PUBLIC WORKS TECHNICAL BULLETIN 200-1-03
31 AUGUST 1999

SOLVENT MINIMIZATION AND SUBSTITUTION GUIDELINES

Public Works Technical Bulletins are published by the U.S. Army Corps of Engineers, Washington, DC. They are intended to provide information on specific topics in areas of Facilities Engineering and Public Works. They are not intended to establish new DA policy.

DEPARTMENT OF THE ARMY
U.S. Army Corps of Engineers
441 G Street, NW
Washington, DC 20315-1000

Public Works Technical Bulletin 31 August 1999
No. 200-01-03

SOLVENT MINIMIZATION AND SUBSTITUTION GUIDELINES

1. Purpose. This Public Works Technical Bulletin (PWTB) provides information on: substituting terpenes, aqueous cleaners, or less hazardous solvents to reduce health and disposal hazards; minimizing solvent use; and increasing the feasibility of solvent reclamation and recycling. Specific information is included in Annex A.

2. Applicability. This PWTB applies to all U.S. Army Public Works activities and facilities having metal cleaning activities.

3. References.

a. Public Law 99-499, Emergency Planning and Community Right-to-Know Act (EPCRA) of 1986.

b. AR 200-1, Environmental Protection and Enhancement, 21 February 1997.

c. See additional references listed in Annex B.

4. Discussion.

a. The EPCRA was enacted to provide the public with information on toxic and hazardous chemicals processed by industrial facilities in their communities. EPCRA requires the creation of emergency planning and notification requirements to protect the public in the event of releases of extremely hazardous substances. Section 313 of EPCRA, the Toxic Release Inventory (TRI) was expanded under the Pollution Prevention Act of 1990. Presidential Executive Order (EO) 12856, Federal Compliance with Right-to-Know Law and Pollution Prevention Requirements(58 FR 41981), was issued on 3 August 1993 and directs all Federal facilities to comply with reporting requirements.

b. The primary goal of the EO 12856 is to "reduce ... total releases of toxic chemicals to the environment and off-site transfers of such toxic chemicals for treatment and disposal by 31 December 1999. To the maximum extent practical, such reductions shall be achieved by implementation of source reduction practices." This Order reinforces long standing DOD policy, which is: (1) to limit the generation of hazardous waste; and (2) to reuse, reclaim, or recycle resources where practical.

c. Numerous solvents, including many used in metal cleaning, have been listed by the U.S. Environmental Protection Agency (USEPA) as hazardous wastes and may be reportable under EO12856 and EPCRA, Section 313. Federal facilities that exceed the manufacturing, processing, or otherwise use-activity thresholds are required to submit TRI reports. Thresholds are set at 25,000 lb for manufacturing and processing activities and 10,000 lb for "otherwise use" activities. Thresholds are chemical specific and do not apply to the aggregate of all chemicals manufactured or used at a facility.

d. On 2 December 1994, Final Rule 59 FR 61801 was issued to control air emissions from cleaning machines using halogenated solvents. Controls must be in place no later than 2 December 1997.

e. On February 13, 1996, the ASA (IL&E) signed a policy memo on "Ozone-Depleting Chemicals (ODC) Elimination at Army Installations." This memo emphasizes the need to rid all Army installations of their dependency on Class I ODCs and establishes the requirement for Army facilities to be ODC-free by the end of FY03.

5. Points of Contact. Questions and/or comments regarding this subject that cannot be resolved at the installation level should be directed to the U.S. Army Corps of Engineers, ATTN: CEMP-RI, 441 G Street, NW, Washington, DC 20314-1000; or the U.S. Army Engineer Research and Development Center, Construction Engineering Research Laboratory, at 1(800) USA-CERL, for Mr. Gary Gerdes (e-mail: g-gerdes@cecer.army.mil).

FOR THE COMMANDER:

/S/
FRANK J. SCHMID, P.E.
Chief, Installation Support Policy Branch

APPENDIX A
SOLVENT MINIMIZATION AND SUBSTITUTION GUIDELINES

1. Background

a. To comply with DOD policies regarding hazardous wastes, it is necessary to: (1) minimize use of those solvents that create hazardous wastes; and (2) when they must be used, to minimize the release of those solvents through good management practices and by reclaiming or recycling used solvents. Although Environmental regulations and health considerations encourage the substitutions of less toxic cleaning agents, substitution might not be possible since the cleaning solvents are application-specific. However, consolidating use to a few different solvents will increase the efficiency of reclamation or recycling.

b. Annex A lists some generally recognized solvent-to-solvent substitutes (refer to Annexes E through G for full discussion). However, where specific requirements must be met, substitution may not be possible. Actual testing may be required to determine whether a substitute for a particular solvent will be acceptable. In this case, the “Standard Protocol for Selecting General Cleaning Agents and Processes” developed by the Army Acquisition Pollution Prevention Support Office, an Army Materiel Command Organization, suggests a five step approach for selecting general parts cleaning products and processes: (1) determine the parameters of the cleaning activity (reason for cleaning and material of the component being cleaned); (2) determine requirements of the cleaner (level of cleanliness to be achieved and materials compatibility evaluation); (3) Select an appropriate cleaner that meets the requirements defined in step 2**;** (4) consider physical and chemical properties of the cleaning agent that are important to the facility or shop; (5) select appropriate cleaning equipment for application and cleaner.

(1) Substitute aqueous cleaning for vapor degreasing. Water-based cleaning methods usually use alkaline based cleaners to displace soils rather than organic solvents to dissolve them. Mechanical agitation or ultrasonic vibration is often used to enhance cleaning. Steam or high pressure hot water also may be used. Aqueous cleaning processes do not produce solvent wastes and the wastewater can go through the wastewater treatment plant. However, the wastewater will contain free and emulsified grease, oil, and other soil particles and normally requires pretreatment before discharge to standard wastewater treatment. Aqueous cleaning with alkaline compounds can be used for many metal cleaning operations, based on general cost comparisons, relative ability to meet production volume requirements, and product quality considerations (R. Rehm, et al.) Numerous studies sponsored by both private and government organizations have shown that aqueous cleaning machines can successfully replace vapor degreasing.

(2) Terpene cleaners. Terpene cleaners have been marketed as an environmentally safe alternative to solvent cleaning. However, due to the numerous disadvantages of this type of cleaning agent, terpene cleaners may not be the best choice for metal parts cleaning at Army installations.

(3) Solvent substitution in cold cleaning. See Annexes E and G.

(4) PD-680, Type II (Stoddard solvent) should be used instead of toluene and xylene to remove oil and grease where solvent residue on the cleaned surface is acceptable. Although

Stoddard solvent is a concern due to it's high VOC content (790 g/l), compared to toluene and xylene, Stoddard solvent is less volatile, less flammable at room temperature (minimum flashpoint 138 F), and considerably less expensive. There are also more commercial facilities for reclaiming Stoddard solvent. Stoddard solvent is suitable for almost all parts cleaning in vehicle maintenance facilities. Except for certain specialized uses, such as carbon removal, Stoddard solvent is preferable to halogenated solvents for cold cleaning because it is less volatile, less costly, and generally less toxic. Use of some chlorofluorocarbons that were used for special uses has been curtailed since the production of those chemicals has been prohibited because of suspected ozone depletion.

(5) Existing and pending laws and regulations contain special restrictions on the use of MEK (e.g., the aerospace NESHAP). In this case, acetone may be used instead of methyl ethyl ketone (MEK) whenever possible. Acetone is considerably less toxic than MEK and about one third as costly as MEK, according to the NAVAIRDEVCEN report. However, acetone has a lower flashpoint than MEK.

(a) There are many possible substitutes for hazardous solvents. But before you make your decision, refer to the "Process Conversion Checklist" in Annex H. It is designed to help you examine your processes and facilities to make sure a proposed new cleaning process does not cause unanticipated problems.

(b) Cleaning Army equipment may require mild detergent or, in some cases, an aggressive solvent with multiple process steps. The "Army Standard Protocol for Selecting Cleaning Agents and Processes" provides a standardized approach by establishing minimum testing requirements that must be met by all replacement or alternative cleaning products. The Protocol can be found in Annex I.

(c) In many cases product substitution is a viable alternative to substituting one hazardous chemical for another. Following is a sample of resources available:

(6) The USEPAs Significant New Alternatives Policy (SNAP) Program. Established under Section 612 of the Clean Air Act, the SNAP mandate is to identify alternatives to ozone-depleting substances and to publish lists of acceptable and unacceptable substitutes. The internet site address for SNAP is: http://www.epa.gov/ozone/title6/snap. You can also phone the EPAs Ozone Protection Hotline at (800) 296-1996.

(7) The Joint Service Pollution Prevention Technical Library is a consolidated document that contains copies of the following documents: (1) links to pollution prevention sites on the world wide web, (2) Tri-Service Pollution prevention Opportunity Handbook, (3) Pollution [prevention Equipment Book, and (4) Defense Logistics Agency (DLA) Environmental Products Category. The purpose of the Tri-Service Pollution Prevention Opportunity Handbook is to identify available "off-the-shelf" pollution prevention technologies, management practices, and to process changes that will reduce the amount of hazardous waste and solid waste being generated at DoD facilities. Copies of the library on Enviroene at: http://es.epa/gov/index.html.

(a) Although not a resource for solvent substitution, the USEPAs SARA Title III List of Lists may be a valuable reference. The list of lists file includes chemicals listed under CERCLA, SARA Title III (EPCRA), and section 112, Title III, Clean Air Act Amendments of 1990. Access via internet: http://www.afcee.brooks.af.mil/p2cd/handlplan/other/012.htm.

(b) Annex A lists solvent-to-solvent substitutions.

(c) Annex B lists solvents pre-determined by the USEPA to create hazardous wastes.

(d) Annex C lists the advantages and disadvantages of two major degreasing solvents (perchloroethylene and methyl chloride.

(e) Annex D gives operational procedures that reduce solvent losses from vapor degreasers.

(f) Annex E discusses solvents commonly used in cold cleaning.

(g) Annex F discusses the advantages and disadvantages of aqueous cleaning.

(h) Annex G discusses terpene cleaners.

(i) Annex H shows an example Process Conversion Checklist by BLR Inc., used with permission.

(j) Annex I is a standard protocol for selecting general cleaning agents and processes.

f. Minimization of hazardous solvent use. Minimize the use of solvents that produce hazardous wastes, as determined by the USEPA.

(a) Solvent minimization in vapor degreasing. Several steps can be taken to reduce solvent losses from vapor degreasing. See Annex D for full discussion.

(b) Solvent minimization in cold cleaning. Solvent should be used as long as it cleans effectively. It should not be discarded when it is merely discolored but still cleans. When necessary, a final rinse in a separate container of cleaner solvent will reduce the frequency of solvent changes in the primary solvent bath.

(c) Separation of waste solvents. To the greatest extent possible, waste solvents should be separated and stored according to their types – to ease reclamation or to minimize disposal costs. Used solvents should not be disposed in waste oil.

4. Conclusion. The use of the most hazardous solvents can be minimized. Aqueous cleaners can almost always replace vapor degreasing and cold cleaning solvents. When aqueous cleaners are not applicable, less toxic and less flammable solvents can often be substituted. In addition, there are various resources for selecting appropriate products substitutions, further minimizing hazardous waste. With planning, solvent wastes can be reclaimed and recycled.

ANNEX A to APPENDIX A
Solvent-to-Solvent Substitutions*

Table A1

Solvent-to-Solvent Substitutions

Solvent	To Be Replaced By	Comments
Methanol**	Isopropanol**	Methanol is a highly toxic compound
Methyl Ethyl Ketone (MEK)**	Acetone**	
	Ethyl Acetate**	
	Aliphatic Naphtha	
Toluene**	Stoddard solvent	
	Varsol	
	Acetone**	
	(Dichloromethane)**	
Xylene**	Stoddard solvent	
	Varsol	
*Adapted from: B.A. Donahue and M. B. Carmer, Solvent "Cradle-to-Grave" Management Guidelines for Use at Army Installations, Technical Report N-168/ADA137063 (U.S. Army Construction Engineering Research Laboratory, November 1983)		
May be reportable under EPCRA, Section 313, TRI **IF a facility exceeds the 25,000 lb manufacturing and processing or 10,000 lb otherwise use thresholds.		
NOTE: **IF** TRI chemicals are released at greater than their respective activity thresholds, they may still be exempt from reporting under the following exemptions: (1) structural component of a facility, (2) routine janitorial and facility grounds maintenance, (3) motor vehicle maintenance, (4) employee personal use, (5) intake water and air, and (6) laboratory activity under direction of a technically qualified individual.		

ANNEX B to APPENDIX A
Solvents Pre-Determined by USEPA To Create Hazardous Wastes

1. F001 - The following spent halogenated solvents used in degreasing: Tetrachloroethylene, trichloroethylene, methylene chloride, 1,1,1-trichloroethane, carbon tetrachloride, and chlorinated fluorocarbons.

2. F002 - The following spent halogenated solvents: Tetrachloroethylene, methylene chloride, trichloroethylene, 1,1,1-trichloroethane, chlorobenzene; 1,1,2-trichloro; 1,2,2-trifluoroethane, ortho-dicholorobenzene, and trichlorofluoromethane.

3. F003 - The following spent non-halogenated solvents: xylene, acetone, ethyl acetate, ethyl benzene, ethyl ether, methylisobutyl ketone, n-butyl alcohol, cyclohexanone, and methanol.

4. F004 - The following spent non-halogenated solvents: cresols and cresylic acid, and nitrobenzene.

5. F005 - The following spent non-halogenated solvents: toluene, methyl ethyl ketone, carbon disulfide, isobutanol, and pyridine.

ANNEX C to APPENDIX A
Advantages And Disadvantages of Two Major Vapor Degreasing Solvents

1. Perchloroethylene

a. Advantages

(1) Recommended for wet systems

(2) Useful for high melting waxes

(3) High condensate volume useful with light gauge parts.

b. Disadvantages

(1) High heat input, for example, needs 40 to 50 psi steam.

(2) Higher solvent consumption

(3) High temperature of cleaned parts

(4) Plastic compounds may warp or melt.

(5) Narrower safety margin (TLV = 100 ppm). Some evidence of carcinogenicity in animals (International Agency for Research on Cancer [IARC] Monographs on the Evaluation of the Carcinogenic Risk of chemicals to Humans – Some Halogenated Hydrocarbons, Vol 20 [IARC]).

(6) It is a listed TRI chemical.

(7) It is a listed Hazardous Air Pollutant.

2. Methylene Chloride

a. Advantages

(1) High solvency may make it the choice for removal of a difficult soil or polymer residue

(2) Lower vapor blanket temperature may make it useful for cleaning temperature-sensitive parts

(3) Reduced heat input required

b. Disadvantages

(6) High solvent losses

(7) Extensive modifications required to convert a trichloroethylene vapor degreaser.

*Is a listed TRI chemical.

ANNEX D to APPENDIX A
Operational Procedures That Reduce Solvent Losses From Vapor Degreasers

1. Close the tank covers when idling or shut down. Covering the degreaser top decreases solvent emissions significantly when heat is not applied.

2. Increase the freeboard height. Freeboard height is the distance from the top of the vapor zone to the top of the degreaser tank. The primary purpose of the freeboard is to reduce air movement near the interface between air and solvent vapor. The Occupational Safety and Health Administration (OSHA) requires at least a 0.50 freeboard height-to-degreaser width ratio or 36 in., whichever is shorter, for all vapor degreasing tanks with a condenser or vapor level thermostat. OSHA also requires a ratio of 0.75 when the solvent is methylene chloride.* Studies have reported a 27 percent reduction in solvent emissions in an area of undisturbed air by increasing the freeboard-to-width ratio from 0.50 to 0.75. A 55 percent emission reduction was measured in a turbulent air area by increasing the ratio to 1.0. A degreaser cleaning oversize loads emitted about 29 percent less solvent when the freeboard height increased from 50 to 125 percent.

3. Limit the hoist system speed. The maximum hoist system speed should be 3.35 m/min (11 ft/min). Introduce the load smoothly to avoid unnecessary turbulence.

4. Limit the load cross-sectional area. The maximum load cross-sectional area ratio should be 0.5 as compared to the degreaser top open area.

5. Remove the work being degreased only when degreasing action (liquid runoff) has stopped.

6. Protect the degreaser from drafts, air currents, and excessively high velocities in exhaust ducts.

7. Install a freeboard refrigeration divide (secondary condenser). Two types of chillers are used above the primary condenser for additional cooling. One operates at a sub-zero temperature range of -23 to -32 °C (-10 to -25 F), and the other operates at a range of 1 to 4 °C (34 to 40 °F). Reported reductions in solvent consumption using a sub-zero chiller are 40 percent for methylene chloride.

* Listed TRI Chemical.

ANNEX E to APPENDIX A
Solvents Commonly Used in Cold Cleaning

1. The following is a brief discussion of the solvents most commonly used in cold cleaning. Tables E1 and E2 show many of the specific properties of these solvents.

2. Halogenated hydrocarbons.

a. This group of chemicals contains various quantities of the halogens chlorine or fluorine in the molecule. Generally, the chlorinated solvents are more toxic and less costly than the fluorinated compounds. The most widely used chlorinated chemicals include trichloroethylene,** perchloroethylene,* and 1,1,1- trichloroethane.** Carbon tetrachloride,* one of the most widely used chlorinated solvents, has been almost completely phased out of use in cleaning applications because of its toxicity, but it is included for comparison. Toxicity varies widely in this group, and the most common industrial problems include depressant effects on the central nervous system, dermatitis, and liver damage.

b. The fluorinated hydrocarbons are characterized by excellent chemical stability, a low toxicity level, nonflammability, low solvent power, and high cost. They are more familiar as aerosol propellants, but the less volatile members of the group are widely used in specialized cleaning situations that can tolerate their relatively high initial cost.

3. Aliphatic hydrocarbons. These are the main constituents of petroleum distillates such as mineral spirits, Stoddard solvent (PD 680), kerosene, and v, m, and p naptha. They are low in solvent power and have a low order of toxicity, being generally inert biochemically. Their primary toxicity problem is they cause dermatitis. All are flammable to a degree that depends on their boiling range. Low boiling fractions like gasoline are extremely flammable and the higher boiling Stoddard solvents and kerosene have flash points above 100 °F. since aliphatic hydrocarbons possess low solvent power, they will readily dissolve oils and some asphaltic materials, although they are not active solvents for resins and plastics. Aliphatic hydrocarbons are very widely used industrially, by themselves and blended with chlorinated hydrocarbons.

4. Aromatic hydrocarbons. (Also known as benzeneoid hydrocarbons because their molecular structure contains the benzene ring.) Typical among these are benzene,* xylene, and toluene.* These chemicals are generally local irritants and can cause severe pulmonary and vascular injury when absorbed in sufficient quantities. They are potent narcotics. Dermatitis and effects on the central nervous system are the primary toxicity hazards of the aromatics. Their air pollution potential is significant and existing legislation limits quantities that may evaporate into the environment. Benzene* is the worst of the group. It also has carcinogenic potential (G.D.

** Listed TRI chemical and ozone-depleting substance.

* Listed TRI chemical.

Clayton and F.E. Clayton, Ed., Patty's Industrial Hygiene and Toxicology, 3d ed., Wiley and Sons, New York, 1981) and is usually totally excluded from cleaning solvent compositions. All are flammable. All possess excellent solvent power and are often included in formulations requiring rapid penetration of tarry asphaltic and resinous soils.

5. Other solvents. Less frequently used in cleaning solvent formulations are alcohols, glycol-ethers*, ketones, and esters. Typical examples include acetone, methyl ethyl ketone*, ethylene glycol monoethylether*, ethylene glycol monobutylether*, and the alcohols – methanol*, ethanol*, and isopropanol*. In this group, methanol stands out as having been responsible for several industrial fatalities. Each of these materials can provide specialized properties to a solvent cleaning formulation. Alcohols and glycol-ethers, for example, will help remove traces of moisture from a surface. Ketones and esters will often help dissolve and remove lacquer and protective coatings.

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Table E1

Properties of Halogenated Solvents Used in Cold Cleaning[a]

Solvent	Boiling Point (°F)	Vapor pressure, mm Hg @ 25 °C	Evaporation Rate CCL_4= 100	Flash Point, Tag, C.C. °F	Flammable Limits; Percent Volume in Air, Lower, Upper	Density lb/gal	Threshold Limit Value (1967), ppm/air	Short-Term Inhalation Limits[b] ppm or mg/m³/min
Methylene chloride	104	420	147	none	none	11.1	500	100/60
Trichlorotrifluoroethane	118	320	170	none	none	13.2	1000	
Chloroform[c]	142	200	118	none	none	12.4	50	
1,1,1-Trichloroethane	165	130	100	none	none	11.1	350	1000/60
Carbon tetrachloride	171	114	100	none	none	13.3	10	
Ethylene dichloride	181	78	79	70	6.2 15.9	10.5	100	
Trichloroethylene[c]	188	70	84	none	none	12.2	100	200/30
Perchloroethylene[d]	250	23	39	none	none	13.6	100	100/60

[a]Adapted from M.Z. Poliakoff, "Solvent Cleaners and How To Use Them, Cleaning Stainless Steel, ASTM 538 (American Society for Testing and Materials, 1973), pp 33-42.[B]Hazardous Chemical Data, Chemical Hazard Response Information System (Department of Transportation, U.S. Coast Guard, October 1978).[c]"Suspect Occupational Carcinogen," Patty's Industrial Hygiene and Toxicology, 1981.[D]"Some Evidence of Carcinogenicity in Animals," TARC Monographs.[E]These solvents have a definite flammable range. Commercially available products vary as to inhibitor content. Values should be requested from suppliers.

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Table E2

Properties of Nonhalogenated Solvents Used in Cold Cleaning[a]

Solvent	**Boiling Point (°F)**	**Vapor pressure, mm Hg at 25 °C**	**Evaporation Rate CCL_4= 100**	**Flash Point, Tag, C.C.°F**	**Flammable Limits; Percent Volume in Air, Lower, Upper**	**Density lb/gal**	**Threshold Limit Value (1967), ppm/air**	**Short-Term Inhalation Limits[b] ppm or mg/m^3/min**
Acetone	133.7	186.0	2.8	0	2.213.0	6.6	1000	
Methyl alcohol	147.4	98.0	5.4	52	6.036.5	6.6	200	(260)/60
Ethyl alcohol	173.3	44.0	14.0	55	3.319.0	6.5	1000	
Methyl ethyl ketone	175.3	71.0	5.8	24	1.811.5	6.7	200	(290)/60
Benzene	176.2	76.0	5.2	12	1.4 8.0	7.3	25	
Isopropyl alcohol	180.0	31.6	14.0	53	2.012.0	6.5	400	
Toluene	231.1	22.0	13.7	40	1.3 7.0	7.2	200	600/30
Mineral spirits	300-400	7.0	25.0	105	0.86.0	6.4	500	4000-7000/60
Turpentine	310-340	4.0	55.0	95	0.8	7.2	100	
0-xylene	291.9			63	1.1 7.0		100	300/30

[a]Adapted from M.Z. Poliakoff, "Solvent Cleaners and How To Use Them, Cleaning Stainless Steel, ASTM 538 (American Society for Testing and Materials, 1973), pp 33-42.[B]Hazardous Chemical Data, Chemical Hazard Response Information System (Department of Transportation, U.S. Coast Guard, October 1978).[c]Suspect occupational carcinogen, Patty's Industrial Hygiene and Toxicology, 1981.

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ANNEX F to APPENDIX A
Alkaline-Based Cleaners

1. Description.

a. Use of alkaline cleaners as a replacement for solvents has increased dramatically in the private sector. There are now hundreds of alkaline type cleaning agents that are commercially available, each with its own uses and limitations.

b. Alkaline cleaners usually contain two basic components -- builders and surfactants. A variety of other components may be added to specialize a given product, such as complexing agents, corrosion inhibitors, buffering agents, etc. These components are used to formulate a cleaner for a specific cleaning application.

c. Builders are alkalis that neutralize acidic soils and provide dispersion properties that enhance soil removal. Sodium hydroxide* and potassium hydroxide* are often used as builders in strong alkaline cleaners. They produce solutions with pH ranging from 13 to 14, are not as good as other builders for removing oil, and should only be used for cleaning iron and steel. Builders commonly used in milder cleaners include silicates, phosphates, and carbonates.

d. Surfactants lower surface and interfacial tension, which allows emulsification and prevents soil redeposition. There are three classes of surfactants, anionic, cationic, and nonionic. Cationic cleaners are generally not used for metal cleaning because they are costly and adsorb onto metal surfaces. Most metal cleaners use anionic surfactants.

e. So-called "quick release" cleaners lift soils from the metal surface and put them temporarily into suspension. After a period of time, oil and solids are released and can be removed by skimming and filtration. These cleaning solutions can be reused until the accumulation of dissolved contaminants limits the effectiveness of the cleaning solution. It is possible a cleaning solution could be reused for at least several months. This type of cleaner may be particularly useful in: recirculating parts cleaning machines, high pressure spray machines, and hot water washers.

2. Advantages.

a. The obvious advantage of using alkaline cleaners is the elimination of RCRA controlled solvents. Discharge to sanitary sewers, with pretreatment, is considerably less expensive than dealing with the documentation and disposal costs of hazardous wastes. However, if alkaline cleaners remove hazardous materials such as heavy metals during the cleaning process, then the waste cleaning solution and/or sediment may become a hazardous waste.

b. In many applications, alkaline cleaners are more effective cleaning agents than the cold cleaning or vapor degreasing operations they replace.

3. Disadvantages.

a. A disadvantage of alkaline cleaners is that the materials are wet after cleaning, which can rust ferrous metals. Drying time is much longer than for most solvents. Use of forced air dryers may be necessary to speed drying time and prevent rusting.

b. Some cleaners are sensitive to heat, and are not effective at certain temperatures. This is true of those with sequestering type phosphate builders.

c. Many alkaline cleaners emulsify oil, making it difficult to remove in pretreatment or at wastewater treatment plants. The use of the "quick release" type cleaners may minimize this problem.

d. Alkaline cleaners may affect wastewater treatment. A study done by Idaho National Engineering Laboratory found that one typical cleaner would not degrade when phenol was present in the wastewater. That cleaner also caused floatation of activated sludge in the clarifiers. The floatation problem was solved by the addition of ferric chloride.

e. Other cleaners may not be affected by biological treatment and simply pass through the system. However, these may not pose a compliance problem, i.e., they may not elevate regulated effluent parameters.

ANNEX G to APPENDIX A
Terpenes

1. Terpene cleaners formulated for degreasing and cleaning of metal surfaces are based predominately on the d-limonene terpene isomer which is extracted from citrus. Terpenes are also extracted from wood by-products. The many terpene based cleaners differ slightly in formulation due to the numerous commercial manufacturers. The terpene cleaners have been found to be effective agents in cleaning of metals, however, there are many other factors that need to be considered before implementation at any Army installations. USACERL performed an evaluation of terpene cleaners, which was included in the report "The Economic and Environmental Benefits of Product Substitution for Organic Solvents" [Sarah O'Connor, USACERL Technical Manuscript N-91/12, May 1991]. Table G1 g summarizes O'Connor's comparison of terpene cleaners and Stoddard solvents.

2. It is evident, through O'Connor's evaluation, that widespread use of terpene cleaners at installations could pose as much, if not more, environmental and economic problems than the solvents they replace. Following is a summary of O'Connor's concerns with the use of the heavy duty commercial terpene cleaners at Army installations.

a. Environmental. Although manufacturers present terpene cleaners as biodegradable at standard temperature and pressure, studies show that the time required to decompose terpene during wastewater treatment depends on the method, bacteria, dilution, and the particular products used. Terpene will inhibit biological treatment at concentrations greater than 100 mg/L as chemical oxygen demand (COD); therefore no more than 40 gal/million gal of sewage flow is recommended to be discharged to a domestic wastewater treatment plant.

(1) Studies show that the terpene cleaners remove oil from the part by solubilizing the oil. It should be expected that the use of terpene cleaners will cause more oil to enter the sanitary sewer. Emulsified or dissolved oil cannot be removed in a gravity- type oil/water separator. Oil in concentrations greater than 100 mg/L has been known to inhibit a biological treatment system. This could lead to wastewater exceeding NPDES permit limits for oil or other parameters, resulting in Notices of Violation (NOVs).

(2) At high concentrations, the cleaners will have an adverse effect on aquatic organisms and stream life, e.g., they may cause fish kills. Special precautions must be taken to control effluent discharges to receiving waters.

(3) Terpene cleaners are very photochemically reactive. The d-limonene terpene, present in most terpene metal surface cleaners is listed in the highest reactivity class. This photoreactivity classification indicates that the d-limonene base terpenes can contribute to smog formation.

(4) Terpene cleaners are not recyclable either by conventional methods or ultrafiltration. Contaminants do not physically separate from the cleaners, and concentrated terpene cleaners destroy ultrafilter adhesives and support materials.

b. Safety. The low boiling point of the terpene cleaners make them unsuited for heated cleaning processes because they release nauseating and harmful vapors. Flash points of the terpene cleaners vary around 120 °F. Due to the low flash points, these cleaners are not to be heated or used in vapor degreasers. When the cleaner is diluted with water, the resulting emulsion can provide a flash point comparable to or higher than 140 °F, but with reduced cleaning strength. This low flash point of the diluted cleaner makes it unsafe for use with hot water washers. The terpene cleaners operate at relatively high pH levels, which could result in burns or irritation upon skin contact.

c. Cleaning. Aluminum surfaces and galvanized surfaces can be etched and painted surfaces can be softened and even stripped due to high pH. Extensive use of the terpene cleaners indicated abrasive action on plastic materials. Tests show that the cleaners can cause softening, swelling, and sometimes severe crazing of plastic materials.

(1) The terpene cleaners are diluted in water and in most instances require a clear water rinse. As with most aqueous cleaners, this may cause rusting.

(2) The terpene cleaners have slow evaporation rates, comparable to water, and therefore require extra drying time (and in some instances drying equipment) before handling.

(3) Unlike Stoddard solvents, terpene cleaners do not leave a protective oil film on the cleaned parts. It is recommended that, for cleaned parts that will not be immediately coated with primer, a corrosion prevention compound or light lubrication oil (VV-L-80) be applied.

(4) Terpene cleaners require enhancement methods such as air agitation, mechanical agitation or ultrasonic agitation, to achieve cleaning efficiencies equivalent to solvents.

Table G1

Comparison of Terpene and Stoddard Cleaners

Solvent type	**Stoddard Solvent Petroleum Based**	**Terpene Cleaner* Aqueous Based**
Boiling point	367-405 °F	212 - 220 °F
Vapor density (air=1)	5.2	Not determined
Evaporation rate(water=1)	0.21	0.8 - 1.0
% Volatile	100	70 – 80
% Solubility in h20	<0.1	Forms emulsions
Vapor pressure (mmhg)	<1.0	Not determined
Specific gravity	0.772 (60 °F/60 °F)	0.94 - 0.98 (75 °F/75 °F)
Flash point	>140 °F	117 - 125 °F
PH	Not applicable	9.8 - 10.2 (in 10% solution)
Appearance	Colorless/clear	Light yellow/clear
Odor	Kerosene-like	Citrus
TLV (ppm) - federal standards	100	3

Solvent type	Stoddard Solvent Petroleum Based	Terpene Cleaner* Aqueous Based
Volatile organic compounds	795 g/l not recognized as an ozone depleting substance	500 g/l not recognized as an ozone depleting substance.(averages 50% of the cleaner, depends on the percentage of terpene based material and ethanolamine contained in the product. In a 2:1 dilution voc content is approx. 166 g/l)
Hazardous chemical compounds subject to reporting (under SARA regulation)	None	D-limonene= 50% Ethanolamine= 10 - 15% Di&mono butylether= 2-3%
Health hazardous	Eye, skin, throat, & nose irritation	Eye, skin, nose irritation corrosive to throat
Toxicity	Defatting of skin nervous system depression permanent brain damage	Defatting of skin nervous system damage possible carcinogen
Biodegradable	No	Partially, in appropriate treatment system
Recyclable	Yes	No
Reactivity	Stable under normal conditions-avoid strong acids, bases & selected amines-avoid all sources of ignition	Stable under normal conditions avoid strong acids and all sources of ignition highly photoreactive substance
Fire hazardous ranking	Slight-moderate	Moderate-high (concentrated formula)
Corrosiveness	Safe for all metals and plastics	Corrosive to selected metals and plastics
Cleaning process	Solvent only cleaning process	Cleaner at specified dilution rate rinsing required enhancement methods required apply corrosion protection allotted drying time
Disposal	Recycled to greatest extent sludge soil is incinerated, blended, sold, or used as a fuel substitution	Rinse waters - waste water treatment Oil & grease skimming - separation, reclamation Cleaning tank bottoms- treat as hazardous waste contaminated with metals, plastics, oils and grease
Cost ($/gallon)	1.50 – 3.00	11.00 - 13.00 (concentrated form)

ANNEX H to APPENDIX A
Process Conversion Checklist

1. Process-Related Issues

a. Are the parts' materials (metal, plastic, etc.) compatible with the proposed process/chemistry?

b. What are the financial limitations on new equipment purchases?

c. Is new process labor intensive compared with old process?

d. Is new process batch or continuous? Is it automated? How does this affect throughput rates -- equipment needs?

e. Will the cleaning process affect the upstream or downstream processes? (For example will a change in lubricants be needed to be compatible with the new cleanser; will the time required in the drier be compatible with current throughput rate?)

f. Will the cleaning process harm the surface of the part?

g. Will additional surface preparation be needed after cleaning?

h. Is an acceptable and sufficient quantity of the new chemical or equipment available at a reasonable cost?

i. Can current equipment be used “as is” (drop-in substitution)?

j. Can existing equipment be retrofitted for the proposed method?

k. Is the retrofit more economical than replacing the equipment?

l. Is the material of your existing equipment compatible with your new chemistry/process? (For example, will there be corrosion, embrittlement, chemical reaction, or heat transfer difficulties?)

m. Is sufficient containment available (shielding for spraying, edges to prevent drips)?

n. Is humidity control adequate?

o. Are pumps adequate?

p. Can closed-loop recycle and reuse methods be practically applied within the process?

q. Will the wastewater include biocides, foaming agents, or metals?

r. Will existing contracts need to be changed to reflect the new cleaning method?

s. Will the product meet quality control and assurance specifications?

t. Will the customer require proof that specifications are met and, if so, what kind?

u. Is resistance to the change likely among line operations people and others?

v. What type of training should be set up to properly prepare workers for the new cleaning method?

w. Are incentive programs and monitoring programs appropriate for your facility?

2. Facility - Related Issues To Consider

a. Are existing chemical handling facilities/practices applicable and adequate?

b. Have closed-loop recycle and reuse methods within the plant been investigated?

c. Is there sufficient space for any necessary new equipment or to retrofit old equipment?

d. Is there enough space to hold parts for drying if a longer time is required for this activity?

e. Do recycling facilities need to be added?

f. Is humidity control adequate?

g. Are pumps adequate?

h. Will additional electricity be required?

i. Will additional drains or vents be required?

j. Will more water be needed?

k. Is additional water available from the other processes in the plant or will total plant intake need to be increased?

l. Is additional water available to your plant in general (will this depend on geographic region)?

m. Is the existing plumbing system adequate?

n. Is the water supply clean enough and, if not, are facilities available to clean the water (distill, deionize, filter)?

o. Will the volume of wastewater on-site change?

p. Will this be a problem for your on-site wastewater treatment facility, if applicable?

q. Will the contents or temperature of your on-site wastewater change?

r. Will your on-site wastewater treatment system accommodate any changes?

s. Will the volume of wastewater discharged to the sewer change?

t. Will the contents or temperature of the water stream be discharged to the sewer change?

u. Do you need to adjust the pH of your wastewater stream?

v. Is available air clean/dry enough for drying or other processes and, if not, what pretreatment (dehumidification, filtration, etc.) will be needed?

w. Is needed air pretreatment currently available?

x. Will the volume, content, temperature, or location of air emissions change?

y. Will the emissions require a change in stack or local air cleaners?

z. Will the volume or contents of solid waste change?

aa. Will the waste be classified as hazardous?

bb. Will hazardous waste treatment/disposal be needed on-site or off-site?

cc. Will you need additional hazardous waste treatment/disposal services?

3. Regulatory Issues

a. Will you be allowed to discharge a new wastewater stream to the sewer?

b. Will adjustments to the pH of the discharge be required?

c. Will the effluents (air, water, solids) require regulatory reporting under the Toxic Release Inventory or elsewhere?

d. Will the emissions be classed as a hazardous air pollutant or a volatile organic compound?

e. Will the emissions be covered under the Emergency Planning and Community Right-to-Know Act or the Comprehensive Environmental Response, Compensation, and Liability Act -- in terms of immediately reporting any releases in excess of reportable quantities? Will the effluents require regulatory reporting and permitting (i.e., National Pollutant Discharge Elimination System permits)?

f. Will the changes reduce regulatory reporting?

g. Will any solid waste be classified as hazardous, and therefore possibly alter your status as a generator (e.g., large-quantity generator)?

h. Will new or changed permits be needed for chemical purchase or storage?

i. Will new or changed permits be necessary for water intake changes?

j. Will new or changed permits be necessary for changes in volume, temperature, or contents (including biocides, foaming agents, metals) of water discharged to the sewer?

k. Will new or changed permits be needed for changes in volume, temperature, or contents of air emissions?

l. Will new or changed permits be needed for changes in volume or contents of any solid waste?

m. Even if you do not need a water permit, will you need to notify local officials that your use will increase?

n. Do local regulations covering biological oxygen demand and chemical oxygen demand apply to any wastewater discharge changes?

4. Safety-Related Issues

a. Are the new chemicals flammable as stored or as used in the new process?

b. Are there sufficient procedures in place to avoid hazards to workers and others (fires, explosions, adverse reactions, etc.)?

c. Do you need to increase, decrease, or maintain operator eye protection, as a result of the changes?

d. Do you need to increase, decrease, or maintain operator hearing protection?

e. Do you need to increase, decrease, or maintain operator breathing apparatus?

f. Do you need to increase, decrease, or maintain ventilation levels for operator safety?

g. Do you need to increase, decrease, or maintain air cleaning level to provide operator safety?

h. Do you need to increase, decrease, or maintain operator protection for possible liquid spills -- acids, alkali, heat, toxics?

i. Do you know the threshold limit values, American Society of Heating, Refrigeration, and Air Conditioning Engineers ventilation standards (including changes since the older process was implemented), and Occupational Safety and Health Administration procedures that apply to any process changes?

j. Do you need to revise operator safety training?

ANNEX I to APPENDIX A
Standard Protocol For Selecting
General Cleaning Agents and Processes

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1. SCOPE

a. **Purpose of the Protocol.** The purpose of the Army standard protocol for selecting cleaning agents and processes is to standardize the approach to solvent substitution efforts by establishing minimum testing requirements that must be met by all replacement or alternative cleaning products. This guide is intended to assist design engineers, manufacturing/industrial engineers, and production managers in selecting the best fit cleaning agent and process. The procedures presented in this protocol are the same procedures which are featured in the "Standard Guide for Selecting Cleaning Agents and Processes", currently being developed by the American Society for Testing and Materials (ASTM). When the ASTM standard guide is published (likely in 1998), it will supersede this guidance.

This protocol is not to be considered as a database of acceptable materials. It will guide engineers and managers through the cleaning material selection process, calling for the engineers to customize their selection based on the cleaning requirements for the cleaning task(s) at hand. If a part can be cleaned and kept clean, it can be cycled through several process steps that have cleaning requirements. This eliminates extra cleaning process steps during the total process. A total life cycle cost analysis or performance/cost of ownership study is recommended to compare the methods available.

b. **Why Replace Cleaning Solvents?** Cleaning of Army equipment is one of the most prevalent manufacturing or maintenance activities performed in the Army. In some cases, the cleaning requirements are simply for cosmetic purposes or to remove gross amounts of dirt and grime accumulated from field activities. At other times, the cleaning requirements are for critical applications, such as the cleaning of aircraft flight safety parts prior to liquid dye penetrant inspections, or critical cleaning processes in munitions manufacturing. These two groups of cleaning tasks have widely varying requirements for cleanliness and cleaners. For the first group a mild detergent may be sufficient, whereas for the second group an aggressive solvent and multiple process steps may be required to provide sufficient levels of cleanliness.

Technical manuals (TMs), depot maintenance work requirements (DMWRs), and other process documents contain specific requirements for the cleaning of components and materials. These technical documents often contain references to hazardous or environmentally unacceptable solvents, including ozone-depleting chemicals (ODCs). These materials were selected in the past because of their cleaning effectiveness but now must be avoided. Starting in the early 1990s, with the then-impending production ban on ODCs, other hazardous or environmentally unacceptable materials, such as volatile organic compounds (VOCs) have also been increasingly scrutinized. Thus there is a need to eliminate requirements for many of these highly effective, but environmentally unacceptable products. At the same time we must determine the best economically feasible, environmentally acceptable replacements that are also safe from the worker health and safety standpoint.

c. Adoption of a Standard Approach. The primary purpose of this protocol is to standardize the approach to solvent substitution efforts, by defining the requirements for the level of cleanliness and the material compatibility for various general cleaning applications. This protocol allows design engineers to select an effective cleaner for the cleaning task at hand, based on standard evaluation procedures and sound engineering principles and practices. It must be stressed that these requirements are intended to be minimum standards, applied across all commands. If the engineers at a particular command believe that there are special cleaning requirements under their cognizance that require additional tests or evaluations, they should certainly specify them. Further, engineers may want to consider functional testing to validate their cleaning agent/process selection.

Under this standard approach, the technical requirements for the cleaning task are established by using a series of matrices. After evaluating their particular cleaning application, the engineer can then select the cleaning products that meet the minimum requirements. The industrial/maintenance engineer may need other types of information to make the final decision for his particular situation. These factors may include:

Toxicological information	Cost
Flash point	Disposal requirements
Odor	pH values
Required personal protective equipment	Worker health and safety
Processing time	Drying time

These factors should be evaluated and compared only for those products that have first met the technical requirements for the cleaning task at hand. Section 4 e contains a more detailed discussion of these secondary evaluation criteria.

d. **Why is Protocol Limited to General Cleaning?** This protocol is geared specifically toward general industrial and field cleaning. The reason for this limitation is that general cleaning requirements represent the greatest portion of the hazardous materials problems associated with cleaning in the U.S. Army. Other technical knowledge must be brought to bear on solving more specific cleaning problems, such as:

Precision cleaning	Electronics cleaning	Sealant/adhesive removal
Optical cleaning	Paint removal	Oxygen cleaning

Some of these topics may be addressed by future guidance using the approach presented in this protocol to ***re-engineer*** processes by determining the reason a particular cleaning activity is being performed, thus possibly eliminating certain “problematic” processing steps.

2. REFERENCED DOCUMENTS
Presented below are the documents that are referenced throughout the protocol. In deference to the tenets of Acquisition Reform, an aggressive attempt was made to reference only commercial or industry consensus specifications and standards.

a. **ASTM Standards**

- D 56 Test Method for Flash Point by Tag Closed Tester
- D 92 Test Method for Flash and Fire Point by Cleveland Open Cup
- D 93 Test Method for Flash Point by Pensky-Martens Closed Cup Tester
- D 903 Peel or Stripping Strength of Adhesive Bonds
- D 945 Test for Stress Corrosion of Titanium Alloys
- D 1002 Strength Properties of Adhesives in Shear by Tension Loading
- D 1781 Climbing Drum Peel Test for Adhesives
- D 1876 Peel Resistance of Adhesives
- D 2240 Test Method for Rubber Property - Durometer Hardness
- D 2919 Determining Durability of Adhesive Joints Stressed in Shear by Tension Loading
- D 3167 Floating Roller Peel Resistance of Adhesives
- D 3519 Foam in Aqueous Media (Blender Test)
- D 3601 Foam in Aqueous Media (Bottle Test)
- D 3707 Storage Stability of Water-in-Oil Emulsions by the Oven Test Method
- D 3709 Stability of Water-in-Oil Emulsions Under Low to Ambient Temperature Cycling Conditions
- D 3762 Adhesive Bonded Surface Durability of Aluminum (Wedge Test)
- E 70 Test Method for pH of Aqueous Solutions with the Glass Electrode
- E 1720 Determining Ready, Ultimate, Biodegradability of Organic Chemicals in Sealed Vessels, CO_2
- F 483 Method For Total Immersion Corrosion Test for Aircraft Maintenance Chemicals
- F 484 Test Method for Stress Crazing of Acrylic Plastics in Contact with Liquid or Semi-Liquid Compounds
- F 485 Test Method for Effects of Cleaners on Unpainted Aircraft Surfaces
- F 502 Test Method for Effects of Cleaning and Chemical Maintenance Materials on Painted Aircraft Surfaces

- F 519 Method for Mechanical Hydrogen Embrittlment Testing of Plating Processes and Aircraft Maintenance Chemicals
- F 1104 Test Method for Preparing Aircraft Cleaning Compounds, Liquid Type Water Base, for Storage Stability Testing
- F 1110 Test Method for Sandwich Corrosion Test
- F 1111 Corrosion of Low Embrittling Cadmium Plate by Aircraft Maintenance Chemical
- G 121 Preparation for Contaminated Test Coupons for Evaluation of Cleaning Agents
- G 122 Evaluating the Effectiveness of Cleaning Agents

b. Other Documents

- AMS 3204/AMS 3209 Test for Rubber Compatibility
- Annex B, Test for Effect on Polyimide Insulated Wire

3. TERMINOLOGY

a. **Definitions.** A number of terms are used throughout this document to describe aspects of the protocol or to explain certain portions of its execution. Some of these terms may mean different things to different people, so it is important to define them as they are to be understood within the confines of this document.

(1) Aqueous Cleaner: A cleaning medium that uses water as the primary cleaning component. Additive products are used in these agents primarily to prepare the water as a vehicle for capturing or removing soils from the dirty component. Additives may also be used to reduce the corrosivity of the water, increase wetability, emulsify soils, add a dye marker, or change the pH of the water.

(2) Cleaning Efficiency: The measure of how well a cleaning agent is able to clean a substrate.

(3) Level of Cleanliness: The degree to which a part must be cleaned so that the next manufacturing or maintenance procedure, can be performed successfully. Level of Cleanliness is determined on a sliding scale based on how clean the part needs to be for the next maintenance action. Level 1 is the least stringent Level of Cleanliness, while level 4 is the cleanest. Each level of cleanliness used in this protocol is defined in Table I-3.

(4) Semi-aqueous Cleaner: A cleaning medium that uses a water-soluble concentrate chemical to remove soils. The typical semi-aqueous cleaning process will have a wash step (where the cleaning agent is used), followed by an emulsion rinse, then several water rinses, and finally a drying cycle.

(5) Type I Solvents: Non-ozone depleting (EPA Class I or II), non-volatile organic compound (VOC) solvents that have been evaluated and are not carcinogens, mutagens, reproductive or developmental toxins, and are not hazardous air pollutants (HAPs), or SARA

Title III reportable chemicals.

(6) Type II Solvents: All other non-ozone depleting solvents (those that do not fit the description of a type I solvent).

b. **Protocol-specific Terminology.** The following terms are used throughout the document, and are defined below.

(1) Specific Tests: Standard tests for materials compatibility.

(2) Basic Tests: Standard evaluation criteria to ascertain various chemical, physical, and material safety properties of a cleaning agent.

(3) Test Protocol: A combination of one or more specific tests that must be performed on a cleaning agent to ensure that its use will not damage a particular material.

4. PROTOCOL SUMMARY

a. **Overview**. When selecting an environmentally acceptable alternative cleaning agent, there are two critical requirements:

- To ensure that the new agent gets the component ***clean enough*** for subsequent processing steps
- To ensure that the new agent ***does not compromise the structural integrity*** of the component being cleaned (or any adjoining components)

To date, there have been a number of Army efforts designed to replace ODCs or other hazardous solvents in technical documents or maintenance processes. Some of these efforts have included laboratory and field testing of replacement products, as well as toxicological screening. Others however, have relied on anecdotal information, a manufacturer's claim, or other potentially unreliable data. The result has often been that replacement cleaning agents have been selected based on insufficient data. The Army must pursue a single standard approach to selection.

The following is a summary of the five step approach for selecting general parts cleaning products and processes for use in manufacturing, overhaul, and maintenance processes in industrial operations:

- ***Step 1*:** Determine the parameters surrounding the cleaning of the component
- ***Step 2*:** Determine the cleaning code
- ***Step 3*:** Select an appropriate cleaner
- ***Step 4*:** Consider other physical and chemical properties of the cleaning agent
- ***Step 5*:** Select the proper cleaning equipment

This remainder of this section presents a detailed discussion of some of the ***key factors*** regarding the use of the protocol. This section provides much of the needed background for the user to effectively employ the procedures of the protocol that are presented in Section 6.

b. **Discussion of Step 1: Determining Parameters**

(1) **Reasons for Cleaning.** The following reasons for cleaning represent broad processing categories. The users of this protocol should feel free to use one of these descriptions on a best-fit basis for similar applications.

(a) **Pre-cleaning.** Pre-cleaning is performed to remove gross soil from a component to avoid contamination of the follow-on cleaning processes. Typically this is performed by steam cleaning, brushing, scraping, presoaking, or pressurized spray cleaning with already-contaminated cleaning solutions.

(b) **Cosmetic Cleaning.** Cosmetic cleaning may be required when cleaning a component or surface after use or disassembly. Although no immediate maintenance action follows, this type of cleaning may be necessary to facilitate subsequent handling of the part during other maintenance procedures. Cosmetic cleaning may also be necessary to make a component look aesthetically pleasing, or to facilitate assembly.

(c) **Pre-paint Cleaning**. Pre-paint cleaning is performed to clean a component or surface prior to the application of paint or primer, and is intended to aid coating adhesion. Various coatings and materials require different degrees of surface cleanliness.

(d) **Pre-plate Cleaning.** Pre-plate cleaning is performed to clean a component or surface prior to plating, welding, anodizing, the application of metal spray, or similar surface finishing or chemical treatment, and is performed to aid adhesion of the surface finish. Different plating processes require different degrees of surface cleanliness.

(e) **Pre-bond Cleaning.** Pre-bond cleaning is performed to clean a component or surface prior to the application of an adhesive or sealant for the express purpose of bonding that surface or component to another. This category of cleaning includes the critical cleaning requirements for structural bonding.

(f) **Pre-Non Destructive Test (NDT) Cleaning.** The most critical NDT cleaning requirements are for fluorescent dye penetrant inspections. To facilitate their detection during the NDT process, all cracks in the part must be clean enough to allow the fluorescent dye to penetrate into them. The levels of cleanliness suggested in this protocol for the NDT category are for fluorescent dye penetrant inspection. The user of this protocol may lower this cleanliness requirement for other forms of NDT, as experience dictates. For magnetic particle inspection, care must be exercised to ensure that the working fluid will not de-wet from the part being inspected. Therefore, the cleaning process selected must achieve a level of cleanliness that prevents de-wetting. Cleanliness levels may also be adjusted for eddy current inspection as experience dictates.

(g) **Special Cleaning: Hydraulic Parts and Bearings.** Hydraulic components and bearings require a high level of cleanliness due to close tolerances or other physical parameters that cannot be satisfied by less stringent cleanliness requirements.

(2) **Determining Reason for Cleaning.** The reason for cleaning a part usually corresponds to the next maintenance action to be completed. To determine the reason for cleaning, analysis of the entire maintenance process must be performed. For example, a task statement in a DMWR may simply say to clean a component using a solvent cleaner. This simple statement provides almost none of the information that is required for selecting a replacement for this solvent cleaner. Both the past activities of the part and the future maintenance actions to be performed on it must be analyzed to accurately determine the appropriate product and process to be utilized.

It is sometimes assumed that because an aggressive cleaner has been recommended for use in a given cleaning task, an alternative cleaner must be equally aggressive. This is not always true. The writers of past technical documents often did not perform the type of analysis that is required by this protocol, instead settling on using one cleaner for a variety of purposes. In many cases this turned out to be too aggressive a cleaner, and in other cases the cleaner chosen was not effective enough. Following this protocol will solve that problem.

Although knowledge of the previous maintenance activity is important, the most critical aspect of determining why the part is being cleaned is to identify the next maintenance action or process step. Disassembling a part that was in service and removing some of the soil to make the part easier to handle is dramatically different than the cleaning required immediately prior to liquid dye penetrant inspection. Both the cleaning product used, and the process employed are likely to vary based on the reason for cleaning.

The best way to determine the reason for cleaning is to examine the cleaning statement task in the context of the entire maintenance operation. Consider the following statement:

Clean part with a rag soaked with MEK.

This statement by itself provides little information that would allow an engineer to make an informed choice as to a replacement cleaner or process. The statement must instead be viewed within the context of the entire maintenance procedure. For example, consider the following three statements together:

1. *Remove part from aircraft landing gear.*
2. *Clean part with a rag soaked with MEK.*
3. *Examine part for cracks using liquid dye penetrant process.*

Now there is a basis of information from which an intelligent choice of alternative cleaner and process can be made. The part has been removed directly from the weapon system, which means it was probably subjected to in-service dirt, grime, etc. And most importantly, this part is to be checked for cracks using liquid dye penetrant inspection techniques, so a cleaner capable of removing contamination from potential cracks is required.

(3) **Materials to Be Cleaned**

Most of the general and industrial cleaning activities are performed on some type of metal, composite, or plastic surface. The material of the component is a critical factor because each material has certain physical properties that, when combined with the chemical or physical properties of a cleaning agent or process, could make the material subject to degradation. This material degradation can take the form of cracks, corrosion, or a small impingement that could lead to the premature replacement or failure of the component. Table 1 lists the materials that the Army Solvent Substitution Program has selected as being representative of most of the component materials that are subject to cleaning during U.S. Army maintenance. If a specific material is not listed in Table 1, technical engineering judgment must be applied to determine the critical material properties dictating the selection of cleaning agents and processes. As experience and technical knowledge dictate, these other materials may be grouped with those listed.

The material of the component being cleaned is a critical, but often overlooked element in selecting the appropriate cleaning technology and product. One cleaner may be very effective and safe to use on metals, but very harmful to rubber or plastics. A cleaner might work well on an aluminum part but cause stress corrosion cracking in titanium parts. Not only should the material of the component be known, but the material of the adjacent parts should also be considered when they could be exposed to the cleaning agent during the cleaning operation.

Identification of the substrate's coating material including type (e.g. epoxy, lacquer, enamel, varnish, polyurethane, etc.), thickness and physical condition will also affect the selection of cleaning agent. Additionally, coating material sensitivity to a particular cleaner may change with age, oxidation, or physical damage and should be considered as part of the material evaluation process. In the worst case a cleaner may be benign to the substrate metal or composite material but damage the coating to the extent that total replacement of the coating may be required. The opposite situation may be encountered where a cleaner will not damage the coating but attack the substrate material through areas of damaged coating. Knowledge of both substrate and coating is required to properly identify a cleaning agent and cleaning process.

The most effective way to ascertain the material and coating of a given component may be for a knowledgeable person to examine the part in question. Other effective ways are to analyze the drawing of the component or to contact the component manufacturer.

Table I-1. Typical Component Materials

• Carbon and Low Alloy Steel	• Metal Honeycomb
• Cobalt alloys	• Rubber Compounds
• Nickel alloys	• Thermoset Plastics
• Titanium alloys	• Thermo Plastics
• Stainless Steel	• Acrylics
• Iron	• Polycarbonates
• Aluminum	• Optics
• Magnesium	• Polyamide wiring (insulation)
• Brass	• Leather and fabrics
• Bronze	• Coated surfaces
• Copper alloys	• Polysulfides

(4) History of the Part. It is important to analyze where a particular part came from in order to determine what soil (dirt, oil, hydraulic fluid, etc.) the part has been subjected to. Questions to be asked about the history of the part to determine the aggressiveness of the cleaner required include the following:

- Is the part in the manufacturing process?
- Is the part new out of the box?
- Has the part been subjected to prior maintenance?
- Was the part taken directly out of service?

The answers to these questions may help the user determine the type of soil that must be removed from the component. Soil determination is crucial because the overall performance of a cleaning agent is usually directly related to the soil being removed. For example, when removing light preservative oil, a cleaner may get the component to a level 4 cleanliness (the highest level of cleanliness contemplated by this standard). However, when faced with removing heavy hydraulic oil, the same cleaner may clean the part to only a level 3 cleanliness. (See section 3 c (2) for a complete discussion of level of cleanliness.)

To assist in determining the soil a component may have been subjected to, this standard protocol defines four classes of soils, which can be found in Table I-2 (see Annex A). The soil class determination is to be used in conjunction with the Level of Cleanliness to provide further confidence that the cleaners selected will perform to the level of cleanliness required. Users of this protocol should use Table I-1 as a guide for evaluating level of cleanliness data for a particular cleaner. For example, if a cleaner has passed the wipe test (level 2), the user should examine the soil tested to ensure it is as difficult to remove as will be seen on the actual parts.

An additional aspect of part history is component sensitivities; environmental or operational. These sensitivities (e.g. thermal cycling, vibration, fluid sensitivities or material incompatibility) should be a consideration when selecting the cleaner and cleaning process to ensure equipment operational longevity and minimize unscheduled maintenance due to unanticipated component failure. This information should be available from design specifications, technical drawings or obtained by consulting with the component manufacturer.

c. **Discussion of Step 2: Cleaning Code**

(2) **Material Compatibility.** Material compatibility requirements ensure that the cleaner selected will not damage the material(s) of the component being cleaned. A list compatibility tests can be found in Table I-5. Many of these tests need to be conducted in conjunction with others to ensure that material degradation will be prevented. Table I-6 lists the specific material compatibility tests that are included in each test protocol (A through R).

To ascertain which test protocol to use, see the cleaning code identification matrix (Table I-4). Down the left-hand column of that table are the 22 different types of materials from Table I-1. Find the material type that most closely represents the material of the component to be cleaned, and follow it across until a match in the “reason for cleaning” column is made. The letter portion of the alphanumeric code in that cell is the test protocol for the material. Table I-6 shows all the tests that must be performed as part of that protocol. Using Table I-4 serves to eliminate cleaners for the given application. For example, for cleaning an aluminum component three cleaners might be acceptable from the standpoint of meeting the cleanliness requirement. However one of them might cause pitting corrosion on the aluminum component. The use of Table I-4 avoids this unsuitable cleaner by considering the material to be cleaned.
It must be remembered that none of these tests (Table I-5) are necessarily pass/fail. It is left up to the user to determine whether the test results are acceptable.

(3) **Level of Cleanliness.** The level of cleanliness required is determined on a sliding scale based on how clean the part needs to be for the next maintenance action. Level 1 is the least stringent level of cleanliness, while level 5 is the cleanest. Table I-3 (see Annex A) presents the levels of cleanliness, the type of inspection required to determine if this criterion has been met, and a description that will assist in determining whether the code standard of cleanliness has been achieved.[1]

Once the next maintenance action and thus the level of cleanliness required has been determined, the cleaning code (Table I-4) is used to narrow the choice of potential cleaners. There are potentially many more cleaners that will pass the wipe test than will pass the ASTM cleaning standard test, for removal of more than 95% of the contaminants. The cleaning code serves as a starting point for selecting the proper cleaning product.

d. **Discussion of Step 3: Selection of Appropriate Cleaner.** Once the cleaning code has been established using Table I-4, the next task is to determine the field of appropriate alternative

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[1] The descriptions of the inspections are based on the definitions found in ASTM G-93.

cleaners. With the vast number of cleaning products available, it is a daunting task for any one command or industrial facility to know all of their cleaning effectiveness', as well as which materials tests they have been evaluated against. However, there are several ways to ascertain this information including the following:

- Manufacturer's test results
- Results from an independent laboratory
- Results from other industrial facilities that have conducted testing

An engineer should review the results of all testing received by these sources for a given product to determine whether the results satisfy the requirements of the protocol, and their cleaning application.

e. Discussion of Step 4: Other Properties

(1) **Environmental Concerns.** As more National Environmental Standards for Hazardous Air Pollutants (NESHAPs) are adopted (e.g. an aviation standard has already been adopted), the use of conventional technologies that are less environmentally friendly will require very large investments in emission control equipment. No consideration of the economic feasibility of this control equipment is allowed. Therefore, it is important that the specifier of cleaners select the most environmentally preferable technology available so that emission control costs can be kept to a minimum. Regulatory requirements of the selected cleaner should also be part of the evaluation process. Disposal costs may be a significant factor in the overall cost of implementing replacement cleaning processes.

To assist in making this evaluation, Table I-7 lists four categories of cleaners, ranked in order of environmental preferability. Preference 1 is the most environmentally preferable choice, while preference 4 is the least. For example, if the user has the choice of two acceptable cleaners, one that is semi-aqueous and another that is a solvent, the semi-aqueous product should be selected, *unless* there are other mitigating circumstances such as; effluent pre-treatment and certification requirements, toxicity considerations, etc. [(also see Section 4 e (2)]. The final determination for environmental preference shall be made by the using command environmental coordinator.

(2) **Physical and Chemical Properties.** All cleaning products have chemical and physical properties that must be considered before a final selection is made. The weight given to each of these properties is an individual choice that must be made by the engineer at the using site, based on the circumstances of that particular facility. Table I-8 is a partial list of these properties, and associated basic tests that will assist in comparing cleaning products. Table I-8 is not an exhaustive list of possible factors or properties; examples of other considerations include the odor of the agent, personal protective equipment required, the procurement and operational costs, and the disposal requirements. One or more of these properties may be critical to a particular user or industrial operation. For example, say that toxicity is a critical property at a given facility. If there are two acceptable cleaners, one that has questionable toxicity data, and another that has more favorable toxicity data, the engineer should choose the less toxic substance.

(3) **Worker Health and Safety.** One of the goals of any solvent substitution effort should be to make the workplace safer for the individuals using the products. To support this goal the Army has established a Toxicity Evaluation Program (TEP) in the Directorate of Toxicology at the U.S. Army Center for Health Promotion and Preventive Medicine (CHPPM). The TEP assures that materials and chemical products in the military system are safe for personnel and the environment. This is accomplished through chemical hazard identification and recommendations on preventive procedures for avoiding or minimizing hazardous exposures. Before a new cleaning product is introduced into the Army maintenance environment, it must be submitted to the TEP for review. Their toxicity evaluation will use the latest computerized data bases, comprehensive literature surveys and extensive consultations with other health experts to determine the risk/benefit options with respect to the new product. If they determine that the product is acceptable, CHHPM will issue a toxicity clearance. Only products granted a toxicity clearance by CHPPM are acceptable for Army use. Limited quantities of products may however be used to evaluate their cleaning effectiveness.

(4) **Other Technology Considerations.** Eliminating unnecessary cleaning steps in the maintenance cycle of a part is an important alternative for achieving pollution prevention goals. For example, if the maintenance documents dictate to clean the part, store it, and then clean it again before performing the next maintenance action, this may be a waste of resources. If a part can be economically and effectively cleaned once and then kept clean (for example by changing the way it is stored), this is certainly preferable to cycling the part through several process steps that each require cleaning. The no-clean option must always be kept at the forefront of possibilities and selected wherever feasible.

Nothing in this protocol should be construed as limiting the consideration of other, more exotic technologies for addressing specific cleaning applications. Exotic technologies such as plasma, pressurized gas, and supercritical fluid cleaning may be preferable alternatives. Abrasive and liquid blasting also have their applicability, but their use should be considered carefully due to possible generation of significant amounts of hazardous waste. As with the other products, users must carefully analyze product and process costs, waste handling/disposal costs, and potential capital equipment costs and compare these factors with the more traditional approaches.

f. **Discussion of Step 5: Cleaning Equipment**. In the case field operations, the cleaning product selected will probably be used for hand-wipe cleaning operations. At industrial facilities however, there is a much broader range of cleaning process options, and the shape, size or weight of the part may be the critical parameter. This protocol does not address the size and weight considerations, but it does address shape. There are three basic shapes (Table I-9). Once the user has determined which of these shapes most closely resembles the part to be cleaned, Table I-10 can be used to choose appropriate cleaning processes/equipment.

5. USES AND SIGNIFICANCE

The protocol is to be used by anyone developing cleaning requirements, specifications, etc. for manufacturing, maintenance, or overhaul. This protocol has been designed to be application specific for each cleaning task, and allows the design engineer to rest assured that the process selected by the industrial/manufacturing engineer will be compatible with both the part material and the subsequent process(es). It allows the industrial/manufacturing engineer to customize the selection of a cleaning product based on the materials of the part to be cleaned, cleanliness required for the subsequent process(es), environmental concerns, and health and safety concerns.

6. PROCEDURES

This section presents a step-by-step approach for using this protocol. To select a technically acceptable product for a general cleaning task, a five-step process that uses a series of tables and matrices has been developed.

- Step 1: Determine the parameters surrounding the cleaning of the component
- Step 2: Determine the cleaning code
- Step 3: Select an appropriate cleaner
- Step 4: Consider other physical and chemical properties of the cleaning agent
- Step 5: Select the proper cleaning equipment

a. **Initial Product Selection**

(1) **Step 1: Determine Parameters**

(a) Determine ***reason for cleaning*** [see 4 b (1) and 4 b (2)] by analyzing written maintenance documentation.

(b) Analyze ***history of the part*** [see 4 b (4)] and select the appropriate ***class of soil*** that the part or component was subjected to.

(c) Determine ***material(s) of the component*** being cleaned [see 4 b (3)] by reviewing component drawings, consulting with maintenance personnel, or directly contacting the manufacturer.

(2) **Step 2: Determine Cleaning Code**

(a) Determine ***level of cleanliness*** required [see 4 c (2)] by selecting the *column* in Table I-4 that corresponds to the reason for cleaning (from step 1).

(b) Determine ***material compatibility*** [see 4 c (1)] by selecting the *row* in Table I-4 that corresponds to the material of the component (from step 1).

(c) The corresponding alphanumeric code in Table I-4 is the ***cleaning code***.

(3) **Step 3: Select Appropriate Cleaner.** Using the cleaning code from step 2 and test protocol requirements from Table I-6, perform *the initial selection of alternative cleaners* (see 4 d), choosing cleaners that meet the requirements of the cleaning code (for both level of cleanliness and material compatibility).

b. **Example Initial Selection Procedure**

As an example, let us go through the first three steps of the protocol using the DMWR example from Section 4 b (2):

- *Remove part from aircraft landing gear.*

- *Clean part with a rag soaked with MEK.*
- *Examine part for cracks using liquid dye penetrant process*.

From this information and from researching part drawing to determine the materials involved, we know the following:

- *Reason for cleaning*: The part being cleaned is to be inspected using liquid dye penetrant inspection.
- *History of the part and class of soils*: Since the part is being removed from an in-service aircraft, it has been subjected to at least light maintenance soils, but more likely heavy maintenance soils because it is being removed from the landing gear.
- *Material of the component*: The part is made of aluminum.

c. Using Table I-3: we determine that the proper cleaning code is 5-C:

- The level of cleanliness is 5.
- The material compatibility test protocol is C. Table I-6 shows that this requires three tests:
    - o A total immersion corrosion test
    - o An effects on unpainted surfaces test
    - o A sandwich corrosion test

Thus, any product that has been successfully evaluated against the 5-C test requirement is an acceptable cleaner for the stated maintenance action.

d. **Narrowing The Selection: Consideration Of Other Factors.** Following steps 1 through 3 to arrive at a group of cleaning products that are technically acceptable from the standpoint of cleanliness and material compatibility is the most important aspect of the cleaning agent selection effort. However, the work of the engineer is not yet complete. Additional factors must be considered in narrowing the choice of products down to one or two. The final two steps of the protocol will consider the following additional factors: physical, chemical, environmental, health and safety, and economic properties; and the type of equipment to be used.

(1) **Step 4: Consider Other Factors**

(a) From the acceptable cleaners determined in step 3, take into account ***environmental concerns*** [see 4 e (1)] and select the most environmentally acceptable cleaner, using Table I-7.

(b) Consider ***physical and chemical properties*** [see 4 e (2)] of the acceptable cleaners that are important to the facility (see Table I-8, for a partial list).

(c) Consider ***worker health and safety concerns*** [see 4 e (3)] and obtain a toxicity clearance from U.S. Army CHPPM.

(d) Consider ***other technologies*** [see 4 E (4)] that could satisfy your cleaning requirement.

(2) **Step 5: Select Equipment**

(a) Determine the shape[2] of the part using the descriptions presented in Table I-8

Based on the shape of the part use Table I-10 to determine the ***appropriate cleaning equipment*** (see 4 f).

(b) Review manufacturer's recommendations to ensure the selected cleaner is compatible with the cleaning equipment selected.

(3) **Example Selection Narrowing Procedure**

Consider other factors: Assume that five cleaning products were determined to be acceptable after completion of protocol step 3:

- Product A: Aqueous cleaner, pH - 7.0
- Product B: Aqueous cleaner; pH - 7.2
- Product C: Aqueous cleaner; pH - 11.5
- Product D: Semi-aqueous cleaner
- Product E: Type I solvent

From step 4, we can eliminate products D and E because they do not represent the most environmentally acceptable alternative (see Table I-7). If pH is a critical evaluation factor for the facility, we can drop product C because it has a higher pH value than the other two alternatives.

Select Equipment: We next determine that the part is a solid part (shape X in Table I-9). Using this information with Table I-10, we find that any of the equipment types listed in that table can be used. The final choice of either product B or C may be a function of product, process, or equipment costs.

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[2] Note: Other factors not addressed here - such as part size, throughput, footprint, and part weight - should also be considered when determining the appropriate cleaning equipment.

APPENDIX A to ANNEX I

PROTOCOL TABLES
Table I-2. Classes of Soils

Soil Category	Title	Soil Examples
I	Light manufacturing soils	Machine tool coolants (water-based) Machine tool lubricants (hydrocarbons)
II	Heavy manufacturing soils (may be in combination with category I soils)	Extrusion waxes Silicon oils Silicon greases Synthetic lubricants and preservatives 0-80 µm particulate*
III	Light maintenance soils (may be in combination with category I and/or II soils)	0-200 µm particulate* Cured thickness: 0.2-0.4mm of soil
IV	Heavy maintenance soils (may be in combination with category I, II and/or III soils)	Heavy hydraulic oils Petroleum-based oils and greases Water and hydrocarbon based fluorescent dye penetrants Cured thickness: 0.4-0.8 mm of soil

* Note 6 ASTM G-121

Table I-3. Levels of Cleanliness

LEVEL *	INSPECTION TYPE	DESCRIPTION
1	**Visual inspection (white light)**	Under strong white light, the item is inspected for the presence of contaminants and for the absence of accumulation of lint fibers. This method will detect particulate matter larger than 50 µm and moisture, oils, greases, etc., in visual amounts.
2	**Wipe test (white glove test)**	Should be used to detect oils and other surface contaminants that may be inaccessible or undetectable by visual inspection. Rub the surface lightly with a clean white paper, then examine the paper under white light. The area should not be rubbed hard enough to remove the oxide film, as this could be confused with surface contamination.
3	**Water break test**	This test may be used to detect some oily residues not found by other means. Wet with a spray of distilled water. If the part is free of these oily residues, the water should form a thin layer that remains unbroken for at least five seconds. "Beading" of water droplets indicates the presence of oil contaminants.
4	**ASTM G-122 standard test**	Test method is based on coupon testing to determine the effectiveness of cleaners and uses the weight of the contaminant removed to determine the cleaning efficiency.

* 1 is the least stringent level of cleanliness, 4 is the most.

Table I-4. Cleaning Code Identification Matrix[1]

Precleaning	Pre-plate cleaning [2]	Pre-NDT cleaning[3]	Pre-bond cleaning	Pre-paint cleaning	Cosmetic cleaning	Special cleaning: hydraulic parts and bearings	
Carbon & low alloy steel	1-A	3-A	4-A	4-D	3-A	2-A	3-A
Cobalt alloys	1-A	3-A	4-A	4-D	3-A	2-A	3-A
Nickel alloys	1-A	3-A	4-A	4-D	3-A	2-A	3-A
Titanium alloys	1-B	3-B	4-B	4-E	3-B	2-B	3-B
Stainless steel	1-A	3-A	4-A	4-D	3-A	2-A	3-A
Iron	1-A	3-A	4-A	4-D	3-A	2-A	3-A
Aluminum	1-C	3-C	4-C	4-F	3-C	2-C	3-C
Magnesium	1-C	3-C	4-C	4-F	3-C	2-C	3-C
Brass or Bronze	1-C	3-C	4-C	4-F	3-C	2-C	3-C
Copper alloys	1-C	3-C	4-C	4-F	3-C	2-C	3-C
Metal honeycomb	1-A	3-A	4-A	4-D	3-A	2-A	3-A
Rubber compounds	1-G	N/A	N/A	1-H	3-G	2-G	3-G
Thermoset plastics	1-J	3-J	N/A	4-J	3-J	2-J	3-J
Thermo plastics	1-I	3-I	N/A	4-J	3-I	2-I	3-I
Acrylics	1-K	3-K	N/A	4-L	3-K	2-K	3-K
Polycarbonates	1-K	3-M	N/A	4-L	3-K	2-K	3-K
Optics	1-J	3-J	N/A	4-M	3-J	2-J	N/A
Polyamide wiring	1-N	N/A	N/A	N/A	3-N	2-N	3-N
Leather & fabrics	1-O	N/A	N/A	4-O	3-O	2-O	N/A
Painted surfaces	1-P	N/A	N/A	N/A	3-P	2-P	3-P
Polysulfides	1-Q	N/A	N/A	4-R	3-Q	2-Q	3-Q

Footnotes:

1 The cleaning codes are in the following format: (cleanliness level)-(test protocol). Cleanliness levels are shown in Table A-2 and test protocols are given in Table A-5. The recommended cleanliness levels are *minimums,* and may be exceeded as necessary. This is especially relevant with regard to adhesive bonding of composites

2 Metallic bonding includes plating, welding, metallic spray, and any other metal-metal fusing, reduction process or chemical treatment.

3 Levels of cleanliness suggested in this protocol for the NDT category are for fluorescent dye penetrant inspection.

Table I-5. Specific Material Compatibility Test Titles and Standards

Test #	Test Title	Standard	Standard Title
1	Total immersion corrosion	ASTM D-930/ ASTM F-483	Method for Total Immersion Corrosion Test for Aircraft Maintenance Chemicals
2	Effects on unpainted surfaces	ASTM F-485	Test Method for Effects of Cleaners on Unpainted Aircraft Surfaces
3	Effects on painted surfaces	ASTM F-502	Test Method for Effects of Cleaning and Chemical Maintenance Materials on Painted Aircraft Surfaces
4	Hydrogen embrittlement	ASTM F-519	Method for Mechanical Hydrogen Embrittlement Testing of Plating Processes and Aircraft Maintenance Chemicals
5	Sandwich corrosion	ASTM F-1110	Test Method for Sandwich Corrosion Test
6	Stress corrosion of titanium alloys	ASTM F-945	Test for Stress Corrosion of Titanium Alloys
7	Polyamide wire	See Annex B	Test for Polyamide Wire Compatibility
8	Stress crazing of acrylic plastics	ASTM F-484	Test Method for Stress Crazing of Acrylic Plastics in Contact with Liquid or Semi-Liquid Compounds
9	Rubber compatibility	AMS 3204/3209	Test for Rubber Compatibility
10	Low-embrittling cadmium plate corrosion	ASTM F-1111	Corrosion of Low Embrittling Cadmium Plate by Aircraft Maintenance Chemical
11	Effects on polysulfide sealant	ASTM D-2240	Test Method for Rubber Property - Durometer
12	Floating roller peel resistance of adhesives	ASTM D-3167	Floating Roller Peel Resistance of Adhesives
13	Peel resistance of adhesives	ASTM D-1876	Peel Resistance of Adhesives
14	Climbing drum peel test for adhesives	ASTM D-1781	Climbing Drum Peel Test for Adhesives
15	Strength properties of adhesives in shear by tension loading	ASTM D-1002	Strength Properties of Adhesives in Shear by Tension Loading
16	Determining durability of adhesives joints stressed in shear	ASTM D-3762	Adhesive Bonded Surface Durability of Aluminum (Wedge Test)
17	Adhesive-bonded surface durability of aluminum (wedge test)	ASTM D-3762	Adhesive Bonded Surface Durability of Aluminum (Wedge Test)
18	Peel or stripping strength of adhesive bonds	ASTM D-903	Peel or Stripping Strength of Adhesive Bonds

Table I-6. Material Compatibility Test Protocol Requirements

Protocol	Applicable Tests (from Table A-5)
A	1, 2, 4, 5, 10
B	1, 2, 4, 5, 6, 10
C	1, 2, 5
D	1, 2, 4, 5, 10, 12, 13, 14, 15, 16, 17, 18
E	1, 2, 4, 5, 6, 10, 12, 13, 14, 15, 16, 17, 18
F	1, 2, 5, 12, 13, 14, 15, 16, 17, 18
G	2, 9, 11
H	2, 9, 12, 13, 16, 18
I	8, 11
J	8, 11, 12, 13, 14, 15, 16, 17, 18
K	8
L	8, 12, 13, 14, 15, 16, 17, 18
M	13, 14, 15, 16
N	2, 7, 9, 11
O	2
P	1, 3
Q	11
R	11, 12, 13, 14, 15, 16, 17, 18

Table I-7. Environmental Preference

Preference *	Chemistry of cleaner	Product examples
1	Aqueous	Detergents, soaps (non-terpene)
2	Semi-aqueous	Emulsion cleaners (soluble oils, water-reducible terpenes), ammonia solution, 10% isopropanol
3	Type I solvents(low vapor pressure HC [<7mm Hg], not listed as HAPs or SARA 313, evaluated and are not carcinogens, mutagens, reproductive or developmental toxins)	Paraffinic and aliphatic hydrocarbons (Stoddard solvent, varsol, naptha)Hydrocarbon/Terpene blendsExempt halogenated solvents
4	Type II solvents (all other non-ODC solvents)	MEK, acetoneNonexempt halogenated solvents

* 1 is the most preferable, 4 is the least.

Table I-8. Basic Tests for Non-critical Properties

Test #	Test Title	Standard	Standard Title
A	Flash point	ASTM D-56ASTM D-92ASTM D-93	Test Method for Flash Point, Tag Closed Tester and/or Cleveland Open Cup, and/or Pensky-Martens Closed Cup
B	pH value	ASTM E-70	Test Method for pH of Aqueous Solutions with the Glass Electrode
C	Foaming properties	ASTM D-3519ASTM D-3601	Foam in Aqueous Media, (Blender Test) and/or (Bottle Test)
D	Toxicity	N/A	U.S. Army CHPPM (Toxicity Clearance)
E	Biodegradability	ASTM E-1720	Determining Ready, Ultimate, Biodegradability of Organic Chemicals in Sealed Vessels, CO_2
F	Storage stability	ASTM D-3707	Storage Stability of Water-in-Oil Emulsions by the Oven Test Method
G	Storage stability	ASTM F-1104	Test Method for Preparing Aircraft Cleaning Compounds, Liquid Type Water Base, for Storage Stability Testing
H	Temperature stability	ASTM D-3709	Stability of Water-in-Oil Emulsions Under Low to Ambient Temperature Cycling Conditions

Table I-9. Shape of Component to Be Cleaned

Shape	Description
X	Solid parts, or parts with large or shallow holes
Y	Hollow parts, or parts with small or deep holes
Z	Delicate or honeycomb composite parts

Table I-10. Cleaning Equipment Selection Table

		Application*			
Equipment Number	**Process type**	**General Pre-Clean**	**Part shape "X"**	**Part shape "Y"**	**Part shape "Z"**
1	Agitated bath - cold	No	Yes	Yes	No
2	Agitated bath - hot	No	Yes	Yes	No
3	High pressure spray - glove box	No	Yes	No	No
4	High pressure spray - rotating spray	No	Yes	No	No
5	High pressure spray – turntable	No	Yes	No	No
6	Hand wipe	No	Yes	Yes	Yes
7	Immersion bath – cold	Yes	Yes	Yes	No
8	Immersion bath - hot	Yes	Yes	Yes	No
9	Manual-steam clean	Yes	Yes	Yes	No
10	Manual - mechanical	Yes	Yes	Yes	No
11	Spray booth	No	Yes	No	No
12	Spray bottle	No	Yes	Yes	Yes
13	Ultrasonic immersion	No	Yes	Yes	Yes
14	Vapor degreaser	No	Yes	Yes	Yes

* From Table A-9

APPENDIX B to ANNEX I

TEST FOR EFFECT ON POLYIMIDE INSULATED WIRE

1. The cleaning compound shall not cause dissolution, crazing, or dielectric breakdown of polyimide insulated wire in excess of that produced by distilled water.

a. Coil two segments of MIL-W-81381/11-20 wire approximately 61 cm (24 in) tightly around a 0.3 cm (.125 in) diameter bar and place into separate 118 ml (4 oz) wide mouth jars. To one jar add sufficient concentrate cleaning compound to completely cover the wire coil. To the other jar (control sample) add sufficient distilled water to completely cover the wire coil. Cap both jars and store at room temperature for 14 days.

b. At the end of the storage period remove both coils, rinse thoroughly with distilled water and suspend to allow complete draining and drying.

c. Uncoil the wires, examine each closely for dissolution, and record the results.

d. Both wires shall then be subjected to a double reverse wrap on a 0.3 cm (.125 in) diameter bar and examined for cracking under a 10 power lens. If cracking occurs the results shall be recorded.

e. Wire passing 1.4 and 1.5 above shall then withstand a one minute dielectric test of 2,500 volts (rms), using a Hypot model number 4045 or equivalent, and examined for breakdown and/or leakage.

2. Wire immersed in the cleaner shall perform equally well as the control wire immersed in distilled water.

APPENDIX B

Literature Cited in Appendix A

1. Final Rule 59 FR 61801, to control air emissions from cleaning machines using halogenated solvents, issued 2 December 1994.
2. Substitution and Minimization of Solvent Cleaners Used at the Naval Air Rework Facilities, Naval Air Development Center (NAVAIRDEVCEN) Report No. NADC-79278-60 (5 March 1980).
3. Joint Services Pollution Prevention Technical Library: http://es/epa.gov.gov/index.html
4. EPA's SARA Title III List of Lists: http://www.afcee.brooks.af.mil/p2cd/handplan/other/012.htm
5. EPA's Significant New Alternatives Policy (SNAP) Program: http://www.epa.gov/ozone/title6/snap
6. Bush, Thomas A., and Koehler, David A., Army Facility Ozone-Depleting Chemical Abatement Plan, August 1996.
7. U.S. Army Acquisition Pollution Prevention Support Office and U.S. Army Center for Technical Exchange for Solvent Substitution, Standard Protocol for Selecting General Cleaning Agents and Processes.