AEROSPACE INFORMATION REPORT

AIR787™	REV. B
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(R) Filter Element Cleaning Methods

RATIONALE

Revision B was created to clarify cleaning requirements and the filter element cleaning guide table. In addition, the document has been significantly updated editorially.

FOREWORD

Satisfactory cleaning methods can be developed for most "cleanable" filter elements. The technical or economic feasibility of the cleaning method may be limited, however, by:

- The incompatibility of filter element construction materials,
- By mechanical weaknesses
- The lack of corrosion resistance to withstand repeated or continued cleaning
- By the presence of unusually tenacious contamination

These factors should be considered when selecting approaches to the development of specific methods.

The primary reason for cleaning filters is to eliminate the cost of the replacement of them. Additional considerations include:

- The reduction of logistic problems in stocking new replacement filter elements.
- The conservation of strategic materials and skills in the event of a national emergency.

When considering all of these factors, the total cost of cleaning should be less than the total cost of replacement for a given situation. While process economy is desirable for its own sake, economic evaluation and decision for a particular case can be undertaken by the user alone.

The applicable cleaning processes are mainly determined by the geometry and materials of construction used in the filter. Additionally, final cleanliness requirements and the characteristics of contamination plugging the filter should be considered.

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1. SCOPE

This SAE Aerospace Information Report (AIR) provides technical information to assist the development of specific cleaning methods for those filter elements which are designated as "cleanable" and cannot be cleaned by simple and obvious procedures.

1.1 Purpose

The purpose of this report is to provide details of economical and technically sound methods for cleaning and testing filters. These methods are intended to provide a uniform basis for the development of detailed procedures by the prospective users.

2. APPLICABLE DOCUMENTS

The following publications form a part of this document to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other publications shall be the issue in effect on the date of the purchase order. In the event of conflict between the text of this document and references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

2.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724776-4970 (outside USA), www.sae.org.

AIR844 Sensitization and Corrosion in Stainless Steel Filters

AIR888 Fine Wire Mesh for Filter Elements

ARP599 Aerospace - Dynamic Test Method for Determining the Relative Degree of Cleanliness of the Downstream Side of Filter Elements

ARP725 Evaluating Effectiveness of Filter Element Cleaning Methods

ARP901 Bubble-Point Test Method

ARP4386 Terminology and Definitions for Aerospace Fluid Power, Actuation and Control Technologies

3. GENERAL FILTER ELEMENT CLEANING INFORMATION

The general problem of establishing a program for developing filter element cleaning methods may be divided into a study of cleaning technology and an investigation of required test methods. Because of the immediate need for uniform, economical methods, emphasis should be placed on the application of existing information rather than new research. Specific objectives which are developed to fulfill general program requirements should be attacked by an inductive process of problem definition and measurement of results, followed by appropriate action.

3.1 Cleaning

Cleaning is an empirical art for which few scientific principles have been established. While an extensive cleaning technology and literature exist (especially in the fields of metal finishing, chemical process industry maintenance, and electronic-component cleaning), the successful application of these techniques requires both experiment and judgment. A prerequisite to a rational cleaning procedure specification is knowledge of the cleaning process mechanisms, filter material and geometry characteristics, and contamination composition. Cleaning methods will be restricted by considerations such as the cost and safety of the process. Cleaning limitations also dictate the filter construction design and the contamination specification limits.

3.1.1 Cleaning Mechanisms

While any real cleaning process combines a number of simultaneous reactions, the abstract description of characteristic mechanisms is a useful tool for predicting process effects. Classifications of commonly used processes are found in metal-finishing literature.

3.1.2 Filter-Construction

The materials and geometry of a filter dictate chemical and physical limitations of the cleaning process. These limitations are deciding factors in selecting a cleaning procedure. Conversely, filter design considerations should include the requirement of responding to and withstanding the proposed cleaning procedure. Filter data is available from the manufacturers. Also refer to AIR888.

3.1.3 Contamination

Although knowledge of dirt composition is useful in selecting a cleaning process, especially if certain chemical types predominate, practical considerations require an assumption that various types of dirt may be present. Then each category of contamination can be attacked in logical sequence with suitable cleaning mechanisms. The cleaning method is not required to completely remove all types of contamination, however, but should only produce a result which is functionally and economically acceptable.

3.1.4 Testing

Test methods for determining the effects of a cleaning process should be predicated on previously defined product requirements which are capable of rejecting dirty or damaged filters if the process becomes inadequate or harmful. Since the cleaned filter should be functionally satisfactory, three major test areas are implied: dirt holding capacity, residual contamination, and physical or chemical damage. The test methods should be economically feasible as well as technically sound.

3.1.5 Dirt Capacity

The cleaning process should restore the dirt-holding capacity to substantially new-filter condition. Since dirt-loading tests before and after cleaning are only for information purposes, non-simulative tests should be used.

3.1.6 Residual Contamination

The cleaned filter should not contain residues which are detrimental to the filter or the system in which it will be installed. Tests should be employed to detect harmful residues.

3.1.7 Filter Damage

The cleaning process selected should not affect the fit, form, or function of the filter. Chemical or metallurgical damage may result from the cleaning process or be the result of previously undetected damage such as carbide precipitation or sensitization in stainless steel wire mesh. Physical damage may be detected by inspection tests such as "bubble-point" testing or lot based destructive metallurgical tests

3.1.8 Summary

Filter element cleaning methods should be developed by an orderly approach based on objective knowledge rather than opinion. Since cleaning is an art which depends on the detail definition of cleanliness requirements and process parameters, where the best methods are usually proprietary, only general direction can be given. Ultimate responsibility for the application of basic cleaning and testing methods should be assumed by the user.

4. FILTER ELEMENT MATERIALS, CONTAMINANTS, THEORY, AND CURRENT PRACTICES OF CLEANING

4.1 General

This section presents basic data on filter element materials of construction, contaminants, and some information on cleaning theory and current cleaning methods.

4.1.1 Filter Element Materials

A study of the filter elements being produced has led to the classification covered in 4.1.3. Classes of filter elements for which cleaning methods should be developed are established herein. The filter elements are classified by materials of construction to allow the determination of compatibility with the cleaning methods.

4.1.2 Filter Elements Excluded

Any filter elements which do not fall into these classes should be handled as special cases. There will be many filter elements that will fall into the categories listed because of their materials of construction which, because of their size and configuration, will be comparatively low priced. Filter elements which cost less than the direct cleaning cost should not be cleaned but should be discarded and replaced. The only exception to this would be a case of non-availability of replacement filter elements.

Examples of excluded types are plastic membrane, felted fiber, woven nonmetallic fiber, and granule beds. Non-compatibility of cleaning compounds, with the operating fluid of the systems from which the filter element was removed, is another case which may result in exclusion of filter elements from the cleanable category unless these fluids are removed with a suitable pre-cleaning operation.

4.1.3 Classes of Cleanable Filter Elements

The following listing covers filter elements which are used in large quantities in various service operations at the present time. The classifications listed are meant only to embrace types in current use and are not intended to include other hypothetical possibilities and combinations.

4.1.4 Complete Stainless Steel Construction

The filter element media and all parts of the support structure are stainless steel, and no other material is used, either as a joining or repair agent.

4.1.5 Stainless Steel and Brazing Alloys

The filter element media and support structure are stainless steel. The filter element components are joined together with either a silver or copper brazing material.

4.1.6 Stainless Steel and Epoxy

The filter element media and support structure are stainless steel. Epoxy is used as an filter element repair or bonding material.

4.1.7 Stainless Steel, Aluminum, and Epoxy

Stainless steel is used as the filter element media, aluminum for the supporting structure, and epoxy to join the components.

4.1.8 Copper-Based Alloys

All components of the filter element are made of a copper-based alloy.

4.1.9 Copper-Based Alloys and Epoxy

All components of the filter element are made of copper-based alloy, and epoxy is used as a bonding agent.

4.1.10 Multiple Materials

Many filter elements are made with carbon steel plated with cadmium in conjunction with both aluminum and stainless steel. Fiber glass is very popular as a disposable filter media. The cleaning of fiber glass filter media is not recommended.

4.2 Contaminants

This section covers the type of contamination which collects on filters to obstruct fluid flow in normal fluid systems and which should be removed during cleaning. This report is not concerned with chemical reactions, heat effects, nuclear radiation effects, absorption, electromotive displacement, and metallic deposition, etc., on the filter element materials. Stains on the filter elements are excluded from consideration except where they have significance beyond that of color alone.

Because almost all known materials can be collected on filter elements during their life, this section should necessarily be used only as a guide in the analysis of the cleaning problem facing the filter user. Consideration of the probable sources of the contaminant and the expected materials from these sources, coupled with the cleaning techniques described in other sections of this report should prove to be an effective approach to the filter cleaning problem.

4.2.1 Definition of Contamination

Contamination is defined as foreign matter contained in, or potentially capable of being contained in, a system fluid (liquid or gas). This foreign matter is capable of moving along with the system fluid and of being deposited upon or forming upon system filters. It may be in a solid, gelatinous, liquid, or gaseous form.

4.2.2 Particulate Contaminant

Particulate contaminant is defined as solid particles of contaminant which are insoluble in the system fluid under operating conditions. They may vary in shape from spherical particles to wires and fibers.

4.2.3 Gelatinous Contaminant

Gelatinous contaminant is defined as semirigid colloidal agglomeration of a solid contaminant with a high percentage of liquid. It may include bacteria or other microorganisms.

4.2.4 Liquid Contaminant

Liquid contaminant is defined as any foreign liquid which can be carried in the system fluid and/or in a filter element.

4.2.5 Gaseous Contaminant

Gaseous contaminant is defined as any foreign gas which can be carried in the system fluid and/or in a filter element. Since this contaminant is primarily a system state and problem, it will not be discussed further in this section.

4.3 Types of Contaminant

The basic types of contaminants derived from normal sources may include particulate contaminants and fluid decomposition products. The following list includes those contaminants most likely to be encountered in the cleaning of service-dirtied filter elements. Possible sources for these materials also are listed.

4.3.1 Metals

This group consists of the free metallic particles generally introduced into the working fluid by component wear, machining operations, handling, system-filling equipment, and ambient air conditions.

4.3.2 Fibers

There are two general categories of fibers: organic and inorganic. Typical organic fibers include cellulose, polymeric, protein (wool and hair). Typical inorganic fibers include asbestos, glass, mineral wool, and metal. They generally originate from cleaning of system parts with rags, settling or airborne particles into open portions of the system, fluid additions, packaging materials, clothing and bodies of assembly and maintenance personnel, and migration from system components.

4.3.3 Polymers and Resins

PTFE, paint, elastomers, epoxy, rubber, and plastics from system seals are typical of this group. Scuffing of plastic system components, sealants shedding, filter elements migrating or disintegrating, are other sources.

4.3.4 Process Residue

Lapping compounds, parting compounds, cleaning residue, brazing or welding fluxes, casting materials, etc. are a major source of contaminants in a newly assembled fluid system. This group includes all materials used in manufacturing of fluid system components.

4.3.5 Insoluble Oxides

This group includes corrosion from system components, forging scale, heat-treating scale, and contaminated fluid storage vessels. These oxides may be formed during manufacture or storage of system components and may not be completely removed by cleaning prior to installation.

4.3.6 Silica Sand

Silica sand and other similar siliceous substances are carried into systems on improperly cleaned castings and dirty fluid storage containers. They may also be introduced as airborne contaminant into open sections of the system.

4.3.7 Bacterial Growth

Organisms which can live in the fluid system are primarily a problem in fuel systems but can occur in other systems.

4.3.8 Ceramics

Ceramic particles from bearings, seals, and processing equipment. They are generated by wear and by being carried into the system on air, components, and in fluid.

4.3.9 Carbon

Major sources are carbon seals and bearings generating particles during installation and use. Carbon black used in O-ring compounding is also a major source.

4.3.10 Dirt

Particles of soil and other miscellaneous materials that exist in all fluid systems.

4.3.11 Varnishes

These are paint-like coatings deposited on the surface of filters. They are caused by overheated hydraulic and lubricant fluids causing partial breakdown of the fluid. They may also be caused by gaseous, liquid, or particulate contaminant reacting chemically with the system fluid.

4.3.12 Tars, Gels, Gums

These are heavy deposits of semiliquid contaminant usually deposited on filters or in dead-end portion of fluid systems. They are caused by system conditions similar to those described in 4.3.11.

4.3.13 Combustion Products

These consist of hydrocarbons, solid carbon, miscellaneous oxides, etc. They are primarily encountered on filter elements used in hot gas applications, but may occur in other systems from airborne particles and handling.

4.4 Theory and Current Practices of Cleaning

In theory, cleaning of filters consists simply of removing contamination from the filter element. It is the intent of this section to present some of the basic principles of contaminant removal. Many of these principles are currently in use for cleaning filters; in some instances, a combination of methods has been found necessary.

In order to be useful, a cleaning process should attack the contaminant but not the filter. Frequently, it is necessary to make a detailed analysis of both the materials used in the filter (see 4.1) and the nature of the contaminant (see 4.2) in order to establish some difference of material, form, structure, or other physical or chemical characteristics which will aid in selection of a cleaning process, if only by eliminating those processes which are either ineffective on the contaminant or harmful to the filter material. Section 5 will be found useful in establishing the compatibility of many of these processes.

An additional factor in the selection of a process is the possibility of damage to the filter as a result of cleaning residue or previously undetected metallurgical damage, such as carbide precipitation or sensitization of the wire mesh (refer to AIR844). Use of water containing cleaning agents may cause metallurgical degradation of the wire mesh materials causing the mesh to disintegrate under certain conditions; therefore, such cleaning agents should be carefully checked for effect before use. Adequate rinsing, or flushing, and neutralization should follow any cleaning operation.

4.4.1 Cleaning Processes

The general groups of cleaning processes to be discussed are physical processes and chemical processes and a special category for ultrasonic cleaning

Cleaning processes should be selected which will be effective on most "cleanable" filters under usual circumstances. Cleaning methods developed according to this report should be evaluated by the methods of ARP725. The test methods should detect inadequately cleaned or damaged filters.

4.4.2 Physical Processes

Physical processes remove dirt without causing a major chemical change in the contaminant. Physical methods of cleaning may be grouped according to their mode of action, as dissolving, dispersion, mechanical action, heat and pressure action.

4.4.3 Dissolving into Solution

This cleaning process involves dissolving the contaminant into the cleaning solution, such as occurs in a vapor degreaser. There is no chemical action; the solvent can generally be distilled and re-used. Typical solvents are hydrocarbons and other organic solvents, such as alcohol, petroleum ether or methylethylketone (MEK) (environmentally friendly solvents should only be used). These solvents are generally used to remove oils, waxes, greases, or other organic materials.

4.4.4 Dispersion

In this process, solid contaminants are removed by physical displacement into minute particles which are then dispersed through the cleaning solution. Emulsification and deflocculation are two specific types of dispersions; they share one common requirement - the surface should first be wetted. Some wetting agent is either included in the cleaning compound or should be added separately. In aqueous (water-base) cleaning, a detergent is generally used for this purpose.

4.4.5 Emulsification

Removal of an oily contaminant with a water-base solvent can be accomplished through the process of emulsification. Soap is a common example; it aids in wetting the surface, and in so doing forms minute globules of oil which separate from the surface. The oil may then be rinsed from the surface being cleaned along with the water and soap. Some emulsions are permanent, that is, each oil globule is held separate. In other (quick-breaking) emulsions, the oil droplet is free to coalesce with other droplets and rise to the liquid surface as a film which may be skimmed off, thus leaving the balance of the dispersant uncontaminated and free to continue its emulsifying action.

4.4.6 Deflocculation

This is a process wherein solid soils are broken into minute particles and dispersed through the cleaning solution. The exact mechanism of deflocculation is not completely understood, but it is believed to involve neutralization of the forces responsible for attraction between solid particles. As in the case of emulsification, a wetting action should first occur.

4.4.7 Mechanical Action

Reverse Flushing or Back Flushing is a common form of mechanical cleaning action. Most commonly, this process is undertaken by reversing the direction in which the fluid flows through the filter, which pushes off the contaminants that have been trapped on the surface. This method is effective at releasing particulate that has settled onto the filter surface, but additional cleaning methods may be required for contamination entrapped with the filter.

Brushing, wiping, air blasting, and vibration are less common forms of mechanical cleaning action. These methods are of limited usefulness in cleaning filter elements because of the nature of the problem. Some degree of pre-cleaning can be obtained, but generally the mass of the particle is so small and the mechanical forces entrapping the particle so great that little gain is realized.

4.4.8 Heat Action

Heat by itself is seldom used as a cleaning method. Actual combustion of the contaminant is a chemical (oxidation) process and will be discussed later. Heat is often used indirectly as a means of accelerating the action of other cleaning processes.

4.4.9 Pressure Action

Like heat, pressure is seldom used alone as a cleaning means. Elevated pressure may be used to advantage in increasingly the maximum operating temperature of volatile cleaning systems, while reduced pressure is useful in "vacuum-sonic" cleaning techniques to increase cavitation effects by degassing the solution and to impregnate the pores of the filter with the cleaning agent.

4.4.10 Chemical Processes

Chemical cleaning processes involve a chemical reaction within the contaminant, generally producing an innocuous or an easily removed product. Typical chemical processes are saponification, combination reactions, oxidation-reduction reactions, and non-aqueous reactions.

4.4.10.1 Saponification

The reaction of alkaline materials with fatty acids in animal or vegetable oils, resulting in the formation of soap further aids the process by detergent action. Since mineral and petroleum oils do not contain fatty acids, they cannot be saponified and cleaning should be by solvent action or emulsification.

4.4.10.2 Combination Reactions

This is a chemical process wherein the contaminant reacts directly with the cleaner resulting in a completely new compound. For example, nitric acid reacts with insoluble copper oxide (tarnish), resulting in soluble copper nitrate plus water. If a filter is contaminated with a material for which a similar chemical reaction can be found, cleaning is greatly simplified.

Certain precautions should be observed, however, that the cleaning chemical (frequently a strong acid or alkali) will not attack any part of the filter assembly, and that the chemical reaction will not result in some residue even more difficult to remove or hazardous than the original contaminant. Previous sensitization of the extremely fine wires used in many filter media is another hazard which should be considered; this sensitization may result in failure by intergranular corrosion.

4.4.10.3 Oxidation - Reduction (Redox) Reactions

These reactions occur because of the transfer of electrons from one substance to another. These reactions may be either oxidizing or reducing with respect to the contaminant. Reaction energy may be provided by chemical reagents or by an external electrolytic cell as in electropickling and electropolishing operations.

4.4.10.4 Combustion Reactions

A special case of an oxidation reaction exists when the contaminant is combustible. Again, care should be exercised; many contaminants will leave a combustion residue far more difficult to remove than the original contaminant.

4.4.10.5 Nonaqueous Reactions

Nonaqueous chemical reactions include all those reactions which are not conducted in a water solution. While some of these reactions are presently utilized in cleaning technology, many others have not yet been adequately investigated.

4.4.11 Fused Melts

Molten alkali hydroxides and salts have been used to react with metallic oxides, dissolve acidic oxides, and pyrolyze organic materials. Molten sodium hydroxide and various salt mixtures may be used to accomplish many reactions analogous to those produced by aqueous chemical processes.

4.4.12 Nonaqueous Solvents and Vapors

While not yet widely used, nonaqueous solvents such as boron tetrafluoride have attracted interest for use in cleaning processes. Vapor phase reactions involving organic and inorganic acid vapors and similar materials are also of interest. Gas phase pickling of ferrous metals with anhydrous hydrogen chloride is a commercial process.

4.4.13 Ultrasonic Cleaning

Ultrasonic cleaning applies intense, high-frequency sound to liquids, producing intimate mixing and powerful chemical and physical reactions. The process ("cavitation") is, in effect, "cold boiling" and results from the creation and collapse of microbubbles in the liquid, producing shock waves. The technique is used to accelerate reactions, treat wastes, disperse fine particles and suspend slurries, homogenize and emulsify, and clean surfaces and porous materials. This work entails imparting turbulence to suitable fluid medium, with powerful sound energy. Particulate matter is sonically dislodged from the media and is carried away by the cleaning solution. Used in conjunction with a cleaning solution, ultrasonic cleaning is one of the most popular methods used in the cleaning of filter elements.

4.4.14 Packaging Considerations

Once the filter element is cleaned and inspected, it should be packaged to protect it against both corrosion and contamination. If the filter element is to be immediately installed in its housing for service, no particular precautions need be taken; the assembly should merely be flushed and filled with pre-cleaned system fluid. However, if the filter element is to be packaged separately, it should be degreased and packaged in either a heat-sealed or zip-lip plastic bag. In certain climates, the bag should be purged with dry nitrogen to avoid condensation of moisture after packaging.

In no case should the filter element be flushed with preservative oil and packaged wet. These oils tend to dry out in time and form gums which are difficult to remove from filter pores. The effective result of such a packaging would then be to plug the filter element.

5. FILTER ELEMENT CLEANING METHODS

5.1 Introduction

Study and experience indicate that there is no single foolproof procedure that will clean all types of contamination from all types of filter elements while maintaining an adequate safety level. A review of contamination usually found in aircraft hydraulic, lube-oil, and fuel filters indicates that a sequence of steps should be followed in cleaning a service-contaminated filter element. The chart provided in Table 1 has been prepared as an aid for those working on specific filter cleaning problems. The chart should be interpreted as a suggested approach to the formulation of detailed cleaning procedures.

Table 1 - Filter element cleaning guide

Procedure Classification				Solvent Extraction				Dispersion												Chemical Conversion						
								Surfactant		Saponifiers		Alkaline Solutions						Electro Cleaning	Oxidation			Acid Solutions[4]				
Suggested Cleaning Agents				Gasoline (unleaded)	Methylene Choride	Methyl Ethyl Ketone	Petroleum Ether	Non-Ionic	Anionic	Alkali Metal Hydroxides	Ultrasonics	Sodium Hydroxide Solution (10-60%)	Alkaline Etching and Cleaning Compound for Aluminum	Heavy Duty Alkaline Cleaner	Alkaline Detergent	Alkaline Degreaser	Fused Sodium Hydroxide with 1.5-2% Sodium Hydride	Reverse Current procedure, cleaning solutions	Sodium Peroxide	Fused Magnesium Nitrous	Alkaline Potassium Permanganate Solution	Nitric Acid Solution 5%-7%	Mixtures of Citric, Oxalic and Tartaric Acids	Phosphoric Acid with 10% Chromic Acid	Inhibited Hydrochloric Acid Solution	Inhibited Hydrofluoric Acid Solution (40% Max)
Hazard Rating[1]				D	C	C, D	D	B, C	B, C	B		B	B	B	B	B	B	B	B, E	B, E	B, D	B, D	B	B, C	B, C	B, C
Maximum Agent Temp. (°F)				70	100	70	70	212	212	212		212	200	200	200	200	200	240	700	300	300	135	200	320	70	70
Ultrasonic Agitation				No	Yes	Yes	No	Yes	Yes	Yes		Yes	Yes	Yes	Yes	Yes	No	No	No	No	No	No	Yes	No	No	No
Other Useful Mechanical Augmentation[2]				A, B, C	A, C, D, E	A, B, C	B,D	A, B, C, D	A, B, C, D	A, B, C, D	D	B	B, D	B, D	B, D	B, D		B				B, C	A, B, C, D			
Commonly Encountered Contaminants	Fibers	Organic	Cellulose							3	Depends on cleaning agent used	3				1	1	1	1		1			1		
			Polymeric							2		4				4	1	1	1		1			1		
			Protein						3	2		1				1	1	1	1		1	3	3	1		
		Inorganic	Asbestos									4					1	1								1
			Glass									1					1	1								1
			Mineral Wool									1					1	1								1
			Metallic									4				4		1	4		4					
	Particulate Matter	Metallic Particles	Foreign					1	3			4				4		1	4		4	3	3	4		1
			Similar					1				4				4		1								
		Insoluble Metal Oxides						1	1			4				1	1	3	4		4	1	1		1	
		Siliceous Substances										1	2				1	2	1							1
		Inorganic Precipitates						2	1			4				1	1	1	2		4	1	1	4	2	4
		Silicon Carbide						2					2					1								
		Elastomers			3												1	2	1	1	1	2		1		
		Misc. Paint Production			2	3		1	3	2		4				1	1	2	1	1	1			1		
		Nylon - Mylar						2				2					1	2	1	1	1			1		
		Rulon						2									1	2	1	3	3			2		
		Epoxy						2								1	1	2	1	1	1			2		
		PTFE						2									1	2	1	3	3					
	Colloidal Agglomerations or Films	Insoluble Metal Oxides						2	1			4				1	1	2	4	4	4	1	1	4	1	1
		Fluid Decomposition Products	Gels	1	1	1				1		3			1		1	1	1	1	1			1		
			Gums	1	1	1		2		2		3			1		1	2	1	1	1			1		
			Varnish		3	1				1		3			1		1	2	1	1	1			1		
			Tars	1	1	2		2							1		1		1	1	1			1		
		Combustion Products	Hydrocarbons		2	2									1		1	2	1	1	1			3		
			Carbon									3			1	2	1	2	1	1	1			3		
			Oxides									4			1	4	1	2	4		4			1		1
		Biological	Proteins					2	3	1		1				1	1	1	1	1	1	2	3	1	3	1
			Cellulose					3		2		1				1	1									
Compatibility with Element Materials[3]	Aluminum			A	A	A	A	A	A	D		D	B	D	D	D	D	D	A	D	A	A	B	C	B	
	Stainless Steel			A	A	A	A	A	A	A		A	A	A	A	A	A	A	A	A	A	A	A	B	B	
	Carbon Steel			A	A	A	A	A	A	A		A	A	A	A	A	A	A	D	B	D	A	C	A	B	
	Brass and Silver Braze			A	A	A	A	A	A	B		B	B	A	A	B	B	D	D	B	C	A	A	B	B	
	Epoxy Resin			B	B, C	C, D	A	A	A	B		B	B	B	B	B	D	D	D	C	C	A	C	A	A	

1 Hazard Rating:
A. No special precautions necessary
B. Harmful to skin
C. High Toxicity
D. Highly Flammable
E. Explosion tendencies
Warning: Many of the above cleaning agents are known carcinogens. Consult the SDS on handling instructions before use.

2 Other Useful Mechanical Augmentation:
A. Brushing - Wiping
B. Intensive Agitation
C. Jet Nozzle
D. Reverse Flushing
E. Vapor Phase

3 Compatible with Element Materials:
A. Good
B. Minor Problem
C. Major Problem
D. Critical - Do not use

4 Important: Neutralization followed by thorough rinsing must be employed after all acid treatments

5.2 Chart Explanation

Along the left-hand margin of the chart are contaminants commonly encountered in fuel, hydraulic, pneumatic, and hot-gas filter elements, as well as filter element material used in construction.

Across the top of the chart are three fundamental steps which may be employed for the successful filter-element cleaning: solvent extraction, dispersion, and chemical conversion. These are listed from left to right, in order of increasing effectiveness. Preservation is shown as a post cleaning operation. The preservation, while not a cleaning treatment in itself, is a very important part of post-cleaning procedures.

Below each suggested cleaning agent, the maximum recommended operating temperatures, and methods of mechanical augmentation are given as well as the relative hazard involved in using each agent.

5.3 Use of the Chart

Formulate the cleaning procedure in the following steps:

5.3.1 Filter Materials and Contaminants

Ascertain the materials used in filter element construction within the limitation of local facilities. Although knowledge of the specific contaminant is not essential, it may be quite helpful in selecting the most efficient cleaning agent.

5.3.2 Compatibility of Cleaning Agents

Check the compatibility of cleaning agents by following horizontally along the appropriate filter element construction line and eliminating from further consideration such agents as “D" compatibility with materials involved. Likewise, mark as questionable those agents which are not compatible to some lesser degree with the filter element material.

5.3.3 Selecting an Agent

Select a cleaning agent from those not previously eliminated for each of the three basic cleaning steps. Acid solutions and oxidation should be avoided whenever possible, since there is danger of damaging even corrosion resistant filter element materials unless handling is precisely controlled. When stubborn cleaning problems are encountered, and the above treatments are selected they should be employed with extreme caution. The agents are arranged in each category with the most common and safest ones appearing to the left.

5.3.4 Minimum Acceptable Procedure

The next step is one of trial and error to establish the “minimum acceptable" cleaning procedure. Several service-contaminated filter elements should be subjected to the "solvent extraction” procedure. They should be inspected by a suitable control method described in Section 4 to determine their cleanliness level.

If an acceptable cleanliness level has not been achieved, experimentation with more effective mechanical augmentation may be required, e.g., a change from brushing to back-flushing, or back-flushing to ultrasonic scrubbing.

5.3.5 Dispersion and Chemical Conversion

When the strongest methods of solvent extraction have been attempted with unsatisfactory results, the user should consider dispersion. The simpler methods should be tried first, going to more elaborate steps as necessary. Mechanical augmentation should be included to improve cleaning. Similarly, chemical conversion procedures may be brought into use.

5.3.6 Review Hazards

Review the hazards involved with cleaning agents thus established and make compromises as necessary by selecting an agent further to the left for each step.

5.3.7 Effectiveness Check

In cases where specific types of contamination are known, the effectiveness of each cleaning agent should be checked. If none of the agents selected are effective on the contamination involved, try the next stronger agent.

5.3.8 Detailed Procedure

Detail the cleaning procedure thus established by listing the agent, maximum operating temperature and recommended mechanical augmentation for each step.

5.3.9 Minimum Acceptable Procedure

Determine the "minimum acceptable" cleaning procedure on a production basis, evaluate as outlined in ARP725, and adjust on the basis of this evaluation. Only after a thorough evaluation such as this should the procedure receive approval.

5.4 Limitations

The enclosed charts and information should be used with caution since the information presented is intended as a guide to prepare a systematic approach to the proper cleaning procedure. The effectiveness of suggested cleaning agents and their compatibility with various types of filter element materials have not been thoroughly tested.

5.5 Explanation of Codes Used in Cleaning Chart

5.5.1 Hazard Ratings

These are:

A. Nonflammable, nontoxic, harmful to skin only over a long exposure

B. Harmful to skin with short exposure, corrosive

C. Highly toxic, requires ventilation

D. Flammable, caution required

E. Explosion hazard

5.5.2 Mechanical Augmentation

These are:

A. Brush or wipe

B. Agitate intensely the filter element in agent or the agent around filter element

C. Direct agent onto filter element by jet stream

D. Reverse flushing, i.e., force agent through filter media in a flow path opposite to that followed by operating fluid with a fluid velocity greater than that seen in service (also see Appendix A.2.3)

E. Agents normally appearing in liquid stage should be used in the vapor phase (vapor degreaser)

5.5.3 Effectiveness of Cleaning Agents on Various Classes of Contamination

These are:

1. Re-agent is particularly useful for removing contamination.

2. It is mildly effective.

3. Preconditioned for further attack in later steps.

4. Effective on some, but not all contaminants in this group.

Blank indicates that this re-agent is normally not effective for removing this type of contamination.

5.5.4 Compatibility of Cleaning Agents with Filter Element Materials

Compatibility ratings are given at maximum recommended operating temperatures. As a general rule, chemical reaction rate can be reduced by decreasing the temperature; however, the effectiveness of the re-agent will also be reduced.

A. No harmful reaction at maximum recommended operating temperatures for an extended period of time.

B. Minor reactions at maximum recommended temperature, i.e., material will be slightly damaged by the agent when exposed to it for periods of time greater than 30 minutes. This re-agent could be used with the filter material for several cleanings.

C. Major reaction at maximum recommended temperature. Materials will be seriously damaged if exposed to agents for longer than 30 seconds. Exposure of the filter element to these cleaning agents for 1 or 2 seconds may be allowed a limited number of times.

D. Re-agent will cause serious damage to material with momentary exposure. The use of this combination should be avoided completely.

5.5.5 Ultrasonic Agitation

Ultrasonic energy, as a tool in the cleaning of filter elements, is especially useful and thus merits special attention. Ultrasonic cleaning is extremely effective in the seemingly simple task of bringing relatively uncontaminated liquid cleaning agent in contact with the contamination. Because of the intricate cavities which exist in the filter media, mechanical agitation or even the high forces produced by cavitation in the sonic bath may be required to dislodge contaminant particles which would otherwise be difficult or impossible to remove.

NOTE: High intensity ultrasonic energy levels can permanently damage some filter elements.

6. METHOD OF CONTROL

There are two basic types of controls which should be considered for cleaning filter elements.

These are process controls and product control. The methods discussed in this section are for use as inspection controls on production cleaned filter elements. They should not be confused with the referees control methods outlined in Section 5 which are recommended for the initial evaluation of cleaning procedures.

6.1 Process Control

ARP725 Section 7 requires process controls including various inspections which can be applied to the cleaning process to maintain a consistent level of effectiveness. Generally, for chemical cleaning agents, frequent checks on such properties as temperature, specific gravity, and the acidity (pH) should be maintained. Maintenance of these characteristics within predetermined limits by daily checks will help insure consistency.

Some proprietary cleaning agents, principally the alkaline ones, include buffers in the solution. The cleaning action does not result from alkalinity, rather, alkalinity is maintained merely to allow the principal cleaning factors to function. In these instances, there will be no pH difference in an active new solution from in an exhausted one. The supplier of the proprietary agent should be consulted to define proper control. ARP725 Section 7 may be referred to for detail control.

6.2 Product Controls

The cleaning procedure defines a process whereby a clean, undamaged filter element is required; therefore, maintenance of consistent quality levels through inspection is extremely important. Several methods of post cleaning inspection are suggested.

6.2.1 Gravimetric Method

In order to use this method, it is necessary for the filter element manufacturer to accurately weigh each filter element, in a "factory clean" condition, immediately prior to initial shipment. The exact weight is then permanently marked in a suitable location. When servicing the filter element in the field, the cleaned filter element weight is compared to the original weight indicated on the filter element. A relative degree of cleanliness is thus achieved.

6.2.1.1 Advantages of Gravimetric Method

This control method is most effective when the particulate contaminant has an appreciable density. In a case history where this method has been employed, the control filter element had a clean dry weight of approximately 1400 grams and a dirt-holding capacity, using controlled contamination of 14 grams, or about 1% of the total filter element weight.

Weighing accuracies both at the manufacturer and at the using services were maintained at 1/10 of 1%.

6.2.1.2 Disadvantages of Gravimetric Method

These are:

1. It is nonfunctional. Neither the number of open pores nor the opening size is determined; therefore, the serviceability desired is not represented by the test.

2. Some contaminants, such as PTFE, thermal oxidation products of the fluid, paint chips, and lint, have a high "pore-binding-to-weight ratio" and thus a relatively small weight of contaminant may cause considerable increase in filter element differential pressure. Gums, tars, and varnish, with very little mass, may cause considerable plugging and yet weigh very little.

3. Such contaminants can occur in any system, and therefore the gravimetric system alone cannot be relied upon as a single cleanliness inspection procedure.

4. In addition to the above disadvantage, it is impractical to apply this procedure to most of the filters now in the field. It would be necessary to return each filter element to the manufacturer to be cleaned, weighed, dirt-loaded to verify that it had been fully cleaned, and then re-cleaned. The cost of this procedure would, in many cases, exceed the replacement cost of a new filter element.

5. It loses accuracy rapidly as the ratio of filter element weight to weight of contamination capacity increases.

6. Very small filter elements may not have sufficient space for marking weight.

Another disadvantage which has been encountered in utilizing this method of control relates to poor cleaning procedure. Some cleaning procedures may be harmful to the filter element to the extent that a chemical reaction occurs with the filter element material and a subsequent loss of clean filter element weight results. Applying the control over the course of several cleaning cycles may result in service-contaminated filter elements which weigh less than the original clean filter element. The pore size rating of the filter elements is also changed as a result of such a cleaning procedure, because the clean filter element weight is reduced after each such cleaning; no real control on filter element cleanliness is achieved.

Similarly, filter element repairs may increase or decrease filter element weight. In such cases filter elements should be re-weighed and remarked after repair.

6.2.2 Flow Test

The degree of filter element cleanliness can be determined if the media contribution of the filter element differential pressure can be measured. The differential pressures should be measured near the media to eliminate housing and fitting losses.

Filter elements that have been cleaned should have a filter element differential pressure below the maximum filter element differential pressure and at or above the new/unused filter element differential pressure. If the cleaned filter element has a filter element differential pressure below that of the new/unused filter element, the filter may be damaged, and an additional investigation is recommended.

NOTE: Comparison testing between the cleaned filter element and a new/unused filter element must be completed at the same test conditions (i.e., Fluid Type, Viscosity, Flow Rate).

6.2.2.1 Advantages of Flow Test

These are:

1. Results indicate more directly than gravimetric or visual controls the percent of media area which has been cleaned.

2. Basic equipment required for this method of control is generally universally available.

3. When properly performed, this method is less susceptible to human error than either of the other two.

4. Go and no-go limits of acceptability may easily be established.

6.2.2.2 Disadvantages of Flow Test

These are:

1. The test fluid should be supplied in a very clean condition in order to prevent recontamination of the filter elements and to maintain consistency in test results.

2. Differences in test apparatus such as holding fixtures, pressure pickups, etc. can cause appreciable error in results achieved when air is used as the test fluid. A high degree of standardization in these areas is an absolute requirement in the successful utilization of this method of control.

3. The viscosity of fluids is affected by absolute temperature; thus, relatively constant test temperatures are required.

6.2.3 Visual Method of Control

This method consists of examining the media surface of a cleaned filter element for the presence of particulate matter, fibers, and film type contamination. With filter elements rated at 40 µm or larger this may be done with the naked eye; however, on finer rated filter elements, a microscope should be employed. A microscope is most valuable for detecting the presence of occasional fibers and transparent films.

6.2.3.1 Advantages of Visual Method

The principal advantage of this method is that no testing need be done by the filter manufacturer, as in the gravimetric and flow control methods.

6.2.3.2 Disadvantages of Visual Method

These are:

1. Skilled personnel are required to conduct checks. Correlation of the test results is required between inspection personnel at a given station as well as inspection personnel between stations using standard samples.

2. Large complex filter elements require a statistical analysis of the visual observations.

3. It is practically impossible to perform this method of control on cylindrical filter elements having an inside-out flow path or filter elements with convoluted or shielded media design.