which the components of the non-distillative purification device and/or the batch of solvent need to be replaced, thereby increases consumer exposure to solvent and environmental impact.

Therefore, there is a need for an improved dry cleaning process and system that is safe, efficient, sustainable through multiple laundering cycles without user intervention while producing satisfactory cleaning results to the fabric articles processed through each laundering cycle.

SUMMARY OF THE INVENTION

During a laundering operation, it is often observed that the wash eluent from the wash cycle has floating suds, soils and an unappealing murkiness, all of which signal to the consumers that the laundering operation is successful in removing soils from the fabric articles. This wash eluent is discarded without hesitation. One would never consider reusing this murky, contaminated wash eluent to treat the next load of laundry. Surprisingly, Applicants have found success in re-using this "soiled" wash eluent through multiple laundering operations and still produce satisfactory cleaning results in the laundered fabric articles. Applicants have found that high purity solvent is needed only for a specific part of the laundering process to achieve effective cleaning results in the laundered fabric articles.

The dry cleaning process of the present invention employs separate solvent recycling or recirculating loops for the wash cycle and the rinse cycle, respectively. Specifically, the dry cleaning process of the present invention employs a recirculating wash fluid which needs only occasional reformulation to replenish the laundry additives or solvent lost during the laundering operations, and a clean rinse fluid which is subjected to intensive purification treatment between laundering operations. Since high purity
solvent is required only for the rinse cycle, this new process greatly reduces the demand on the solvent purification components such that the system can operate through many cycles before user intervention is needed. It is found that this new process greatly extends the sustainability of the laundering system.

While the low purity wash solvent may contain laundry soils and detergent ingredients, it does not appear to have much impact on the effectiveness of the overall cleaning process. We have found that so long as we remove most of the used wash solvent from the fabric articles and use high purity solvent in the rinse cycle, we achieve satisfactory cleaning results in the laundered fabric articles. It is believe that by separating the used wash solvent from the fabric articles, the carry-over of soils and/or contaminants from the wash cycle into the rinse cycle is minimized; consequently, the re-deposition of soils and/or contaminants onto the fabric articles is also minimized. More importantly, the residues of soils and/or contaminants that are carried over by the fabric articles can be easily removed by the high purity rinse solvent.

Additionally, we are surprised to find that the detergent ingredients in the low purity solvent can be reused in subsequent laundering operations and still provide detersive functions effectively. This provides additional cost advantages. First, it is easier and cheaper to acquire low purity wash solvent since it would not be necessary to purify the solvent extensively. Typically, removal of particulate matter from the low purity wash solvent is all that is required between laundering operations. Second, it is also more cost efficient not having to add all the detergent ingredients back into the cleaned solvent for the subsequent laundering operation.

**BRIEF DESCRIPTION OF THE DRAWINGS**

FIG. 1 is a block diagram demonstrating an embodiment of the present invention;

FIG. 2A to 2D demonstrate the accumulation of soils through multiple laundering cycles according to an embodiment of the present invention (with clean rinse) or a conventional dry cleaning process (without rinse);

FIG. 3 is a perspective view, partly in section, of one embodiment of a multifunctional filter in accordance with the present invention; and

FIG. 4 is a perspective view, partly in section, of an alternative embodiment of the multifunctional filter.
DETAILED DESCRIPTION OF THE INVENTION

Definitions

The term 'fabric article' as used herein means any article that is customarily cleaned in a conventional aqueous laundry process or in a dry cleaning process. As such the term encompasses articles of clothing, linen, drapery, and clothing accessories. The term also encompasses other items made in whole or in part of fabric, such as carpets, tote bags, furniture covers, tarpaulins, car interior, and the like.

The term 'fabric treatment composition' or 'fabric treating composition' or "wash composition" as used herein means a lipophilic fluid-containing composition that comes into direct contact with fabric articles to be cleaned. It is understood that the composition may also provide benefits other than cleaning, such as conditioning, sizing, and other fabric care treatments. Thus, it may be used interchangeably with the term 'fabric care composition'. Optional cleaning adjuncts (such as additional detersive surfactants, bleaches, perfumes, and the like) and other fabric care agents may be added to the composition. It is understood that the term 'laundry additives/agents' or 'fabric treating agents/additives' encompasses the cleaning adjuncts and the finishing/fabric care additives.

The term "dry cleaning" or "non-aqueous cleaning" as used herein means a non-aqueous fluid is used as the dry cleaning solvent to clean a fabric article. However, water can be added to the "dry cleaning" method as an adjunct cleaning agent. The amount of water can comprise up to about 25% by weight of the dry cleaning solvent or the fabric treating composition in a "dry cleaning" process. The non-aqueous fluid is referred to as the 'lipophilic fluid' or "dry cleaning solvent".

The terms "soil" or 'laundry soil' as used herein means any undesirable extraneous substance on a fabric article that is the target for removal by a laundering process. The term "water-based" or "hydrophilic" soils, as used herein means soils comprises water at the time it first came in contact with the fabric article, or the soil retains a certain amount of water on the fabric article. Examples of water-based soils include, but are not limited to, beverages, many food soils, water soluble dyes, bodily fluids such as sweat, urine or blood, outdoor soils such as grass stains and mud. On the other hand, the term 'lipophilic' soils, as used herein means the soil has high solubility in or affinity for the lipophilic
fluid. Examples of lipophilic soils include, but are not limited to body soils, such as mono-, di-, and tri-glycerides, saturated and unsaturated fatty acids, non-polar hydrocarbons, waxes and wax esters, and lipids. Soils or laundry soils also encompass textile treating agents or laundry additives, such as dyes or surfactants, which are incidentally removed from the fabric articles during the laundering process.

The term "insoluble" as used herein means that a material will physically separate (i.e. settle-out, flocculate, float) from the liquid medium (a dry cleaning solvent or water) within 24 hours after being added to the liquid medium, whereas the term "soluble" means that a material does not physically separate from the liquid medium within 24 hours after addition.

The term "contaminant" as used herein means any undesirable extraneous substance that is the target for removal by a solvent purification process. For example, laundry additives and soils in the dry cleaning solvent, the rinse eluent or the wash eluent are considered contaminants.

The Dry Cleaning Process

The dry cleaning process of the present invention is carried out in the laundering apparatus of the present invention following the general laundry process, which comprises a wash cycle comprising one or more wash steps and a rinse cycle comprising one or more rinse steps. Specifically, the dry cleaning process of the present invention employs separate solvent recycling or recirculating loops for the wash solvent and the rinse solvent. Each solvent loops comprises one or more of the following operations: recirculating the solvents during the treatment cycles, purifying of the solvent, reformulating of the solvent, and re-using the solvent in subsequent dry cleaning operations. Specifically, the fluid used in the wash loop can be reused repeatedly, with occasional reformulating. On the hand, the fluid used in the rinse loop is subjected to intensive purification treatment between laundering operations.

The laundering treatment of the fabric articles is carried out in a treatment drum of the laundering apparatus of the present invention. The dry cleaning solvent used in the present process comprises primarily lipophilic fluids in the amount of at least about 50%, preferably at least about 80%, and more preferably at least about 90% by weight of the dry cleaning solvent. During the wash cycle, the fabric articles are contacted by a wash
composition. The wash composition comprises a lipophilic fluid and at least one laundry additive. Soils are removed from the fabric articles, and the wash composition is thereby converted into a wash eluent. At the end of the wash cycle, the wash eluent is collected and reused as the wash composition in subsequent wash cycles or optionally, converted to the wash composition by replenishing the amounts of the laundry additive or lipophilic fluid lost during the wash cycle. One or more particulate filters may be employed in the wash cycle to remove lint, buttons, or other particulate matters from the wash composition and the wash eluent. Contrary to the conventional wisdom, it is found unnecessary to process the wash eluent to high purity or to formulate the wash composition from fresh or high purity solvent after completing a wash cycle. Surprisingly, the double-looped dry cleaning process of the present invention is capable of delivering satisfactory cleaning results using the wash eluent as is, notwithstanding the presence of laundry soils in the wash eluent. It may be beneficial to maintain the concentration of the laundry additive in the wash composition at or above a pre-determined level; this can be accomplished by reformulating the fluid in the wash loop with the laundry additive and/or the lipophilic fluid. It is also beneficial to maintain the lipophilic fluid above a pre-determined threshold level (e.g. sufficient to provide an immersive or non-immersive treatment of the fabric articles), thus, the lipophilic fluid is replenished when needed.

During the rinse cycle, the fabric articles are contacted with a rinse fluid. The rinse fluid comprises a high purity dry cleaning solvent. Typically, residues of laundry additives and/or soils from the fabric articles are incorporated into the rinse fluid during the rinse cycle. The rinse fluid is thereby converted to a rinse eluent. The rinse eluent is collected and subjected to intensive solvent purification treatment, thereby converting the rinse eluent back to the high purity rinse fluid, which is re-used in subsequent rinse cycles.

In a typical dry cleaning process of the present invention, the wash eluent is removed from the fabric articles such that the fabric articles are substantially free of the wash eluent before entering the rinse cycle. The term "substantially free" as used herein, means the fluid absorbed by the fabric articles is less than about 0.8, preferably less than 0.6, and more preferably less than 0.4, of the absorption capacity of the fabric articles. Test protocol for measuring absorption capacity of a fabric article is described in detail in U.S. Patent 6,898,951. The removal can be carries out in many known methods, such as
spinning, twisting, wringing, squeezing, or like mechanical methods. A removal step may also be included in the process of the present invention to remove the rinse fluid from the fabric articles such that the fabric articles are substantially free of the rinse fluid, prior to entering the drying cycle. However, the removal of rinse fluid is optional.

The process of the present invention may also include a drying step, during which heat or reduced pressure may be employed to remove (e.g., via evaporate) the dry cleaning solvent. The dry cleaning solvent vapor is preferably captured and re-used in the dry cleaning process, either as the replenishing fluid for the wash composition or as the high purity solvent for the rinse fluid.

The Dry Cleaning System or The Laundry Apparatus

The present invention also includes a dry cleaning system or the laundry apparatus suitable for use in the process described above. The system (see FIG. 1) comprises a fabric article treating drum 1, a wash composition tank 10, a rinse fluid tank 20, and conduits to connect them.

The apparatus of the present invention may optionally include one or more sensors. In one embodiment, a sensor is used for monitoring the laundry additive concentration and/or soil concentration in the wash eluent. When laundry additive concentration falls below some pre-determined value, the sensor would signal, directly or indirectly via the cleaning apparatus or other external control/monitoring device, that laundry additive needs to be replenished. An intensive solvent purification device may also be included as an integral part of the system/apparatus or as a stand-alone device, in fluid communication with the dry cleaning system.

FIG. 1 is a block diagram of an embodiment of the dry cleaning system according to the present invention. The wash eluent (i.e., the used wash composition) is separated from the fabric articles by mechanical means, such as spinning. The wash eluent is then returned to the wash composition tank 10 to be used as the wash composition in a subsequent wash cycle. The wash sensor 13 samples the wash composition in the wash loop conduit or in the wash composition tank 10 for the concentrations of various laundry additives. Due to the loss of the laundry additives in the laundering operation, it may be necessary to occasionally replenish the laundry additives such that the concentration of the laundry additives in the wash composition is maintained at a pre-determined level. In one
embodiment, the laundry additives are supplied from one or more laundry additive sources 14. The laundry additive source 14 may contain individual additive or premixed composition containing the additives in the desired ratios. Optionally, a fluid level sensor 15 is employed to monitor the fluid level in the wash composition tank 10. When fluid level drops below a pre-determined level, the dry cleaning solvent is supplied from a solvent source (not shown) to replenish the dry cleaning solvent. The particulate filter 12 may be equipped with a pressure sensor 17. When the pressure differential across filter 12 exceeds a threshold level, filter 12 is replaced with a fresh one.

During the wash cycle, valves 102, 103, 104 and 106 are positioned to allow fluid communication among tank 10 and drum 1 such that the wash composition circulates in the wash loop and optionally an in-line wash filter 12 may be included in the wash loop. The wash filter 12 may be a particulate filter for removing lint, buttons and particulate soils having a particle size of at least about 50 microns, or a carbon filter for removing contaminants, especially textile treating agents such as dyes. In one embodiment, the wash loop runs through wash filter 12 for a set time, then the wash loop is switched to by-pass the wash filter.

On the other hand, during the rinse cycle, clean rinse fluid is released from tank 20 into drum 1. The rinse fluid contacts fabric articles in the drum to extract soils and laundry additives from the fabric articles. Optionally, the rinse fluid may circulate through an in-line particulate filter during the rinse cycle. Optionally, laundry additive source 16 may be included in the system to add the laundry additives effective in the rinse cycle into the drum directly or via the conduit within the rinse loop. Then, at the end of the rinse cycle, the rinse eluent (i.e., the spent or dirty rinse fluid) is released into tank 21. The rinse eluent is purified through filter 22 and the purified rinse fluid is stored in tank 20. During the drying cycle, the solvent vapor is collected and condensed in condenser 18, and the condensed solvent vapor is returned to tank 10.

After the spinning operation, the washed fabric articles enter the rinse cycle with a set amount of residual laundry additives and soils residing on the washed fabric articles. The rinse cycle employs a high purity rinse fluid supplied from the rinse fluid tank 20. The rinse fluid extracts the residual laundry additives and soils from the fabric articles such that there are only trace amount of laundry additives and soils remaining on the
rinsed fabric articles. The term "trace amount" means that the laundry additives and soils remaining on the laundered fabric articles are below the sensory detection limits of an ordinary consumer. The most commonly used senses by a consumer for the laundered fabric articles are sight and smell. The fabric articles enter the drying cycle. The solvent vapor from the drying process is collected, condensed in condenser 18 and returned to the wash composition tank 10, thus the overall laundering process experiences minimal solvent loss. The rinse eluent is separated from the fabric articles by mechanical means such as spinning. The rinse eluent is purified in an intensive solvent purification treatment, for example by contacting it with a rinse filter 22 to remove the residual laundry additives and the soils. The treated wash eluent becomes a high purity solvent, which is returned to the rinse fluid tank 20 to be used as the rinse fluid in a subsequent rinse cycle. In a typical embodiment, the rinse filter 22 is equipped with a pressure sensor 24 to monitor the pressure differential across filter 22. If the pressure differential exceeds a threshold level, filter 22 is replaced with a fresh one. Optionally, a rinse sensor 23 is employed to sample rinse fluid taken from the rinse fluid tank 20 for purity or levels of contaminants such as soils or laundry additives. If purity falls below a threshold level, it indicates rinse filter and/or rinse fluid in tank 20 need to be serviced or replaced.

In one embodiment, the wash filter 12 and the rinse filter 22 may be arranged in a side-by-side configuration or a concentric configuration, each filter having its own inlet outlet, and conduits such that the fluid in the wash loop does not commingle with fluid in the rinse loop. This compact arrangement of filters offers a space saving advantage to the overall dry cleaning system.

Because only residual amounts of laundry additives and soils are carried over from the wash cycle into the rinse cycle, the amounts of contaminants to be removed from the rinse eluent during the intensive purification process is quite small. Consequently, the filter used in the intensive purification process can be quite durable. That is, the filter can be used through multiple laundering operations before it reaches its capacity and needs to be replaced. In one embodiment, a pressure sensor is used to measure the differential pressure between the inlet and the outlet of the filter. When the differential pressure exceeds a threshold value, the filter has reached its capacity and should be replaced. Typically, filter replacement is desired when the pressure reading increased by about 10
times or greater, or about 20 times or greater, or about 30 times or greater, compared to the reading of the original filter. In another embodiment, the eluent from the filter is monitored by a sensor, filter replacement is indicated when sensor reading of contaminants exceeds a threshold value. Typically filter replacement is desired when sensor reading indicates the contaminant level has increased by at least about 10 times, or at least about 50 times, or at least about 100 times, compared to the reading of the original filter. Sensors suitable for this purpose include, but are not limited to, turbidity sensor, color sensor, conductivity sensor.

The effectiveness of the present system employing a "soiled" wash fluid and a clean rinse fluid is best described via mass balance. All masses used below are exemplary and should not be interpreted as the actual capacity of the system or the apparatus. A typical laundry load comprises about 3 kilograms of fabric articles, which contain about 2.5 grams of soils. In the wash cycle, this load of fabric articles is contacted with a wash composition containing about 100 grams of laundry additives in about 30 liters of a dry cleaning solvent. The washing operation results in a distribution of the soils and laundry additives between the load of fabric articles and the solvent. After spinning and separating the fabric articles from the wash eluent, the wet fabric articles may retain about 1 liter of residual solvent, which contains about 1/30 (or about 0.08 gram) of the residual soils and about 1/30 (or about 3.3 grams) of the laundry additives. Thus, the residual solvent, soil and laundry additives are carried into the rinse cycle by the fabric articles. In the rinse cycle, this load of fabric articles is contacted with a rinse fluid composed of about 10 liters of high purity dry cleaning solvent. The residual soils and residual laundry additives are extracted from the fabric articles and distributed between the fabric articles and the rinse fluid. After spinning and separating the fabric articles from the rinse eluent, the wet fabric articles may contain about 1 liter of residual solvent, which contains about 1/11 of the residual laundry additives and residual soils (about 0.3 gram and about 0.07 gram, respectively). Then, ten liters of rinse eluent containing about 10/11 or the balance of the residual laundry additives and the residual soils (about 3 grams and about 0.07 gram, respectively) is purified into 10 liters of high purity solvent containing nearly no contaminants. That is, in the intensive purification process, about 3 grams of laundry additives and about 0.07 gram of soils are trapped by the filter. The resulting high purity
solvent is used as the rinse fluid in the next rinse cycle. The fabric articles are dried. The solvent vapor from the drying process is collected, condensed and returned to the wash composition tank. Thus, there is essentially no net loss of solvent at the end of the laundering cycle. The amount of laundry additives lost during the laundering cycle (about 3.3 grams) may be replenished so that the wash composition maintains a pre-determined amount of laundry additives in each wash cycle. Alternatively, the laundry additives may be replenished when the concentration in the wash composition drops below a threshold value. We found that even as the soils accumulates in the wash fluid from successive laundering operations, the laundered fabric articles consistently contain only trace amounts of laundry additives and soils.

Based on the capacity and soil level of the above example, the "soiled" wash composition may be re-used for at least about 50 to about 75 laundering cycles, or at least about 100 to about 250 laundering cycles before the soil concentration in the wash composition exceeds the threshold level. Therefore, it is believed that the dry cleaning system of the present invention may need a thorough wash composition clean up or replacement only about once to about four times a year, depending on the amount of wash solvent or system capacity, the soil level of the laundry being treated and the loads of laundry being treated per week. Thus, the present invention provides a sustainable dry cleaning system that can be operated through multiple laundering cycles without user interference. The dry cleaning system of the present invention requires only occasional service and replacement of the solvent and/or filter. The present invention provides tremendous advantages in minimizing the handling and exposure to dry cleaning solvents.

In comparison, the conventional process employed by dry cleaning services typically comprises only the "soiled" wash cycle without the clean rinse cycle. As such, laundered fabric articles contain increasing amount of soils due to exposure to the cumulative amounts of soils in the wash composition. Thus, the conventional dry cleaning process suffers not only from less effective soil removal but also higher soils re-deposition, both of which contribute to less than satisfactory cleaning results. In addition, the conventional dry cleaning system quickly exceeds the soils threshold level and requires frequent system clean up and solvent replacement.
The cumulative effect of the conventional dry cleaning process is dramatically different. Assuming the same load of fabric articles is treated with the same wash composition according to a conventional dry cleaning process (i.e., without the clean rinse step), the treated fabric articles at the end of the first laundering cycle would carry a higher level of residual soils and laundry additives. After 10 cycles, the cumulative effects on the treated fabric articles and on the soiled wash composition are dramatically different between the conventional dry cleaning process and the present invention. The Table below demonstrates the cumulative effects, after multiple laundering cycles, in a system according to the present invention (with clean rinse) or a conventional dry cleaning process (without rinse). More dramatic differences in soil accumulation after multiple laundering cycles are demonstrated in FIG. 2.

<table>
<thead>
<tr>
<th></th>
<th>Clean Rinse</th>
<th>No Rinse</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cycle 1</td>
<td>Cycle 10</td>
</tr>
<tr>
<td>Soils in wash composition, ppm</td>
<td>83</td>
<td>728</td>
</tr>
<tr>
<td>Soils on garments, mg/g</td>
<td>0.002</td>
<td>0.022</td>
</tr>
</tbody>
</table>

In one embodiment of the present invention, the volume ratio of wash composition to rinse fluid is at least 1:1, preferably 5:1 and more preferably 3:1. In one embodiment, the weight ratio of fabric articles to the wash composition is from about 1:1 to about 1:40, preferably 1:2 to 1:20 and more preferably 1:3 to 1:10.

The processes and systems of the present invention may be used in the home or in a service, such as a cleaning service, diaper service, uniform cleaning service, or commercial business, such as a laundromat, dry cleaner, linen service which is part of a hotel, restaurant, convention center, airport, cruise ship, port facility, or casino.

The methods of the present invention may be performed in an apparatus that is a modified existing apparatus and is retrofitted in such a manner as to conduct the method of the present invention in addition to related methods. Nonlimiting examples of suitable fabric article treating apparatuses include commercial cleaning machines, domestic, in-home, washing machines, and clothes drying machines. Another example of an apparatus that can be retrofitted is disclosed in US 2002/013386A1.

The methods of the present invention may also be performed in an apparatus that is specifically built for conducting the present invention and related methods.
Further, the methods of the present invention may be added to another apparatus as part of a dry cleaning solvent processing system. This would include all the associated plumbing, such as connection to a chemical and water supply, and sewerage for waste wash compositions.

The methods of the present invention may also be performed in an apparatus capable of "dual mode" functions. A "dual mode" apparatus is one capable of both washing and drying fabrics within the same vessel (i.e., drum). Dual mode apparatuses for aqueous laundry processes are commercially available, particularly in Europe. Additionally, the method of the present invention may also be performed in an apparatus capable of performing "bi-modal" cleaning functions. A "bi-modal" apparatus is one capable of performing both non-aqueous washing and aqueous washing in the same vessel, wherein the two washing modes can be performed in sequential washing cycles or in a combination washing cycle. Additionally, the bi-modal machine is capable of fully drying the clothes without having to transfer them to a separate machine. That is, a machine can have the bi-modal function as well as the dual-mode function.

An apparatus suitable for use in the present invention will typically contain some type of control systems, including electrical systems, such as "smart control systems", as well as more traditional electro-mechanical systems. The control systems would enable the user to select the size of the fabric load to be cleaned, the type of soiling, the extent of the soiling, the time for the cleaning cycle. Alternatively, the control systems provide for pre-set cleaning and/or refreshing cycles, or for controlling the length of the cycle, based on any number of ascertainable parameters the user programmed into the apparatus. For example, when the collection rate of dry cleaning solvent reaches a steady rate, the apparatus could turn its self off after a fixed period of time, or initiate another cycle for the dry cleaning solvent.

In the case of electrical control systems, one option is to make the control device a so-called "smart device", which provides smart functions, such as self diagnostics; load type and cycle selection; Internet links, which allow the user to start the apparatus remotely, inform the user when the apparatus has cleaned a fabric article, or allow the supplier to remotely diagnose problems if the apparatus malfunctioned. Furthermore, the apparatus of the present invention can also be a part of a cleaning system, the so called
"smart system", in which the present apparatus has the capability to communicate with another laundry apparatus that performs a complimentary operation (such as a washing machine or a dryer) to complete the remainder of the cleaning process.

The Intensive Solvent Purification Treatment

The intensive solvent purification treatment removes laundry additives and/or soils from the rinse eluent to produce the purified dry cleaning solvent. It is understood that the purified dry cleaning solvent suitable for use as the rinse fluid in the rinse cycle of the present invention may still contain traces of laundry additives and/or soils in varying amounts. In view of the tendency for soils to generate odors, rancid smells, discoloration, and the like, all of which are readily detectable by the consumers and generally interpreted as signals for unsatisfactory dry cleaning results by the consumers, the acceptable amount of soils in the purified solvent is generally lower than the acceptable amount of laundry additives. For example, the amount of soils (such as body soils or dyes) may be present at less than about 0.1% by weight of the purified solvent. On the other hand, the amount of laundry additives (such as detersive surfactant) in the purified solvent may be less than about 5% by weight of the purified solvent. In a typical embodiment, the soil may be present at amounts from about 0.00001% to about 0.1%, or from about 0.0001% to about 0.05%, or from about 0.001% to about 0.01%, by weight of the purified solvent. On the other hand, the amount of a laundry additive in the purified solvent may be less than about 5%, or from about 0.0001% to about 5%, or from about 0.001% to about 2%, or from about 0.01% to about 1%, by weight of the purified solvent.

The intensive solvent purification treatment of the of the present invention generally employs non-distillative separation methods, optionally, in combination with other separation methods, such as distillation, membrane filtration, and other separation or purification methods described in U.S. Patent Publications 2002/0004952A1 and 2005/0009724A1.

Typically, the method comprises contacting the rinse eluent with one or more adsorbent or absorbent materials. Suitable absorbent materials include those water absorbing polymers or gel materials described in U.S. Patent 6,855,173. Suitable adsorbent materials include, but are not limited to, activated carbons, clays, polar agents, apolar agents, charged agents, zeolites, nanoparticles, and mixtures thereof. In one
embodiment, the adsorbent material is added to the mixture as solid particulates/powders. In another embodiment, the adsorbent material is contained in a cartridge filter or like container.

Suitable activated carbons may have one or more of the following properties: (i) an internal surface area at least about 1200 m²/gram, preferably from about 1200 to about 2000 m²/gram, and more preferably from about 1300 to about 1800 m²/gram; and (ii) an average pore diameter less than about 50 Angstroms, preferably ranging from about 20 to about 50 Angstroms and more preferably from about 30 to about 40 Angstroms; and optionally (iii) a cumulative surface area at least about 400 m²/gram, preferably ranging from about 400 to about 2000 m²/gram, preferably from about 500 to about 1800 m²/gram, and more preferably from about 600 to about 1600 m²/gram. Further, the activated carbons suitable for use herein typically have an Adsorption Capacity from about 150 to about 600 mg contaminants per gram of adsorbent, preferably from about 300 to about 550 mg contaminants per gram of adsorbent, and more preferably from about 400 to about 500 mg contaminants per gram of adsorbent.

The internal surface area and cumulative surface area can be determined by the well known BET method that measures nitrogen adsorption at 77°K. The cumulative pore volume and average pore diameter can be determined by the BJH method that measures nitrogen adsorption at 77°K under BJH mesopore volume/size distribution. These methods are disclosed in more details by Brunauer et al., in J. Am. Chem. Soc., Vol. 60, 309 (1938); and Barrett et al. in J. Am. Chem. Soc., Vol. 73, 373 (1951). The BET and BJH measurements can be conducted with an Accelerated Surface Area and Porosity (ASAP) instrument, Model 2405, available from Micromeritics Instrument Corporation, Norcross, GA.

Nonlimiting example of a suitable activated carbons include Nuchar® RGC, available from Mead Westvaco Corporation, Stamford, CT; Acticarbone® BGX, available from Atofina Chemicals, Inc. Philadelphia, PA; Norit® GF-45 and Norit® C, available from Norit America, Inc. Atlanta, GA.

Nonlimiting examples of polar agent suitable for use herein as the adsorbent include: silica, diatomaceous earth, aluminosilicates, polyamide resin, alumina, zeolites and mixtures thereof. In one embodiment, the polar agent is silica, more
specifically silica gel. Suitable polar agents include Silfam® silica gel, available from Nippon Chemical Industries Co., Tokyo, Japan; and Davisil® 646 silica gel, available from W. R. Grace, Columbia, MD.

Nonlimiting examples of apolar agents suitable for use herein as the adsorbent material include: polystyrene, polyethylene, and/or divinyl benzene. The apolar agent may be in the form of a fibrous structure, such as a woven or nonwoven web. Suitable apolar agents include Amberlite® XAD-16 and XAD-4, available from Rohm & Haas, Philadelphia, PA.

Nonlimiting examples of charged agents suitable for use herein as the adsorbent material include polymers having charged substitutents, wherein the polymer backbone may be: polystyrene, polyethylene, polydivinyl benzene, polyacrylic acid, polyacrylamide, polysaccharide, polyvinyl alcohol, copolymers of the above; and the substitutents may be charged moieties such as sulfonates, phosphates, carboxylates, quaternary ammonium salts and mixtures thereof, or protonable moieties such as those derived from alcohols; diols; salts of primary and secondary amines and mixtures thereof. Suitable charged agents are available from Rohm & Haas, Philadelphia, PA, under the designation IRC-50.

When designing the filter, it is desirable to optimize the adsorbent activity in order to efficiently remove the contaminants from the rinse eluent. It is also desirable to have as low a pressure differential as possible across the filter because the larger the pressure drop the more energy is needed to maintain the same flow rate of fluid through the filter. It is further desirable to have adequate flow rate such that a fixed amount of rinse eluent is purified within unit time. The flow rate can be adjusted by a combination of factors, such as pressure drop across the filter, the size of the filter and associated conduits, the average particle size and distribution of the adsorbent material, and the packing density or porosity of a compressed block of adsorbent material.

In one embodiment where a filter containing adsorbent materials is used, it is desirable to optimize the residence time needed to purify the solvent effectively. As used herein, "residence time" means the length of time during which the rinse eluent is in contact with the adsorbents inside the filter. The desired residence time is influenced by the types of contaminants, the levels of contaminants and the affinity between the
contaminants and the adsorbent materials. For example, when the adsorbent material is activated carbon, the residence time needed to remove dyes from the rinse eluent is shorter than the residence time needed to remove surfactants from the same rinse eluent. The residence time can lengthened by using a filter having a low flow through rate. Alternatively, the residence time can be lengthened by recirculating the rinse eluent through the filter repeatedly. In such embodiment, the residence time is the total contact time between the rinse eluent and the filter over multiple recirculations. For practical purposes, the residence time to convert the wash eluent to a high purity rinse fluid is less than about 12 hours (i.e., overnight filtration) so that the high purity rinse fluid is ready to be reused the next day. In other embodiments, the residence time can be less than about 8 hours, or less than about 4 hours.

In one embodiment, the filter comprises adsorbent material composed of activated carbons in the form of fine powders having average particle sizes in the range of about 0.1-250 microns, preferably 0.1-100 microns, more preferably about 0.1-50 microns. The average particle size can be measured by ISO 9001 EN-NS 45001 sieve analysis (using U.S. Standard Testing Sieves) or ASTM D4438-85.

In one embodiment, the filter is composed of activated carbon powders and a binder, wherein the two components are compressed or fused together to form a porous block. The porous block is permeable to fluids and has interconnected pores forming a plurality of tortuous pathways from one surface or location to another surface or location of the block. The activated carbon powders are described hereinabove. The binder is typically a polymer, and preferably a thermoplastic polymer. Nonlimiting examples of binder material include polyolefins such as polyethylene, polypropylene and copolymers; vinyl or diene polymers such as polyvinyl acetate, polybutadiene; polyacetals such as polyacetaldehyde; polyacrylics such as polyacrylic acid, polymethacrylic acid, polyacrylamide, and copolymers thereof; fluorocarbon polymers such as polytetrafluoroethylene, perfluorinated ethylene-propylene polymer; polystyrene and copolymers such as acrylonitrilebutadiene-styrene (ABS); polyamides; polyimides; polyesters; and the like. The block can be made by extrusion, molding, compression, and other known methods.
In one embodiment, the porous block is composed of carbon powders having an average particle size of about 30 microns and binders at the level of about 5-40%, or about 20-30% by weight of the block. It is desirable to use activated carbon powders having small particle size and uniform particle size distribution. It is also desirable to select the activated carbons having high adsorption capacity for the target contaminants.

In one embodiment, the adsorbent materials are contained in a filter or a container, such as a housing, a pouch, a bag, a sachet or like container. The filter can have any shape or size. At the minimum, it should hold sufficient adsorbent materials to render the dry cleaning solvent substantially free of contaminants for an overnight (about 12 hours) filtration operation.

In one embodiment, the filter may comprise adsorbent materials embedded in or coated on or bound to a fibrous structure, such as a nonwoven or woven fibrous web. The loading level of the adsorbent material in the nonwoven web ranges from about 10 to about 500 grams per square meter (gsm), preferably from about 25 to about 400 gsm and more preferably from about 50 to about 300 gsm. The thickness of the nonwoven web is generally in the range of from about 0.01 to about 10 mm, preferably from about 0.1 to about 5 mm. The non-woven web is desired to have a basis weight in the range of from about 5 to about 1000 gsm, preferably from about 10 to about 300 gsm. The fibrous substrate may be formed into sheets, films, membranes or other configurations. The sheet configuration includes well-known variations, such as tubes, hollow fibers, spiral wound modules and flat sheets in plate and frame units.

In one embodiment, the filter comprises a fibrous substrate and a porous block contained in a filter housing. FIG. 3 illustrates such an embodiment wherein the filter comprises a filter housing 50, which comprises a rigid apertured cylindrical external cage 51 and an internal cylindrical core element 58 having a central passageway 57 coaxially disposed. The apertures 52 in the rigid external cage 51 allow fluid to flow therethrough. The fibrous structure is in the form of a longitudinally pleated sheet 53 placed such that the individual pleats are oriented radially relative to the filter cartridge's longitudinal axis. The porous blocks of activated carbons and binders are placed in the space between the external cage and the internal core element and are contiguous with the pleats. It is believed the combination of pleated fibrous substrate and the porous block adsorbent...
reduces clogging of the porous block by insoluble contaminants. Clogging may lead to increased pressure differential across the filter and channeling through the filter such that the adsorbent materials within the filter are not fully and evenly utilized, all of which result in frequent replacement of the filter.

In an alternative embodiment as shown in FIG 4, the filter comprises a rigid, fluid impermeable, cylindrical filter housing 210, a top flange 220 and a bottom flange 230 having apertures 140 to allow fluid to flow through the filter. One or more distinctive zones 240, 250, 260 and 270 are layered in between the flanges such that fluid flows through the zones in the perpendicular direction. The zones are optionally separated by fluid permeable element 130. The fibrous structure in the form of a radially pleated sheet 170 is placed in each zone such that the individual pleats are oriented radially relative to the filter cartridge's horizontal axis. The porous blocks of activated carbons and binders are placed between the pleats.

In another embodiment, the filter may contain more than one adsorbent materials commingled and dispersed inside the filter housing. In another embodiment, the filter may comprise multiple compartments; each compartment contains a single adsorbent material or multiple adsorbent materials. If the filter has both a particulate and an adsorbent and/or absorbent (e.g., activated carbon) material compartment, either for the filter used in the wash cycle or in the rinse cycle, an optional configuration for the filter design would allow replacing the particulate filter portion without replacing the adsorbent/absorbent material filter portion.

In a further embodiment, the filter may comprise particulates of adsorbent materials that are dropped into the treating vessel or the solvent reservoir directly and mixed with the rinse eluent by agitation, tumbling, or other known mixing techniques. The mixture of the adsorbent material and the rinse eluent form a suspension or a slurry with a weight ratio of adsorbent material to rinse eluent about 0.001:1 to 0.1:1. This approach makes a particular effective use of the adsorbent materials because it provides maximum contacts between the fluid being purified and the particulates. An optional sieve filter may be used to remove the particulate adsorbent materials from the purified solvent.

**Lipophilic Fluid**
"Lipophilic fluid" as used herein means any liquid or mixture of liquid that is immiscible with water at up to 20% by weight of water. In general, a suitable lipophilic fluid can be fully liquid at ambient temperature and pressure, can be an easily melted solid, e.g., one that becomes liquid at temperatures in the range from about 0 °C to about 60°C, or can comprise a mixture of liquid and vapor phases at ambient temperatures and pressures, e.g., at 25 °C and 1 atm. pressure.

The suitable lipophilic fluid may be non-flammable or, have relatively high flash points and/or low VOC (volatile organic compounds) characteristics, these terms having conventional meanings as used in the dry cleaning industry, to equal to or exceed the characteristics of known conventional dry cleaning fluids, such as perc (perchloroethylene chloride). As used herein, the "dry cleaning solvents" useful in the present invention refers to the lipophilic fluids.

Non-limiting examples of suitable lipophilic fluid materials include siloxanes, other silicones, hydrocarbons, glycol ethers, glycerine derivatives such as glycerine ethers, perfluorinated amines, perfluorinated and hydrofluoroether solvents, low-volatility nonfluorinated organic solvents, diol solvents, other environmentally-friendly solvents and mixtures thereof.

"Siloxane" as used herein means silicone fluids that are non-polar and insoluble in water or lower alcohols. Linear siloxanes (see for example US Patents 5,443,747, and 5,977,040) and cyclic siloxanes are useful herein, including the cyclic siloxanes selected from the group consisting of octamethyl-cyclotetrasiloxane (tetramer), dodecamethyl-cyclohexasiloxane (hexamer), decamethyl-cyclopentasiloxane (pentamer, commonly referred to as "D5"), and mixtures thereof. A suitable siloxane comprises more than about 50% cyclic siloxane pentamer, or more than about 75% cyclic siloxane pentamer, or at least about 90% of the cyclic siloxane pentamer. Also suitable for use herein are siloxanes that are a mixture of cyclic siloxanes having at least about 90% (or at least about 95%) pentamer and less than about 10% (or less than about 5%) tetramer and/or hexamer.

The lipophilic fluid can include any fraction of dry-cleaning solvents, especially newer types including fluorinated solvents, or perfluorinated amines. Some perfluorinated amines such as perfluorotributylamines, while unsuitable for use as
lipophilic fluid, may be present as one of many possible adjuncts present in the lipophilic fluid-containing composition.

Other suitable lipophilic fluids include, but are not limited to, diol solvent systems e.g., higher diols such as C6 or C8 or higher diols, organosilicone solvents including both cyclic and acyclic types, and the like, and mixtures thereof.

Non-limiting examples of low volatility non-fluorinated organic solvents include for example OLEAN® and other polyol esters, or certain relatively nonvolatile biodegradable mid-chain branched petroleum fractions.

Non-limiting examples of glycol ethers include propylene glycol methyl ether, propylene glycol n-propyl ether, propylene glycol t-butyl ether, propylene glycol n-butyl ether, dipropylene glycol methyl ether, dipropylene glycol n-propyl ether, dipropylene glycol t-butyl ether, dipropylene glycol n-butyl ether, tripropylene glycol methyl ether, tripropylene glycol n-propyl ether, tripropylene glycol t-butyl ether, tripropylene glycol n-butyl ether.

Non-limiting examples of suitable glycerine derivative solvents include 2,3-bis(1,1-dimethylethoxy)-1-propanol; 2,3-dimethoxy-1-propanol; 3-methoxy-2-cyclopentoxy-1-propanol; 3-methoxy-1-cyclopentoxy-2-propanol; carbonic acid (2-hydroxy-1-methoxymethyl)ethyl ester methyl ester; glycerol carbonate and mixtures thereof.

Non-limiting examples of other silicone solvents, in addition to the siloxanes, are well known in the literature, see, for example, Kirk Othmer's Encyclopedia of Chemical Technology, and are available from a number of commercial sources, including GE Silicones, Toshiba Silicone, Bayer, and Dow Corning. For example, one suitable silicone solvent is SF-1528 available from GE Silicones.

In one embodiment, the lipophilic fluid comprises more than 50% by weight of the lipophilic fluid of cyclopentasiloxanes (e.g., D5) and/or linear analogs having approximately similar volatility, and optionally complemented by other silicone solvents.

The amount of lipophilic fluid, when present in the treating compositions according to the present invention, is from greater than about 50% to about 99.99%, or from about 60% to about 95%, or from about 70% to about 90% by weight of the treating composition.
Laundry Additives And Fabric Treatment Compositions

The fabric treatment composition for use in treating/cleaning fabric articles may comprise a lipophilic fluid and at least one laundry additive. Optionally, the fabric treatment composition may further comprise water and/or polar solvents.

Each laundry additive, when present in the composition, typically comprises from about 0.01% to about 80%, or from about 0.5% to about 60%, or from about 1% to about 50% by weight of the composition. The laundry additives are not required to be present at the same concentration. For example, an enzyme can be present at a level of about 1/10 to about 1/100 of the level of a detersive surfactant.

When the composition is diluted with the lipophilic fluid to form the wash liquor, each laundry additive, when present, typically comprises from about 0.0001% to about 50%, or from about 0.01% to about 30%, or from about 1% to about 20% by weight of the wash liquor.

In some embodiments, polar solvents may optionally be incorporated into the wash liquor as well. The polar solvent may be added as a component of the fabric treatment composition or as a co-solvent of the lipophilic fluid in the wash liquor. The polar solvent can be water, and optionally also includes linear or branched C1-C6 alcohols, C1-C4 glycols and mixtures thereof.

When present, the polar solvent ranging from about 99% to about 1%, or from about 5% to about 40%, by weight of the composition; and cleaning adjuncts ranging from about 0.01% to about 50%, or from about 5% to about 30%, by weight of the composition.

Laundry additives include, but are not limited to, soil release polymers, detersive surfactants, bleaches, enzymes, perfumes, softening agents, finishing polymers, dyes, dye transfer inhibiting agents, dye fixatives, fiber rebuild agents, wrinkle reducing and/or removing agents, fiber repair agents, perfume release and/or delivery agents, shape retention agents, fabric and/or soil targeting agents, antibacterial agents, anti-discoloring agents, hydrophobic finishing agents, UV blockers, brighteners, pigments (e.g., Al₂O₃, TiO₂), pill prevention agents, skin care lotions (comprising humectants, moisturizers, viscosity modifiers, fragrances, etc.), insect repellents, fire retardants, and mixtures thereof. Of these, some are more useful than others for inclusion into the rinse cycle, such
as soil release polymers, perfumes, softening agents, finishing polymers, dyes, dye fixatives, fiber rebuild agents, wrinkle reducing and/or removing agents, fiber repair agents, perfume release and/or delivery agents, shape retention agents, antibacterial agents, anti-discoloring agents, hydrophobic finishing agents, UV blockers, brighteners, pigments, pill prevention agents, skin care lotions, insect repellents, fire retardants, and mixtures thereof. Exemplary laundry additives are disclosed in US 2003/0087793A1 (P&G case 8632M); US 20050000029 A1 (P&G case 9542M); and US 20050009723A1 (P&G case 9293M).

In one embodiment, the wash composition comprises one or more of the surfactants: from about 0.01% to about 30% by weight of the composition of a silicone surfactant, from about 0.01% to about 90% by weight of the composition of a nonionic surfactant, from about 0.01% to about 50% by weight of the composition of a Gemini surfactant, and from about 0.01% to about 50% by weight of the composition of an anionic surfactant.

All documents cited in the Detailed Description of the Invention are, in relevant part, incorporated herein by reference; the citation of any document is not to be construed as an admission that it is prior art with respect to the present invention. To the extent that any meaning or definition of a term in this written document conflicts with any meaning or definition of the term in a document incorporated by reference, the meaning or definition assigned to the term in this written document shall govern.

While particular embodiments of the present invention have been illustrated and described, it would be obvious to those skilled in the art that various other changes and modifications can be made without departing from the spirit and scope of the invention. It is therefore intended to cover in the appended claims all such changes and modifications that are within the scope of this invention.
WHAT IS CLAIMED IS:

1. A dry cleaning process comprising a wash cycle and a rinse cycle, wherein the wash cycle comprises the steps of:
   a. contacting fabric articles with a wash composition, whereby the wash composition is converted into a wash eluent;
   b. removing the wash eluent from the fabric article, whereby the fabric articles become substantially free of the wash eluent; and
   c. treating the wash eluent, whereby the wash eluent is converted into the wash composition for re-use in step (a), preferably said treating comprises one or more of the following: replenishing laundry additive, replenishing lipophilic fluid, preferably with a lipophilic fluid that comprises linear or cyclic silicones, more preferably with octamethyl cyclopentasiloxane (D5), passing through a particulate filter, and combinations thereof;

   the rinse cycle comprises the steps of:
   d. contacting fabric articles with a rinse fluid, whereby the rinse fluid is converted into a rinse eluent;
   e. removing the rinse eluent from the fabric articles such that the fabric articles are substantially free of the rinse eluent;
   f. purifying the rinse eluent, preferably purifying the rinse fluid such that said rinse fluid comprises less than 0.0001% or less than 5% laundry additive, or both, whereby the rinse eluent is converted to the rinse fluid for re-use in step (d), preferably purifying the rinse eluent comprises contacting the wash eluent with a rinse filter, more preferably purifying the rinse eluent comprises contacting the rinse eluent with a rinse filter comprising an adsorbent material, most preferably said rinse filter comprises activated carbon.

2. The process of claim 1 further comprising the steps of:
   g. drying the fabric article whereby trace of lipophilic fluid on the fabric article is converted into lipophilic fluid vapor;
   h. condensing lipophilic fluid vapor; and
i. adding the condensed lipophilic fluid vapor to the wash composition of step (a).

3. The process of any preceding claim wherein said activated carbon exhibits one or more of the following characteristics:
   i) an average particle size in the range from 0.1 to 50 microns;
   ii) an adsorption capacity of at least 150 mg per gram of an adsorbent;
   iii) an internal surface area at least 1200 m$^2$/gram;
   iv) an average pore diameter less than 50 Angstroms;
   v) a cumulative surface area at least 400 m$^2$/gram; and
   vi) combinations thereof.

4. The process of any preceding claim wherein the filter further comprises a binder, a fibrous substrate, or both.

5. The process of any preceding claim further comprising the step of replacing the rinse filter when the pressure differential across the filter increased by ten times or higher.

6. The process of any preceding claim wherein the wash cycle comprises an optional step of passing the wash eluent through a particulate filter.

7. A dry cleaning apparatus exhibiting sustainable efficiency in removing soils from discrete loads of soiled fabric articles, the apparatus comprising:
   a. a treatment chamber for retaining the fabric;
   b. a first lipophilic fluid source for supplying wash composition to the treatment chamber, the wash composition is converted into wash eluent when contacted by the fabric articles;
   c. a second lipophilic fluid source for supplying rinse fluid to the treatment chamber, the rinse fluid is converted into rinse eluent when contacted by the fabric articles;
   d. a rinse filter for removing residues of laundry additives and/or soils from rinse eluent preferably comprising activated carbon, and optionally a binder, a fibrous substrate, or both, whereby the rinse eluent is converted into the rinse fluid;
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e. means for separating fabric articles from wash eluent and/or rinse eluent; and
f. preferably an in-line wash pre-filter for removing particulates from the wash composition;
preferably the wash composition and the rinse fluid comprise linear or cyclic siloxanes,
more preferably the wash composition and the rinse fluid comprise decamethyl cyclopentasiloxane.

8. A dry cleaning process exhibiting sustainable efficiency in removing soils from
discrete loads of soiled fabric articles, the process comprises a wash cycle using a wash composition and a rinse cycle using a rinse fluid, the wash composition and the rinse fluid are treated and reused in the process repeatedly, wherein after treating 10 loads of soiled
treatment, soil concentration in the wash composition is 75% to 90% of soil concentration in the wash composition in a control process which has no rinse cycle or
treatment, soil residue on laundered fabric articles is 5% to 15% of soil residue on laundered fabric
articles in a control process which has no rinse cycle.
With Clean Rinse

![Graph of Soil concentration in wash with Clean Rinse](image)

FIG 2a

Without Clean Rinse

![Graph of Soil concentration in wash without Clean Rinse](image)

FIG 2c

Soil residual amounts on clothes after each cycle.

![Graph of Soil residue with Clean Rinse](image)

FIG 2b

Soil residual amounts on clothes after each cycle.

![Graph of Soil residue without Clean Rinse](image)

FIG 2d