R-61-01

Society of Automotive Engineers, Inc.
TWO PENNSYLVANIA PLAZA, NEW YORK, N.Y. 10001

AEROSPACE INFORMATION REPORT

AIR 787

FILTER-ELEMENT CLEANING METHODS

Issued 10-15-65
Revised

TABLE OF CONTENTS

1. INTRODUCTION

1.1 Scope - This Aerospace Information Report provides technical information to assist the development of specific cleaning methods for filter elements. Consideration is limited to filter elements which are designated as "cleanable" (not "disposable"), but which cannot be cleaned by simple and obvious procedures. Cleaning methods developed according to this report should be evaluated by the methods of ARP 725 and ARP 849.

Satisfactory cleaning methods can be developed for most "cleanable" filter elements. Technical or economic feasibility of the cleaning method may be limited, however, by incompatibility of filter-element construction materials, by mechanical weakness or lack of corrosion resistance to withstand repeated or continued cleaning, or by the presence of unusually tenacious contamination. These factors must be considered when selecting approaches to the development of specific methods.

1.2 Objectives - The purpose of this report is to provide 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.

1.2.1 Economic Requirements - The primary reason for cleaning filters is to eliminate the cost of replacement. Additional considerations include the reduction of logistic problems in stocking new replacement filters and the conservation of strategic materials and skills in the event of a national emergency. Considering all of these factors, the total cost of cleaning must 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.

1.2.2 Technical Requirements - 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 must be considered. Cleaning processes should be selected which will be effective on most "cleanable" filters under usual circumstances. Test methods must detect inadequately cleaned or damaged filters.

1.3 General - 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 must 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.

1.3.1 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 a knowledge of cleaning process mechanisms, filter material and geometry characteristics, and contamination composition. Cleaning methods will be restricted by considerations such as cost and safety of the process. Cleaning limitations also dictate filter construction design and contamination specification limits.

1.3.1.1 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.

1.3.1.2 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 must include the requirement of responding to and withstanding the proposed cleaning procedure. Filter data is available from the manufacturers.

1.3.1.3 Contamination - Although a 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 must only produce a result which is functionally and economically acceptable.

1.3.2 Testing - Test methods for determining the effects of a cleaning process must 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 must be functionally satisfactory, three major test areas are implied: dirt holding capacity, residual contamination, and physical or chemical damage. Test methods must be economically feasible as well as technically sound.

1.3.2.1 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 useful only for information purposes, nonsimulative tests must be used.

1.3.2.2 Residual Contamination - The cleaned filter must not contain residues which are detrimental to the filter or the system in which it will be installed. Tests must be employed to detect harmful residues.

1.3.2.3 Filter Damage - The cleaning process selected must not significantly damage 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.

1.3.3 Summary - Filter-element cleaning methods must 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 must be assumed by the user.

2. ELEMENT MATERIALS, CONTAMINANTS, THEORY AND CURRENT PRACTICES OF CLEANING

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

2.2 Element Materials - Classes of elements for which cleaning methods must be developed are established herein. The elements are classified by materials of construction to allow the determination of compatibility with the cleaning methods.

2.2.1 Elements Excluded - A study of the elements being produced has led to the classification covered in paragraph 2.2.2. Any elements which do not fall into these classes shall be handled as special cases.

There will be many 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. 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 nonavailability of replacement elements.

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

2.2.2 Cleanable Elements - The following listing covers 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.

2.2.2.1 Complete Stainless Steel Construction - The 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.

2.2.2.2 Stainless Steel and Brazing Alloys - The element media and support structure are stainless steel. The element components are joined together with either a silver or copper brazing material.

2.2.2.3 Stainless Steel and Epoxy - The element media and support structure are stainless steel. Epoxy is used as an element repair or bonding material.

2.2.2.4 Stainless Steel, Aluminum, and Epoxy - Stainless steel is used as the element media, aluminum for the supporting structure, and epoxy to join the components.

2.2.2.5 Copper-Based Alloys - All components of the element are made of a copper-based alloy.

2.2.2.6 Copper-Based Alloys and Epoxy - All components of the element are made of a copper-based alloy, and epoxy is used as a bonding agent.

2.2.2.7 Multiple Materials - Many elements are made with carbon steel plated with cadmium in conjunction with both aluminum and stainless steel.

2.3 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 element materials. Stains on the 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 must 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.

2.3.1 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 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.

2.3.1.1 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.

2.3.1.2 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.

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

2.3.1.4 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.

2.3.2 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.

2.3.2.1 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.

2.3.2.2 Fibers - There are two general categories of fibers: organic and inorganic. Typical organic fibers include cellulose, polymeric, protein (cotton, dacron, wool, hair, paper). 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.

2.3.2.3 Polymers and Resins - Teflon, paint, elastomers, nylon, Mylar, Rulon, 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.

2.3.2.4 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.

2.3.2.5 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.

2.3.2.6 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.

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

2.3.2.8 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.

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

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

2.3.2.11 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.

2.3.2.12 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 2.3.2.11.

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

2.4 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 must attack the contaminant but not the filter. Frequently, it is necessary to make a detailed analysis of both the materials used in the filter (ref. 2.2 et seq) and the nature of the contaminant (ref. 2.3 et seq) 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 3 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 (ref. AIR 844*). Use of water containing cleaning agents may cause metallurgically unsound wire 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.

2.4.1 Cleaning Processes - The general groups of cleaning processes to be discussed are physical processes and chemical processes and a special category for ultrasonic cleaning.

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*This document is currently in preparation. Publication is expected in or before the spring of 1966.

2.4.2 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.

2.4.2.1 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 trichloroethylene, parchloroethylene, alcohol, benzene, petroleum ether or methylethylketone (MEK). These solvents are generally used to remove oils, waxes, greases or other organic materials.

2.4.2.2 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 must first be wetted. Some wetting agent is either included in the cleaning compound or must be added separately. In aqueous (water-base) cleaning, a detergent is generally used for this purpose.

2.4.2.2.1 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.

2.4.2.2.2 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 must first occur.

2.4.2.3 Mechanical Action - Brushing, wiping, air blasting and vibration are 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.

2.4.2.4 Heat Action - In itself, heat is seldom used as a cleaning device. 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.

2.4.2.5 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.

2.4.3 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.

2.4.3.1 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 must be by solvent action or emulsification.

2.4.3.2 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 must 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 than the original contaminant. Previous sensitization of the extremely fine wires used in many filter media is another hazard which must be considered; this sensitization may result in failure by intergranular corrosion.

2.4.3.3 Oxidation - Reduction (Redox) Reactions - These reactions occur because of the transfer of electrons from one substance to another. These reactions may be either oxiding 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.

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

2.4.3.4 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.

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

2.4.3.4.2 Nonaqueous Solvents and Vapors - While not yet widely used, nonaqueous solvents such as anhydrous ammonia and 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.

2.4.4 Ultrasonic Cleaning - While ultrasonic cleaning is generally used in conjunction with a solvent or chemical cleaner, the importance of ultrasonic energy in cleaning filter elements merits special discussion. Unfortunately, a great deal of controversy exists at the present time as to what frequency, power level and technique are most effective in cleaning filters. Ultrasonic equipment is available with frequencies ranging from above 400 KC (Piezoelectric transducers) to 10 KC (magnetostrictive transducers). Much of the disagreement centers upon what power levels are required, the major difficulty appearing to be that no simple, repeatable method of measuring actual cavitation energy in the cleaning solution has been devised. Until such a measuring device is available and tests are conducted on actual filter elements, no good answer will be available as to which type of equipment is optimum. An example of the degree of controversy is suggested by the fact that one company proposes measuring the rate of temperature rise of the fluid as a direct measure of power level, while another contends that the more rapidly the fluid heats, the less efficient the cleaner, since (they maintain) heating of the fluid is a direct result of coupling inefficiency. Regardless of the many claims, it is safe to say that ultrasonic energy is a good way to clean filter elements if used in conjunction with effective cleaning solutions. Further testing may evolve simpler and cheaper methods, but the present state of the art indicates that an ultrasonic unit is a useful tool in the cleaning of filter elements.

2.5 Packaging Considerations - Once the filter element is cleaned and inspected, it must be packaged to protect it against both corrosion and contamination. If the element is to be immediately installed in its housing, no particular precautions need be taken; the assembly should merely be flushed and filled with precleaned preservative fluid. However, if the 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 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.

3. FILTER ELEMENT CLEANING METHODS

3.1 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 element. The Filter-Element Cleaning Guide (page 11) 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.

3.2 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 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.

3.3 Use of the Chart - Formulate the cleaning procedure in the following steps:

3.3.1 Filter Materials and Contaminants - Ascertain the materials used in 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.

3.3.2 Compatibility of Cleaning Agents - Check the compatibility of cleaning agents by following horizontally along the appropriate 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 element material.

3.3.3 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 resistent 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.

PROCEDURE CLASSIFICATION	SOLVENT EXTRACTION							SURFAC
SUGGESTED CLEANING AGENTS	Freon TF	Trichloroethylene	Gasoline (unleaded)	Methylene Chloride	Methyl Ethyl Ketone (MEK)	Toluene, Xylene, Etc.	Petroleum Ether	Non-Ionic
HAZARD RATING	A	C	D	C	D	D	D	A
MAXIMUM AGENT TEMPERATURE (F)	100	188	70	100	70	70	70	212
ULTRASONIC AGITATION RECOMMENDED	Yes	Yes	No	Yes	Yes	Yes	No	Yes
OTHER USEFUL MECHANICAL AUGMENTATION	C D E	A C D E	A B C	A C E D	A B C	A B C	B D	A,B C,D
COMMONLY ENCOUNTERED CONTAMINANTS — FIBERS — ORGANIC — Cellulose								
COMMONLY ENCOUNTERED CONTAMINANTS — FIBERS — ORGANIC — Polymeric								
COMMONLY ENCOUNTERED CONTAMINANTS — FIBERS — ORGANIC — Protein								
COMMONLY ENCOUNTERED CONTAMINANTS — FIBERS — INORGANIC — Asbestos	Particularly suitable in ultrasonic equipment for oil, grease and otherwise insoluble soils.							
COMMONLY ENCOUNTERED CONTAMINANTS — FIBERS — INORGANIC — Glass								
COMMONLY ENCOUNTERED CONTAMINANTS — FIBERS — INORGANIC — Mineral Wool								
COMMONLY ENCOUNTERED CONTAMINANTS — FIBERS — INORGANIC — Metallic								
PARTICULATE MATTER — METALLIC PARTICLES — Foreign								1
PARTICULATE MATTER — METALLIC PARTICLES — Similar								1
PARTICULATE MATTER — Insol. Met. Oxides								1
PARTICULATE MATTER — Siliceous Substances								
PARTICULATE MATTER — Inorganic Precipitates								2
PARTICULATE MATTER — Silicon Carbide								2
PARTICULATE MATTER — Elastomers		3		3				
PARTICULATE MATTER — Misc. Paint Prod.		2		2	2			1
PARTICULATE MATTER — Nylon – Mylar								2
PARTICULATE MATTER — Rulon								2
PARTICULATE MATTER — Epoxy								2
PARTICULATE MATTER — Teflon								2
COLLOIDAL AGGLOMERATIONS OR FILMS — Insol. Met. Hydroxides								2
COLLOIDAL AGGLOMERATIONS OR FILMS — FLUID DECOMPOSITION PRODUCTS — Gels		1	1	1	1	1		
COLLOIDAL AGGLOMERATIONS OR FILMS — FLUID DECOMPOSITION PRODUCTS — Gums		1	1	1	1	1		2
COLLOIDAL AGGLOMERATIONS OR FILMS — FLUID DECOMPOSITION PRODUCTS — Varnish		2		2	1	1		
COLLOIDAL AGGLOMERATIONS OR FILMS — FLUID DECOMPOSITION PRODUCTS — Tars		1	1	1	2	1		2
COLLOIDAL AGGLOMERATIONS OR FILMS — COMBUSTION PRODUCTS — Hydrocarbons		2		2	2	2		
COLLOIDAL AGGLOMERATIONS OR FILMS — COMBUSTION PRODUCTS — Carbon								
COLLOIDAL AGGLOMERATIONS OR FILMS — COMBUSTION PRODUCTS — Oxides								
COLLOIDAL AGGLOMERATIONS OR FILMS — BIOLOG. GROWTHS — Proteinaceous								3
COLLOIDAL AGGLOMERATIONS OR FILMS — BIOLOG. GROWTHS — Cellulostic								3
COMPATABILITY WITH ELEMENT MATERIALS — Aluminum	A	A	A	A	A	A	A	A
COMPATABILITY WITH ELEMENT MATERIALS — Stainless Steel	A	A	A	A	A	A	A	A
COMPATABILITY WITH ELEMENT MATERIALS — Carbon Steel	A	A	A	A	A	A	A	A
COMPATABILITY WITH ELEMENT MATERIALS — Brass and Silver Braze	A	A	A	A	A	A	A	A
COMPATABILITY WITH ELEMENT MATERIALS — Epoxy Resin	A	B	B	B,C	C	B	A	A

FILTER-ELEMENT CLEANING GUIDE

DISPERSION										CHEMICAL CON		
TANTS	SAPONIFIERS	ULTRASONICS	ALKALINE SOLUTIONS						ELECTRO CLEANING	OXIDATIO		
Anionic - Such as Alkyl aryl sulfonate	Alkanolamines, Alkali metal hydroxides		Sodium Hydroxide Solution (10-50%)	Alkaline Derusters	Alkaline Etching and Cleaning Compound for Aluminum	Heavy Duty Alkaline Cleaner	Alkaline Detergent	Fused Sodium Hydroxide with 1-1/2-2% Sodium Hydride	Reverse current procedure cleaning solutions	Ignition	Sodium Peroxide, etc.	Fused Magnesium
A	B		B	B	A	A	A	B	B	C, D	E	E
212	212		212	200+	200	200	200	700	240		700	300
Yes	Yes	-	Yes	Yes	Yes	Yes	Yes	No	No	No	No	No
A, B C, D	A, B C, D	D	B	B D	B D	B D	B D		B			
	3	DEPENDS ON CLEANING AGENT USED	3	1				1	1	1	1	1
	3		4	4				1	1	1	1	1
	2		1	1				1	1	1	1	1
			4					1	1			
			1					1	1			
			1					1	1			
			4	4					1		4	
			4	4					1		4	
			4	4					1			
			4	1				1	2		4	
			1		2			1	2		1	
			4	1				1	1		2	
					2				1			
(cond)								1	2	1	1	1
	2		4	1				1	2	1	1	1
			2					1	2	1	1	1
								1	2	1	1	2
				1				1	2	1	1	1
								1	2	1	1	2
			4	1				1	2		4	4
	1		3				1	1	1	1	1	1
	2		3				1	1	2	1	1	1
	1		3				1	1	2	1	1	1
							1	1		1	1	1
							1	1	2	1, 3	1	1
			3	2			1	4	2	4	1	1
			4	4			1	1	2		4	
	1		1	1				1	1	1	1	1
	3		1	1				1				
	D		D	D	B	D	D	D	D	D	D	A
	A		A	A	A	A	A	A	A	B	A	A
	A		A	A	A	A	A	A	A	A	A	D
	B		B	B	B	A	A	B	B	C	D	D
	B		B	B	B	B	B	D	D	D	D	D

VERSION								PRESERVATION	
N		ACID SOLUTIONS						PHYSICAL	
Nitrate	Alkaline Potassium Permanganate Solutions	Nitric Acid Solution (5–70%)	Mixtures of Citric Oxalic and Tartaric Acids	Phosphoric Acid (conc.) with 10% Chromic Acid	Inhibited Hydrochloric Acid Solution	Solfuric Acid (conc.)	Inhibited Hydrofluoric Acid Solution (40% max.)	Organic (Preservative Oils)	MIL-P-116-B
	B	B	A	C	B, C	B	B, C		
	200	135	200	220	70	70	70		
	No	No	Yes	No	No	No	No		
		B C	A, B C, D	B C D	B	B C	B C		
	1			1		1			
	1			1		1			
	1	2	2	1		1			
							1		
							1		
		2					1		
	4								
	4	1	2	4		4	1		
	4	1	1		1				
							1		
	4	2	1	4	2	4	4		
	1			1		1			
	1		2	1		1			
	1			1		1			
	2			2		2			
	1			2		2			
	3								
	4	1	1	4	1	4	1		
	1			1		1			
	1			1		1			
	1			1		1			
	1			1		1			
	1			2		2			
	1			2		2			
	4			1		1	1		
	1	2	2	1	2	1	1		
	D	A	A	B	C	A	B		
	A	A	A	A	B	B	B		
	B	D	A	C	A	B	B		
	B	C	A	A	B	A	B		
	C	C	A	C	A	B	A		

IMPORTANT: Neutralization followed by thorough rinsing must be employed after all acid treatment.

ABBREVIATED CODE KEY
(See Para. 7.4)

HAZARD RATING
A. No special precautions necessary.
B. Harmful to skin
C. High toxicity
D. Highly flammable
E. Explosive tendencies

MECHANICAL AUGMENTATION
A. Brushing-wiping
B. Intense agitation
C. Jet nozzle
D. Reverse flushing
E. Vapor phase

EFFECT ON CONTAMINATION
1. Good
2. Fair
3. Preconditions
4. Variable

COMPATIBILITY WITH ELEMENT MATERIALS
A. Good
B. Minor problem
C. Major problem
D. Critical - do not use
E. Stains

3.3.4 Minimum Acceptable Procedure - The next step is one of trial and error to establish the "minimum acceptable" cleaning procedure. Several service-contaminated elements should be subjected to the "solvent extraction" rough 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.

3.3.5 Dispersion and Chemical Conversion - When the strongest methods of solvent extraction have been attempted with unsatisfactory results, the next step is dispersion. The simpler ones 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.

3.3.6 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.

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

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

3.3.9 Minimum Acceptable Procedure - Determine the "minimum acceptable" cleaning procedure on a production basis, evaluate as outlined in ARP 725, and adjust on the basis of this evaluation. Only after a thorough evaluation such as this, should the procedure receive approval.

3.4 Limitations - The enclosed chart 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 element materials have not been thoroughly tested.

3.5 Explanation of Codes Used in Cleaning Chart

3.5.1 Hazard Ratings

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.

3.5.2 Mechanical Augmentation

a. Brush or wipe.

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

c. Direct agent onto 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.

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

3.5.3 Effectiveness of Cleaning Agents on Various Classes of Contamination

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

b. It is mildly effective.

c. Preconditioned for further attack in later steps.

d. 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.

3.5.4 Compatibility of Cleaning Agents With Element Materials

a. No harmful reaction at maximum recommended operating temperatures for 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 element to these cleaning agents for one or two 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.

e. Use of this re-agent will result in staining of the material only, but causes no physical damage. Stains are usually removable in subsequent steps.

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

3.5.5 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.

4. 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 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.

4.1 Process Control - ARP 725, Section 7, requires process controls including various inspections which can be applied to the cleaning process to maintain a consistent level of effectiveness. Generally speaking, for chemical cleaning agents, frequent checks on such properties as temperature, specific gravity, and 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. ARP 725, Section 7, may be referred to for detail control.

4.2 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.

4.2.1 Gravimetric Method - In order to use this method, it is necessary for the 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 element in the field, the cleaned element weight is compared to the original weight indicated on the element. A relative degree of cleanliness is thus achieved.

4.2.1.1 Advantages - 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 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 element weight. Weighing accuracies both at the manufacturer and at the using services were maintained at 1/10 of 1% which means that element weights might vary $\pm$ 10% from actual dirt holding capacity.

4.2.1.2 Disadvantages - The principal disadvantages of the gravimetric method of control is that 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.

Some contaminants, such as teflon or aluminum flakes, paint chips, and lint, have a high "pore-binding-to-weight ratio" and thus a relatively small weight of contaminant may cause considerable pressure drop in the element. Gums, tars, and varnish, with very little mass, may cause considerable plugging and yet weigh very little.

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

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 element to the manufacturer to be cleaned, weighed, dirt-loaded to verify that it had been fully cleaned, and then recleaned. The cost of this procedure would, in many cases, exceed the replacement cost of a new element.

A further drawback of the gravimetric procedure is that it loses accuracy rapidly as the ratio of element weight to weight of contamination capacity increases. This ratio also increases when extra equipment such as bypass valves, indicators, special mounting flanges and the like are added to the basic element.

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 element to the extent that a chemical reaction occurs with the element material and a subsequent loss of clean element weight results. Applying the control over the course of several cleaning cycles may result in service-contaminated elements which weigh less than the original clean element. The micron rating of the elements is also changed as a result of such a cleaning procedure, because the clean element weight is reduced after each such cleaning; no real control on element cleanliness is achieved.

Similarly, element repairs may increase or decrease element weight. In such cases elements must be reweighed and remarked after repair.

Very small filters may not have sufficient space for marking weight.

4.2.2 Flow Test - It is generally agreed that a check of pressure drop across a filter assembly using service fluid at rated flow is ineffective in determining the degree of element cleanliness. This is true because, in most well designed filters, the flow resistance of clean media is relatively small compared to that of the housing and associated fittings. However, when the flow characteristics of the media itself can be checked a more accurate, repeatable determination of element cleanliness can be made.

In a test configuration which eliminates housing pressure drops due to the resistance of fluid flow in passages leading to and from the media an acceptable test can be accomplished. By using properly designed pressure probes near the media a usable method appears feasible. The disadvantages noted are concerned more with the inherent practical problems of method than of the general approach.

To apply the control, each size element must have been tested by the manufacturer in a "factory clean" condition and permanently marked with maximum allowable pressure drop value, included as the maximum allowable pressure drop in the overhaul handbook or cleaning instruction.

Cleaning facility personnel would then repeat the test after conducting the cleaning procedures and compare results with those achieved by the manufacturer. Any convenient test fluid ranging from air to heavy oils may be employed, provided identical fluid flow conditions and pressure probes are used by both the manufacturer and the cleaning facility. Different fluids or flow rates can be employed by different facilities on the same element with correction factors applied. This practice is not recommended.

4.2.3 Advantages

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

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

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

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

4.2.4 Disadvantages

a. Test fluid must be supplied in a very clean condition in order to prevent recontamination of the elements and to maintain consistency in test results.

b. 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 "must" in the successful utilization of this method of control.

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

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

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

4.2.7 Disadvantages -

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