REPORT NO. NADC-84002-60

CLEANING COMPOUND EFFICIENCY TEST METHOD FOR AIRCRAFT SURFACE CLEANERS

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22 November 1983

PROGRESS REPORT
AIRTASK F61542001
Work Unit ZA530

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED

Prepared for
NAVAL AIR SYSTEMS COMMAND
Department of the Navy
Washington, D.C. 20361

8400151

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REPORT DOCUMENTATION PAGE

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1. REPORT NUMBER NADC-84002-60	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) CLEANING COMPOUND EFFICIENCY; TEST METHOD FOR AIRCRAFT SURFACE CLEANERS		5. TYPE OF REPORT & PERIOD COVERED PROGRESS REPORT
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) K. G. CLARK		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Naval Air Development Center (Code 6062) Warminster, PA 18974		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS AIRTASK F61542001 Work Unit ZA530
11. CONTROLLING OFFICE NAME AND ADDRESS Naval Air Systems Command Washington, DC 20361		12. REPORT DATE 22 November 1983
		13. NUMBER OF PAGES
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

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17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Soil	Cleaning Compound
Lubricating Oil	Cleaning Efficiency
Hydraulic Fluid	Test Method
Silicone Oil	Coatings

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A reproducible, quantitative method for determining cleaning efficiency is described. The method uses a camouflage paint substrate (gloss = 9.0) and various aircraft fluids mixed with carbon black. Tenacity of the soil, from most difficult to clean to easiest to clean, was as follows: MIL-H-5606, MIL-S-81087, MIL-L-23699, MIL-H-83282, Coolanol 25R.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

This report describes a method for measuring the cleaning ability of modern aircraft exterior surface cleaners. This method contrasts with that of reference (a) by utilizing common aircraft fluids to which carbon black has been added. While reference (a) discusses a "dry" carbonaceous soil, the simulated soils developed for this method using various aircraft fluids are classified as "oily" carbonaceous types. The combination of "dry" and "oily" provide nearly a full spectrum of aircraft soils against which exterior aircraft cleaners can be evaluated. In addition, this method can also be used to evaluate the cleanability (the ease with which a surface may be cleaned) of a paint film, by employing a standard cleaning compound. This is important for paints, such as the new low gloss countermeasure coatings.

This investigation was performed under AIRTASK F61542001, Work Unit No. ZA530 on maintenance chemicals development.

BACKGROUND

The development of cleaning compound specifications, whether military, Federal or commercial, is often complicated by the lack of adequate methods for evaluating the efficiency or ability of the material to perform its intended function - that is, to clean. Several methods have been developed using heavily oxidized oils (as in Military Specification MIL-C-43616) or artificial mixtures of such materials as white mineral oil and hydrogenated vegetable shortening (as in Federal Test Method Standard No. 536 Method 6701). While cleaners procured using such acceptance tests will work well on non-polar hydrocarbons, other soils such as hydraulic fluid residues, silicone oils, and coolants may not be so easily removed.

Another consideration is the type of surface or coating to be cleaned. Until recently, the coating system for nearly all naval aircraft included a gloss topcoat, and nearly any liquid laboratory soil (if not extremely viscous) could be mechanically wiped from the surface without the aid of a cleaning solution. This is not the case with camouflage or low gloss, countermeasure coatings. The surface roughness of these coatings allows the soil to reside in pores not directly contacted by the cleaning pad or cloth. In this situation, agitation on the surface of the coating must produce shear forces of sufficient magnitude in the pore that the adhesive forces binding the soil are overcome. Such shear forces are probably much smaller than those achieved by direct contact of the cleaning pad.

Many substrate/soil combinations cannot be separated without mechanical work, known as the work of agitation, W_{AGIT}. In most cases, only a small part of the work of agitation goes to overcome the work of soil/substrate adhesion. This inefficiency depends on factors such as substrate geometry (porosity, smoothness, etc.), viscosity of the cleaning solution, and cleaning pad construction. A rough or porous paint surface requires much more mechanical agitation than a smooth surface to overcome the same adhesive forces holding the soil.

CLEANING EFFICIENCY METHOD

The test method contained in Appendix A was designed for evaluation of cleaning compounds containing reduced solvent concentrations and is now used in Military Specification MIL-C-85570, Cleaning Compound, Aircraft Exterior. Briefly, a mixture of carbon black (9 percent by weight) and the fluid of interest is milled on a dispersator for 15 minutes to reduce agglomeration. Using a Gardner Heavy-Duty Wear Tester, five drops of this soil are smudged across a test panel topcoated with MIL-C-83286, Coating, Urethane, Aliphatic Isocyanate, For Aerospace Applications (Color No. 36440, 60° Gloss = 9.0).

Panels were cleaned using the same device but angled at +45 degrees then -45 degrees to the cleaning stroke. Panel lightness determined using the Lab color coordinate system measured prior to soiling (L_v), after soiling (L_s), and after cleaning (L_c), were used to calculate cleaning efficiency:

$$\text{(3)} \quad \text{Cleaning efficiency (percent)} = \frac{L_c - L_s}{L_v - L_s} \times 100$$

When the cleaning efficiency test method is used with a single, standard cleaning compound where the independent variable in the procedure is the substrate to which the soil is applied, then the measured value is known as the cleanability of the substrate. This work will be reported at a later date in a study of the cleanability of low gloss urethane topcoats.

TEST RESULTS

Cleaning efficiencies of four proprietary aircraft surface cleaners were measured using four aircraft fluids mixed with carbon black: MIL-H-5606, Hydraulic Fluid, Petroleum Base, Aircraft Missile and Ordnance; MIL-S-81087, Silicone Fluid, Chlorinated Phenyl Methyl Polysiloxane, NATO Code Number H-536; MIL-H-83282, Hydraulic Fluid, Fire Resistant, Synthetic Hydrocarbon Base, Aircraft, NATO Code Number H-537; and MIL-L-23699, Lubricating Oil, Aircraft Turbine Engine, Synthetic Base. In order to choose test parameters which minimized variability, three different series were examined: Series (1) baked soil (220°F (104°C) for 30 minutes) with a cleaner concentration of 20 volume percent, Series (2) unbaked soil with a cleaner concentration of 20 volume percent, and Series (3) unbaked soil with a cleaner concentration 10 volume percent.

Horizontal bar charts shown in Figures 1, 2, and 3 illustrate the results of Series (1), (2), and (3) respectively. Each cleaning efficiency value at the end of a bar on the chart is an average of two cleaning efficiency test results. While two replicates was not suitable for comparing one cleaner against another, it was used to compare the variability of one series with another. This was done by pooling the variance of all results for a single series using the following equation:

$$\text{(4)} \qquad s_p^{\,2} = \frac{\sum_{i=1}^{k} (Y_{i1} - Y_{i2})^2}{2k}$$

where k is the number of replicate pairs (16 pairs for each Series). The pooled standard deviation ($s_p = \sqrt{s_p^{\,2}}$) for each series of tests was as follows:

Series	Pooled standard deviation (S_p)
(1) Baked (Cleaner Conc. = 20%)	3.99
(2) Unbaked (Cleaner Conc. = 20%)	2.69
(3) Unbaked (Cleaner Conc. = 10%)	2.64

While Series (3) appeared to have the least inherent variability, it should be noted that an F-test showed no difference in variability between any two series at the 5 percent level of significance.

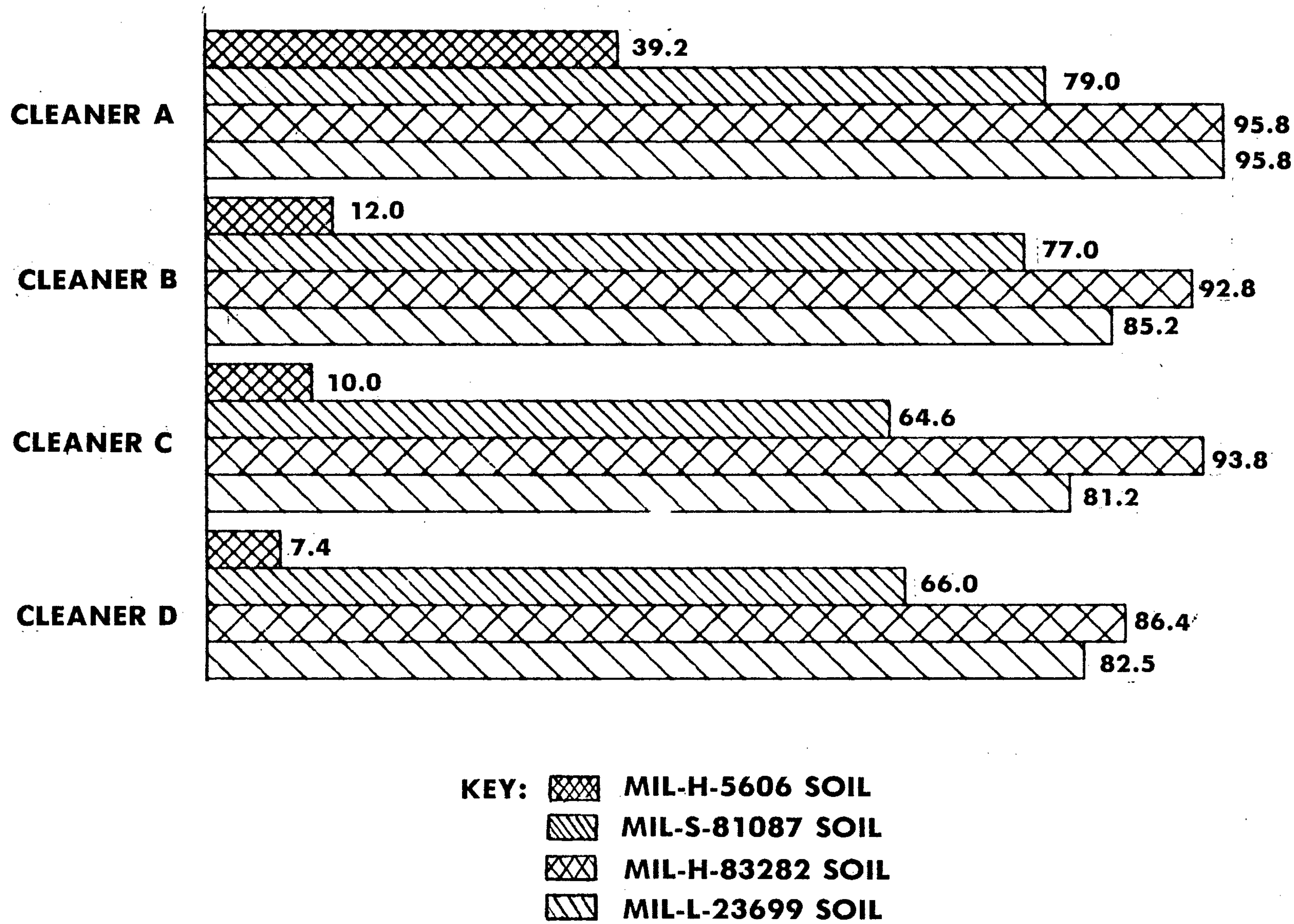

Figure 1. Cleaning efficiencies (in percent) of four aircraft surface cleaners (Series No. 1: Baked soils, Cleaner Concentration = 20 volume percent.)

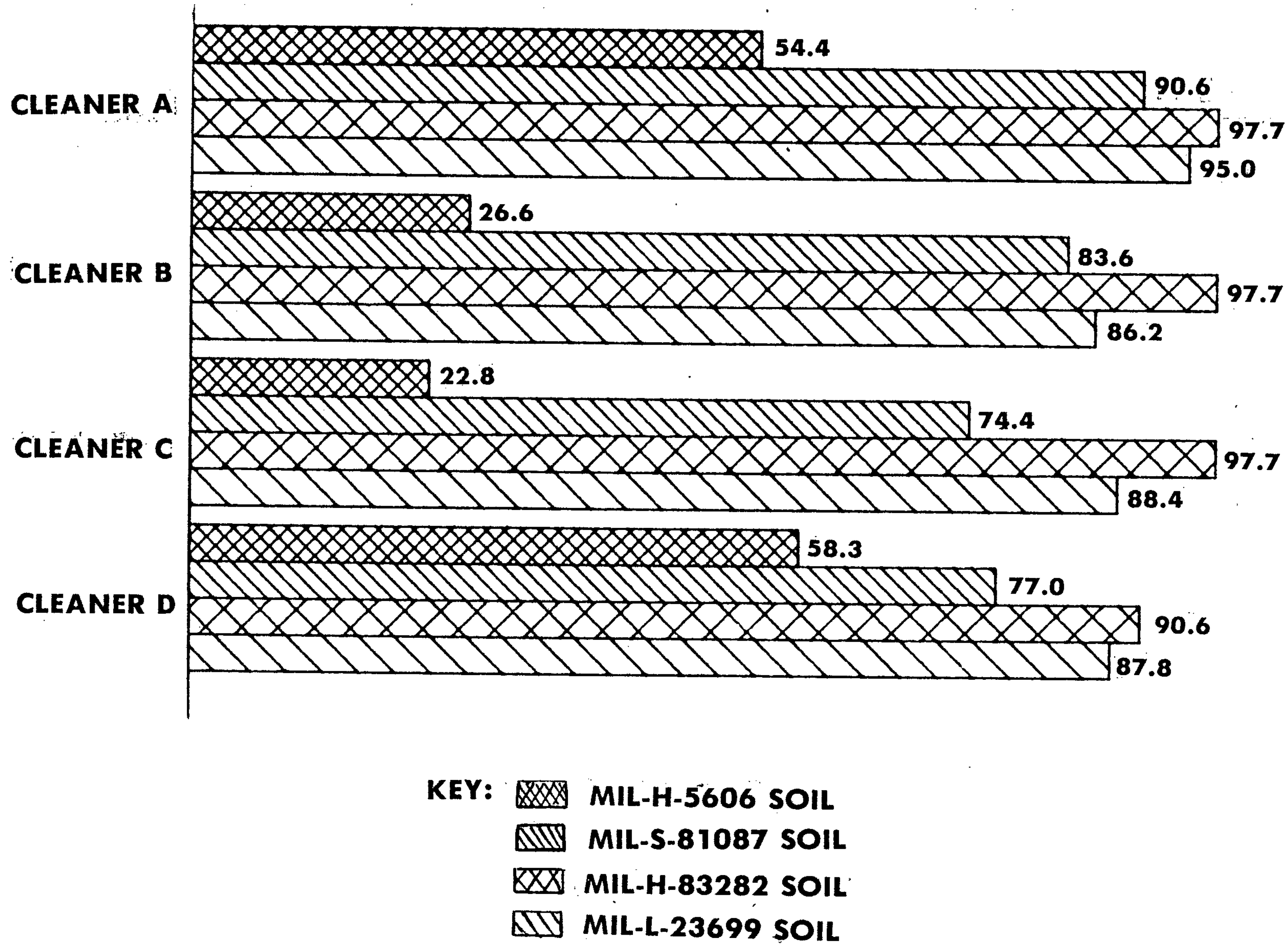

Figure 2. Cleaning efficiencies (in percent) of four aircraft surface cleaners (Series No. 2: Unbaked soils, Cleaner Concentration = 20 volume percent)

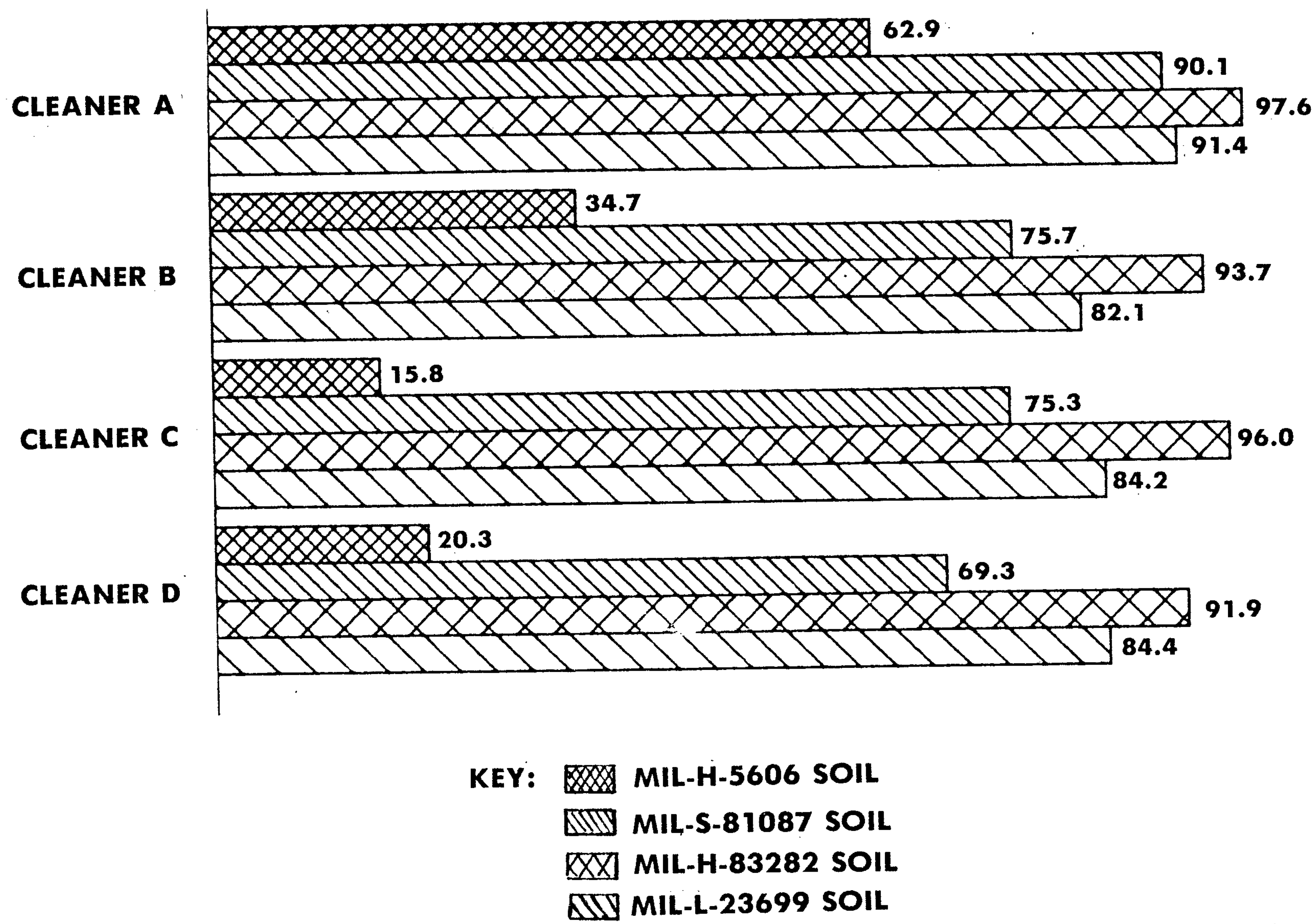

Figure 3. Cleaning efficiences (in percent) of four aircraft surface cleaners (Series No. 3: Unbaked soils, Cleaner Concentration = 10 volume percent)

Table I summarizes the results of Figures 1, 2 and 3 by averaging the results of all four cleaners for each soil/post treatment combination.

Table I
Cleaning Efficiency Results
(percent soil removal)

Series	#1	#2	#3
Post treatment	Baked @220°F	None	None
Cleaner concentration (%)	20	20	10
SOIL			
MIL-H-5606	17.15	40.52	33.42
MIL-S-81087	71.65	81.40	77.60
MIL-H-83282	92.20	95.92	94.80
MIL-L-23699	86.18	89.35	85.52

While there is relatively little variation in soil removal results for MIL-S-81087, MIL-H-83282, and MIL-L-23699 soils between the three series, a large deviation is noted for MIL-H-5606 when baked (Series No. 1). The tenacity of the soils, as determined by the average soil removal results (Table I), follows the same order for each series: MIL-H-5606 (most tenacious, lowest soil removal results) $\gg$ MIL-S-81087 $>$ MIL-L-23699 $>$ MIL-H-83282 (least tenacious, highest soil removal results).

Finally, cleaning efficiencies were also measured using Monsanto's Coolanol 25R mixed with carbon black. However, all measured efficiencies exceeded 95 percent. Since results which are bunched at one end of the 0 to 100 percent soil removal range tend to exhibit limited variability, the Coolanol results were not included in variance calculations in order to better judge the variability of the method.

CONCLUSION

The relatively small standard deviations associated with this cleaning efficiency test method make it an important tool for evaluating the effectiveness of a cleaner and for developing performance requirements for procurement specifications. In addition, the method can be used to determine the tenacity of various maintenance fluid soils as well as to identify cleaning compounds efficient in removing them.

In addition, it has been shown that artificially aged soils are somewhat more difficult to remove than unaged soils, especially in the case of MIL-H-5606. This fluid is composed of a light petroleum oil and an acrylic viscosity modifier. When the oil is made to evaporate by baking, the residual acrylic matter becomes very difficult to remove. Even without baking, MIL-H-5606 is quite tenacious. Listed in order of decreasing tenacity, the soils are:

MIL-H-5606	Baked	
MIL-H-5606	Unbaked	
MIL-S-81087	Baked	Difference may be insignificant
MIL-S-81087	Unbaked	
MIL-L-23699	Baked or Unbaked	
MIL-H-83282	Baked or Unbaked	
Coolanol 25R	(Monsanto)	

RECOMMENDATIONS

This test method was recommended for and has been adopted in the latest revision of Military Specification MIL-C-85570, Cleaning Compound, Aircraft Exterior. It is recommended that further work be performed on the various low gloss paint systems to determine any differences in cleanability which might hinder wash rack crews. This method may also be useful in topcoat specifications to specify a minimum acceptable level of cleanability, as measured by the cleaning efficiency of a standard cleaner.

REFERENCES

(a) Clark, K.G. and Vinson, J.H., "Carbonaceous Soil Removal, Part I - Method for Evaluation of Cleaning Compounds," Report No. NADC-77313-60 of 3 Jan 78.

ACKNOWLEDGEMENT

The author wishes to acknowledge the dedicated, untiring support of Mr. Edward T. Heebner, Jr. in performing these experiments.

APPENDIX A

Scope. This test method measures the cleaning efficiency of aircraft surface cleaners using soils prepared from common military aircraft maintenance fluids mixed with carbon black.

Apparatus.

1. Gardner Heavy-duty Wear Tester (see Figure A-1). The wear tester shall be fitted with a wooden block, 2.6 inches by 3.7 inches (66 millimeters by 94 millimeters) to which a white, fibrous cleaning pad covered with terry or flannel cloth may be attached. The pad shall exert 0.40 ± 0.01 pounds per square inch (2.76 ± 0.07 KPa) of pressure on the test panel. A template (see Figure A-2) shall be used with the wear tester to hold test panels at the required angle to the direction of the block movement.

2. High shear mixer. Premier Mill Corporation Dispersator or equivalent Cowles-type mixer.

3. Colorimeter. McBeth Model MC-1010S or other device suitable for measuring test panel lightness (the value L from the Lab color coordinate system) to ± 0.1 units.

4. Disposable pipette with a tip outside diameter of 0.055 ± 0.004 inches (1.4 ± 0.1 millimeters).

Materials.

1. Aircraft maintenance fluids as required.

2. Carbon black. Columbian Carbon Company Raven 1040 or equivalent.

3. Test panels. Aluminum test panels, 2.5 inches by 6 inches by 0.020 inches (64 mm by 152 mm by 0.51 mm), shall be finished and dried as shown in Table A-1.

4. Flannel cloth. CCC-C-458, Type II, Class 1.

5. Terry cloth. MIL-C-1164.

6. Cleaning pad. MIL-C-83957, Type I.

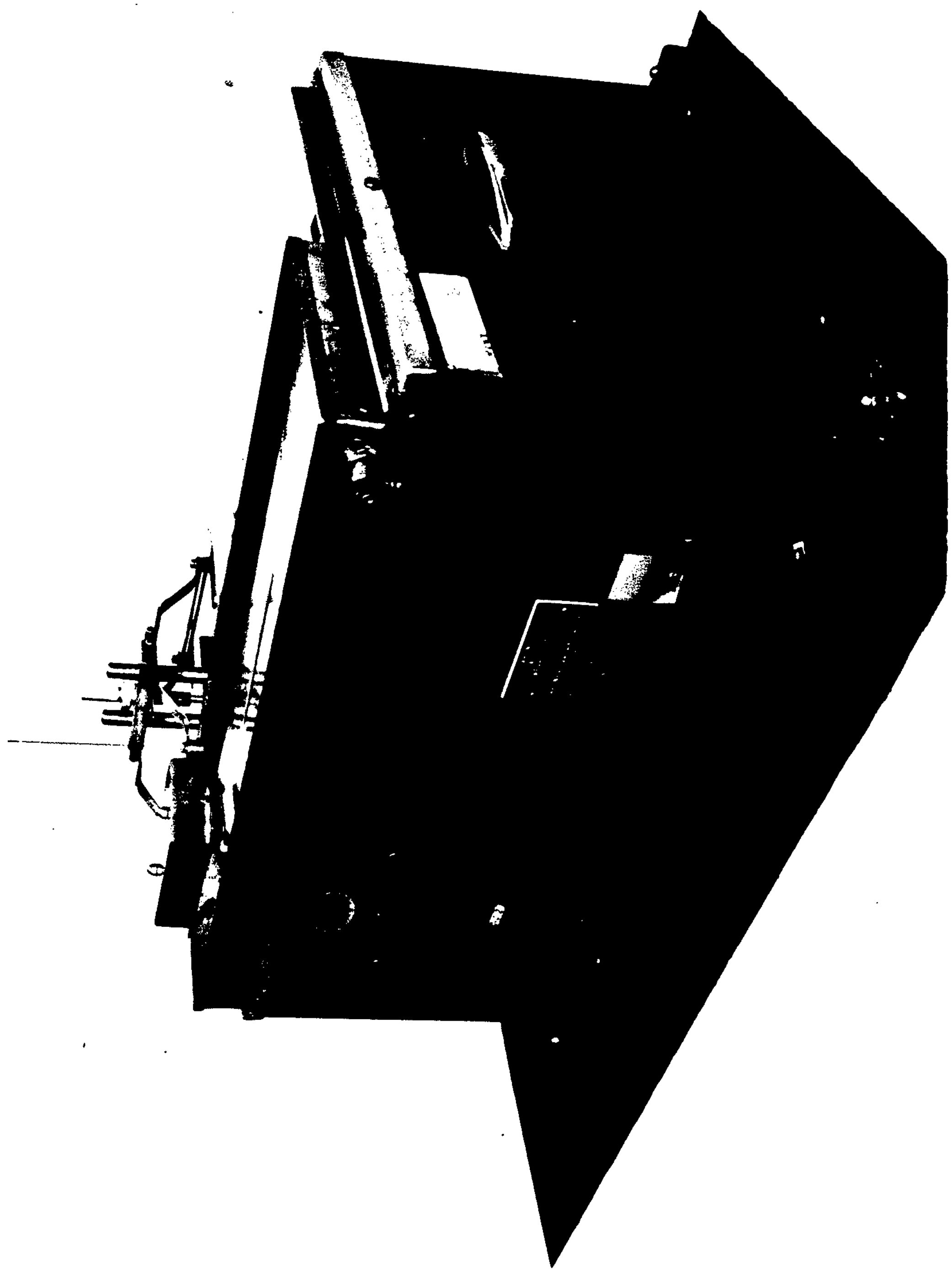

Figure A-1. Gardner Heavy-Duty Wear Tester

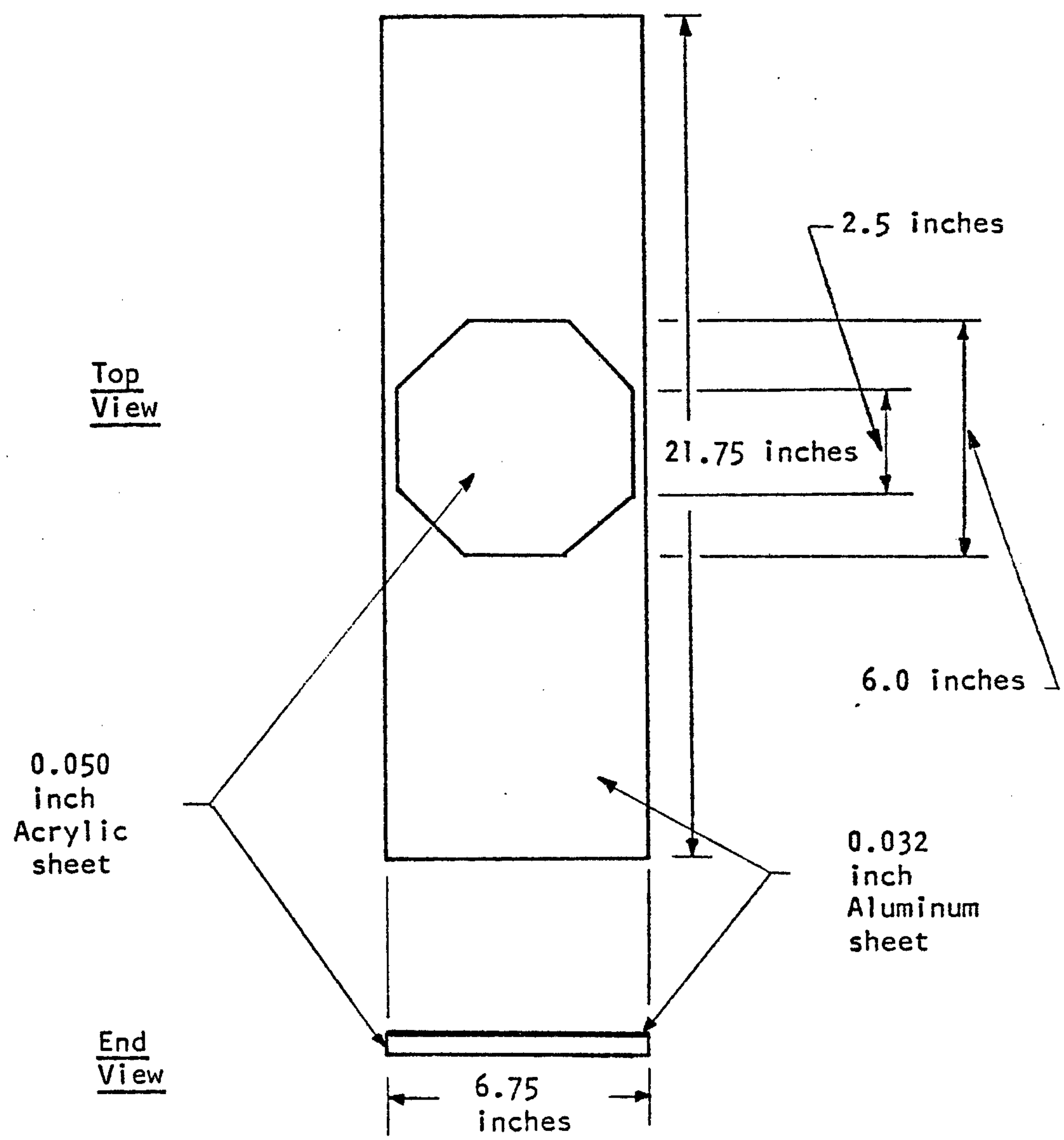

Figure A-2. Assembled template (Note: aluminum sheet is screwed to the acrylic sheet with countersunk machine screws ¼-inch in length)

TABLE A-I. TEST PANEL FINISHING

Step	Coating	Drying time	Drying temperature
1	MIL-C-5541 chemical conversion coating	2 hours	ambient
2	MIL-P-23377 epoxy primer (thickness = 0.6-0.9 mils)	1 hour	ambient
3.	MIL-C-83286 polyurethane topcoat, camouflage: 60-degree gloss = 9.0 $\pm$ 1.0 (thickness = 2.0 mils)	1 week	ambient
4	-	1 week	150^{o}F

Soil Preparation. Add 50 grams (0.011 pounds) carbon black to 500 grams (1.10 pounds) of the fluid of interest and mill for 15 minutes at the highest speed obtainable on the high shear mixer without splashing. If any carbon black agglomerates can be seen, continue mixing until homogeneous.

Procedure. Determine the lightness of an unsoiled test panel (Lv). After manually shaking the soil in its container to assure uniformity, deposit five drops of the soil of interest across the narrow dimension of a test panel about one-half inch from one end. Draw the soiled pipette across the drops without removing or adding soil. Place the test panel in the template parallel to the block movement with the soiled end toward the block. Attach the flannel and cleaning pad to the block and activate the wear tester to smudge the soil across the test panel for 20 cycles of the wear tester. One cycle consists of two passes over the test panel - one in each direction. Remove the test panel and bake, if required. Immediately, determine the lightness of the soiled test panel (L_s) and perform the following cleaning operation within 1 hour.

Place the soiled test panel in the template at +45 degrees to the block movement. Attach the terry cloth and cleaning pad to the block soaking the block with the cleaning solution to be tested. Immediately, pour enough cleaning solution onto the test panel to cover it for 30 seconds. After the 30 second dwell time, activate the wear tester to clean the test panel for 10 cycles. Then lift the panel from the template and replace it at -45 degrees to the block movement and continue the cleaning for 10 additional cycles. Rinse without agitation under running tap water and blot dry with absorbent tissue. Determine the lightness of the cleaned panel (L_c) only at a point exposed to all 20 cleaning strokes.

Calculate the cleaning efficiency of the solution as follows:

$$\text{(A1)} \quad \text{Cleaning efficiency (percent)} = \frac{L_c - L_s}{L_v - L_s} \times 100$$

Report.

1. Cleaning compound.
2. Cleaning compound concentration in the cleaning solution.
3. Aircraft fluid.
4. Baking time and temperature, if any.
5. Cleaning compound efficiency. Report the average and standard deviation of 4 test panels for each set of conditions.

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