Rock Island Arsenal Laboratory

TECHNICAL REPORT

DRY LUBRICANTS AND CORROSION

By

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DRY LUBRICANTS AND CORROSION

ABSTRACT

This paper discusses dry film lubricants from the standpoint of use by the military services, the Army in particular. For military purposes, a dry film lubricant is defined as a solid material which reduces friction and wear and at the same time provides corrosion protection.

A summary of the types of dry lubricants and their desirable characteristics is given along with a discussion of the factors affecting the efficiency of the dry film lubricants.

Recent work on the development of a dry film lubricant with a long wear life and corrosion protective properties is discussed. This work shows that graphite is not a desirable component in a dry film lubricant because it accelerates corrosion.

The paper lists general applications for dry film lubricants and specific Ordnance applications such as on the XM34 Littlejohn Rocket Launcher.

Bibliography

1. Devine, M. J., Lamson, E. R., and Bowen, J. H. Jr., "Inorganic Solid Film Lubricants". Unpublished report, Aeronautical Materials Laboratory, Naval Air Material Center, Philadelphia, Pa.

2. Devine, M. J., Lamson, E. R., and Bowen, J. H., Jr., "Inorganic Solid Film Lubricants". ACS - Petroleum Division Preprint, Symposium on Lubrication Under Extreme Conditions.

3. Lavik, M. T., "Ceramic Bonded Solid Film Lubricants", WADD Technical Report 60-530.

4. Electrofilm, Inc. Technical Bulletin #2068, "Solid Film Lubricants in Vacuum and Space".

5. Meade, F. S., and Murphy, G. P., "Investigations of Resin Systems as Bonding Agents For Dry Lubricants". Rock Island Arsenal Laboratory Report Number 59-1515.

6. Murphy, G. P. and Meade, F. S., "The Effect of Vapor Degreasing on Wear Life and Salt Spray Life of Resin-Bonded Solid Film Lubricants". Rock Island Arsenal Laboratory Report No. 62-652.

7. Hart, W. C., and Rubin, B., "Evaluation of Dry Film Coatings". WADC Technical Report 53-466, Parts I and II, September 1954.

8. Cox, W. L., and Rice, W. L. R., "Effects of Nuclear Radiation on Solid Film Lubricants". WADC Technical Report 58-499, January 1959.

9. Proposed Limited Coordination Military Specification MIL-L- (ORD), Lubricant, Dry Film, Packaged in Self-Pressurized Spray Applicator. (Project No. 9150-A-12Y).

10. Military Specification MIL-L-22273(WEP), Lubricant, Solid Film, Dry.

11. Military Specification MIL-L-25504B, Lubricant, Solid Film.

12. Krause, H. H., Cosgrove, S. L. and Allen, C. M., "Phthalocyanines Promise Good 1000-deg. F, Lubricants", Aerospace Engineering, October 1960, page 161.

13. Bowden, F. P., Research, Vol. 3, 195, page 147.

14. Heslop, S., "Metals vs Plastics", The Journal of the Birmingham Metallurgical Society, Vol. 33, No. 3, 1953, page 121.

15. Lavik, Melvin T., "High Temperature Solid Dry Film Lubricants". WADC Technical Report 47-455 Part II, October 1958, page 73.

16. Murphy, G. P. and Meade, F. S., "Development of an Improved Resin-Bonded Dry Film Lubricant", Rock Island Arsenal Laboratory Report No. 60-2192.

17. Meade, F. S. and Murphy, G. P., "A Corrosion Protective Resin-Bonded Dry Film Lubricant System Which Provides Good Wear Life", Rock Island Arsenal Laboratory Report 61-4164.

18. "Survey of the Nature of the Friction Forces in Molybdenum Disulfide Lubrication", Midwest Research Institute Project No. 129-P-65, Final Report, 10 October 1955, page 3.

19. Military Specification MIL-P-16232B, Phosphate Coatings, Heavy, Manganese or Zinc Base, For Ferrous Metals.

20. Military Standard MIL-STD-171A, Finishing of Metal and Wood Surfaces.

21. Midgley, J. W. and Wilman, H., "The Nature of Heat Protection of Mild Steel Caused by Phosphatizing", J. Mech. E. (London) Conference on Lubrication and Wear, October 1957, Paper No. 84.

22. Federal Specification QQ-P-416a, Plating, Cadmium (electrodeposited).

23. Military Specification MIL-A-8625A, Anodic Coatings, for Aluminum and Aluminum Alloys.

24. Rock Island Arsenal Purchase Description RIAPD-651, Lubricant, Dry Film, Resin-Bonded.

25. Rossmiller, R. G., Design Engineer, Rock Island Arsenal. Personal communication to the authors, dated 1 August 1962.

Dry Lubricants and Corrosion

From the point of view of the Military Services, a dry lubricant may be defined as a solid material which, when placed between two surfaces subject to relative motion, will prevent contact of the bearing surfaces, reduce wear, reduce friction, and prevent corrosion of the bearing area. The two factors, wear reduction and corrosion prevention must be inherent in a dry lubricant or the material is of no practical interest to the Military Services.

This definition immediately rules out dry materials such as graphite and molybdenum disulfide when used alone because these lubricants, under certain conditions, promote rather than inhibit corrosion.

This discussion will be limited primarily to resin-bonded dry film lubricants because these materials are at the present time the most widely used types meeting this definition.

The simplest way to prevent corrosion of a bearing surface is to coat the surface with material which acts as a barrier to corrosive agents. In theory, a resin-bonded dry film lubricant provides such a barrier. In practice, this barrier is often faulty.

A resin-bonded dry film lubricant meeting the above definition can be made by combining the proper lubricative pigments with a resin solution in the presence of a solvent system. The resulting mixture is really a paint with lubricating and corrosion preventive properties.

Devine[1] has proposed a list of desirable characteristics for inorganic solid film binders. These characteristics also apply to organic binders and are as follows:

1. Capability of being deposited in the form of a binding film.

2. Ability to retain hardness and chemical stability at elevated temperatures.

3. Capability of forming a tenacious bond at temperatures which would not produce dimensional changes in the metal substrate.

4. Compatibility with a variety of lubricating pigments.

5. Resistance to abrasion.

The following additional requirements may well be added to the above list.

6. The ability to produce wear debris which is not detrimental to lubrication.

7. The ability to prevent corrosion on metal surfaces when applied in an extremely thin film.

Three types of bonding agents have been developed, each of which, when pigmented with lubricative pigments, provides superior performance in certain specific areas.

The earliest type of bonding agents consisted primarily of inorganic salts such as silicates, phosphates, and borates. These materials were deficient in that they were not resistant to moisture. Recently, Devine[2] has developed a sodium silicate binder and method of curing it which is extremely effective when pigmented with molybdenum disulfide and operated at temperatures as high as 1000°F. However, the use of this material is restricted to high temperature applications where moisture contamination is not a problem. This development greatly extends the operational temperature range for dry film lubricants.

One of the most promising inorganic binders is boric oxide (B_2O_3). Lavik[3] found that when this oxide was pigmented with lead sulfide(PbS), it produced a lubricating film satisfactory for temperatures as high as 1000°F. However, the lubricating properties of this film are unsatisfactory at lower temperatures.

The most common type of bonding agent consists of a solution of one or more thermosetting resins. This type of resin requires baking to produce maximum hardness. Thermosetting resins, when pigmented with lubricative pigments, provide hard surfaces and long wear life over the temperature range -300°F. to +500°F. In general, the higher the baking temperature, the longer the wear life and the higher the temperature to which the bearing surface can safely be exposed. Current studies at Rock Island Arsenal indicate that a high baking temperature may be detrimental to the lubricating film from the point of view of corrosion protection. The most common thermosetting resins used as binders for dry film lubricants are the epoxies, phenolics, silicones, and mixtures of these resins. The selection of the thermosetting resin bonding agent is based upon a knowledge of the end use of the dry film lubricant. The epoxies provide excellent adhesion to metal surfaces but their wear debris does not permit a long service life. The phenolics do not have quite as good adhesive properties but their wear debris is less abrasive. Recent studies by Electrofilm, Inc.(4) have shown that the phenolic resins provide the most satisfactory binders for dry film lubricants for use under conditions of high vacuum. The silicone resins provide superior bonding at high temperatures but their wear debris promotes a short service life. Meade and Murphy(5) have shown that an extremely satisfactory general purpose bonding agent can be made from a combination of an epoxy and a phenolic resin.

It is possible to avoid the baking requirement of thermosetting resins by formulating a two component system wherein one component of a pigmented resin and the second component consists of a curing agent. Such a system would require accurate mixing just prior to use and only the amount to be used should be prepared at one time. These requirements are undesirable from a military standpoint. The use of molecular sieves containing the curing agent have not proved satisfactory to date. In the present state of the art, thermosetting resins require baking and are thus not suitable for field application.

Properly formulated and cured thermosetting resin-bonded dry film lubricants provide long wear life, good corrosion protection, high resistance to organic solvents, and a useful temperature range from -300°F. to +500°F.

Murphy and Meade(6) report that a thermosetting, resin-bonded, solid film lubricant can be subjected to conventional trichloroethylene vapor degreasing for periods up to ten minutes with no deleterious effect on the wear life or corrosion protection provided by the lubricant film.

Hart(7) and Cox(8), after extensive studies, report that nuclear radiation in general had very little effect on the wear life, corrosion protection, fluid resistance, and thermal stability provided by thermosetting resin-bonded dry film lubricants.

A type of bonding agent rapidly becoming more common consists of a solution of one or more thermoplastic resins. These resins can be cured by simple solvent evaporation and require no baking. Like the thermosetting resin-bonded dry film lubricants, the thermoplastic based lubricants can be regarded as paints. These lubricants provide fairly hard surfaces with moderately good wear life, fair corrosion protection, fair solvent resistance, and a useful temperature range of -200 to +300°F. The usual thermoplastic resins include the acrylics and lacquer-like materials. A serviceable thermoplastic resin-bonded dry film lubricant can be formulated with a lubricative pigment dispersed in a floor varnish. This type of lubricant is readily packaged in self-pressurized spray containers. After spraying and waiting a few minutes for the solvent to evaporate, the bearing components are ready for assembly. It is usually best to wait several hours before the lubricated bearing is placed in service to permit complete resin cure. Self-pressurized spray containers are particularly useful for field application and touch-up work. The Rock Island Arsenal Laboratory is at the present time involved in the preparation of a limited coordination specification(9) covering a resin-bonded dry film lubricant packaged in self-pressurized spray containers.

At the present time, there are two military specifications covering resin-bonded dry film lubricants. These are: MIL-L-22273(WEP)(10), a product specification, and MIL-L-25504A(11), a performance specification. It is probable that only thermosetting based lubricants can meet the requirements of these specifications. Currently, an effort is being made by the Department of the Navy to combine these two specifications into one fully coordinated military specification.

A number of investigators have evaluated many organic and inorganic compounds as possible lubricative pigments for dry film lubricants. Organic materials, because of their relatively low decomposition temperatures, are probably the least attractive candidates. However, Krause(12) reports that the phthalocyanines show promise as lubricants in the 800-1300°F. temperature range. Polytetrafluoroethylene (Teflon) has excellent lubricating properties but it also has several serious limitations. Bowden(13) reports that this material is a poor thermal conductor and has a high coefficient of thermal expansion. Heslop(14) reports that polytetrafluoroethylene undergoes a sharp drop in strength and decomposes at about 750°F. The effect of these changes on its lubricative properties is not definitely known.

Lavik[15] has prepared two comprehensive surveys covering inorganic materials. The first survey consists of a list of inorganic compounds which warrant investigation as high temperature lubricative pigments, and the second survey consists of a list of inorganic compounds which are considered inherently unsatisfactory for consideration. These two lists serve as an excellent starting point for further investigations of the use of inorganic materials as lubricative pigments.

Graphite and molybdenum disulfide have been studied in detail by many workers. It is now definitely known that an absorbed water vapor layer is essential for graphite lubrication. If this water vapor layer is removed, either by high temperature or vacuum conditions, the graphite loses its lubricating properties and becomes quite abrasive.

Murphy and Meade[16] examined fourteen inorganic compounds and five powdered metals to determine the lubricating effectiveness of these materials when added to a resin-bonded dry lubricant formulation containing molybdenum disulfide and graphite. This study showed antimony trioxide to be the most effective lubricative pigment when used in conjunction with molybdenum disulfide and graphite.

Meade and Murphy[17] have shown conclusively that graphite in a resin-bonded solid film lubricant is deleterious from the point of view of corrosion protection provided by the lubricant. It, therefore, becomes evident that the use of graphite in a resin-bonded dry film lubricant is to be avoided. To use graphite is to invite corrosion difficulties in the presence of moisture.

Recent studies have shown that molybdenum disulfide does not depend upon an adsorbed vapor layer for its lubricating properties. In fact, investigators at the Midwest Research Institute[18] found that molybdenum disulfide provided better lubrication under vacuum conditions than it does in an ordinary atmosphere.

It has been found that extremely finely divided molybdenum disulfide accelerates corrosion when this material is used to pigment a resin-bonded solid film lubricant. However, the use of a larger particle size molybdenum disulfide greatly reduces the corrosion promoting properties of this material. Both graphite and molybdenum disulfide are stable to temperatures above the decomposition temperatures of current thermosetting resin bonding agents.

There are nearly as many instruments for evaluating the wear life of resin-bonded dry film lubricants as there are investigators in this field. The Falex Lubricant Tester and modifications of the McMillian tester are the most widely used. It is known that the correlation between the test results obtained with different testing instruments leaves a great deal to be desired. The military specification covering resin-bonded dry film lubricants under preparation by the Department of the Navy will utilize the Falex Lubricant Tester. This instrument choice was based on the fact that the Coordinating Research Council found the Falex Tester to provide more nearly reproducible results than the next most widely used tester, the Alpha Molykote LFW-1 tester. The dry lubricant development work conducted at Rock Island Arsenal was done with the aid of a Falex tester. This instrument is shown in Figure 1 and consists primarily of a motor driven pin revolving at 290 rpm between two V-blocks to which a wide range of loads can be applied. The load mechanism of this instrument is shown in Figure 2. It is impossible to devise a tester which will simulate all or even a good portion of the anticipated operating conditions to which a dry lubricant may be subjected. The Falex tester is probably as satisfactory for this purpose as any other test instrument, even though the load and test period are the only major variables subject to operator control.

It is a simple matter to predict in general the degree of corrosion protection which can be obtained with a dry lubricant prior to use. However, in service the lubricant film wears and becomes thinner with each operating cycle. A point will eventually be reached where the film no longer provides corrosion protection. It is nearly impossible to predict this point. Therefore, for the sake of safety, it must be assumed that a dry film lubricant, after service, will provide no corrosion protection. In the present state of their development, dry film lubricants can be regarded as corrosion protection devices only during the period prior to use of the lubricated mechanism.

Many investigators have found that the quality of a resin-bonded dry film lubricant coating, in terms of wear life and corrosion protection, is highly dependent upon the quality of the substrate overwhich the lubricant film is applied. For applications over steel surfaces and where corrosion protection is not a major factor, it is recommended that steel surfaces be either manganese or zinc phosphatized.

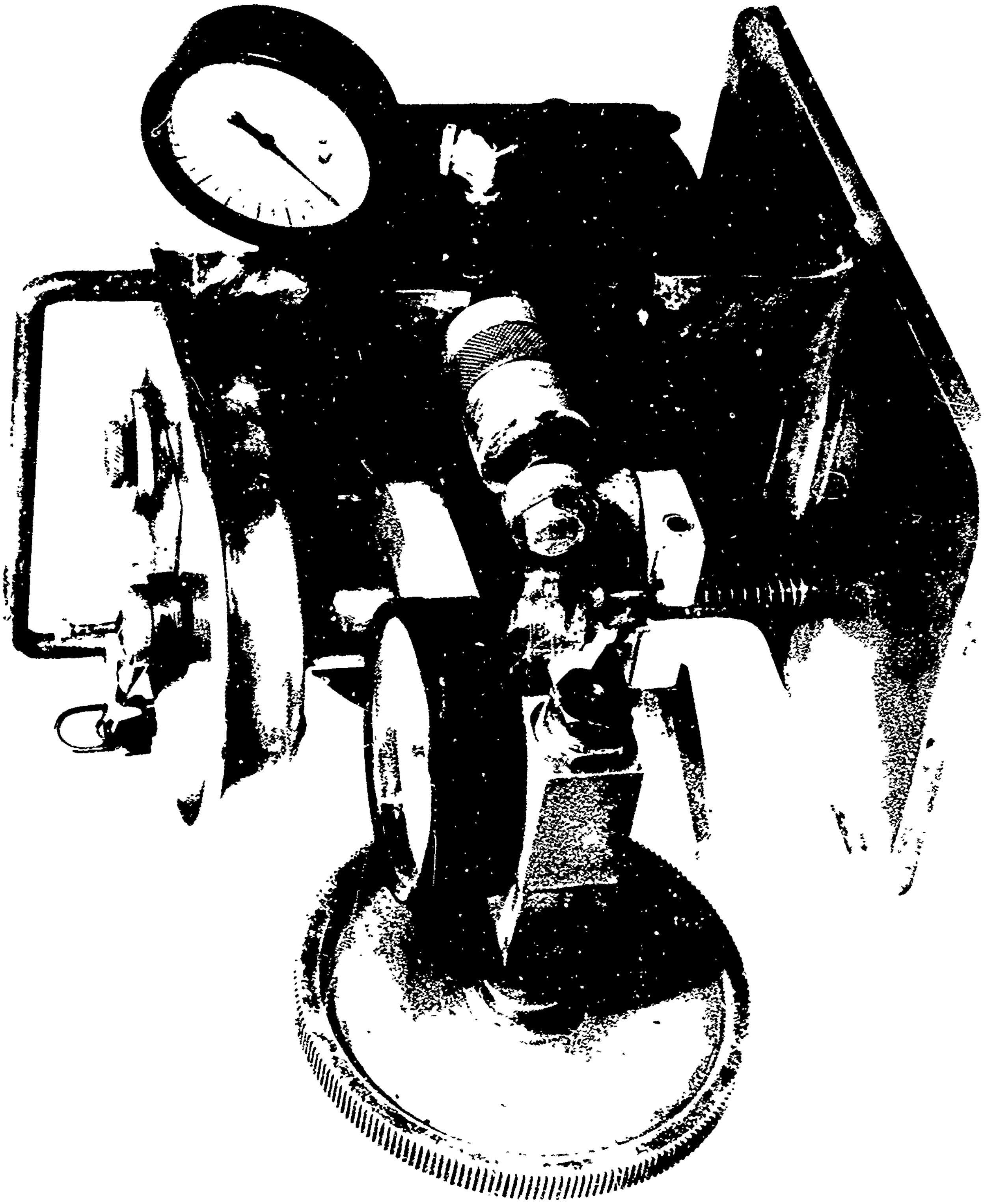
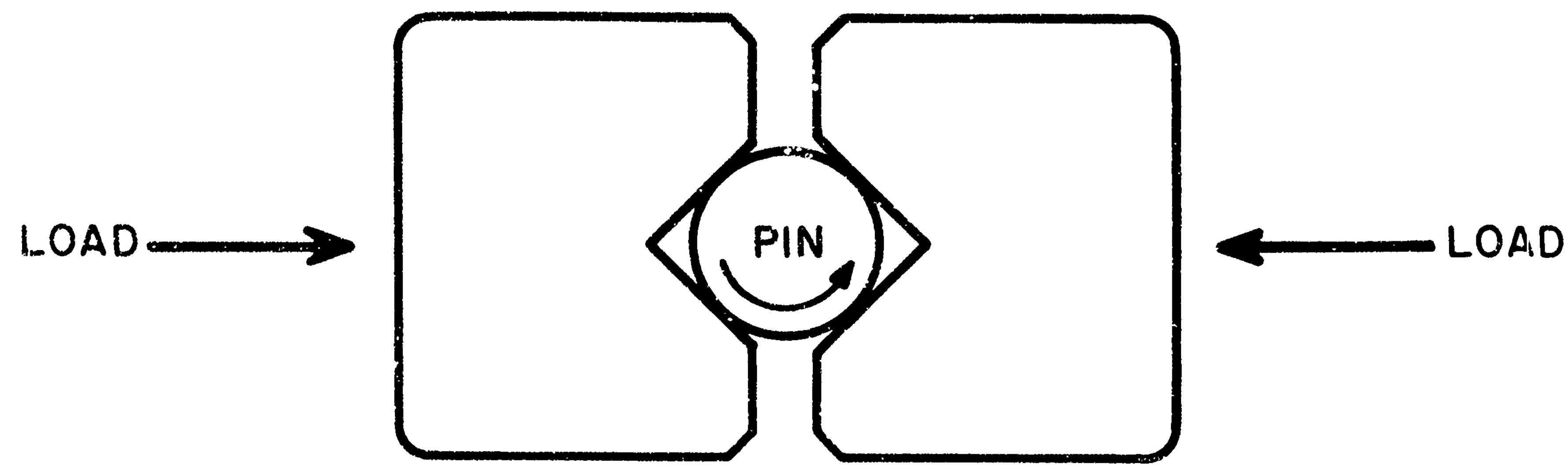


FIG. I FALEX LUBRICANT TESTER



LOAD MECHANISM
FALEX LUBRICANT TESTER

FIG. 2

Studies made at Rock Island Arsenal have shown that the type of phosphatizing applied prior to the application of a resin-bonded dry lubricant is of no significance from the point of view of wear life and corrosion protection. Rock Island Arsenal has had considerably more experience with zinc phosphatized substrates and, therefore, prefers this type of pretreatment It has been found that highly satisfactory wear life and corrosion protection results can be obtained if a resin-bonded dry film lubricant is applied to steel surfaces which have been phosphatized in accordance with Military Specification MIL-P-16232E[19], Type Z, Class 3, or paragraph 5.3.2.3 of Military Standard MIL-STD-171A[20]. It cannot be too strongly emphasized that the phosphatized coatings must be in accordance with either of the above two documents if satisfactory wear life and corrosion protection are to be obtained with resin-bonded dry film lubricants. Substandard phosphatized coatings drastically reduced wear life and corrosion protection. Midgley[21] has recently drawn attention to a simple explanation of a beneficial action, a certain smoothing capacity, obtained with phosphatized steel. This smoothing capacity of the phosphatized coating, in conjunction with the resin-bonded dry film coating, seems to produce a desirable synergistic effect.

If a high degree of corrosion protection is desired on steel bearing surfaces throughout the wear life of a resin-bonded dry film lubricant, it is necessary that the ferrous surface be plated with either cadmium followed by zinc phosphatizing or zinc followed by zinc phosphatizing or zinc followed by zinc phosphatizing. Cadmium plating followed by zinc phosphatizing provides the maximum corrosion resistant substrate for resin-bonded dry film lubricants when applied to steel. However, the wear life of such a substrate and lubricant system is considerably reduced, being approximately 25% of the wear life obtained on a similar bearing surface without the cadmium plating. Zinc plating followed by zinc phosphatizing provides less corrosion protection in conjunction with a resin-bonded dry film lubricant but also a less drastic reduction in wear life. Experience at Rock Island Arsenal has shown that an excellent substrate from the point of view of both wear life and corrosion protection during service can be obtained by cadmium plating and zinc phosphatizing steel bearing surfaces in accordance with Federal Specification QQ-P-416a[22], Class 1, Type III.

Studies at Rock Island Arsenal have shown that aluminum bearing surfaces should be anodized and sealed prior to the application of a resin-bonded dry film lubricant for maximum wear life and corrosion protection. Highly satisfactory wear life and corrosion protection can be obtained by chromic acid anodizing and sealing in accordance with Military Specification MIL-A-8625A[23], Type I or sulfuric acid anodizing in accordance with the same specification, Type II. Wear life and corrosion protection are independent of the type of anodizing.

Bearing surfaces of such metals as stainless steel, chromium plate, and copper alloys which have a certain amount of inherent corrosion resistance should be slightly roughened prior to application of a resin-bonded dry film lubricant to provide a "tooth". Vapor blasting or liquid honing have been found to provide excellent pretreatments for these surfaces.

The optimum lubricant film thickness falls within the range from 0.0003" to 0.0006". This thickness range can be obtained by brushing, dipping, or spraying, the choice of method being dependent upon the particular application. Ideally, both the moving and stationary components of a bearing assembly should be coated with the lubricant. If circumstances permit the coating of one bearing component only, the moving component should be coated. After coating, the bearing components must be baked, the baking time and temperature being dependent upon the bearing metal. While resin-bonded dry film lubricants are relatively hard, they are considerably softer than any metal to which they would be applied. Excessive lubricant will be either removed during assembly or during the first few cycles of operation. It has been found that excessive lubricant can be satisfactorily removed by light abrasion with crocus cloth.

The corrosion protective properties of resin-bonded dry film lubricants can be evaluated by a number of test methods. Rock Island Arsenal used the 20% salt fog test described in Method 4001.1 of Federal Test Method Standard No. 791[24]. This method produces results in a reasonable length of time and the results agree quite closely with outdoor exposure tests currently in progress.

From the point of view of wear life and corrosion protection, resin-bonded dry film lubricants are extremely sensitive to a number of factors. These factors are given in Table I. A small variation in ay of these factors will most assuredly affect the quality of the lubricant coating.

TABLE I

FACTORS AFFECTING QUALITY OF LUBRICANT COATINGS

1. Type of resins comprising bonding system.
2. Ratio of resins within bonding system.
3. Type of lubricative pigments.
4. Ratio of lubricative pigments.
5. Particle size of lubricative pigments.
6. Ratio of resins to pigments.
7. Method of combining ingredients.
8. Quality of bearing surface pretreatment.
9. Baking time and temperature.

Rock Island Arsenal has evaluated all of the commercially available resin-bonded dry film lubricants which have come to their attention. It was found that the longest wear life, when evaluated with the Falex Lubricant Tester, was 250 minutes and the longest corrosion protection period, when evaluated with the 20% salt fog cabinet, was 72 hours. Incidentally, these results were not obtained on the same product. Commercial products appear to be formulated to produce either a long wear life or a long corrosion protection period. Test results obtained by Rock Island Arsenal did not always agree with the results claimed by the commercial manufacturer.

The Rock Island Arsenal Laboratory has developed a resin-bonded dry film lubricant which, when applied over zinc phosphatized steel, and evaluated with a Falex Lubricant Tester, provides a minimum wear life of 500 minutes. This lubricant, when applied over zinc phosphatized steel and evaluated with the 20% salt fog cabinet, provides a minimum corrosion protection period of 100 hours. The lubricant will provide several thousand hours corrosion protection when applied over anodized and sealed aluminum or zinc phosphatized cadmium plated steel and exposed in a 20% salt fog cabinet. This lubricant, designated RIA Compound 9A, has been subjected to and passed qualification tests made by the Naval Air Material Center, Philadelphia, under Specification MIL-L-22273(WEP)[10]. In order to assure the purchase of this superior lubricant, Rock Island Arsenal Purchase Description RIAPD-651[24] was prepared. Currently RIA Compound 9A is being procured from a commercial source under this purchase description.

Resin-bonded dry film lubricants have several inherent deficiencies, one of which lies in the fact that such lubricants are not self-healing. When the lubricant film has been removed by wear, the bearing assembly must be disassembled for relubrication. There is no other method for reapplying this type of lubricant. A second weakness lies in the fact that when resin-bonded dry film lubricants are operated in conjunction with conventional fluid lubricants, their wear life is drastically reduced. The reason for this phenomenon, which is certainly unexpected, is not readily apparent. It is postulated that the conventional fluid lubricant washes from the bearing area the wear debris which would otherwise set as a lubricant. Conventional fluid lubricants do not soften thermosetting resin binders. Accidental fluid lubricant contamination can be removed effectively from dry lubricated bearing surfaces by wiping the bearing surface with a cloth moistened with naphtha. A third and minor weakness lies in the fact that the application of a resin-bonded dry film lubricant requires the expenditure of more time and money for surface pretreatment and baking than is ordinarily required for conventionally lubricated bearings. Resin-bonded dry film lubricants can be applied to highly polished bearing surfaces and not baked, but if this is done, only a small part of the potential of the lubricant is realized. A general list of applications for which dry film lubricants should not be considered for use is given in Table II.

Resin-bonded dry film lubricants have a number of characteristics which warrant their consideration in many general applications. One of their outstanding characteristics is that their lubrication and torque properties are relatively insensitive to temperatures over the range -300 to +500°F. Their temperature range is far beyond the capability of any fluid lubricant, conventional or exotic. A second desirable characteristic is that the type of lubricant is not affected by either water or most organic solvents. To be sure, it is not recommended that bearings lubricated with this type of lubricant be operated more than a very few cycles in the presence of water or organic solvents, but short time contacts will have no deleterious effect on the lubricant film. A third desirable characteristic lies in the fact that this type of lubricant is capable of carrying considerably higher loads than nonfortified fluid lubricants. This characteristic becomes of paramount importance in the initial start-up of heavily loaded machinery. The first few critical cycles of operation can be safely accomplished by supporting the load on the dry lubricant film until satisfactory bearing surfaces are established for fluid lubrication. Properly formulated resin-bonded dry lubricants will provide lubrication under vacuum conditions which are completely beyond the range of fluid lubricants.

It thus becomes apparent that resin-bonded dry film lubricants are capable of performance impossible to obtain with conventional fluid lubricants. A list of general applications for which these types of dry lubricants are satisfactory is given in Table III. This table is self-explanatory.

Rock Island Arsenal has had considerable experience in the use of resin-bonded dry lubricants in the past five years. Figures 3 through 6 show some of the earlier applications. At the time these photographs were made, a commercial dry lubricant was applied over zinc phosphated steel. It will be noted that considerable rusting took place. Because of this condition, RIA Compound 9A, a corrosion inhibiting type of dry lubricant is currently being used in conjunction with steel bearing surfaces which have been cadmium plated and zinc phosphatized and aluminum bearing surfaces which have been anodized and sealed prior to application of the dry lubricant. Thus, maximum corrosion protection is being obtained simultaneously with satisfactory wear life. At present, this corrosion inhibiting dry lubricant is being applied to properly pretreated bearing areas on rocket launchers (including the LittleJohn), trailers, and artillery components.

TABLE II

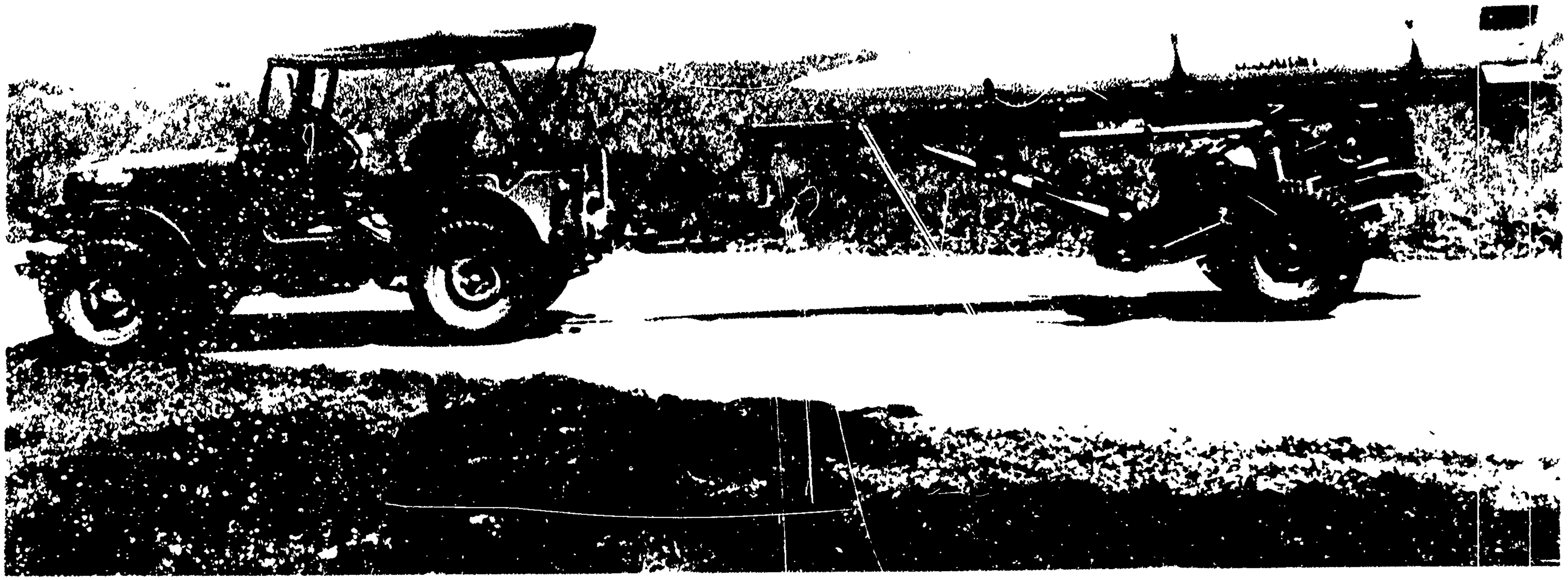
APPLICATIONS NOT SUITABLE FOR RESIN-BONDED SOLID FILM LUBRICANTS

1. Temperatures continuously above 500°F.
2. Rolling element bearings.
3. Contact with fluid lubricants.
4. Mechanisms subject to a large number of operating cycles.

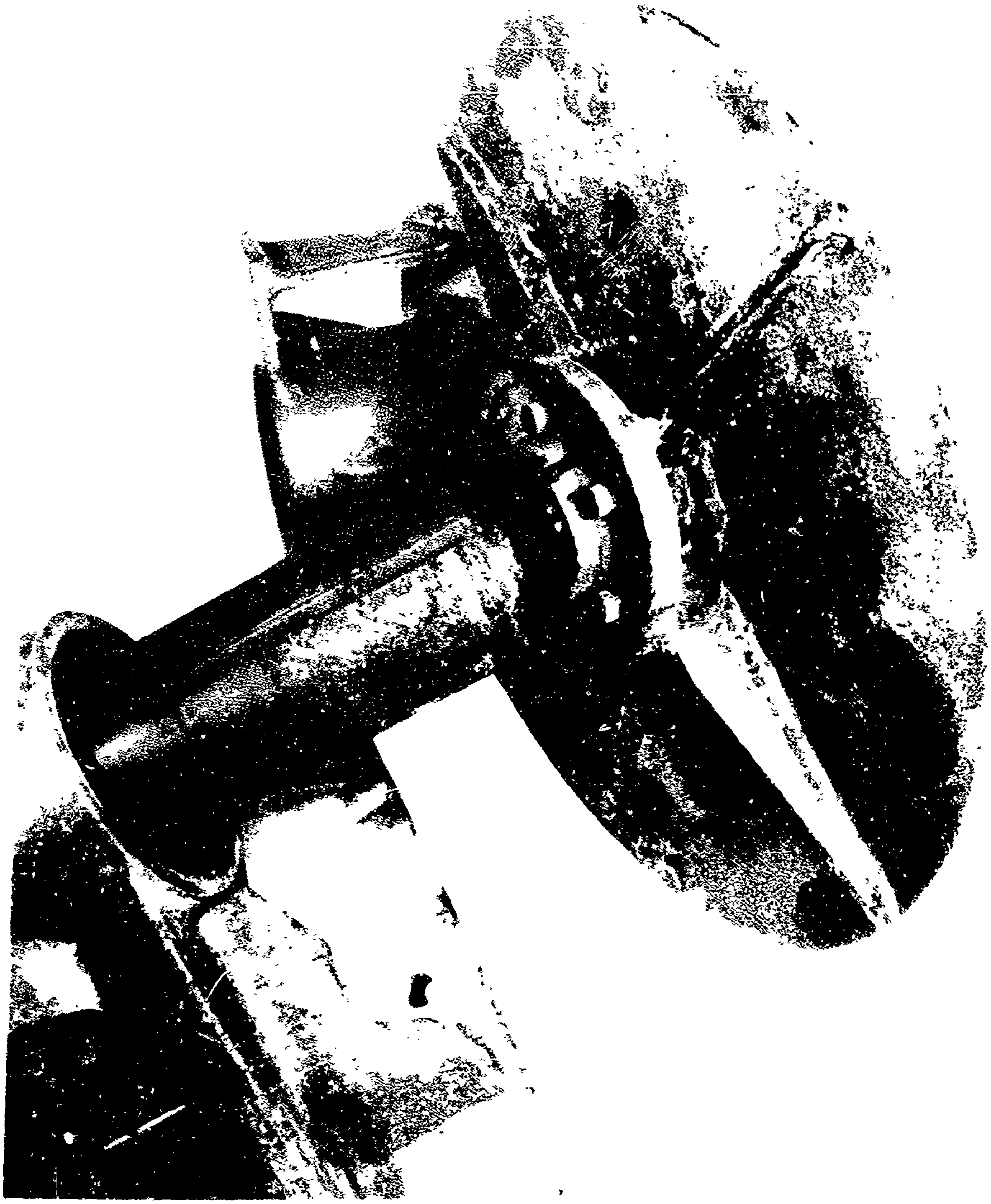
TABLE III

SUGGESTED APPLICATIONS, RESIN-BONDED SOLID FILM LUBRICANTS

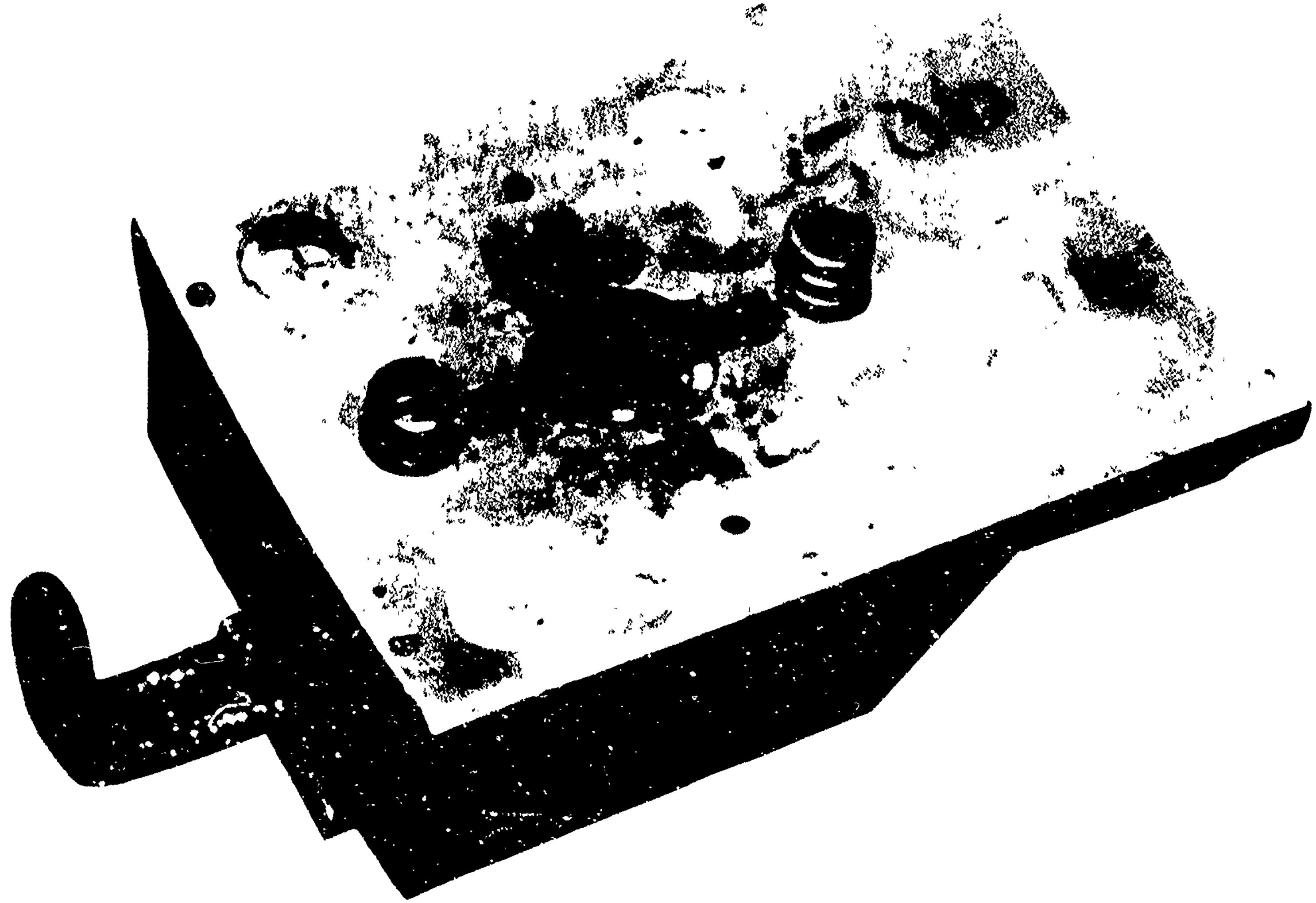
1. Lightly loaded plain and spherical bearings.
2. Sliding motion under light to moderate loads.
3. Temperature range, -300°F. to +500°F.
4. Break-in lubrication with fluid lubricants.
5. Mechanism lubricated for life.
6. Where conventional means of lubrication aren't satisfactory.
7. Mechanisms infrequently used.
8. Mechanisms where lubrication may be neglected.
9. Mechanisms stored for long periods.
10. Mechanisms exposed for dusty atmospheres.
11. Mechanisms exposed to drastic weather conditions.
12. Mechanisms subject to high initial loads.
13. Mechanisms which can't tolerate fluid lubricant contamination.
14. Mechanisms subject to high temperature and periodic disassembly.
15. Mechanisms subject to mildly corrosive atmospheres.



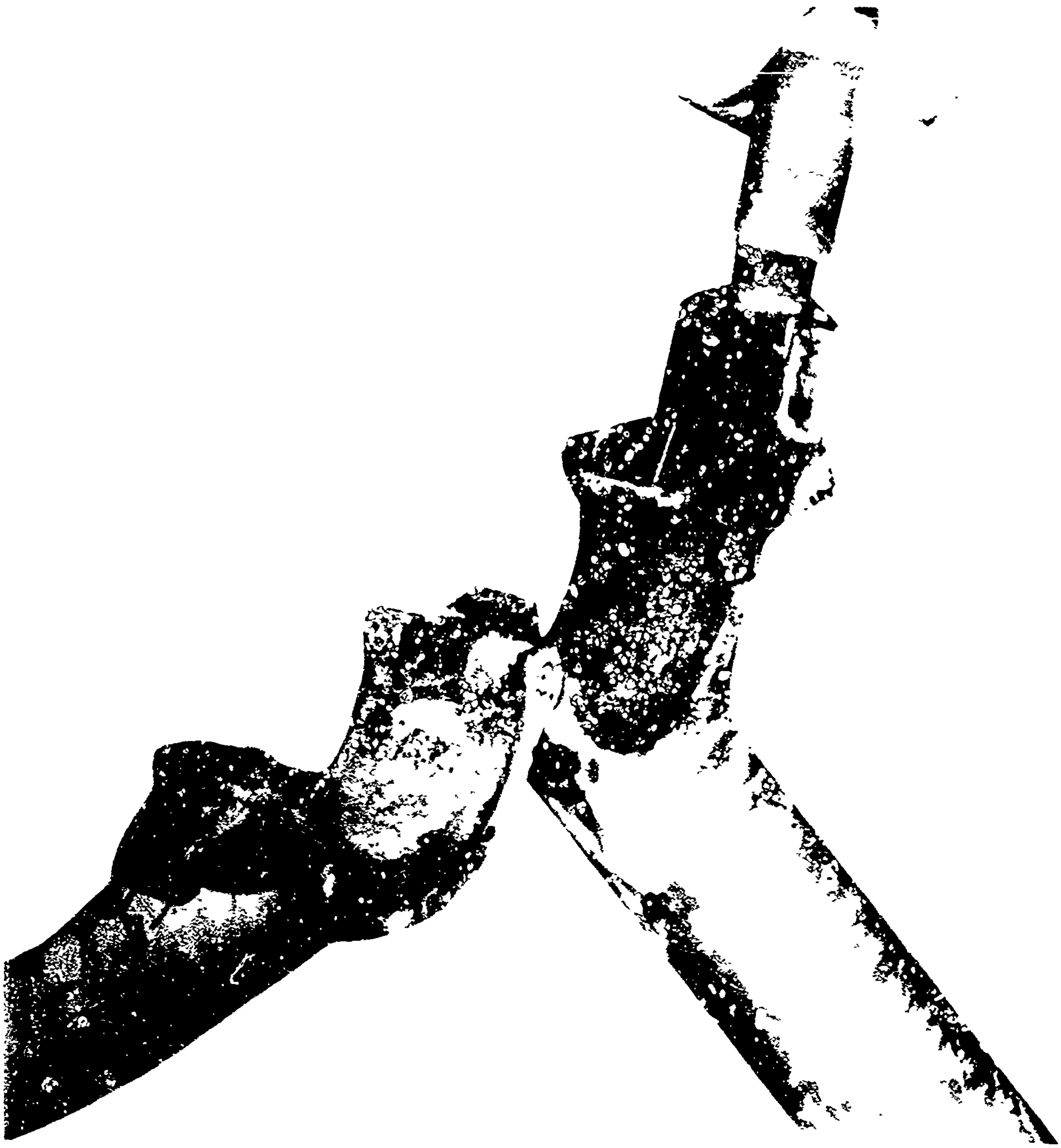
XM34, LITTLEJOHN ROCKET LAUNCHER
Fig. 3



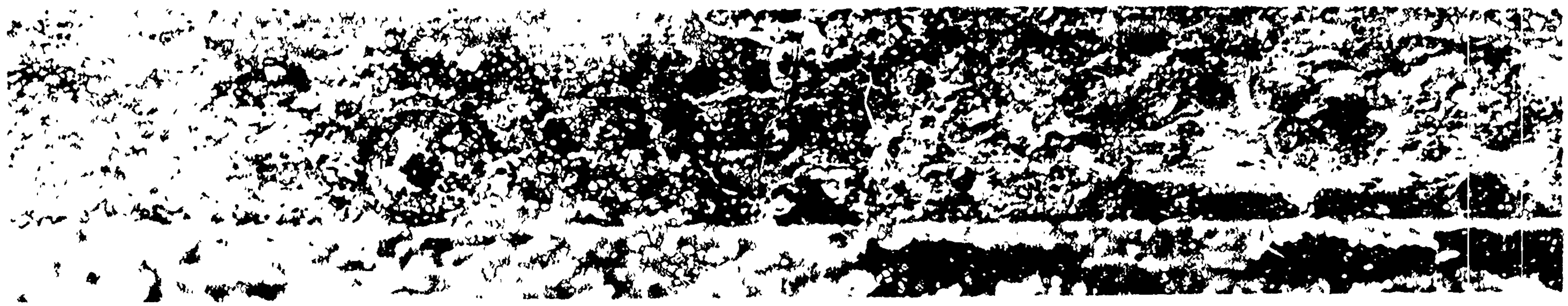
JACK FLOAT, LITTLEJOHN ROCKET LAUNCHER
Fig. 4



FRONT ROCKET SHOE, LITTLEJOHN ROCKET LAUNCHER
Fig. 5



UPPER WHEEL ELEVATING STRUT ASSEMBLY
Fig. 6



REAR LAUNCHER RAIL, LITTLEJOHN ROCKET LAUNCHER

Fig. 7

A list with pertinent comments concerning current specific applications of a resin-bonded dry film lubricant by Rock Island Arsenal follows:

XM34, Rocket Launcher (Littlejohn)

Ball sockets on the base of cross level jack.
(Exposed to extreme weather conditions and mud, sand and ice.)

Sliding cover support members of acme thread jack screw.
(Satisfactory service except for occasional squeaking noise.)

Sliding cam on tripping mechanism.
(Operates under heavy load.)

Rocket launcher beam trunion.

Moving parts in handwheel handles.
(Excellent except for occasional squeaking noise.)

Large area pintle support.
(Anodized aluminum bearing surfaces separated only by dry film lubricant. No failures in four years service under extreme conditions.)

Exposed pinion and gear sector used for traversing mechanism.
(Exposed to road dirt and severe weather conditions.)

Bearing support points on the wheel elevating mechanism.
(Exposed to the extremely severe conditions of a nonsprung suspension open to the weather.)

Slide dust covers on elevating mechanisms.
(Several of these mechanisms have been in service for four years and are still giving satisfactory service. These tubes cover a ball-screw mechanism and are open to the elements on the outside. Neoprene seals slide over the dry lubricated surface. The bearing areas are anodized aluminum on anodized aluminum separated only by the dry lubricant film. The success in desert areas is due to the fact that dirt and sand cannot adhere to the dry film surface as would be possible with fluid lubricants.)

Moving parts on hand brakes.
(Exposed to weather conditions.)

Pin bearings on kinematic links in the firing mechanism.

Chain and sprocket drive.

Spring loaded plunger mechanisms.
(Exposed to heavy side loads.)

Stop and lock levers and pins.
(Exposed to weather conditions.)

Threads on a screw actuated pressure plate brake.
(Excellent results under extreme load conditions.)

XM3E2, Loading Platform, Truck Mounted

Crane section applications

Telescoping tube assembly.

Support assembly.

Column assembly.

XM449, Trailer

Used in nine major areas including caster wheel assembly, threads, removable pins, pintle bearings, and pin yoke bearing areas.

Used on warhead mating fixture.

XM552, Trailer

Four applications.

XM505, Trailer

Elevating mechanism housing.

Torsion bar suspension axle.

Frame assembly at bearing areas.

M79, 106 Rifle Mount

Planetary gears and housings.

Elevating mechanisms.

XM32, Rocket Launcher

A frame.

Elevating mechanisms.

Telescopic tubes, elevating mechanism.

Rear trail pivot pin.

Rear trail locking pin.

XM31, 105 MM Howitzer

Ball pivot.

Ball pivot locking plate.

Ball pivot retainer (firing base).

Side support brackets.

Axle.

Axle locking pins.

Firing mechanism plunger shaft.

Cradle trunnion liners

Trunnion bushings.

Breech operating cam.

Breech operating cam pivot shaft.

Axle bushings.

Axle lock handle spindle.

One of the shops at Rock Island Arsenal recently experienced difficulty in obtaining the minimum acceptable firing rate with overhauled Browning Automatic Rifles. These weapons, after overhaul, zinc phosphatizing, and lubrication with conventional oil, were simply too tight to fire rapidly. It was found that coating the zinc phosphatized bolt assembly with a resin-bonded dry lubricant, followed by lubrication with the conventional oil, permitted the weapon to pass the firing tests. The dry lubricant film provided lubrication during the first few critical cycles of operation until satisfactory oil lubricated bearing surfaces could be established. The fact that the dry lubricant was rapidly removed from the bearing area by the oil was of no consequence. By that time, conventional oil lubrication was satisfactory. This is an example of the use of a resin-bonded dry lubricant as a sacrificial lubricant.

The following statement by Rossmiller[25] represents the current attitude of the Design Engineering Branch, Rock Island Arsenal, concerning resin-bonded dry lubricants:

"The use of RIA Compound 9A at Rock Island Arsenal is part of an overall plan to eliminate the grease gun and field lubrication of any kind on the M34 Littlejohn Rocket Launcher. Its use also aided in the success of the unit with regards to corrosion protection. So successful were the results of the use of this type of lubricant on the M34 Launcher that the usual complete series of environmental tests were eliminated upon the introduction of the XM34E1 Rocket Launcher. Engineer and Service Test personnel made the statement that if the XM34E1 Launcher was corrosion protected in the same manner as the M34 Launcher, further testing was a waste of money."

Research in the area of dry lubricants is proceeding in a number of directions. Some of the results are published and some of the results become evident as new products come onto the market. It is probable that a resin-bonded dry lubricant will be developed which will provide corrosion protection throughout the wear life of the lubricant. Studies are in progress which will probably lead to the development of compatible anti-friction bearing, dry lubricant systems, thus combining the advantages of anti-friction bearings and dry lubricants. A number of investigations into the areas of wide temperature range dry lubricants are in progress. These studies will probably lead to the development of a dry lubricant which can be used over the temperature range -300°F. to +1500°F. with equal effectiveness. The study of conversion lubricating coatings, whereby the lubricant film is formed integral with the bearing surface is proceeding at a moderate rate. Present research will ultimately result in the dry lubricant of the future which will embody the characteristics given in Table IV. Such a lubricant will find wide application.

TABLE IV

CHARACTERISTICS OF THE DRY LUBRICANT
OF THE FUTURE

1. Provide long wear life.
2. Provide corrosion protection throughout its wear life.
3. Provide lubrication over the temperature range -300°F. to +1500°F.
4. Provide lubrication in the presence of all contaminants.
5. Be relatively simple to apply.
6. Provide lubrication in all types of bearings.