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INTERIM REPORT

IMPROVED RIFLE BORE CLEANER

BY

MARY J. CARROLL

AUGUST 1972

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13. ABSTRACT

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Details of illustrations in
this document may be better
studied on microfiche

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I. INTRODUCTION

Reports from the field have indicated that rifle bore cleaners procured under Specification MIL-C-372b, Cleaning Compound, Solvent (for Bore of Small Arms and Automatic Aircraft Weapons) (1), do not remove copper fouling nor do they completely remove soil from weapons. Soil on weapons is composed of primer and powder residues plus environmental soils such as dust, mud, water, etc. Weapon bores are also fouled by copper. In larger weapons frequently incomplete obturation by a rotating band causes the high velocity gases following the projectile to sweep past the projectile and deposit molten copper in the bore. In small arms, copper is deposited in the bore from gilding metal or jacket ruboff (2). The copper can be found even in minute cracks in chrome plated barrels (3). Since liquid copper can attack Cr-Mo-V steel, the need exists for periodic removal of copper from weapon barrels.

Specification MIL-C-372b supercedes Specification JAN-C-372, Cleaner, Rifle Bore, which was a cleaner of the type that contains an organic soap emulsion or a paraffin oil, solvent, and water. The presence of water in the cleaner was needed to remove corrosive primer deposits. Corrosive primers contained potassium chlorate which formed potassium chloride when the primers were fired. The salt could not be removed by merely wiping the interior of the barrel, nor was it removed by swabbing lubricating oil or grease through the barrel. Moisture absorbed by the salt when the humidity was high initiated barrel corrosion. Washing the barrel with hot water removed the salt, but the weapon then had to be thoroughly dried and lubricated to prevent rusting. Water-and-oil emulsion formulations were preferred since the average soldier disliked using water on a weapon. The emulsion cleaners contained enough water to remove the salt and left an oily film to reduce rusting.

The Germans were using a primer which did not cause rusting in 1900 and the Swiss had one by 1911. The early primers, however, contained fulminate of mercury which has a short storage life. The primers would misfire or hang-fire after being stored a year or two, especially in hot, damp climates. By 1930, commercial noncorrosive primers were widely used in this country, but due to the storage problems, the Army continued to use the corrosive type until August 1949 when a decision was made to abandon the corrosive primer. The change to noncorrosive primers was slow, and as late as 1952 corrosive primers were still being manufactured for military use.

A variety of commercial rifle bore cleaners exist. Many of them claim to be "nitro-solvents" or "powder solvents". Since combustion of the powder was believed to leave an acid residue which caused corrosion, cleaners were based on amyl acetate, acetone, or other solvents known to dissolve powder residues. The theory has been discredited but the cleaners remain.

Copper fouling can be removed by the use of Ordnance Department Metal Fouling Solution, "Ammonia Dope". This is a solution of ammonium persulfate, ammonium carbonate, ammonium hydroxide and water. The gun barrel is stoppered and the bore soaked in this solution. There are a number of disadvantages to the use of this cleaner. It corrodes gun metal at the air-liquid interface, consequently the user has to be very careful to make sure the metal is completely covered with the solution and that none leaks into the breech mechanism. The cleaner has to be prepared fresh because old solutions are corrosive to steel. On occasion, even fresh solution will attack the steel and etch it badly enough to ruin the surface (4). This solution is still recommended for use by the U.S. Army (5). Table I contains the formulations of cleaners and copper removing compositions printed in the open literature.

The removal of copper by dissolving it in an ammoniacal solution in the presence of an oxidizer was the basis of a patent in 1913 for R.R. Moreno (6). Copper forms stable complex ions with ammonia in aqueous solution. Oxygen or another oxidizer is necessary to oxidize the copper to Cu (I) which forms a diammine ion $[Cu(NH_3)_2]^+$. Since Cu (I) in complex cations is generally considered to have a coordination number of four, the formula of the diammine ion does not represent the actual structure of the complex. The tetrammine complex $[Cu(NH_3)_4]^{++}$ is formed when Cu (II) is present. Both these complexes form soluble compounds with Cu (I) and Cu (II) ions.

Cleaners procured under Specification JAN-C-372 were evaluated for weapon cleaning capability at Springfield Armory and the cleaning was found to be unsatisfactory (7). In tests at Rock Island Armory, the specification MIL-C-372b cleaner was found to be poor in all aspects of cleaning (8). However, the rifle bore cleaner was formulated primarily to remove primer salts and cleaning was secondary (9). The tests at Rock Island also showed that residues could be removed from porcelain by cleaning with water containing approximately 5% sodium silicate. Little difference was detected between residue removal with or without a detergent in the water. Tests at the same time showed that Specification P-C-111b, Carbon Removing Compound, removed the soil. Specification P-C-111b was designed as an engine part cleaner but it is also recommended for use by maintenance personnel to remove weapon soil (10). However, the carbon loosener contains chemicals which are considered toxic on prolonged or repeated contact. Both ethylene glycol monobutyl ether (butyl "Cellosolve") and diethylene glycol monobutyl ether (butyl "Carbitol"), for example, can be absorbed through the skin and may damage liver, kidneys and other organs (11). A rifle bore cleaner with this degree of toxicity would be unacceptable for use by soldiers in the field who would not be expected to promptly wash the cleaner from their hands and clothing although such a product may be tolerated for depot, post, and station use where adequate safety measures may be taken. In addition, Specification P-C-111b has no lubricating properties. Since residual moisture on a freshly cleaned ferrous surface would promote corrosion, the need for a lubricant film as residue is readily apparent.

It has been suggested that studies of the surface potential would shed light on the physical processes going on in solvation. Ouilty studied the surface potential of iron oxide and carbon black in water (12). Calculation of the surface potential gives information about the stability of suspensions of particles in a solution so long as the particles are lyophobic. Data collected by numerous investigators show that there is no general direct relationship between either zeta potential or suspending power and detergency (13). In the usual aqueous laundry detergent system where built anionic detergents are used, the electric charge on the fibers and soil particles contribute to detergency. In the case of weapon soil, the propellants do not decompose completely in actual weapon firing, and it is much more likely that decomposition products act as a "glue" to cement particles of carbon to the metal surface. Ball powder, which is a common propellant, is prepared by dissolving wet nitrocellulose in a solvent such as ethyl acetate, adding diphenylamine and chalk, then nitroglycerine. Ball powder is coated with a deterrent such as dinitrotoluene or dibutylphthalate. In studies at the Interior Ballistics Laboratory of Aberdeen Proving Ground, deposits remaining after charring ball powder were identified as degraded cellulose nitrate, aliphatic amides, undecomposed deterrent, plasticizers or stabilizers, and carbon (14). A. H. Milford of Winchester Corp. found about 30% organics in the residue remaining after firing the AR-15 rifle (15). These were characterized as being amides, ureas, and other decomposition products containing NH or $-\overset{\overset{O}{\|}}{C}-N$ groups. Lapagesse points out that combustion of the propellant charge is frequently incomplete and particles of unburned or semiburned powder are often present inside gun barrels (16). The tar-like decomposition products could act as bonding agents for dust and other foreign material. In any solvent system in which any of the decomposition products are soluble, particles will consist of the insoluble portion of the soil and the solublized portion. These particles will be lyophillic. After considering the composition of the weapon soil, it appeared that solubility studies would be more enlightening than studies of surface potential.

Garland reported in March 1971 on the work to encapsulate MIL-C-372b rifle bore cleaner on cotton swabs to relieve the soldier of the necessity of carrying a container of bore cleaner on his person or in the storage compartment of his rifle. He recommended that the swab with the encapsulated cleaner should be improved and subjected to a more thorough field examination (17).

II. DETAILS OF TEST

There is no recommended formula in Specification MIL-C-372b. To correlate performance with composition, rifle bore cleaners, including Specification MIL-C-372b qualified products, were analyzed. Some of the quantitative data regarding composition were obtained by gas-liquid chromatographic separation of the components. The separations were made on a 6 foot column of silicone grease on acid-washed Chromosorb W using a

F&M Model 500 Gas Chromatograph. Twenty microliter samples (as received) were injected for analysis. A programmed temperature rise of 11°C. per minute from an initial temperature of 30°C. was used. The helium flow rate was 100 ml. per minute. The presence of kerosene in the various cleaners was verified by adding kerosene to the cleaner and determining the position of the enlarged peaks. In addition, kerosene was analyzed separately to verify the position of the peaks. To confirm the analysis, kerosene and mineral oil were mixed; the chromatogram obtained from this mixture was similar to the chromatogram of the cleaners.

The volatile components of the cleaners were determined by weighing samples of the cleaners, evaporating for 16 hours at 65°C., cooling, and reweighing. The percentages of residue and volatile were calculated.

To assist in the identification of the components an infrared spectrum of each cleaner was obtained. The cleaners were spread in a thin film on salt plates. Spectra were obtained of the cleaners as received and again on samples which had been dried for five days at 100°C.

To determine the amount of ammonia present in the cleaner a sample was titrated in a nonaqueous medium with alcoholic HCl using Thymol Blue as an indicator. When this was not possible due to the presence of interfering components, like the sodium salts of surfactants, 100 ml. of the sample was heated in a distillation flask. The distillate was collected in standard acid. An aliquot of the acid was titrated and the amount of ammonia calculated. Sodium hydroxide was then added to the sample and it was distilled again. An aliquot was again titrated and the amount of bound ammonia calculated.

To obtain an estimate of the cleaning performance of the cleaners, approximately 0.3 gram of ball powder was burned at atmospheric pressure (isobarically) on segments of gun steel having a composition conforming to AISI No. 4140. The steel samples were 1-1/4 inches in diameter and 3/4 inches high. After the steel had cooled, cleaner was placed on the surface, allowed to stand a measured amount of time, and then wiped off. Wiping the surface approximates the common conditions of using the rifle bore cleaner.

Sufficient weapons fouled with copper were not available for testing, so copper removal was measured by weighing the copper lost from copper plated panels prepared in this Laboratory.

Experimental cleaners were characterized by testing for adherence to the qualification tests described in MIL-C-372b. In addition to the tests presented in Table V, steel panels were prepared as described for the performance test (primer salts removal) of Specification MIL-C-372b. They were slushed by hand and placed in a static humidity chamber for 3 days. The ability of the cleaners to remove standard weapon lubricants and the miscibility of the cleaners with standard oils used to preserve weapons were also tested. Nonmetallic weapon parts were soaked in the cleaner and the parts examined for damage caused by the cleaner.

III. RESULTS OF TESTS AND DISCUSSION

The results of the analysis by gas chromatography for kerosene and the evaporation tests are given in Table II. By comparing the results it can be seen that by evaporating the samples at 65°C. for 16 hours it is possible to obtain an estimate of the amount of kerosene present in this type cleaner, i.e., one which is composed largely of kerosene and mineral oil.

The infrared spectra of the cleaners were similar. A strong band at 2898.5 cm^{-1} is due to C-H stretching. Bands at 1449 cm^{-1} and 1370 cm^{-1} are caused by $C\text{-}CH_3$ and CH_2 stretching. These three strongest bands in the spectra of the cleaner are identical with the spectra of Nujol. Since the presence of mineral oil was established by gas chromatography, the bands are probably due to nonvolatile mineral oil in the dried cleaners. The bands are stronger in the spectra of the cleaners determined from the samples as received. The presence of kerosene was verified by gas-liquid chromatographic separation; a kerosene and mineral oil mixture produces a spectra having these strong bands.

The remaining bands in the infrared spectra were attributed to compounds derived from amines, sulfonates and carboxylic acids. Such bands are characteristic of certain classes of surfactants such as Na-2-ethylhexenyl sulfonate and N(1,2-dicarbonethyl) N-octadecyl sulfosuccinic acid (18).

The cleaners presently in use did not remove burned ball powder from metal surfaces even with rubbing. For removing powder residues from a metal surface the polar solvents (methanol, ethanol, water, and acetone) are more effective than the nonpolar solvents (kerosene, carbon tetrachloride, petroleum ether, and mineral spirits). Only one of the cleaners from the qualified products list removed some copper from plated steel panels. It was found to contain less than 1% free ammonia. Ammonia was not detected in the other cleaners analyzed.

A popular commercial rifle bore cleaner which both cleaned and decoppered was analyzed. It contains ethanol (20%), kerosene (30-40%), ammonia and oleic acid - probably as ammonium oleate - (15%), a saponifible oil, some methyl salicylate and traces of nitrobenzene.

The cleaners presently in use by the army are largely kerosene and mineral oil. They do not remove burned powder from metal surfaces nor do they remove copper effectively. An improved cleaner was developed as described below.

Specification P-C-111b, carbon **removing** compound, removes soil from weapons satisfactorily; for this reason it was used as the basis for developing an improved rifle bore cleaner. The composition of Specification P-C-111b comparison formula is given in Table III. Since water promotes rusting of ferrous surfaces, the water in the cleaner was replaced by an organic solvent with similar solubility properties. Methanol resembles water more nearly than ethanol, but methanol is also more toxic, flammable, and volatile than ethanol. Sodium silicate was omitted, it was not soluble in the nonaqueous formula. The function of the sodium silicate in Specification P-C-111b was to inhibit metallic corrosion encouraged by the water present. Nontoxic dipropylene glycol methyl ether was substituted for the combination of toxic glycol ethers. Monoethanolamine was reduced in quantity and the nontoxic lauryl dimethyl amine oxide which functions as a nonionic detergent in neutral or alkaline solutions was substituted. The resulting cleaner removed burned ball powder from steel rounds. It was then tested on a soiled M16A1 rifle. The cleaner removed soil from the weapon, but was unpleasantly sticky on the hands. The stickiness was found to be caused by the lauryl dimethyl amine oxide; most of which was replaced by ammonium oleate after the following considerations.

A number of copper chelating agents were evaluated for inclusion in the formula. A ligand was desired which was inexpensive, nontoxic, rapidly effective, and soluble in the nonaqueous cleaner solvents. In addition, it was necessary that the ligand react with copper to form a complex soluble in the cleaner and that the ligand not react with iron (or do so very slightly, or very slowly, or with the formation of an insoluble complex). The amines were excluded immediately on the basis of their toxicity, even though they are, as a group, good copper chelants. The hydroxyamines (ethanolamine, diethanolamine, and triethanolamine) complex copper slowly. A more rapid complexing ligand was desired. Both EDTA (ethylene diamine tetracetic acid) and NTA (nitrilotriacetic acid) chelate iron in addition to copper and were eliminated on that basis. Citric acid, which is often used in metal cleaners, is slightly deliquescent and not volatile. Residual citric acid could cause rusting by absorbing moisture while on the metal surface. Gluconic acid is insoluble in most organic solvents although it is very soluble in water. The same is true of the amine acids such as cysteine, glycine, and histidine. Ammonia is an effective copper remover and has been included in gun cleaner formulations for that reason; however, the odor of ammonia is objectionable. Ammonium oleate, the soap of ammonia and oleic acid, removes copper and does not have an objectionable odor. Furthermore, when it is spread in a thin film it disassociates into ammonia and oleic acid. Oleic acid leaves a rust-protecting film on iron surfaces. In addition, ammonium oleate is nontoxic.

The cleaner containing ammonium oleate as a replacement for most of the lauryl dimethyl amine oxide had a very low flash point because of the ethanol present. Ethanol was present to ensure the solubility of the copper-amine complex. Kerosene was substituted for part of the ethanol to reduce the cost of the cleaner. Kerosene is also a good solvent for some weapon lubricants. Palm oil was incorporated into the cleaner to leave a film on the metal surface. Palm oil has been used by the tin plating industry to protect cleaned iron surfaces before coating them with tin. The composition of palm oil varies somewhat depending on the source of the oil, but in general, consists of the glycerides of the following acids: myristic 1-2%, palmitic 40%, stearic 4-6%, oleic 40-50%, and linoleic 8-10%. The composition of the cleaner is given in Table IV, Formula No. 1.

A major difference between Formula No. 1 and the commercial cleaners being used by the Army is the presence of almost 40% diproplyeneglycol methyl ether in Formula No. 1. The glycol ether and the ethanol provide an increased solvency for the more polar soils. In addition, oleic acid and palm oil are noted for forming adherent films on iron surfaces, whereas mineral oil only coats the surface with an easily broken film.

A sample of the rifle bore cleaner, Formula No. 1, was tested for cleaning efficiency by the armorer at Fort Benning, Georgia and found to be acceptable. The letter expressing his opinion is in Appendix B.

Because a cleaner with a higher flash point than the experimental rifle bore cleaner was desired, the remaining ethanol in the experimental rifle bore cleaner was replaced by ethylene glycol, which is polar and could be expected to maintain the solubility of the copper complex. With ethanol omitted, the flash point of the cleaner was acceptable. The cleaner removed weapon soil and copper. This cleaner was tested for compliance with the qualification requirements of Specification MIL-C-372b. The results of this testing are given in Table V. The results of the compatibility testing are given in Table VI. The cleaner did not cause degenerative changes to the weapon parts. In the modified test for primer salts removal, the cleaner protected steel panels from rusting.

Less than 4% ethylene glycol was present in the rifle bore cleaner; a closer investigation of component toxicity revealed that despite the very slight absorption of ethylene glycol by skin, it is not recommended for frequent use on the skin (11). The ethylene glycol in the rifle bore cleaner was replaced by nontoxic propylene glycol. The cleaner was tested for copper removal and found to be acceptable.

Although rapid cleaners containing free ammonia were efficient (one formulation could remove copper plating from steel panels in five minutes), the unpleasant free ammonia odor and the undesirability of perfuming a product designed for war zone use necessitated the rifle bore cleaner be formulated with all the ammonia in the form of ammonium oleate, The formulation is given in Table V, Formula No. 2.

Formula No. 2 was used to clean M16A1 rifle components. Two hundred rounds of ammunition had been fired in these weapons. The photographs show the comparison between the weapon parts cleaned in Formula No. 2 and those parts cleaned in a specification cleaner procured from supply. As may be seen, the specification material did not remove the baked-on soil from the bolt. The baked-on soil could be removed by the Formula No. 2.

The improved rifle bore cleaner, Formula No. 2, has a flash point of 126°F. It will not injure personnel who are in constant contact with it. The most toxic component of the cleaner is kerosene. Dipropylene glycol methyl ether and lauryl dimethyl amine oxide are used in cosmetics and shampoos. Ethanolamine and ammonium hydroxide are combined with the oleic acid into soaps (amonium oleate and ethanolamine oleate). Both these soaps are used in hand cleaners. Propylene glycol is a solvent for pharmaceuticals, and is considered harmless. Palm oil is edible. Only kerosene is relatively toxic. It can be irritating to the skin, but gun cleaners with 30-50% kerosene have been used for many years with no complaints concerning toxicity of this component. The improved cleaner removes copper and soil from weapons and leaves a protective film. It was used at Human Engineering Laboratories, Aberdeen Proving Ground, Maryland to clean weapons and performed satisfactorily in the limited test (see letter, Appendix B).

IV. CONCLUSIONS

1. Rifle bore cleaners presently being used by the Army provide marginal cleaning and negligible decoppering.

2. The need exists for a rifle bore cleaner which removes copper fouling and weapon soil.

3. A rifle bore cleaner was developed in this laboratory by modifying, in a number of ways, the comparison formula of P-C-111b, Carbon Removing Compound. This cleaner removes weapon soil and copper fouling; it is nontoxic and compatible with existing weapon systems. Modification of the P-C-111b formula appears to be an effective approach to the development of a suitable bore cleaner.

4. Use of the improved rifle bore cleaner in the current revision of MIL-C-372b would provide for procurement of better cleaners than are presently being supplied to the Army.

V. RECOMMENDATIONS

1. Since limited field testing has indicated that the improved rifle bore cleaner is favorably accepted this product should be subjected to a more thorough field evaluation.

2. The improved rifle bore cleaner should be considered for use as a comparison formula in the current revision of MIL-C-372b to enable procurement of better cleaners than are presently being supplied to the Army.

3. Research sould be continued to improve the efficiency of rifle bore cleaners. The development of two different cleaners is suggested. One, packaged in small units for use by the individual soldier, and the other capable of rapid cleaning and decoppering, restricted to use at depots, posts, and stations where adequate safety features are available.

VI. ACKNOWLEDGMENT

The assistance of the many people in AMSAA, ARDC, MTD and TECOM who provided weapon parts, samples of gun powder, and expert advice is gratefully acknowledged.

VII. REFERENCES

1. Military Specification MIL-C-372b, "Cleaning Compound, Solvent (for Bore of Small Arms and Automatic Aircraft Weapons)", General Services Administration, 3 January 1962.

2. A. R. Hankins, USATECOM, DPS Report No. 2664, "High Temperature Bore Fouling of 5.56 mm M196 Tracer Cartridges in M16A1 Rifle", Aberdeen Proving Ground, Maryland, February 1968.

3. W. T. Ebihara, "Investigation of Erosion in 7.62 mm Machine Gun Bands", Proceedings of Interscience Technical Meeting on Gun Tube Erosion and Control, Watervliet, New York, February 1970.

4. Julian S. Hatcher, Hatcher's Notebook, Revised Edition, Philadelphia, Pa., Stackpole Co., 1962.

5. Technical Manual (TM-9-1005-249-34), "Direct and General Support Maintenance Manual Including Repair Parts and Special Tool List", Headquarters, Department of the Army, August 1968.

6. R. R. Moreno, U. S. Patent No. 1050678, 4 January 1913.

7. A. H. Hitchins, Springfield Armory Memorandum Report No. 160-1050, "Methods and Cleaning Solutions for Cleaning the Bore and Chambers of Rifle Barrels", 5 March 1949.

8. C. J. Quilty, U. S. Army Weapons Command Technical Report 68-1943, "Detachment of Carbon Deposits from a Solid Surface", August 1968.

9. David Bootzin, Rock Island Arsenal Laboratory Report No. 62-2996, "Cleaning of Weapons After Firing Blank Ammunition", 5 September 1962.

10. "Small Arms Cleaners, Lubes and Preservatives", Preventive Maintenance Monthly, P.S. Issue 202, U. S. Army Maintenance Board, Fort Knox, Kentucky, September 1969.

11. Frank A. Patty, Industrial Hygene and Toxicology, Volume II, Interscience Publishers, John Wiley and Sons, Inc., New York, 1967.

12. C. J. Quilty, Rock Island Arsenal Technical Report 68-560, "Stability of Lyophobic Colloids in Aqueous Media", March 1968.

13. A. M. Schwartz, J. W. Perry, and J. Berch, *Surface Active Agents and Detergents*, Vol. II, Interscience, Inc., 1958.

14. Carl Wellman, Interior Ballistics Laboratory, Aberdeen Proving Ground, Maryland, 23 May 1968 (unpublished).

15. A. H. Milford, "Function and Fouling Tests of AR-15 Rifle No. 201548", quoted by L. Stiefel and B. W. Brodman in Frankford Arsenal Report R-1936, "M16 Rifle Gas Tube Fouling, Composition, Properties, and Means of Elimination", August 1969.

16. Eugenio Lapagesse, "Explosive Compounds and Ballistic Powders", *Int. Crim. Police Review*, 1970, 25 (238) 158-65, (239) 176-83.

17. W. F. Garland, U. S. Army Weapons Command, Technical Report RE-70-194, "Development of Improved Bore Cleaning Swabs for Small Arms", March 1971.

18. D. Hummel, *Identification and Analysis of Surface-Active Agents*, Interscience Publishers, New York, 1962.

APPENDIX A

TABLE I

Compositions of Weapon Cleaners (From the Open Literature)

1. Belgian Patent 652,199 Alfred Chantreux
    - 70% gas oil
    - 5% turpentine
    - 20% kerosene
    - 5% heavy petroleum residue

2. BSA Safti Paste (Birmingham Small Arms Co.)
    - 44% mineral oil
    - 13 % water and amyl alcohol
    - 43% dry soap (soluble in alcohol)

3. Canadian Patent 282,110 Josef Wagner
    - 81.5g mineral oil
    - 3.5g ethyl lactate
    - 15g alcoholic oleic acid alkali

4. Chapels Powder Solvent
    - 33% acetone
    - 33% turpentine
    - 33% sperm oil

5. Frankford Arsenal Nitrosolvent Gun Cleaner No. 8
    - one part acetone
    - one part turpentine
    - one part kerosene
    - 250g lanolin per 800 cc

6. Hoppies Nitrosolvent No. 9
    - 54% kerosene and amyl acetate
    - 24% neutral nonsaponifable oil
    - 6% nitrobenzene
    - 16% ammonium oleate

7. Rock Island Rifle Bore Cleaner (similar to RIXS-205)
    - 26% paraffin oil
    - 7.7% triethanolamine
    - 19.0% isomeric amyl alcohols
    - 15.4% oleic acid
    - 12.8% butyl "Cellosolve"
    - 19.0% Stoddard Solvent

8. Springfield Armory Cleaner
    - 6 parts amyl acetate
    - 19 parts spirit of turpentine
    - 26 parts kerosene
    - 19 parts acetone
    - 58 parts sperm oil

9. U. S. Patent 1,036,383 O. Tromsness
    - one part acetone
    - one part turpentine
    - one part amyl acetate
    - three parts sperm oil

TABLE I - Continued

Copper Removing Compositions (From the Open Literature)

1. "Ammonia Dope", Standard Ordnance Department Metal Fouling Solution

4 oz water	1 oz ammonium persulfate
200 g ammonium carbonate	60 oz ammonia (28%)

2. Chapels Metal Fouling Solution

60 cc water	220 g ammonium persulfate
100 g ammonium carbonate	90 cc ammonia (28%)

3. U. S. Patent 1,050,678 R. R. Moreno
   Ammoniacal solution in the presence of air

TABLE II

Characteristics of Rifle Bore Cleaners on the Qualified Products List of MIL-C-372b

Cleaner	% Kerosene (estimated by GLC	% volatile (by evaporation)	% nonvolatile (by calculation)
A	30-36	43	57
B	18-25	23	77
C	51-58	53	47

TABLE III

Composition of Federal Specification P-C-111b, "Carbon Removing Compound"*, Comparison Formula (Type II)

Component	Percent by Volume
Ethylene gylcol monobutyl ether	7.7
Diethylene glycol diethyl ether	6 7
Diethylene glycol monobutyl ether	3.9
Diethylene glycol monomethyl ether	2.0
Detergent, nonionic	1.8
Oleic acid	2.0
Monoethanolamine	20.3
Sodium silicate solution	55.6

Mix all ingredients together (in the order shown) except the sodium silicate solution. Stir the mixture into the sodium silicate solution. Caution: Use goggles and avoid skin contact.

*General Services Administration, 7 July 1966.

TABLE IV

Composition of Improved Rifle Bore Cleaner

Component	Formula No. 1, %	Formula No. 2, %
Dipropylene glycol methyl ether	38.74	39.91
Ethanol	3.87	--
Propylene glycol	--	4.0
Oleic acid	9.76	10.1
Ethanolamine	0.96	0.96
Ammonium hydroxide	2.32	0.88
Palm oil	3.87	4.0
Kerosene	38.74	39.91
Lauryl dimethyl amine oxide	0.19	0.24
Dowanol P-Mix	1.55	--

TABLE V

Tests for Compliance with the Qualification Tests of MIL-C-372b

Test	Requirement	Improved Cleaner
Flash point	120°F. min.	126°F.
Viscosity	15 cs max. (100°F.)	4 cs
	1500 cs max. (20°F.)	20-25 cs
Freezing	No separation	Pass
Heating	No separation	Pass
Appearance	Clear	Pass
Odor	Not offensive	Pass
Water displacement and water stability	Rust prevention	Pass

TABLE VI

Tests for Compatibility with Nonmetallic Weapon Components

Weapon Part	Time Immersed	No Result
Plastic insulator, gun, automatic, 20mm M39A3	5 hours	No damage
Firing circuit, gun, automatic, 20mm M39A2	16 hours	No damage
Firing circuit, gun, automatic, 20mm M39A2	2 weeks	No damage
M16 rifle buffer	4 days	No damage
Firing pin cushion, grenade launcher, 40mm LAU	4 days	No damage
Firing cam assemble, gun, automatic, 20mm M61	4 days	No damage

APPENDIX B

DEPARTMENT OF THE ARMY
UNITED STATES ARMY INFANTRY BOARD
FORT BENNING, GEORGIA 31905

STEBC-MO-M

20 September 1971

Mr. H. Amlung
Acting Director
Coating and Chemical Laboratory, ATTN: AMXRD-CC
US Army Research and Development Center
Aberdeen Proving Ground, Maryland 21005

Dear Mr. Amlung:

At the request of Mr. Carroll a sample of your bore cleaner was tested by the armorer at the USA Infantry Board. Approximately one-fourth of the sample has been used, and the following comments were reported.

a. General cleaning. Good, cleans as well and as easily as other cleaners he had been using (both military and commercial).

b. Copper removal. Excellent, removed copper particles from the bore that the armorer was not aware were present.

c. After cleaning with the new solvent the weapon does not have the "shining" appearance that the armorer was accustomed to seeing. The armorer attributed this to the fact that large amounts of copper were removed.

Sincerely,

ROBERT M. JONES
Captain, Infantry
Meth & Instr Branch

DISPOSITION FORM

For use of this form, see AR 340-15; the proponent agency is The Adjutant General's Office.

REFERENCE OR OFFICE SYMBOL AMXRD-HEL	SUBJECT Rifle Bore Cleaner

TO Dir, Coating & Chemical Lab.

FROM Dir, HEL

DATE 29 Feb 72

CMT 1

Mr Corona/saf/4061

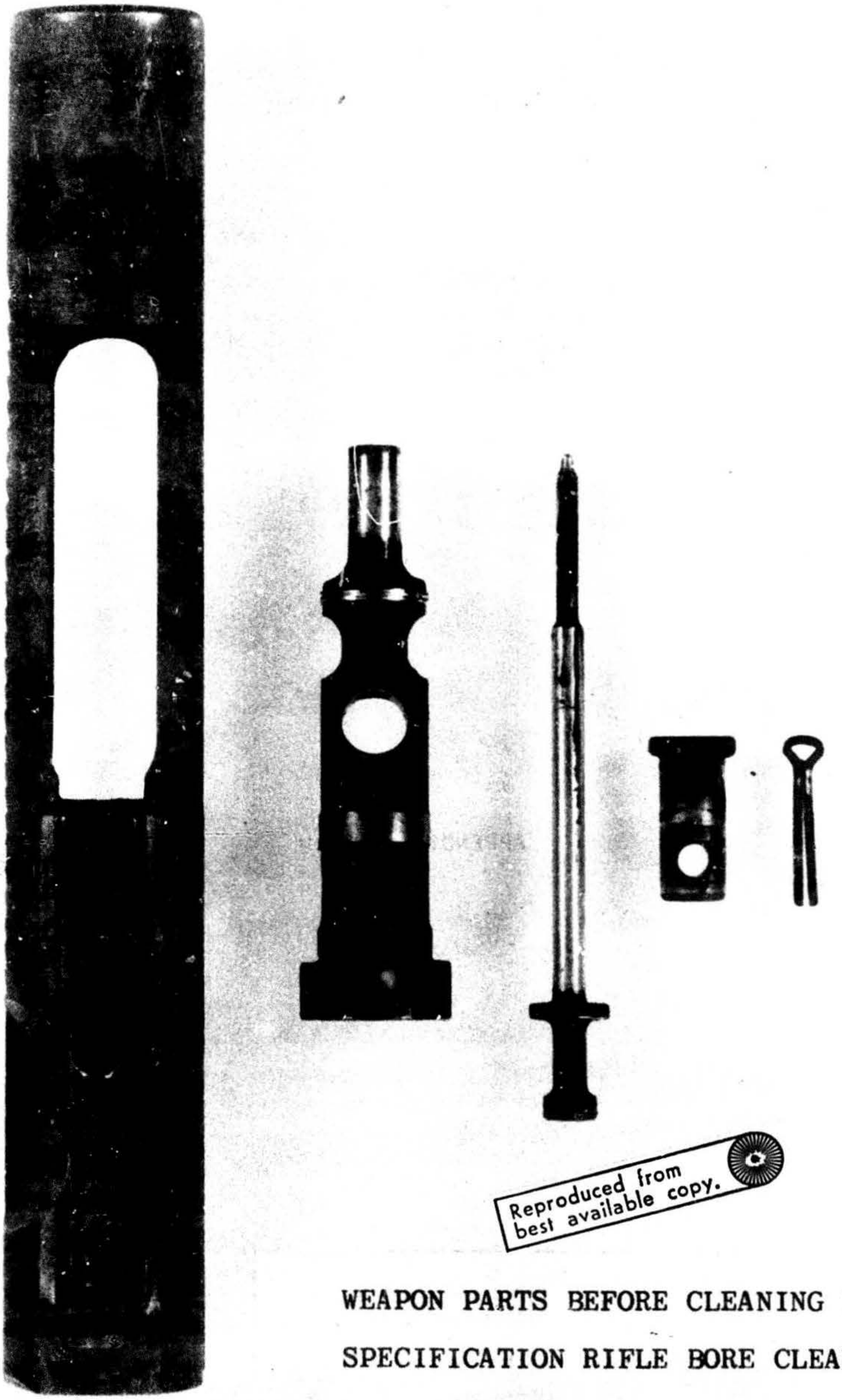
During January 1972, Mrs. Carroll of your laboratory provided HEL with an experimental rifle bore cleaning solution. HEL utilized this solution for normal bolt/barrel cleaning of M-16 rifles. These rifles were used daily in a field experiment (10 days). Each, of two weapons, were subjected to approximately 400 rounds of ball ammunition each day. In our estimation the bore cleaning solution provided by Mrs. Carroll did a superior job in removing powder residue and carbon on the bolt face, bolt interior mechanism, chamber and barrel areas. Under ordinary circumstances the removal of these firing by-products necessitates vigorous scraping and prolonged soaking in current issue bore cleaner.

John D. Weisz

JOHN D. WEISZ
Director

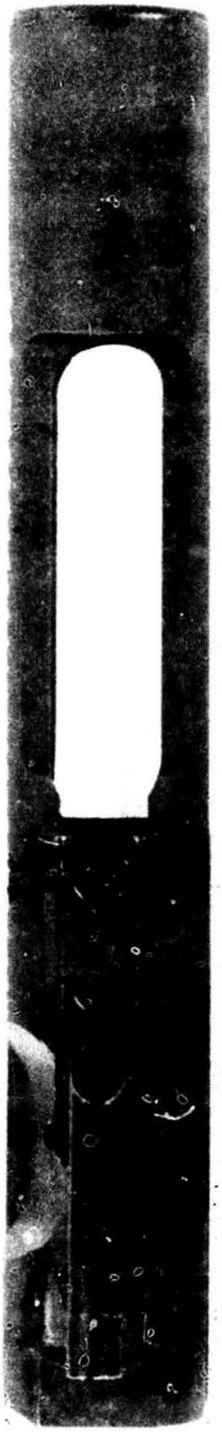
DA FORM 1 FEB 62 2496 REPLACES DD FORM 96, EXISTING SUPPLIES OF WHICH WILL BE ISSUED AND USED UNTIL 1 FEB 63 UNLESS SOONER EXHAUSTED.

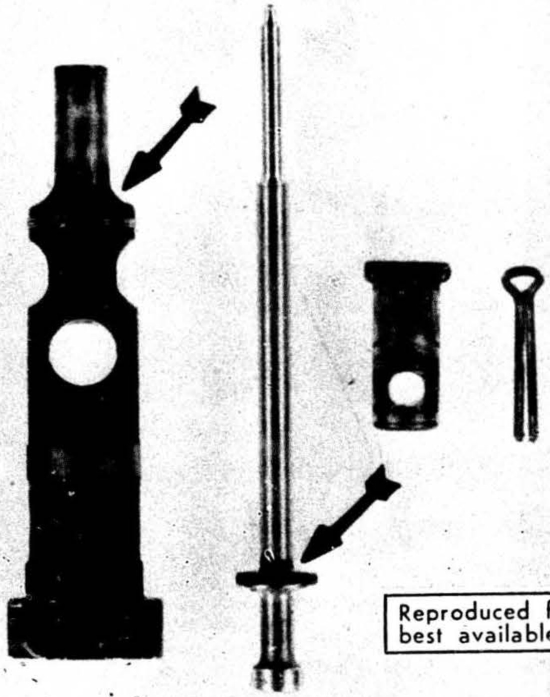
APPENDIX C



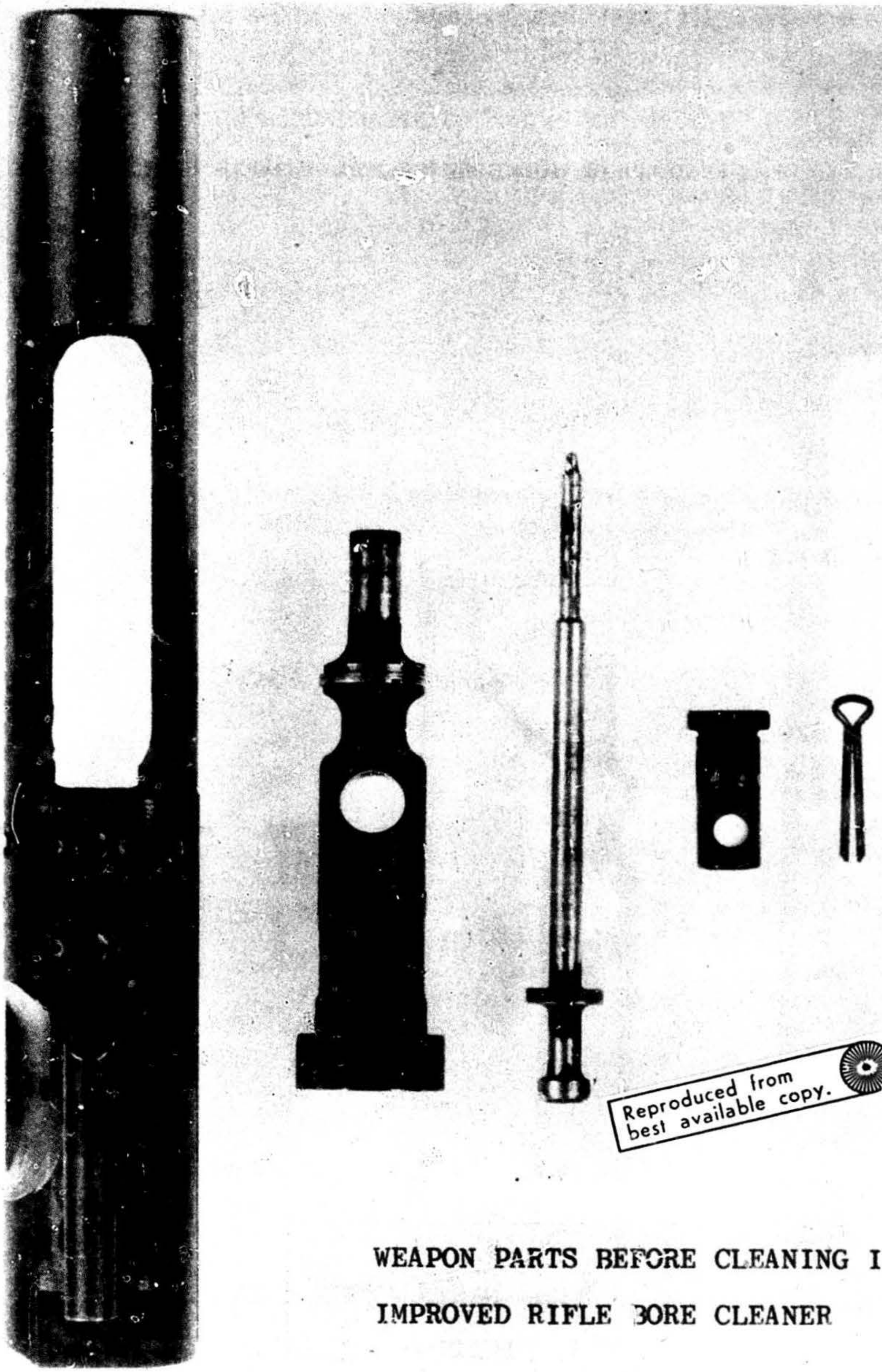
WEAPON PARTS BEFORE CLEANING IN SPECIFICATION RIFLE BORE CLEANER

THE ARROWS POINT TO AREAS WHERE SOIL WAS NOT REMOVED BY THE SPECIFICATION RIFLE BORE CLEANER.



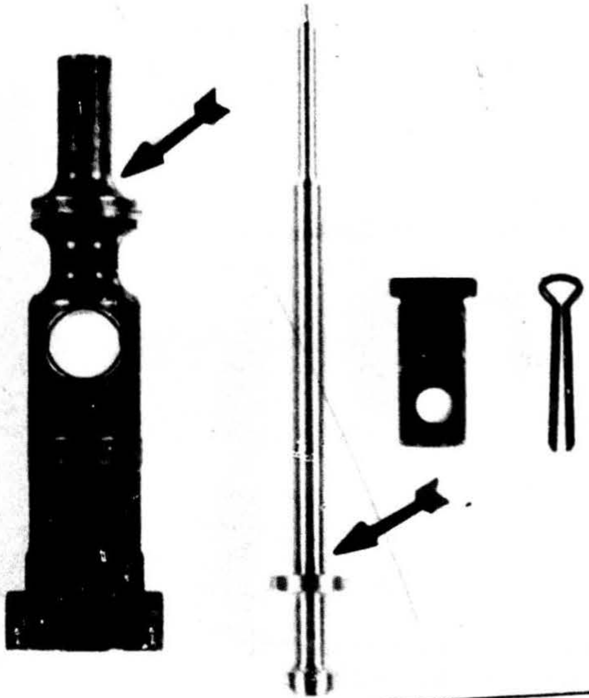


WEAPON PARTS AFTER CLEANING IN SPECIFICATION RIFLE BORE CLEANER



WEAPON PARTS BEFORE CLEANING IN IMPROVED RIFLE BORE CLEANER

THE ARROWS POINT TO THE AREAS WHERE SOIL (NOT REMOVED BY THE SPECIFICATION RIFLE BORE CLEANER) WAS REMOVED BY THE IMPROVED RIFLE BORE CLEANER.



WEAPON PARTS AFTER CLEANING IN IMPROVED RIFLE BORE CLEANER