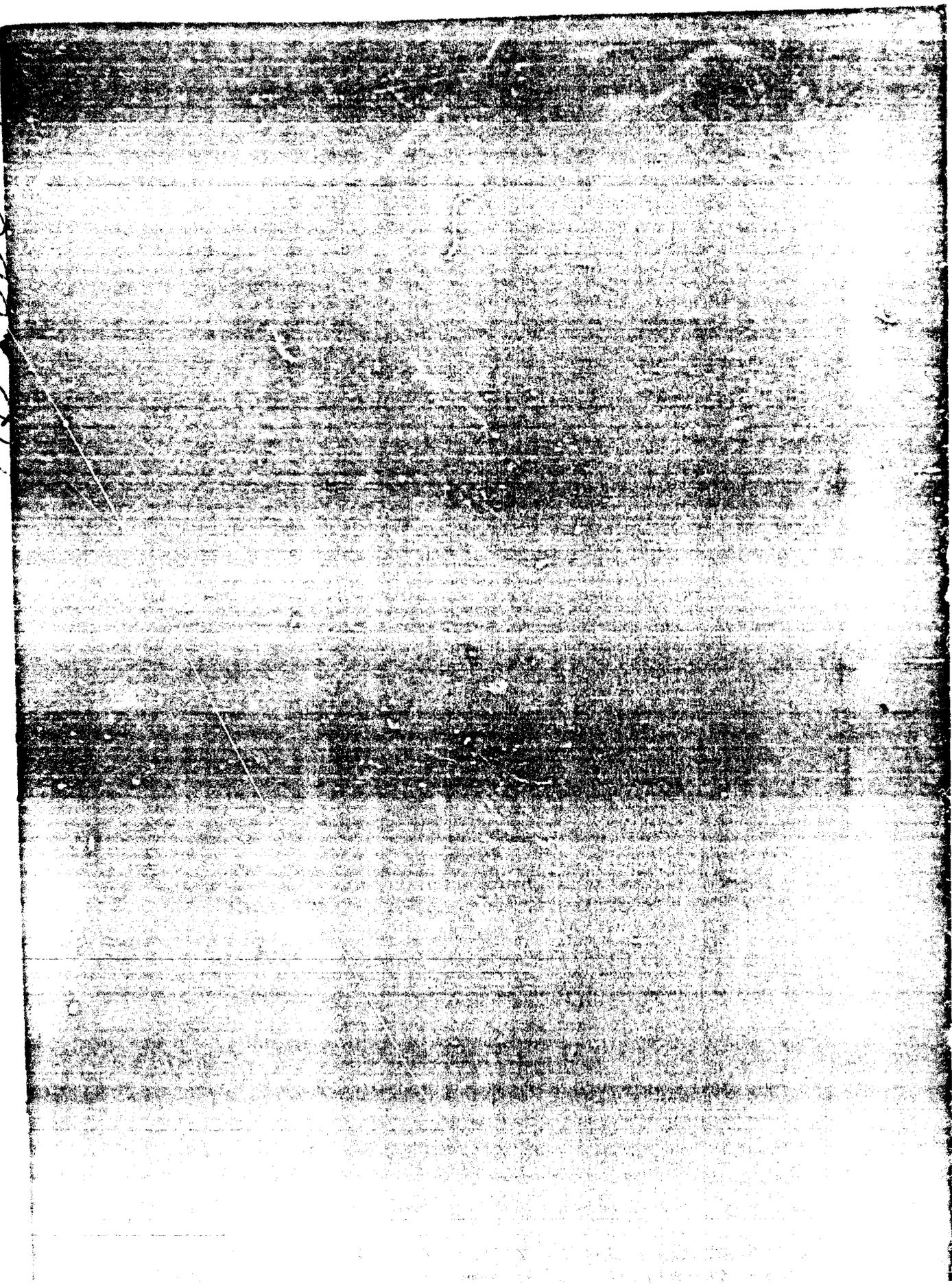


AD 488034



COATING MATERIAL FOR THE PROTECTION OF
AIRCRAFT INTEGRAL FUEL TANKS

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488034

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FOREWORD

This report was prepared by Products Research and Chemical Corporation, 2919 Empire Avenue, Burbank, California, under USAF Contract No. AF 33(615)-2414.

The contract was initiated under Project No. 7381, Task No. 738107, and was administered under the direction of the Air Force Materials Laboratory, Systems Engineering Group, with Mr. Sidney Childers, MAE, acting as Program Monitor.

Work here reported was conducted from March, 1965 to February, 1966.

The personnel of Products Research and Chemical Corporation assigned to the project were Robert N. Gilliland, Senior Research Chemist; Wesley T. Maurice, Research Chemist; and James N. Anderson, Senior Technician; under the direction of R. Loren Varner, Administrative Chemist. The major contribution of Lester Morris, Chief Chemist, is gratefully acknowledged.

Manuscript released by the authors April, 1966 for publication as an AFML Technical Report.

This technical report has been reviewed and is approved.

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ABSTRACT

A number of polysulfides, fluoroelastomers, polyurethanes, epoxides, polyols and polybutadiene copolymers were evaluated as potential one-package, fill and drain type surface coatings suitable for the preservation of aircraft integral fuel tanks against attack by corrosive elements. Very inferior acid, distilled water, and salt water /JRF resistance was found with polysulfide polymers which were cured with epoxides, isocyanates, or combinations of both. A surface coating derived from PR-1560-M (Part A), an isocyanate adduct, and Hycar MTBN, a mercaptan-terminated polybutadiene: acrylonitrile copolymer, exhibited good acid, water and fuel resistance. The adhesion to MIL-C-5541 Alodined aluminum surfaces was marginal and could only be improved at the expense of acid resistance. Isocyanate cured fluoroelastomer coatings containing carbon black possess superior acid, water and fuel resistance. Efforts to increase the moderate aluminum adhesion were unsuccessful. A surface coating composed of PR-1057/PR-1560-M (Part A)/cellosolve acetate in a 5.5:2.0:2.5 weight ratio was formally tested under the conditions of specification MIL-C-27725A (USAF). All requirements of the specification applicable to a one-package system were passed. The formulation applies easily to clean and dry MIL-C-5541 aluminum surfaces by fill and drain, brush or spray techniques.

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resistance was prepared from Hycar MBN, a mercaptan-terminated polybutadiene-acrylonitrile copolymer, and PR-1560-M (Part A). The formula, however, possessed one adverse feature. Adhesion to Alodined aluminum panels was only marginal. This defect could be partially alleviated by incorporation of various silane adhesion promoters. Unfortunately, the improved film to metal adhesion was accompanied by decreased acid resistance.

A study was made of isocyanate cured fluoroelastomers. A superior surface coating, with regard to overall chemical resistance, was developed from PR-1710 (Part B) and PR-1560-M (Part A). However, this coating possessed several drawbacks. Carbon black was necessary in the formula in order to attain the high level of chemical resistance. Film adhesion to MIL-C-5541 Alodined aluminum surfaces was only moderate. Extensive efforts were made to find a substitute for carbon black and also improve film adhesion. Studies were conducted on fluoroelastomer formulations containing anhydrous talc, MgO and trioctylphosphine. In no case was any improved chemical resistance or adhesion found. In general, the coatings were severely degraded in both 5% acetic acid and 0.5% iron chloride test media. Excessive blistering was found on Alodined aluminum panels which had been exposed to distilled water and salt water/JRF. While PR-1560-M (Part A) was by far the best isocyanate curing agent for the fluoroelastomers, carbon black is a necessity if good overall chemical resistance is to be obtained.

Experience with urethane surface coatings suggested that these materials might offer a good chance of success. A major portion of the program was devoted to the development of new and/or isocyanate modified surface coatings. A variety of polyfunctional isocyanates and isocyanate terminated prepolymers were cured with the following organics:

- A. Aromatic and aliphatic epoxides
- B. Polymercaptans
- C. Aromatic and aliphatic polyols
- D. Mixed epoxide-mercaptans
- E. Modified polyurethanes

In general, the acid and distilled water resistance of isocyanate based films containing either polyols, epoxides or mercaptans was very poor. Formulas containing mixed epoxide-mercaptans or straight polymercaptans exhibited the least Alodine adhesion. Also, there was the ever-present problem of maintaining one-part storage stability with such highly functional components. Good overall chemical resistance accompanied by moderate one-part stability and adhesion was found in the isocyanate or modified isocyanate systems. Three such materials which displayed the most promise were PR-1058, PR-1560-M (Part A) and PR-1057. Considerable time was expended in order to improve film adhesion and gain one-part storage stability.

An excellent coating was developed from PR-1560-M (Part A) and PR-1057. The candidate, formula 2414-501.4, is composed of PR-1057/PR-1560-M (Part A)/cellosolve acetate in a 5.5:2.0:2.5 weight ratio. It was formally tested under the conditions of MIL-C-27725A, and passed all requirements of the specification pertinent to a one-package system.

A brief study of aluminum surface application indicated that 2414-501.4 can be applied easily via fill and drain (dip-coating), spray or brush on clean dry metal.

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SECTION I

INTRODUCTION

The purpose of this study contract was to investigate and optimize a one-part fill and drain type surface coating. The coating material will be employed to protect military aircraft integral fuel tanks against corrosive environments. The candidate coating must meet the specification requirements as set forth in MIL-C-27725A (USAF). In addition, a brief investigation was made to derive improved methods for applying the candidate coating to integral fuel tanks.

A. General Background Information

The process of corrosion is an extremely complex form of material deterioration. While a wealth of information has been gathered over the years on the phenomenon, the process itself may assume manifold subtle forms for which no corrective action is readily available. The price of corrosion in terms of reduced equipment service life, as well as the funds spent to prevent and control it, runs into billions of dollars each year. These costs, which include labor, materials, and repairs, continue to rise. This is due to the introduction of new materials, new application methods, and hence the accompanying new corrosion problems which arise faster than solutions can be found.

In the case of metals, a corrosive environment may consist of salt water, chemicals, industrial gases, food, earth, or even micro-organisms. Thus, any media containing oxygen or moisture can be potentially corrosive to metals.

For purposes of this study, protection of aluminum surfaces is of prime interest. Aluminum is the most important single metal employed in the aircraft industry today. The major advantages of aluminum over other metals are its high strength-to-weight ratio and good general corrosion resistance. In order to attain certain specific high strength properties, basic aluminum must be alloyed with other metals such as zinc and copper. The overall effect of the alloying process is generally to decrease corrosion resistance.

The high reactivity of aluminum and its alloys towards oxygen affords a large degree of inherent protection against corrosion. Upon exposure to air, a thin, relatively impenetrable and tenacious oxide film is formed on any fresh aluminum surface. This protective film prevents further attack of potentially harmful oxidizing agents which may accelerate corrosion. This same tendency of aluminum to form such oxides is the basis for the artificially applied Alodined and anodized protective finishes.

For many years, the manufacturers and users of aluminum alloys have attempted to prevent and control its destruction by corrosive elements. The various approaches have included use of pure aluminum surface skins to protect the more susceptible alloys, chemical surface passivation as well as chemical surface coating application. As the demand and uses for aluminum alloys grow, the requirements for protective coatings have become

far more specialized and varied since the initial development of zinc chromate alkyds and dispersion resins.

The introduction of integral fuel tanks, accompanied by the wide range of military aircraft operating conditions, also inaugurated the use of wing tank coatings. The first wing tank coatings were based upon solvent solutions of such fuel resistant materials as Buna N modified with various phenolics for better aluminum adhesion. These coatings were not primarily developed in order to protect the metal surface from corrosive elements, but rather for tank sealant protection during the period when the early sealants were fuel sensitive. Over the years, as both the nature of aircraft fuels and airframe construction alloys varied, flight service records indicated a need for improved surface coatings possessing a higher degree of protection against corrosion.

During this period, it was fully realized that the performance requirements of integral fuel tank coatings would become more restrictive as aerospace and military aircraft technology progressed. As a result, new surface coatings would be needed to meet the expected future demand. In order to accomplish this, the environmental parameters relevant to the corrosion of fuel tank alloys must be determined and evaluated. Also, studies are needed of existing tank coatings with regard to their ability to cope with current and expected environmental corrosion conditions. The completion of such analyses would afford a firm starting point for the investigation and optimization of new surface coating materials.

B. The General Corrosion Process

At this point, some discussion is necessary with regard to the corrosion process as encountered in both actual service and qualification exposures. In order to provide adequate protection against corrosion for aluminum, the parameters pertinent to the overall process must be understood.

The position of aluminum in the electromotive series of metals designates it as an extremely reactive element. Aluminum, with a normal electrode potential of 1.7 volts, approaches the highly reactive alkali metals in the tendency to displace hydrogen from water. The readily formed oxide film or various chemical passivation treatments generally provide a coating which permits practical use of the metal. Aluminum also exhibits a hydrogen overvoltage which tends to increase corrosion resistance. This overvoltage simply reduces the effective system potential difference between the anode and cathode. Since galvanic corrosion is dependent upon a flow of current, the presence of a hydrogen overvoltage which reduces the system potential will also impede the rate and degree of corrosion. Thus, any prevailing conditions which remove the oxide film or reduce the overvoltage will result in a higher rate of corrosion.

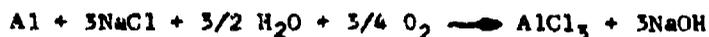
The reaction between aluminum and water, which is sluggish at ambient temperature, is shown below:



The presence of gelatinous hydroxide, oxide film or hydrogen all contribute to the system's stability. Due to the fact that metals are such good conductors, the total resistance of the galvanic circuit is usually a function of the solution or electrolyte resistance. Consequently, no appreciable galvanic corrosion will be generated in distilled water due to its poor conductance. Addition of tap water or salt water will supply sufficient ionizable salts to make the water conductive. This results in an increase in the corrosion rate as a function of temperature. The algebraic sum of the two relevant half-cell reactions is given below:



If oxygen is present in the saline solution, the hydrogen overvoltage will be further reduced, thus causing the aluminum to dissolve more readily.



The water consumption is reduced by one-half, but the same amount of AlCl_3 is produced in the absence of hydrogen. In this instance, the presence of oxygen accelerates corrosion of the aluminum.

Acetic acid, especially in the presence of metallic salts, will attack aluminum and its alloys. This attack is very severe at elevated temperatures, and possibly is caused by removal of the protective hydrogen monolayer.

Another very important source of aluminum corrosion is due to the presence of metallic ions which are below aluminum in the electromotive series. A very good example of this is iron. The aqueous iron chloride exposure test of MIL-C-27725A was chosen for this very reason.



Corrosion of this nature may even occur with thin films of condensed moisture in the presence of either dissolved inorganic salts or ionizable gases which allow for completion of the galvanic circuit. In this case however, the corrosion is usually localized near the points of contact, rather than distributed over the entire anodic surface. This suggests that inorganic pigments such as zinc chromate are less desirable than the alkaline earth chromates with regard to the cathodic series position of the cation relative to that of aluminum. Clearly, aluminum and its alloys are very sensitive to pH, ionic character, and temperature, as well as electrolyte and oxygen concentration.

The test conditions of MIL-C-27725A were so selected that the most probable conditions for aluminum corrosion and protective coating interaction are jointly present. The corrosive environmental media are aqueous sodium chloride, aqueous iron chloride and aqueous acetic acid-sodium chloride.

C. Protective Surface Coatings

The approach taken was to apply a thin film coating to the aluminum surface. The coating would utilize a combination of insulative and inhibitive mechanisms to provide the desired protection against corrosion. There will be interactions between the surrounding media, the coating, and the underlying metal surface. Some relevant parameters to be considered in such a situation are listed below:

1. Character of the Film's Protective Mechanism.

Three fundamental approaches are available to protect metals from their environment by overcoating.

- a. Insulative
- b. Inhibitive
- c. Cathodic

2. Film Permeability

a. Water Vapor

There are no organic membranes, continuous or otherwise, in the range of one mil thickness which will stop the penetration of water vapor. Organic films such as polyethylene yield low penetration rates. These are generally in the range of 0.1 gram per square foot per mil per day for films under immersion conditions. At best, even a rate of 0.1 gram per day is enough to corrode nearly an equal weight of aluminum.

b. Oxygen

Organic membranes are found to exhibit widely varying oxygen permeability rates. In general, these films are not significantly impermeable to oxygen at one mil thicknesses to be of any value.

c. Acetic Acid

Hydrocarbon class polymers have good fundamental acetic acid resistance. In nearly all other cases, resistance to acetic acid penetration can be attained only by extensive cross-linking. Unfortunately, such materials exhibit high sensitivity to fuel and consequently must be modified chemically. This is usually accomplished through additional cross-linking or incorporation of polar groups such as trifluoromethyl.

d. Salts

Ionic penetration of salts through a continuous, inert organic membrane, which has not undergone any physical or chemical change, is almost negligible. The effect of time however,

may induce substantial increases in both film penetration and conductivity. The gradual absorption of water produces manifold alterations in organic films. For example, ions may be included in the water migrating through the film barrier. Or, polar sites along the film's backbone become charged media for destructive reactions. In this case, the film is acting somewhat like an ion exchange resin. Still other polymeric types may undergo actual hydrolytic decomposition, furnishing reactive ionic fragments. The incorporation of inorganic pigments within the film produces still further complications. In general, prolonged exposure to water causes the pigment-resin interface to become discharged. This results in development of numerous capillary paths, along which salt solutions may enter the film and even attack the metal surface. The pigment itself may contain some ionic impurities or possess water solubility which slowly develops ionic environments near or against the metal surface. The selection of inert, water insoluble pigments is of great help here.

e. Microbial Resistance

Aqueous acetic acid has been selected as a criteria for evaluating polymer resistance to bacteriological attack. While this is not the sole mechanism by which organisms disrupt organic films, the 140° F., 5-day acetic acid exposure probably simulates quite adequately the effect of lower oxygen and hydrogen levels.

3. Protective Film Undercutting

The situation of film undercutting arising from uncoated edges, surface imperfections and scores is one of the most serious sources of aluminum surface coating failure. Current experimental evidence suggests that electro-osmosis is the primary mechanism by which such ionic migration occurs. When a metal surface coated with a nonconductive film is broken or cracked, the two-sided membrane acts essentially to establish an ionic concentration cell. The initial metal corrosion occurs at the point of film discontinuity where electrons are released to the metal inducing a second half-cell reaction. The oxygen present in the aqueous phase is reduced to hydroxyl ions. The established potential difference causes positively charged water, which may include other cations, to migrate under the organic film. This produces lifting and further film rupture outward from the initial break.

In the special case of aluminum, entrapment of hydroxyl ions (caustic) between the film and metal surface usually results in serious local pitting.

Four basic approaches have been adopted to minimize the degree of electro-osmotic attack:

a. Porous Films

Some films may be so ionically permeable, for example, paint-like coatings, that it is not possible to establish intense potential fields or localized paths under the film. This will permit generalized corrosion, but not film undercutting.

b. Inhibitive Films

The incorporation of pigments which change the charge on the organic film is of some value. For example, red lead has been reputed to accomplish this in steel protection. The effect of this is to lower the corrosion potential.

c. High Film Adhesion

If a membrane can be fabricated which is highly resistant to discharge by water vapor, as well as the corrosion by-products of acid and alkali attack, the electro-osmotic pressure will be incapable of causing film undercutting.

d. Cationic Membranes

Water normally carries a positive charge, while most organic films are negatively charged. In this case, migration of water through the film is quite rapid. If the membrane can be made cationic, it will assume a positive charge upon water immersion and halt migration.

4. Film Configuration

For purposes of this program, one can argue that fuel tank surfaces are only exposed on one side, and therefore any investigation of fully coated panels is redundant. The ribs and stiffeners within the tank are really multifaced panels. Consequently, it seems relevant to examine dip-coated panels where any discontinuities in either the metal surface or surrounding medium can be observed and correlated with the degree of corrosion.

5. The Effect of Film Thickeners on Cure and Physical Properties

This parameter is very important in the case of one-part fill and drain surface coatings. Film thickness will be a function of the polymer wetting characteristics, total percent solids and solvent system. Coatings deposited at varying thicknesses would be expected to exhibit different cure rates and degrees of corrosion resistance. In the case of a moisture curing one-part system, the solvent diffuses out as the polymer network crosslinks. In thick thermosetting coatings, the entrapped solvent often diffuses to the coating-metal interface where it may disrupt the film's adhesion, or even prevent approach of the bonding sites so that poor adhesion results.

SECTION II

PRELIMINARY SCREENING AND DEVELOPMENT

A. Polysulfides

Polysulfide polymers are widely employed for various coating and sealant applications. Some of the attractive properties of these materials are listed below:

1. Good water, oil, and gasoline resistance
2. Low gas permeability
3. Good resistance to sunlight, ozone, and general oxidation
4. Good flexibility at low temperatures

Some of the undesirable properties of the polysulfides are:

1. Fair tear and compression set resistance
2. Poor abrasion resistance
3. Fair flex life
4. Fair resistance to acids and alkalis
5. Relatively low heat resistance

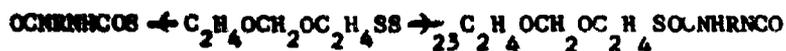
The degree of success achieved in any of the above physical or chemical properties is contingent upon the curing mechanism used. In sealants, for example, only dichromate and manganese oxidation systems have exhibited the high temperature and fuel resistance required by MIL-S-8802C.

In the coating field, many aircraft protective finishes are based upon various epoxide-polysulfide combinations. The epoxide-polysulfide copolymers have far superior impact resistance, better flexibility, lower water vapor transmission and improved wetting properties, as well as lower cure temperatures and shrinkage.

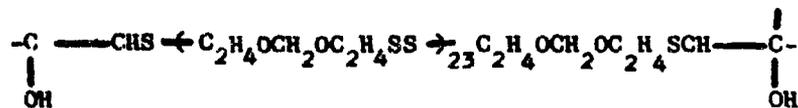
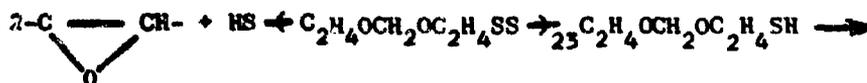
Consequently, polysulfide polymers appeared a logical point of departure for this investigation. Thiokol LP-32 was chosen as a good representative of the general series. While LP-32 is a low molecular weight, mercaptan terminated, disulfide containing, bis (ethyleneoxy)methane, it possesses polymeric properties producing a tough, yet flexible surface coating.

i. Cure Systems

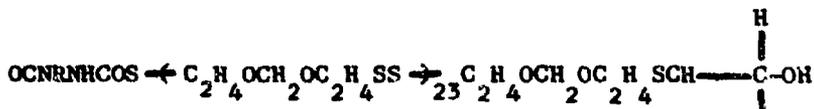
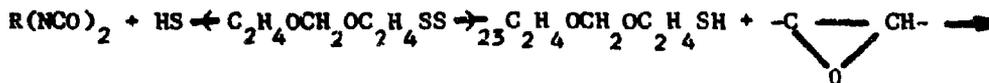
a. Isocyanate cures



b. Epoxide cures



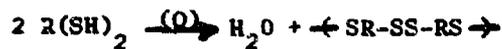
c. Epoxide-Isocyanate cures



d. Oxidation cures

(1) Sodium dichromate

(2) Manganese dioxide



2. Screening Test Results

Ambient temperature cures of LP-32 were attempted with aromatic and aliphatic isocyanates, epoxies, and various combinations of both. Oxidation cures also were studied with sodium dichromate and manganese dioxide systems.

In general, the acid, distilled water, and salt water/JRF resistance of the films was rather poor. The isocyanate cured coatings were quite soft, with pencil hardnesses in the range of 6B to F. By utilizing a more active catalyst a higher state of cure was attained, with increased hardness, but at the expense of one-package stability. These materials gelled within 24-60 hours at ambient temperatures. The film hardness also could be raised either by introducing an epoxide into the formulation, or by increasing the already present epoxy level. Unfortunately, this increased film hardness was accompanied by a drastic reduction in resistance to acetic acid, and in some instances, to iron chloride. The degree of corrosion exhibited on test panels was directly proportional to the epoxide content. Conversely, as the isocyanate level was raised, corrosion resistance was improved.

This detrimental effect of using epoxies in combination with isocyanate cured polysulfide systems was confirmed only when epoxy cured polysulfide materials were investigated.

In all cases these coatings were inferior to the isocyanate cured ones. Sylkem 90 and PAGE were found to be the worst epoxy components whether used individually or in combination with various isocyanates.

PR-1560-M (Part A), and Mondur MR were found to be the most effective isocyanates, with the former yielding the better corrosion resistant coatings. Polysulfide formulations 2414-100.1 through 2414-109 failed to pass either the distilled water or the salt water/JRF exposure tests. In all cases, failure was due to loss of adhesion rather than lack of resistance to these test fluids. All of the above formulations containing epoxies failed to yield corrosion resistant coatings upon exposure to acetic acid.

The probability of developing a successful one-part oxidation curing polysulfide surface coating is quite small. Nevertheless, it is interesting to determine what level of corrosion resistance such a material would have. Two MIL-S-8802C sodium dichromate and manganese dioxide curing sealants were chosen as model materials. The sealing compounds were reduced in solids content approximately three-fold by solvent dilution. Both formulations, 2414-419 and 419.1, coated extremely well and had very satisfactory ambient temperature cure rates. It must be realized that these materials are not designed for thin film surface coating applications, and consequently, their performance as coatings in no way represents their properties as true sealants. The resulting coatings performed poorly during the iron chloride and acetic acid screening tests. Film decomposition occurred within 24 hours at 140° F. The exposed test panels are shown in Figure 1 of Appendix II.

The results of this phase of the program have shown that polysulfides do not afford surface coatings with acceptable acid or distilled water resistance. None of the cure systems given in the previous section was able to provide a suitable material. The polysulfide/epoxy formulas were found to have the least acid and water resistance. A slight improvement in overall chemical resistance could be attained by adding an isocyanate to the various polysulfide formulations listed in Appendix I.

B. Fluoroelastomers

The excellent resistance of fluorinated hydrocarbon polymers to oils, fuels, acids and solvents is well known. Solvent dispersions of such fluorinated materials as Kel-F or Viton are interesting as non-curing, one-package surface coatings. The major drawbacks of such systems, for purposes of this study, are the absence of an ambient temperature cure as well as low level adhesion to aluminum surfaces.

The Viton series of fluoroelastomers was chosen as model compounds for study because of the wide range of molecular weights available. The Viton fluoroelastomers can be cured with three general types of agents; polyfunctional amines, peroxides and high energy radiation. Selection of amine curing agents was made because of handling and processing ease.

While a hindered diamine, hexamethylenediamine carbamate, is recommended for Viton cures, two major problems remain. Elevated temperatures are required for complete cure and adhesion to metal surfaces still remains marginal. For purposes of this investigation, a resistant but flexible surface coating is required possessing good adhesion to aluminum surfaces. Thus, a complete cure of the fluoroelastomer to a rigid film is not necessary.

Prior work has disclosed that isocyanates in general yield good corrosion resistant surface coatings.

Hexamethylene diisocyanate is the precursor of the hindered carbamate normally employed as the curing agent for Viton polymers. Consequently, use of this isocyanate appeared to be a logical starting point in the curing agent evaluation.

Curing agents were selected on the basis of potential corrosion resistance as well as the ability to afford a polyfunctional amine.

The curing agents studied were:

1. Mondur NX, hexamethylene diisocyanate
2. PR-1058, a one-part polyurethane coating
3. PR-1560-M (Part A), an isocyanate adduct
4. Desmodur N, an aliphatic polyisocyanate
5. NACCONATE H12, 4,4'-methylene bis(cyclohexylisocyanate)

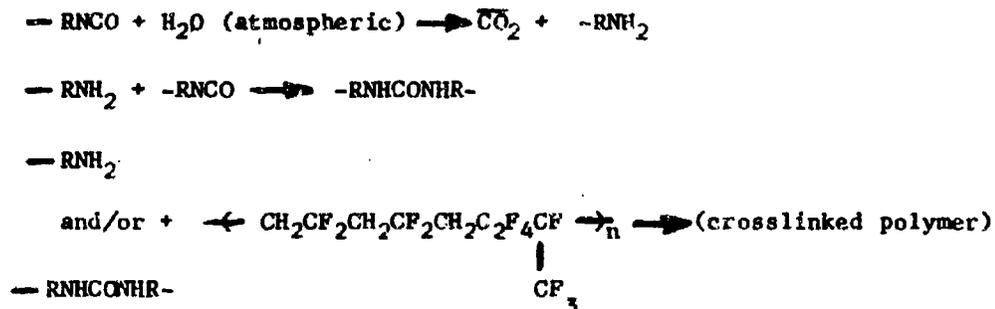
6. DDI, an aliphatic 36 carbon diisocyanate
7. Versamid 415, an aliphatic polyamide
8. A-1100, gamma-aminopropyltriethoxysilane

The eight curing agents were evaluated against the following fluoro-elastomer bases:

1. PR-1710 (Part B)
2. Carbon black and MgO pigmented Viton
3. MgO pigmented Viton
4. Talc and MgO pigmented Viton
5. Talc pigmented Viton
6. Unpigmented Viton

The extremely good resistance to the four screening test media observed with initial isocyanate cured fluoroelastomer formulations 2414-406 and 407 prompted an extensive developmental study of these materials. The prime goal was improved cure and film adhesion to MIL-C-5541 Alodined aluminum surfaces. A wide variety of aromatic and aliphatic isocyanates as well as aliphatic amines was formulated with PR-1710 (Part B) and Vitons A, B and LM.

The philosophy behind employment of isocyanate curing agents was as follows: Under the conditions imposed by MIL-C-27725A, the surface coating must cure within 14 days at ambient temperature. This type of environment is ideal for an atmospheric moisture induced polyurethane cure mechanism. For example, as the isocyanate reacts with water, an amine is generated which is available to cure the Viton fluoroelastomer. An illustration is given below.



Initial efforts centered on isocyanate cured fluoroelastomer coatings containing both carbon black and MgO. These formulations yielded films with superior fuel and acid resistance. PR-1560-M (Part A) was by far the best isocyanate curing agent. Mondur HX and Desmodur N exhibited good iron chloride and distilled water resistance, although significantly below that of PR-1560-M (Part A). Formulations containing PR-1058, a high molecular weight one-part polyurethane coating, and DDI, a 36 carbon aliphatic diisocyanate were much less successful. A degree of incompatibility was noted between PR-1058 and the fluoroelastomer solution which may have been due to the high molecular weight of the urethane polymer. The 5% acetic acid resistance of DDI cured films was extremely low. Some examples of iron chloride and acetic acid exposed test panels are presented in Figures 2 through 13 of Appendix II.

In Figure 2, 5% acetic acid exposed MIL-C-5541 Alodined aluminum test panels for formulas 2414-406 and 407 are shown. These two coatings, (see Table 1 of Appendix I, consist of PR-1710 (Part B) and PR-1560-M (Part A). The panels are completely free of blistering, underfilm corrosion and pin-point penetration. The two formulations afforded equivalent results in 0.5% iron chloride. The distilled water and salt water/JRF test panels were devoid of any attack, although film to metal adhesion was only moderate at best.

Examples of the Mondur HX and Desmodur N induced cures, after acetic acid and iron chloride exposure, are shown in Figures 3 and 4 of Appendix II. These formulations, 2414-414 and 415.1 of Appendix I, did not display the high degree of acid resistance found in those fluoroelastomer coatings containing PR-1560-M (Part A). While the salt water/JRF resistance was good, film adhesion was very poor in distilled water.

Equivalent results were observed with formulations 2414-418.31, 418.32 and 2414-417.6 through 417.4, which contained Viton A, carbon black and MgO. (See Figure 5 of Appendix II.)

If a PR-1710 (Part B)/fluoroelastomer coating is formulated with either Versamid 415 or A-1100, gamma-aminopropyltriethoxysilane, a much better film is attained. The coatings have a higher degree of cure and initial adhesion to Alodined aluminum is materially improved. Unfortunately, the resulting screening tests were much less successful. There was a complete loss of film adhesion, excessive blistering and underfilm corrosion, as well as partial film decomposition in both acetic acid and iron chloride. This is quite vividly documented in Figures 6 and 7, where 2414-408, PR-1710 (Part B)/Versamid 415, is compared with formulas 2414-406 and 407 iron chloride and acetic acid test panels. Formula 2414-416, PR-1710 (Part B)/A-1100, acetic acid and iron chloride test panels are shown in Figure 8. These same formulations exhibited very poor adhesion in both distilled water and salt water/JRF. Very similar test results were found with NACCONATE H12. (See Figure 9 of Appendix II.)

A second approach was undertaken to improve adhesion as well as chemical resistance. In general, as the degree of cure or cross-linking increases, so does acid and fuel resistance. Thus, to promote a further cure, anhydrous

MgO was incorporated into fluoroelastomer formulations as the hydrofluoric acid acceptor. Anhydrous talc was employed to improve film adhesion. As a control, the study also included unpigmented Viton coatings. The acetic acid and iron chloride test exposures are shown in Figures 10 through 13 of Appendix II.

Viton A, B and LM resins were formulated with MgO and talc as well as the two separately. Results from the screening test data indicated that the unpigmented Vitons as well as those containing talc yield inferior, corrosion prone coatings. Figure 10 shows 5% acetic acid exposed test panels for fluoroelastomer coatings 2414-417.4, Viton LM/PR-1560-M (Part A), and 2414-418, Viton A/PR-1560-M (Part A). Although 2414-417.4 may appear superior to 2414-418, both test panels exhibited extensive underfilm corrosion in iron chloride as well as acetic acid. This slight difference in acid resistance is attributed to a lower isocyanate level in the latter formulation. The failure of formula 2414-418 to pass either the distilled water or salt water/JRF screening tests is again attributed to a lower isocyanate content.

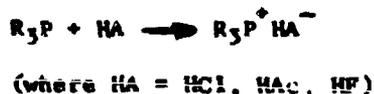
If fluoroelastomer-isocyanate formulations contain either MgO or talc-MgO combinations, the resulting coatings are extremely corrosion prone when exposed to iron chloride or acetic acid. Several excellent examples of two such formulations are represented by Figure 11. Panel A, 2414-418.13, consisting of Viton LM/PR-1560-M (Part A)/MgO, exhibits complete pinpoint penetration and underfilm corrosion. Panel B, 2414-418.26, containing Viton A/PR-1560-M (Part A)/MgO, shows extensive film decomposition in addition to excessive underfilm corrosion. Since both of these formulations contain nearly the same Viton/isocyanate weight ratio and the same percent total solids, Viton LM appears to have slightly better acid resistance than Viton A. This has not been observed in fact. In general, the molecular weight of the Viton series does not appear to be a significant fuel and/or acid resistance parameter in the formulations studied.

It now seems that carbon black is necessary in the isocyanate cured fluoroelastomer coatings if any reasonable degree of iron chloride or acetic acid resistance is to be realized. It is interesting to note that in the absence of carbon black, both the MgO, MgO-talc or even unpigmented Viton formulations are subject to extreme corrosion in acidic media. MgO or MgO-talc containing coatings would be expected to be liable to acid attack. While the true contribution of carbon black is not known, it may play a combination of roles in the film's protective mechanism. For example, the carbon black may either adsorb the evolved CO_2 as the isocyanate progresses through the cure cycle, or via capillary paths around carbon particles, CO_2 would escape from the film. Either instance would provide a surface coating essentially free of mechanical strain and small pinpoint voids.

Carbon black may also act as an adsorbent screen for acid and/or fuel molecules as they enter the upper coating monolayers, thus preventing attack upon the aluminum surface.

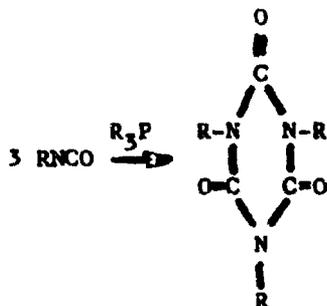
While carbon black is essential for protection against corrosion, its black opaqueness may present certain application and maintenance problems.

Consequently, a trialkylphosphine was selected as a possible substitute for carbon. This type of organic was selected for several reasons. The trialkylphosphines are able to form stable salts with both inorganic and organic acids, which in the case of our test media are:

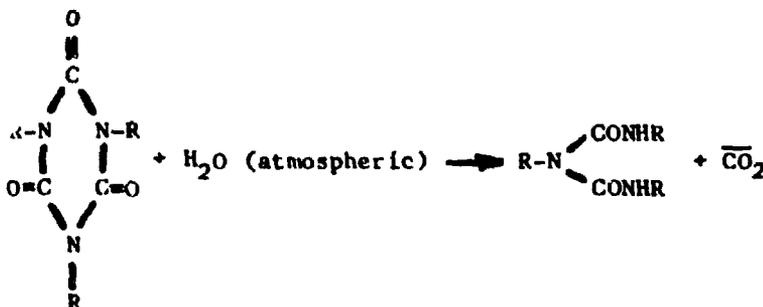


This type of complex is highly desirable in the case of isocyanate cured fluorocastomer coatings. A portion of the cure of Viton requires abstraction of HF from the fluorocarbon resin. Trioctylphosphine is a very weak organic base with a pKa of about 10.9. It is nevertheless, highly nucleophilic. Consequently, it may well tend to complex with HF, HCl and HAc. In this way the phosphine would replace MgO as the HF acceptor.

The trioctylphosphine might also act as an adhesion promoter. Urethane coatings which are heat cured, in excess of 80-100° C, generally exhibit improved adhesion. Also, as the cure temperature is raised, biuret formation is favored, suggesting that an increased biuret level may lead to better adhesion. Trialkylphosphines are also known to induce dimerization and trimerization of isocyanates as shown below.



These isocyanate trimers react further with water or atmospheric moisture to yield biurets and CO₂.



Thus, the trioctylphosphine may act as an acid acceptor while simultaneously promoting a polymer network containing a higher percentage of biuret linkages.

Formulations 2414-422 through 422.7 comprise a series of Viton B/PR-1560-M (Part A)/trioctylphosphine coatings. The expected improved acetic acid and iron chloride resistance was attained only at lower phosphine concentrations. There was underfilm corrosion and pinpoint penetration, but not to the same extent as in formulations containing MgO, MgO-talc or unpigmented Viton. There was also a material improvement in adhesion with the iron chloride exposed test panels. Surprisingly, there was a complete reversal of fuel resistance in salt water/JRF and acetic acid/JRF. Excessive blistering was observed in the fuel phases, but corrosion was reduced in both the acetic acid and salt water phases. The series was a complete failure in distilled water. Very large blisters appeared in distilled water after 10-13 days at 140° F. Film adhesion to MIL-C-5541 Alodined aluminum panels was almost nonexistent.

In conclusion, the two initial isocyanate cured fluoroelastomer surface coatings studied, 2414-406 and 407, proved to be the most successful. Acetic acid and iron chloride resistance was superior. Distilled water and salt water/JRF resistance was very good. The one problem with these coatings is the moderate adhesion to MIL-C-5541 Alodined aluminum surfaces. Although its role is not fully understood, carbon black is an essential component if any degree of acid resistance is to be attained. Its black opacity may, however, present application problems.

C. Polyurethanes

Organic isocyanates have wide general application in the field of surface coatings. Recent advances in isocyanate chemistry have afforded new materials possessing highly desirable physical and chemical properties. Isocyanate cured finishes usually combine hardness with good flexibility, impact strength and chip resistance. In addition to superior durability, the majority of isocyanate cured coatings also exhibit good acid and solvent resistance. Some isocyanate films may swell upon prolonged exposure to strong solvents such as dioxane or organic esters, but they are not dissolved or degraded to any extent. While urethane coatings have good resistance to solvent and dilute acids, they may become brittle upon prolonged exposure to concentrated acids.

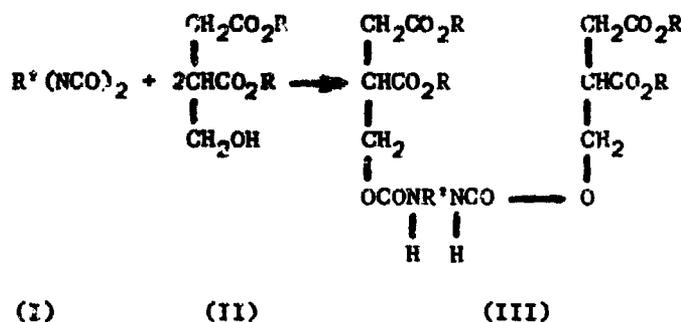
The object of this phase of the program was to screen or develop one-package isocyanate and/or modified isocyanate, corrosion resistant surface coatings. There are five basic types of conventional urethane surface coatings. The basic types can further be broken down into either one or two-package systems. The categories are:

1. Urethane Oils (prereacted isocyanate modified drying oils)

The urethane modified drying oils are the reaction products of hydroxyl containing drying oils with polyfunctional isocyanates. In general, these materials are useful in areas where high chemical resistance is not of prime

importance. The major advantages of such a system are its long-term stability and variable curing rates. The curing mechanism proceeds through an oxidative polymerisation of the unsaturation contained within the drying oil's fatty acid portion of the molecule. Examples of the reaction sequence are given below.

A polyfunctional isocyanate (I) reacts with a hydroxyl containing drying oil (II) affording the modified drying oil (III).

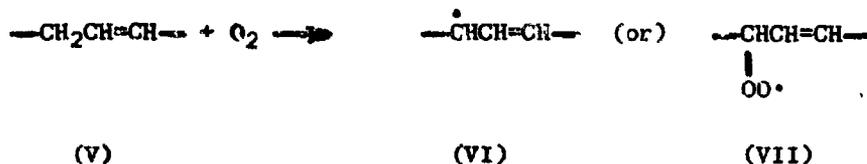


Where (R-), the fatty acid portion of the molecule, corresponds to (IV).

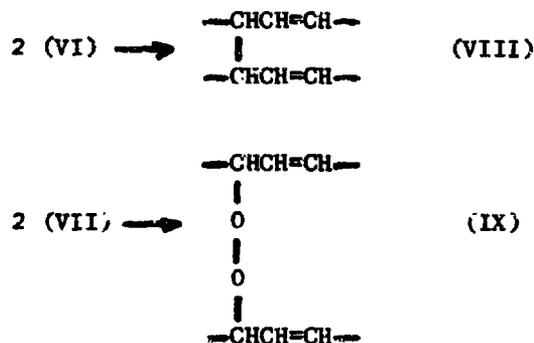


(IV)

Since all the isocyanate is consumed during formation of (III), the mechanism of the oxidative cure proceeds according to a typical reaction as follows:



These radicals propagate further with themselves or (V) to yield such high molecular weight structures as (VIII) or (IX).



2. Blocked Isocyanates

The "blocked" isocyanate surface coatings, while rather unique, are of little interest in this study. The reactive isocyanate sites of a molecule are prereacted with a phenol. This imparts one-package stability to the system. The blocked coating cures via regeneration of the free isocyanate by application of heat and/or organotin catalyst. An example of such a reversible reaction is given below.



3. Moisture Curing Isocyanates

A third type of one-package urethane coating is that which cures by exposure to atmospheric moisture. A simple cure mechanism is represented below.



For purposes of a one-package system applicable to the program, this type of surface coating is most appropriate. The uniqueness of this type of cure system is such that a wide variety of isocyanate containing materials can be employed. For example, any polyfunctional isocyanate, or isocyanate terminated prepolymer derived from polyesters, polyols, castor oil or polyethers may be utilized as a surface coating. Also, organics containing active hydrogens which react with isocyanate as well as urethane linkages may be incorporated into the formulation to impart specific physical and/or chemical properties to the coating.

4. Polyhydroxyl Cured Polyisocyanates

In general, a coating of this nature is a two-package system. By proper selection of chemical equivalencies and monomer functionality, this type approaches the moisture cured system in stability. The basic reaction is simple formation of a substituted polyurethane.



5. Catalyst Cured Polyisocyanates

This type of two-part system is really a variation of No. 3. A catalyst, usually a tertiary amine or carboxylic acid metal salt, is added to the isocyanate prior to surface application. The coating then can be cured by exposure to heat and/or atmospheric moisture.

Experience in the field of corrosion resistant coatings afforded valuable information as to fruitful areas of investigation. For example, moisture cured isocyanate based coatings display a higher level of acid and fuel resistance than do those coatings derived from commercially available isocyanate modified drying oils. As a result, the major effort within this phase of the program was devoted to the development of new isocyanate and/or isocyanate modified surface coatings.

Several approaches were undertaken which would yield potential isocyanate terminated, one-part surface coatings. Polyfunctional isocyanates as well as isocyanate terminated prepolymers were cured with the following organics:

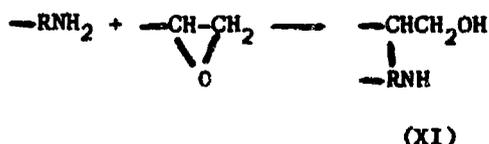
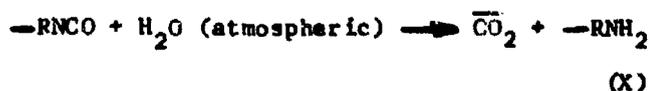
1. Aromatic and aliphatic epoxides
2. Aromatic and aliphatic polyols
3. Polymercaptans
4. Mixed epoxide-mercaptans
5. Modified polyurethanes

The curing of isocyanates with polyfunctional epoxides, alcohols or mercaptans may seem rather inconsistent in view of the one-part stability goal. Nevertheless, since gelation is a function of polymer crosslink density, careful adjustment of overall functional group equivalence, as well as the ratio of trifunctional and tetrafunctional monomers to isocyanate, can impart a certain degree of one-part stability to the system. Consequently, efforts were made to keep the concentration of epoxide, polyol or mercaptan at a level low enough to insure some network crosslinking, but not complete gelation.

Organic surface coatings containing isocyanates and various aliphatic or aromatic epoxides are inferior to those coatings having only trace amounts of epoxide. As the epoxide level is raised, and hence the crosslink density, the film becomes harder and less flexible. Unfortunately, this is also accompanied by a drastic reduction in both acetic acid and iron chloride resistance. On the average, isocyanates cured with aliphatic polyepoxides exhibit slightly higher acid and distilled water resistance than do either aromatic or silicone containing epoxides. Formulations containing isocyanate mixtures of PR-1058 and PR-1560-M (Part A) gave the best acid and water resistance. Examples of these coatings can be found in formulations 2414-200 through 203.1, 2414-207 through 211.1 and 2414-213 through 215.5 of Appendix I.

The drastic reduction in acid and water resistance with increased crosslinking may appear somewhat paradoxical, for in general, acid resistance increases with a higher crosslink density. This poor resistance is probably a culmination of factors such as incomplete epoxide consumption and the presence of pendant secondary amine sites along the polymer chain.

In the first case, if there is incomplete consumption of the epoxide by isocyanate, the residual epoxide is liable to acid as well as water attack. The second case is simply the tendency of acetic acid and aqueous iron chloride to attack the secondary amine groups along the polymer chain. The reaction might proceed as follows during the cure cycle.



Reaction of the isocyanate with atmospheric moisture gives the primary amine (X), which further reacts with the epoxide yielding the adduct (XI). This adduct is capable of reaction with additional isocyanate at both the amine and hydroxyl sites. In the absence of heat or a suitable catalyst, reaction will occur predominantly at the primary hydroxyl resulting in a free secondary amine which is prone to acid attack.

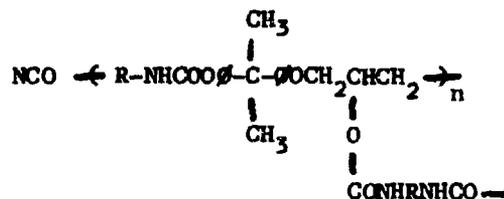
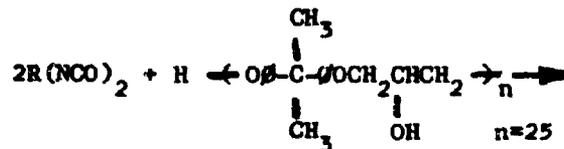
The addition of a tertiary amine catalyst, such as pyridine, which would volatilize during the ambient temperature cure, would favor the reaction between epoxide and isocyanate. While this is highly desirable, such a catalyst would also promote urethane active hydrogen crosslinking, thus destroying the probability of attaining any degree of one-package stability. Some examples of amine catalyzed isocyanate-epoxide coatings are given by formulations 2414-221 through 222.4 and 2414-223 through 223.3 of Appendix I. While there was a slight increase in overall acid resistance, the materials all gelled within 36-72 hours at ambient temperatures.

In order to improve acid resistance, the residual secondary amine functions should be removed from the polymer chain. This could be accomplished if only hydroxyl groups were available for reaction with the isocyanate. Consequently, a series of both low and high molecular weight polyols was studied. As with the epoxides, attempts were made to maintain the hydroxyl concentration low enough to avoid gelation.

Initial work employed two polyester polyols, NIAX 520 and 560, which were formulated with PR-1058 and PR-1500-M (Part A). The screening results were quite discouraging. Formulations 2414-216 through 218.3 and 2414-226 through 229.1 of Appendix I showed no improvement in either acid or water resistance. Incorporation of a urethane catalyst would have helped resistance, but hindered one-part stability. Substitution of an aromatic polyol was unsatisfactory also. Formulas 2414-401 and 401.2 failed in acetic acid, iron chloride and distilled water. This is not too surprising, for phenols, which are more acidic than aliphatic alcohols, react sluggishly with isocyanates at ambient temperatures.

During the second quarter of the program, EPONOL 55 was found to be a very promising corrosion resistant coating component. Two early formulations, 2414-224 and 225, exhibited very good resistance to the four screening test media. A coating composed of PR-1560-M (Part A), PR-1058 and EPONOL 55 provided the best protection. There was very slight #10F blistering in 5% acetic acid. Later attempts to improve upon the two initial formulations met with little success. Formulations 2414-232.1 through 234.5 of Appendix I resulted in greatly lowered resistance to iron chloride and acetic acid. Exclusive of some very slight acetic acid blistering, the area of major concern was that of one-package storage stability. The majority of EPONOL 55 containing formulations formed insoluble gels within 24 to 96 hours at ambient temperatures.

In order to attain one-package stability, five isocyanate terminated prepolymer coatings, formulas 2414-520 through 520.4 of Appendix I, composed of EPONOL 55 and PR-1560-M (Part A) were prepared. As before, insoluble gels were observed at extreme dilutions and NCO/OH equivalent ratios as high as 11:1. This is not too unexpected, for the very high molecular weight and functionality of EPONOL 55, 2000,000 and 25 respectively, would tend to form such highly crosslinked reaction networks as illustrated below.



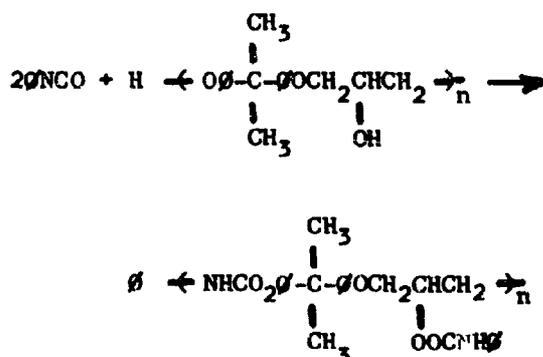
If the functionality of the hydroxyl component were reduced, the probability of gaining long-term stability would be increased. Consequently, EPONOL 53, possessing the same chemical structure as the 55 resin with only 40% the molecular weight, was evaluated with PR-1560-M (Part A). A series of four isocyanate terminated prepolymers was synthesized at 70-85° C. These resins afforded up to two weeks of one-package stability.

Surface coating formulations 2414-520.5 through 520.8, which were based upon these prepolymers, exhibited drastic reductions in iron chloride, acetic acid and distilled water resistance. Coated Alodined MIL-C-5541 aluminum panels were severely blistered and showed extensive underfilm corrosion and poor film-to-metal adhesion.

A true one-package system composed of EPONOL 55 and PR-1560-M (Part A) could be prepared if the hydroxyl functions of the EPONOL resin were first

prereacted with a monoisocyanate. Aromatic isocyanates have two distinct advantages over the aliphatics in this instance. Aromatic isocyanates are far more reactive towards hydroxyl. Also, experimental evidence indicates a higher level of acid resistance for aromatic isocyanates.

An endeavor was made to convert EPONOL 55 into the monocarbamate via reaction with phenyl isocyanate. The synthesis was conducted at 60-80° C for 3 hours. IR analysis indicated about 50-60% hydroxyl consumption. The resulting resin was extremely viscous, possessing only slight solubility in MEK, MIBK, cellosolve acetate, toluene or mixtures of these solvents. The same reaction was repeated substituting IPONOL 53 for the 55 resin. IR analysis of the reaction product indicated 70-80% conversion. The resin was easily soluble in cellosolve acetate/MEK/toluene in a 6:3:1 ratio. The sequence is shown below:

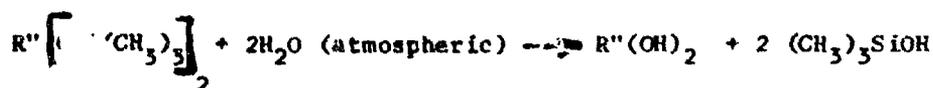
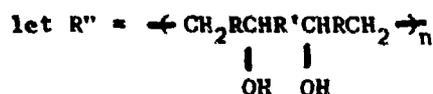
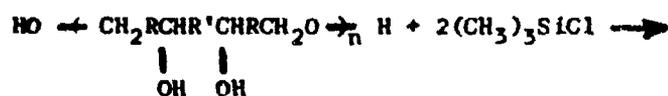


Two coating formulations, 2414-520.9 and 520.10, were made with PR-1560-M (Part A) and the prereacted EPONOL 53/ONCO resin. While there was good indication of one-part stability, the level of acetic acid and distilled water resistance was below that of coatings containing the 55 resin. Apparently, in order to achieve any acceptable degree of acid or distilled water resistance, the higher functionality and molecular weight of EPONOL 55 is required.

A wide variety of mixed cure systems were evaluated with PR-1560-M (Part A). Some examples are: Mercaptan-epoxide, 2414-303.4; epoxy-phenolic, 2414-401.1; polysulfide-phenolic, 2414-401.3; and polysulfide-phenolic-epoxide, 2414-401.6. Generally, these mixed cures resulted in lower acid and distilled water resistance than did each of the components when cured separately with the isocyanate. The most probable explanation is inadequate reaction between the various components. Consider formula 2414-401.6 of Appendix I. The isocyanate should preferentially react first with the mercapto-terminated polysulfide rather than with the more acidic phenolic or the uncatalyzed epoxide. There may also be some secondary interaction between the epoxide and phenolic. Although the majority of such reactions do not proceed well at ambient temperatures, a highly acidic phenol can open an oxirane ring, leaving an essentially non-reactive secondary hydroxyl available for the isocyanate.

Efforts were made to convert PR-1560-M into a one-part surface coating. The approach undertaken was to protect the hydroxyl functionality of the resin with either trimethylchlorosilane or phenyl isocyanate. This would allow later incorporation of polyfunctional isocyanates thus promoting one-part stability.

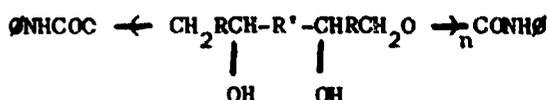
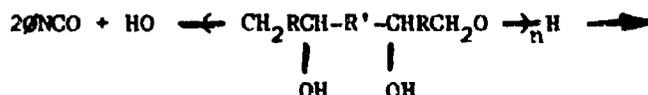
The reaction between trimethylchlorosilane and PR-1560-M (Part B) would convert the polyol into a water reactive silicate ester. The ester would be inert toward isocyanate in an anhydrous system, but upon exposure to atmospheric moisture, revert by hydrolysis to the polyol and alkyl silicic acid. The three step reaction sequence is presented below. The resulting isocyanate terminated polymer would also cure by exposure to atmospheric moisture.



Three attempts were made to convert PR-1560-M (Part B) into the corresponding silicate ester. The reactions were conducted at 50-110° C for 3-7 hours. After the reaction period, vacuum was applied to remove excess chlorosilane and the HCl by-product. IR analysis of the resin indicated only 40-50% conversion to the desired ester. The material would not be suitable in a one-part system, for the addition of a difunctional isocyanate caused gelation within 18 hours at ambient temperature.

Emphasis was shifted to the phenyl isocyanate/PR-1560-M (Part B) reaction as a means of reducing the hydroxyl functionality of PR-1560-M.

An amount of phenyl isocyanate was added to the base resin in 70% theoretical equivalence. The reaction was run for four hours at 80-100° C. Only partial conversion to the urethane was desired. The residual secondary hydroxyl sites were left to insure some degree of crosslinking. The overall reaction is shown below.



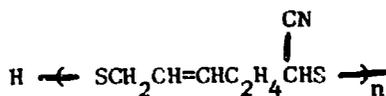
Additions of PR-1560-M (Part A) resulted in a coating which exhibited a 14 day, ambient temperature, constant viscosity. Application of the material to MIL-C-5541 Alodined aluminum panels, either by dip-coating or spray, was extremely difficult. The coatings were found to crawl very badly. Small pinpoint voids appeared in the film during solvent volatilization. Solvent dilution and addition of silane wetting agents were tried to correct the situation, but without success. In view of the good results discussed later in the report, any further efforts to convert PR-1560-M into a one-part coating did not appear justified.

D. Butadiene:acrylonitrile Copolymers

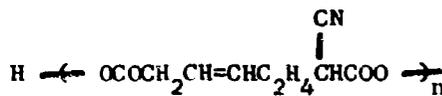
A series of functional and non-functional butadiene copolymers was investigated as potential surface coating components. They are listed below:

1. Hycar MTBN, a mercaptan-terminated polybutadiene:acrylonitrile copolymer.
2. Hycar CTBNX, a carboxyl-terminated polybutadiene:acrylonitrile copolymer.
3. Hycar 1022, a butadiene:acrylonitrile copolymer.

The butadiene:acrylonitrile elastomers possess good fuel and solvent resistance. However, the acid resistance as well as adhesion to MIL-C-5541 Alodined aluminum surfaces is only moderate. If reactive end-groups can be incorporated into the basic polymer, functional cures can be accomplished which may lead to improved acid resistance and adhesion. Hycar MTBN (XII) and Hycar CTBNX (XIII) are two such materials.

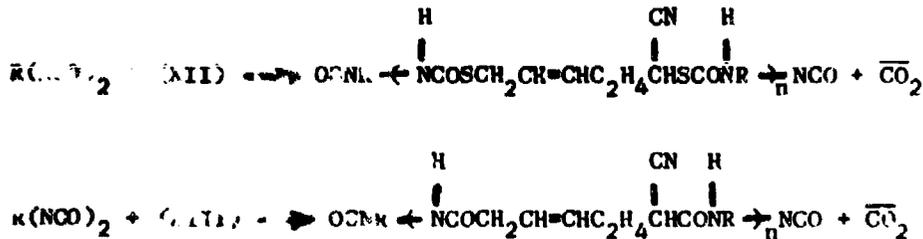


(XII)



(XIII)

Reaction of either (XII) or (XIII) with isocyanates may afford moisture curing surface coatings with improved acid resistance and adhesion as shown below:

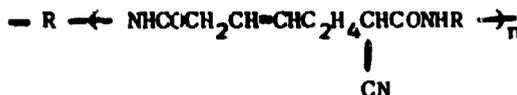


The initial investigation of MTBN surface coatings included isocyanates and aliphatic and silicone containing organic epoxides as the curing agents. Two cure mechanisms were employed. In instances of straight epoxide cures, DMP 30 was the catalyst. Where diisocyanate cures were formulated, the reaction of atmospheric moisture with isocyanate was required to supply the necessary amine catalyst. In those formulations containing both epoxide and isocyanate, the catalyst was either pyridine or DMP 30.

MTBN coatings cured with either Sylkem 90 or polyallylglycidyl ether, 2414-300.1 and 300.3, failed to pass acetic acid, iron chloride and the distilled water screening tests. Acid exposed aluminum test panels exhibited extensive #10M blisters, underfilm corrosion and pinpoint penetration. Film adhesion in distilled water was very poor. If PR-1560-M (Part A) was added to the MTBN-epoxide formulations, 2414-300.4 and 300.5, acid resistance was materially improved. Unfortunately, distilled water blistering and adhesion remained unchanged. By converting to an all isocyanate curing system, 2414-300.2 and 304, a much improved moisture curing coating was obtained. While formula 2414-300.2 displayed improvement over 300.4 and 300.5, 2414-304 yielded a far superior coating. Iron chloride resistance was excellent. There was no evidence of blistering, pinpoint penetration or underfilm corrosion. Exposure to 5% acetic acid yielded some slight #10F blisters with a much higher level of adhesion. There was slight #10F blistering in distilled water and adhesion remained low-level. In order to raise distilled water film adhesion, a known adhesion promoter, beta-mercaptoethyl trimethoxysilane (Y-4522), was incorporated in formulas 2414-306 and 306.1. While there was a slight increase in distilled water adhesion, blistering in acetic acid rose.

Although sulfur has less electronegativity than oxygen, thiols are considerably stronger acids than the corresponding aliphatic alcohols. Consequently, like the phenols, thiols should require a tertiary amine catalyst for reaction with isocyanates. For this reason, DMP 30 was included in formulas 2414-306 and 306.1. The overall effect in either direction was not significant.

Several attempts were made to cure Hycar CTBNX with PR-1560-M (Part A) and PR-1058. Formulations 2414-308, 308.1 and 405 exhibited excessive #6M blistering in distilled water, iron chloride and acetic acid. Distilled water adhesion was almost nonexistent after 30 days at 140° F. A slight improvement in resistance to the four screening test media was observed when PR-1560-M (Part A) was the sole curing agent. These failures were attributed to acid and water attack on the substituted amide structure shown below.



The initial success attained with isocyanate cured fluoroelastomers prompted investigation of isocyanate-Buna N coatings. Consequently, Buna N (butadiene:acrylonitrile copolymer) was evaluated with PR-1560-M (Part A).

Experience with Buna N type surface coatings indicated that the best performance characteristics were obtained when the films were baked at temperatures in the range of 160-180° F for 24 hours. Any significant level of water or ionic resistance is not realized unless an elevated temperature cure is conducted. Over a period of time further crosslinking takes place, resulting in loss of adhesion, peeling and film undercutting.

MIL-C-5541 Alclined aluminum panels were coated with seven variations of Hycar 1022 (Buna N)/PR-1560-M (Part A) formulations. The NCO/Buna N weight ratio was varied from 5.4:1 to 1.1:1. Careful study of test data from formulas 2414-423.3 through 423.5 and 2414-427 through 427.3 indicated that the optimum, although marginal, acetic acid and iron chloride resistance was attained at NCO/Buna N weight ratios in the range 2.0:1 - 3.0:1. Acetic acid and iron chloride exposed test panels exhibited blistering, pinpoint penetration and underfilm corrosion. Similar results were found with the salt water/JRF and distilled water exposures. Film adhesion was poor with some pinpoint penetration in the former, while adhesion was good with moderate #10F blistering in the latter.

In summary, none of the polybutadiene:acrylonitrile copolymers investigated provided satisfactory distilled water adhesion or acid resistance. General chemical resistance was improved by incorporating isocyanates into the formulations. Concurrent efforts to raise film adhesion only resulted in reduced acid resistance. In no way did any of the isocyanate/MTBN surface coatings approach either the isocyanate/Viton or mixed isocyanate formulations in overall chemical resistance or film adhesion.

SECTION III

INVESTIGATION OF ONE-PACKAGE MATERIALS

A. General Information

A one-package moisture curing surface coating can be prepared by employing a polyfunctional isocyanate or isocyanate-terminated prepolymer. Current work has resulted in two isocyanate containing materials possessing good acid and solvent resistance.

Screening test data obtained earlier in the program from isocyanate/epoxide coatings indicated that chemical resistance was inversely proportional to the oxirane concentration. The next logical step was to investigate mixed isocyanate systems.

The initial efforts along this line were rather successful, as evidenced by the environmental test data derived from formulations 2414-200.2, 2414-204.1 through 204.3, 2414-206.1 through 206.4 and 2414-212 through 212.3. Reference to Figure 16 of Appendix II clearly shows the effect of adding PR-1560-M (Part A) to PR-1058. The degree of blistering and under-film corrosion is seen to be inversely proportional to the concentration of PR-1560-M (Part A). While the improvement in acetic acid and iron chloride resistance is readily apparent, the coatings possess low-level aluminum adhesion. Film adhesion was improved by adding an epoxysilane, Y-4086, to the urethane system. This is demonstrated in Figures 17 and 18 of Appendix II. Panel A, 2414-206.1 exhibits excellent acetic acid and iron chloride resistance. Panels B and C, formulas 2414-212.2 and 212.3, each containing 3% by weight of epoxysilane, resulted in coatings with greatly increased adhesion, which retained a major portion of the acid resistance first observed in 2414-206.1.

During the second quarter of the program, formula 2414-217.1 was developed as an outgrowth of the highly successful 2414-206.1.

2414-217.1

PR-1058	-200
PR-1560-M (Part A)	-100

This coating exhibited good overall resistance to the four screening test environmental fluids. The only drawback was the low-level adhesion to Alodine and anodized aluminum surfaces. As a result, the coating was not considered reliable enough for good long-term in-service performance. Considerable effort was devoted to improve film adhesion of this system. The approaches undertaken were as follows:

1. Incorporation of silane adhesion promoters
2. Pigmentation

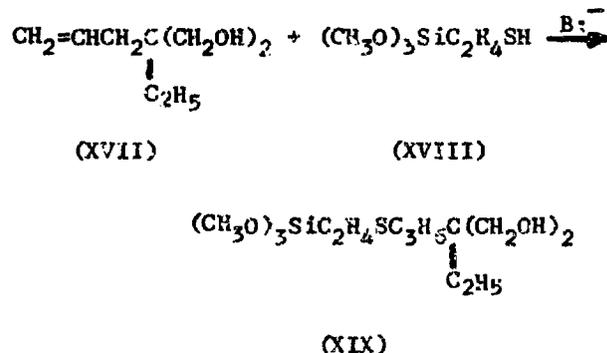
3. Silane-pigmentation combinations
4. Investigation of other isocyanate curing agents
5. Incorporation of other resins to reduce film brittleness

Three silanes, A-153, Y-4086 and Y-4522, were evaluated as potential adhesion promoters for 2414-217.1. Coating formulations 2414-235.4, 235.5 and 240.2, containing A-153, phenyltriethoxysilane, were found to be materially inferior in chemical resistance. There was no visible improvement in distilled water adhesion. Also, moderate #10M blisters were observed on acetic acid exposed test panels, with a definite loss in film adhesion.

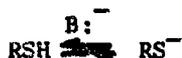
Previous work with PR-1058/PR-1560-M (Part A) coatings containing Y-4086 has already been discussed. A final attempt was made to determine a concentration level of Y-4086 maximizing film adhesion while minimizing acetic acid attack. Although formula 2414-240 provided good adhesion, the coating failed in 5% acetic acid with moderate #10F blistering.

Incorporation of Y-4522, beta-mercaptoethyl trimethoxysilane, into formulas 2414-235 through 235.3 and 240.1 also resulted in higher film adhesion. The optimum adhesion with least acetic acid attack was observed with 2414-235.3 and 240.1. Film adhesion appeared moderately higher and acetic acid blistering slightly less than in cases where the epoxysilane was used. This is not too unexpected, for the mercaptan is directly reactive towards isocyanate, whereas the epoxide usually requires either acidic or basic catalysis.

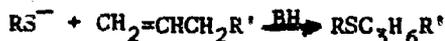
An effort was made to synthesize a silane containing adhesion promoter which would have a higher level of reactivity towards isocyanates than either the epoxysilane or the mercaptosilane. Aliphatic alcohols readily meet this requirement. Hence, if 2-ethyl, 2-allyl-1,3-propanediol (XVII) was converted to the adduct (XIX) by reaction with beta-mercaptoethyl trimethoxysilane (XVIII), a silane containing diol would result. The reaction might proceed as outlined below:



Formation of (XIX) is predicated upon the nucleophilicity of the mercaptide ion (XX), which in the presence of base, adds via an anti-markovnikov mechanism to the highly reactive allyl group. The two-step mechanism is shown below:



(XX)



In order to insure formation of the mercaptide, DMP 30 was added as the basic catalyst. IR analysis of the resulting oil indicated 60-70% conversion to the desired adduct. An attempted reduced pressure distillation of a portion of the crude oil resulted in partial decomposition and formation of a solid polymeric material. Consequently, the crude reaction product was evaluated without further purification in coating formulations 2414-241 through 241.3. In no instance was the expected higher adhesion found. The films blistered in distilled water, iron chloride and acetic acid. Also, significant losses in film adhesion were observed in distilled water and salt water/JRF.

Anhydrous talc was added to 2414-217.1 in order to raise both adhesion and acid resistance. Coating formulation 2414-217.5 exhibited good resistance properties and excellent storage stability. A relatively constant viscosity was maintained over a six-week duration at ambient temperature. Unfortunately, the coating checked rather badly when tested for impact resistance, thus indicating moderate adhesion and excessive brittleness. There was no visible improvement in film adhesion.

A combination of talc and silane additives was incorporated into the basic formula 2414-217.1. Silanes Y-4086 and Y-4522 were evaluated in talc pigmented systems. Coating 2414-217.51, containing talc and epoxy-silane, failed acetic acid exposure due to loss of adhesion, but performed quite well in the other three exposure media. Formulation 2414-217.6, containing mercaptosilane and talc, exhibited outstanding resistance to the four test fluids. (See Figure 19). This system did not afford one-part stability. The material showed a steady viscosity increase with ultimate gellation after 7 weeks.

Four other polyfunctional isocyanates were investigated as possible replacements for the isocyanate adduct in PR-1560-M (Part A). Formulations 2414-245 through 245.5 containing Mondur MR, MDI, NACCONATE H12 and DDI did not approach those coatings cured with PR-1560-M (Part A) in acid or water resistance. Some examples are presented in Figures 20 and 21.

Experimental data gathered on formula 2414-217.1 indicated that the low-level adhesion to Alodined and anodized aluminum was due to its brittleness. The addition of an isocyanate containing resin possessing less functionality should reduce the film's brittleness. PR-1057, a one-

package urethane, is characterized by somewhat greater flexibility than either PR-1058 or PR-1560-M (Part A). Coatings 2414-418.24, 418.29, 418.30 and 419.2, containing these isocyanates, afforded some interesting results. The level of adhesion was found to be directly proportional to the PR-1057 concentration. As the PR-1058 concentration fell, there was a significant increase in film adhesion as well as acetic acid resistance. Maximum film adhesion was attained at 100% replacement of PR-1058 by PR-1057. Acetic acid exposed test panels on formulas 2414-418.24 and 419.2 are compared to 2414-217.1 in Figure 22. Formula 2414-419.2 easily passed the four screening tests. No evidence of blistering, pinpoint penetration or underfilm corrosion could be found on any of the test panels. The coating also exhibited one-package shelf stability for 7 weeks at ambient temperatures, and for 7 days at 120° F. The impact resistance, or brittleness of the cured film was greatly improved over formulations containing PR-1058.

In order to determine whether the PR-1057/PR-1560-M (Part A) system yields optimum chemical and corrosion resistance, other co-curing agents were studied.

Formulas 2414-420.8, 420.9 and 424 contained Mondur MR, MDI and DDI. Examples of acetic acid test exposures for these three coatings compared to 2414-217.1 are shown in Figure 23 of Appendix II. As was found with the previously discussed PR-1058 formulations, the PR-1057/Mondur MR, MDI and DDI coatings also displayed inferior acid and water resistance to those films containing PR-1560-M (Part A).

It was of some interest to determine what level of acid and/or fuel resistance PR-1057 imparts to 2414-419.2. Therefore, a series of PR-1560-M (Part A) cured coatings was prepared containing PR-1057, PR-1057/talc and PR-1057/talc/urethane catalyst. Pictorial results of acetic acid exposed test panels are presented in Figure 24 for formulas 2414-425, 425.1 and 425.2. The scribed panels easily passed the tape adhesion test.

All three coatings readily passed the distilled water, salt water/JRF and iron chloride test fluids with good resistance and adhesion. While film adhesion in 5% acetic acid was quite acceptable, there was enough film blistering and pinpoint penetration to cause failure. Incorporation of anhydrous talc into formula 2414-425.1 did not visibly raise acid resistance. The use of a urethane catalyst in conjunction with talc resulted in a slight reduction of both pinpoint penetration and film blistering. It appears that while both PR-1057 and PR-1058 yield good corrosion resistant surface coatings when co-cured with PR-1560-M (Part A), none of the three materials provides the same degree of chemical resistance or adhesion when employed separately.

B. Final Developmental Studies

Further efforts were made to improve upon formula 2414-419.2. The parameters deemed necessary for study were:

1. Selection of solvent system
2. Optimal PR-1057/PR-1560-M (Part A) ratio

3. Optimal percent solids
4. Catalyst level (if needed)
5. Effect of incorporating pigments
6. Duration of ambient temperature one-part stability
7. Effect of silane adhesion promoters

The evaluations were performed upon coating formulations within the series 2414-425.3 through 2414-505.3.

Either of two anhydrous solvents, chlorobenzene or cellosolve acetate, can be readily utilized in the PR-1057/PR-1560-M (Part A) system. The unpigmented film becomes tack-free earlier with the aliphatic ether, and also presents less of a toxicity hazard to the worker than does chlorobenzene. The best formula with regard to overall film adhesion, corrosion, fuel and blister resistance was found to be 2414-501.4.

2414-501.4

PR-1057	-220
PR-1560-M (Part A)	- 80
Cellosolve acetate	-100

Distilled water, salt water/JRF, iron chloride and acetic acid exposed test panels for the above formula are shown in Figure 25. The acetic acid, salt water/JRF and distilled water panels were scribed for the adhesion tape test, refer to 4.7.20 of MIL-C-27725A, of which all passed quite easily. Careful examination of Figure 25 shows that none of the edges or corners of the defined rectangles on the scribed panels are irregular. This is extremely important, for the absence of edge and corner unevenness or pitting denotes excellent coating adhesion. There was absolutely no chemical attack or blistering on any of the MIL-C-5541 Alodined aluminum surfaces. Addition of a urethane catalyst did not reduce tack-free time significantly or promote a better cured film. Depending upon the relative humidity, the films became tack-free within 2 to 4 hours at ambient temperatures.

An endeavor was made to further improve the already excellent adhesion to aluminum of 2414-501.4. Prior work has shown the most successful urethane adhesion promoter to be beta-mercaptoethyl trimethoxysilane (Y-4522). Incorporation of this silane into the one-part coating did not give any discernible improvement in film adhesion. In fact, as might be expected from previous discussions, there was a very slight reduction in acetic acid resistance.

Pigments usually are incorporated into surface coatings to improve adhesion and chemical or abrasion resistance. On the basis of the four preliminary screening tests, 2414-501.4 does not require any of these. However, the material may require pigmentation simply as a coloring agent

to aid in proper spray or brush application. In order to insure long-term one-part stability, any included pigment must be essentially free of moisture. The effect of talc has been discussed previously. It was of further interest to learn the effect of a highly colored pigment, considering both stability and resistance parameters. Formulas 2414-428 through 428.5 were compounded with Cr_2O_3 . The resulting screening tests were quite interesting. All coatings passed both distilled water and salt water/JRF exposures. Formulations 241A-428, 428.1 and 428.2 easily passed 5% acetic acid, but surprisingly failed the 0.5% iron chloride exposure due to moderate blistering. At a higher PR-1560-M (Part A) concentration, 2414-428.5, there was acetic acid attack. Also, the entire series gelled within 60 hours at ambient temperatures. This was not entirely unexpected, for no effort was made to dry the Cr_2O_3 . The moisture carried into the system by the pigment was enough to react with the isocyanate, thereby reducing acid resistance and inducing gelation. Consequently, any further efforts to incorporate Cr_2O_3 in the 2414-501.4 system must include prior drying of the inorganic, either in a vacuum oven or via azeotropic distillation with benzene.

Formulation 2414-501.4 has maintained a constant ambient temperature viscosity of 21 seconds for 106 days. Other similar coatings, for example 2414-428.7, containing talc have displayed a steady increase in Ford cup viscosity over the same period. Thus, in order to realize any degree of one-part stability, all pigments must be specially dried.

SECTION IV

APPLICATION STUDIES AND QUALIFICATION TESTING

A. Application Studies

A dip-coating technique, as a means of simulating fill and drain conditions, was employed in the preparation of the majority of the test specimens. However, it was considered desirable to evaluate surface coating formula 2414-501.4 under the conditions of spray and brush application as well. The four screening tests were repeated with this formula on Alodined test panels prepared by the latter two methods. The performance of the coating did not differ in any fashion from the results obtained on the dip-coated specimens. All panels conformed, after exposure to the various test conditions, to the requirements of MIL-C-27725A, Amendment 2.

In order to investigate further the application properties of any candidate material, two sections of a Douglas DC-7 wing tank were procured from a scrapped aircraft. The two tank sections were already sealed and overcoated with a polyurethane type surface coating when received. It was therefore necessary to remove the existing coating by means of steam cleaning prior to use in any application study. A portion of the tank cleaning is shown in Figure 26. Unfortunately, the steam cleaning process utilized an alkaline detergent, which adversely affected the Alodine substrate, so that good film adhesion could not be obtained with coating 2414-501.4.

The effect of the alkaline detergent of the steam cleaning process upon the MIL-C-5541 Alodined aluminum surface is exhibited in Figure 27. The aluminum test panel was exposed to the steam from the nozzle blast for fifteen seconds. It can be seen that the Alodined surface treatment has been destroyed and severe corrosion started.

The unexpected surface attack by the steam detergent precluded good overall performance by coating 2414-501.4. Nevertheless, a spray application was made on the stripped wing tank section as well as on a small anodized aluminum float tank which had not been steam cleaned. The spray process on the two tanks is shown in Figures 28 and 29. The material applied quite well, and no difficulty was experienced in obtaining good surface coverage. The coating wet the substrate adequately and gave no indication of crawling. Figure 30 is an interior view of the wing tank section showing the spray applied coating.

The coated tanks were allowed to cure for fourteen days at ambient temperature. As was expected, the coating on the larger tank displayed poor film to metal adhesion. The smaller float tank, which had not been steam cleaned, exhibited excellent film adhesion. The surface coating on the small float tank was subjected to an alkaline detergent steam cleaning for protracted intervals. There were no detrimental effects (see Figure 31 of Appendix II) of any nature observed on either the coating or aluminum substrate. This greatly improved steam cleaning resistance assumes significance when compared to the performance of the original surface coating on

the larger tank, which was easily removed by the cleaning operation.

While the application study was of cursory extent, due to program time limitations, some significant information was gathered. Application data indicates that surface coating 2414-501.4 can be applied by spraying, brushing or fill and drain techniques, all of which yield a satisfactory, corrosion resistant film.

B. Qualification Testing Methods

Formulation 2414-501.4, discussed in Section III of this report, was tested to the full requirements of MIL-C-27725A, Amendment 2, according to the following schedule.

- 3.1 Qualification - Not pertinent.
- 3.2 Materials - The two-part requirement is waived.
 - 3.2.1 Appearance - Determined as described in paragraph.
 - 3.2.2 Toxic products and formulation - No known severely toxic ingredients have been used in the formulation.
 - 3.2.2.1 Toxicity certification - Not pertinent at this time.
- 3.3.1 Application properties - All specimens were prepared by dip-coating.
- 3.3.2 Color - The chromate yellow color requirement not pertinent at this time.
- 3.3.3 Weight per gallon - Determined as described in paragraph.
- 3.3.4 Nonvolatile content - Determined as described in paragraph.
- 3.3.5 Viscosity - Determined as described in paragraph.
- 3.3.6 Application life - Not pertinent for a one-package material.
- 3.3.7 Drying time - Determined as described in paragraph.
- 3.3.8 Cure time - Determined as described in paragraph.
- 3.3.9 Resistance to water - Determined as described in paragraph.
- 3.3.10 Resistance to salt water and fuel - Determined as described in paragraph.
- 3.3.11 Resistance to engine oil - Determined as described in paragraph.
- 3.3.12 Resistance to hydraulic fluid - Determined as described in paragraph.

- 3.3.13 Resistance to iron chloride - Determined as described in paragraph.
- 3.3.14 Fuel contamination - This test was not performed. Past experience has indicated that this type of system does not contain any known fuel soluble materials or fragments.
- 3.3.15 Low temperature flexibility - Determined as described in paragraph.
- 3.3.16.1 Sealing compound to coating material - This requirement was not considered pertinent for a fill and drain system, as the integral fuel tank would of necessity be sealed prior to coating application.
- 3.3.16.2 Coating material to sealing compound - Determined as described in paragraph.
- 3.3.17 Material compatibility with MIL-S-4383 material - This requirement was considered not pertinent. To fill and drain a tank already coated with MIL-S-4383 with 2414-501.4 would be highly undesirable.
- 3.3.18 Accelerated storage stability - Determined as described in paragraph.
- 3.3.19 Repairability - Determined as described in paragraph.
- 3.3.20 Resistance to simulated microbial byproducts - Determined as described in paragraph.
- 3.3.21 Free diisocyanate - Determined as described in paragraph.

The candidate coating performed very creditably when subjected to the above test conditions. Test results are outlined in Table 3 of Appendix I. A series of pictures was taken of the specimens after exposure to the various pertinent specification requirements. These comprise Figures 32 through 40 of Appendix II. Examination of this data will show that surface coating formulation 2414-501.4 conforms to all applicable test requirements.

C. Advantages and Potential Problems of Fill and Drain Systems

Fill and drain operations with a one-package surface coating offer several attractive conveniences over the familiar two-part coating. Current usage of existing two-package systems depends upon either spray or brush application. This type of film application is accompanied by several inherent problems.

The practical application of any two-package surface coating to aircraft integral fuel tanks will often be limited to the degree of wing access. There is also the ever present problem of toxic and/or obnoxious fumes in such restricted areas. This precludes internal coating application unless the worker is well clothed in protective attire and supplied with an

external or self-contained air supply. One partial solution is to precoat the various tank components prior to final assembly. Nevertheless, there will always be some later insertions, portions of which are inevitably left uncoated. The fill and drain process is desirable here because small openings and crevices can be filled with protective material. The coating thus acts as a secondary seal as well as eliminating points where crevice corrosion may initiate. Also, the toxicity consideration is greatly reduced because the worker is no longer exposed to any toxic chemicals which may be contained in the coating.

Unfortunately, the overall fill and drain process is not without its inherent problems. The majority of these problems are of the engineering type, and presumably, can be readily solved. Some examples are enumerated below:

1. Variability of Fill and Drain Material

- a. Solvent volatilization
- b. Batch blending of new materials which meet the specification requirements individually, but in fact do not perform collectively.

The above problems vary in severity, but can be resolved through periodic quality control analysis of solids content and overall film resistance and adhesion.

2. Contamination of one-part Material Affecting Cure and/or Performance Properties

- a. Improper cleaning and maintenance of material transfer lines and storage tanks.
- b. Inadequate cleaning of parts to be overcoated.
- c. Partial chemical conversion of coating material due to contaminants derived from a and b above.

While these problems may appear formidable at first, they are by no means insurmountable. For example, a good engineering approach might contain the following:

- (1) Inert gas, nitrogen or argon, systems to purge storage tanks, transfer lines and surface areas to be coated.
- (2) A canned centrifugal pumping system which does not allow the surface coating material to come in contact with mechanical seals or lubricants.
- (3) The storage tanks and transfer lines should contain an inert inner coating or sleeve. An example of this is Teflon lined, stainless braided flexible hose.

- (4) When not in use, the entire system should be sealed with an inert atmosphere, either gaseous or liquid, to prevent the intrusion of moisture.

In summary, if judicious analysis is made of the engineering requirements for a suitable fill and drain system, as well as the quality control and assurance methods needed to maintain chemical purity of the coating, the problems outlined above can be resolved.

SECTION V

CONCLUSIONS

A moisture curing isocyanate based surface coating was developed which successfully qualified against those portions of specification MIL-C-27725A (USAF) which were applicable to a one-package system. The candidate coating is compounded according to the following formulation:

PR-1057	-220 (Parts by weight)
PR-1560-M (Part A)	- 80
Chlorobenzene or cellosolve acetate	-100

An interesting isocyanate cured fluoroelastomer coating was derived from PR-1710 (Part B) and PR-1560-M (Part A). The formula exhibited exceptional overall chemical resistance to the four screening test media. The coating, however, possesses marginal adhesion to MIL-C-5541 Alodined aluminum. Also, carbon black, which is required in the formula, may present an application problem due to its opacity.

The following isocyanates were evaluated as potential corrosion resistant surface coating components.

1. DDI, an aliphatic 36 carbon diisocyanate
2. Desmodur N, an aliphatic polyisocyanate
3. Mondur HX, hexamethylene diisocyanate
4. NACCONATE H12, an aliphatic diisocyanate
5. E-196, an aromatic isocyanate terminated prepolymer
6. F-84, an aromatic isocyanate terminated prepolymer
7. Mondur MR, an aromatic polyisocyanate
8. PR-1560-M (Part A), an isocyanate adduct
9. TDI, toluene diisocyanate

In general, coatings containing aliphatic isocyanates exhibit much lower acid and distilled water resistance than do the aromatics. Mondur MR and PR-1560-M (Part A) displayed the best overall chemical resistance of the aromatics studied, with the latter by far the better of the two.

Conversely, other additives such as polysulfides, mercaptans or epoxides were observed to drastically reduce acid resistance and film adhesion of isocyanate based coatings.

SECTION VI

RECOMMENDATIONS

The candidate coating, 2414-501.4, has performed excellently when exposed to the various laboratory test requirements of MIL-C-27725A. In order to further confirm its suitability as a corrosion preventive coating for aircraft integral fuel tanks it is suggested that actual service tests be run in operational aircraft.

In these service tests spray or brush application techniques would undoubtedly be used due to the expense of the large volume of material required for a fill and drain operation. The following procedures should be followed in applying 2414-501.4

Surface Preparation

A. Repair of In-Service Tanks

Prepare in accordance with T. O. 1-1-3, Section IX, Paragraph 9-43.

B. New Tanks

To provide optimum adhesion and corrosion resistance the coating should not be applied directly on bare aluminum. A chemical conversion treatment such as Iridite, Alodine, or anodize should be used prior to coating with 2414-501.4.

These chemically treated surfaces must be cleaned thoroughly before application. A progressive cleaning procedure with an oil-free solvent (reclaimed solvents are seldom suitable) that will dissolve oil and wax should be employed. Methyl ethyl ketone or MIL-S-8802-C cleaner are satisfactory. Wash one small area at a time, then dry with a clean cloth before solvent evaporates to prevent redeposition of oil, wax, or other surface contaminants. To maintain a clean solvent supply always pour the solvent on the washing cloth. The washing and drying cloths should be discarded as each area is completed.

Application Equipment

A standard spray gun such as a DeVilbiss P-MBC-510 with a 45-G nozzle combination using an approximate pressure feed tank pressure of 5 psig and an atomizing air pressure of approximately 35 psig is suitable. Provisions must be made to thoroughly remove all condensate and oil from the compressed air supply. The material should be sprayed with a light double pass to a thickness of 0.5 - 0.8 mils.

Cure

The coating, under normal conditions of temperature and humidity, will be tack free within 2 hours and dry to handle in 6 hours. As the film dries it becomes progressively harder. Solvent resistance continues to improve for several weeks. Exposure of the film to water

after the coating has become tack free will not affect the film adversely.

Complete cure requires approximately 14 days at 75° F and a relative humidity of at least 30%. Cure may be accelerated after 12 hours by heating to 120° F for 24 hours or 140° F for 8 hours. The state of cure may be checked by rubbing a test spot with a gauze sponge wet with an aromatic naphtha. Bare metal should not be exposed in 50 double strokes of the pad at moderate pressure when cure is complete.

Repair

In areas where the coating has been scratched, gouged, or otherwise damaged, lightly abrade surrounding area and feather the edges. Clean surface with MEK and apply new coating. If the damage extended into the chemical conversion coating the area must be retreated before application of 2414-501.4.

APPENDIX I - TABLES

TABLE I - FUEL TANK COATING FORMULATIONS

<u>2414-5</u>		<u>2414-100.1</u>	
PR-1560-M (Part A)	-100	LP-32	-200
LP-32	- 50	PR-1560-M (Part A)	-100
Toluene diisocyanate	- 10	Monochlorobenzene	-200
Chlorobenzene	-100	Urethane Catalyst	- 1
<u>2414-6</u>		<u>2414-100.2</u>	
PR-1560-M (Part A)	-100	LP-32	-200
LP-32	-200	PR-1560-M (Part A)	- 50
Chlorobenzene	-200	Monochlorobenzene	-200
		Urethane Catalyst	- 1
<u>2414-8</u>		<u>2414-100.3</u>	
PR-1058	-100	LP-32	-200
PR-1560-M (Part A)	- 20	PR-1560-M (Part A)	- 50
EPON 1031	- 50	Monochlorobenzene	-200
Cellosolve acetate	-100	Urethane Catalyst	- 1
<u>2414-10</u>		<u>2414-100.4</u>	
PR-1560-M (Part A)	-100	LP-32	-200
MTBN	-200	PR-1560-M (Part A)	- 70
Chlorobenzene	-200	Monochlorobenzene	-200
		Urethane Catalyst	- 1
<u>2414-17</u>			
Q 94-002	-100		
MEK	-120		

<u>2414-100.5</u>		<u>2414-104</u>	
LP-32	-200	LP-32	-100
PR-1560-M (Part A)	- 60	PAGE	- 40
Monochlorobenzene	-200	Sylkem 90	- 50
Urethane Catalyst	- 1	DMP 30	- 4.5
		MEK	-190
<u>2414-100.6</u>		<u>2414-105</u>	
LP-32	-100	LP-32	-100
EPON 1031	- 50	PAGE	- 27
Shell H-3	- 20	Sylkem 90	- 33
MEK	-200	PR-1560-M (Part A)	- 12
		MEK	-170
<u>2414-101</u>		<u>2414-106</u>	
LP-32	-100	LP-32	-200
Sylkem 90	-100	Mondur MR	- 50
MEK	-200	MEK	-150
DMP 30	- 5	DMP 30	- 1
<u>2414-102</u>		<u>2414-107</u>	
LP-32	-100	LP-32	-200
Sylkem 90	- 50	DDI	- 50
PR-1560-M (Part A)	- 17	MEK	-150
MEK	-170	DMP 30	- 1
<u>2414-103</u>			
LP-32	-100		
PAGE	- 80		
MEK	-180		
DMP 30	- 4		

	<u>2414-108</u>		<u>2414-201</u>	
LP-32	-200	PR-1058	-100	
NACCONATE H12	- 50	PR-1560-M (Part A)	- 9.2	
MEK	-160	Sylkem 90	- 6	
DMP	- 1	PAGE	- 5	
		MEK	-130	
	<u>2414-109</u>		<u>2414-201.1</u>	
LP-32	-200	PR-1058	-200	
Desmodur N	- 50	Sylkem 90	- 6	
MEK	-150	PR-1560-M (Part A)	- 9.2	
DMP 30	- 1	PAGE	- 5	
		MEK	-130	
	<u>2414-200</u>		<u>2414-202</u>	
PR-1058	-100	PR-1058	-100	
PAGE	- 15	Sylkem 90	- 8.3	
MEK	-120	PAGE	- 7.5	
	<u>2414-200.1</u>		<u>2414-202.1</u>	
PR-1058	-200	MEK	-120	
PAGE	- 15			
MEK	-120			
	<u>2414-200.2</u>			
PR-1058	-100	PR-1058	-200	
Monochlorobenzene	-100	Sylkem 90	- 8.3	
		PAGE	- 7.5	
		MEK	-120	

<u>2414-203</u>		<u>2414-205.1</u>	
PR-1058	-100	PR-1058	-100
PR-1560-M (Part A)	- 13.8	PR-1560-M (Part A)	- 30
Sylkem 90	- 10	Monochlorobenzene	-100
MEK	-130	Y-4086	- 23

<u>2414-203.1</u>		<u>2414-205.2</u>	
PR-1058	-200	PR-1058	-100
Sylkem 90	- 10	PR-1560-M (Part A)	- 40
PR-1560-M (Part A)	- 13.8	Monochlorobenzene	-100
MEK	-130	Y-4086	- 24

<u>2414-204.1</u>		<u>2414-205.3</u>	
PR-1058	-100	PR-1058	-100
PR-1560-M (Part A)	- 30	PR-1560-M (Part A)	- 50
Monochlorobenzene	-100	Monochlorobenzene	-100
		Y-4086	- 23

<u>2414-204.2</u>		<u>2414-205.4</u>	
PR-1058	-100	PR-1058	-100
PR-1560-M (Part A)	- 40	PR-1560-M (Part A)	- 40
Monochlorobenzene	-100	Monochlorobenzene	-150
		Y-4086	- 20

<u>2414-204.3</u>		<u>2414-206.1</u>	
PR-1058	-100	PR-1058	-100
PR-1560-M (Part A)	- 50	PR-1560-M (Part A)	- 50
Monochlorobenzene	-100		

	<u>2414-206.2</u>		<u>2414-208.2</u>	
PR-1058	-100	PR-1058	-100	
PR-1560-M (Part A)	- 55	PR-1560-M (Part A)	- 45	
		EPON 1031	- 37	
	<u>2414-206.3</u>	MEK	- 40	
PR-1058	-100			
PR-1560-M (Part A)	- 60	<u>2414-208.3</u>		
		PR-1058	-100	
	<u>2414-206.4</u>	PR-1560-M (Part A)	- 40	
PR-1058	-100	EPON 1031	- 34	
PR-1560-M (Part A)	- 65	MEK	- 35	
	<u>2414-207</u>	<u>2414-208.4</u>		
PR-1058	-100	PR-1058	-100	
Sylkem 90	- 15	PR-1560-M (Part A)	- 35	
MEK	-115	EPON 1031	- 30	
		MEK	- 35	
	<u>2414-207.1</u>			
PR-1058	-200	<u>2414-208.5</u>		
Sylkem 90	- 15	PR-1058	-100	
MEK	-115	PR-1560-M (Part A)	- 30	
		EPON 1031	- 26	
	<u>2414-208.1</u>	MEK	- 30	
PR-1058	-100			
PR-1560-M (Part A)	- 50			
EPON 1031	- 41			
MEK	- 50			

	<u>2414-208.6</u>		<u>2414-209.1</u>	
PR-1058	-100	PR-1058	-200	
PR-1560-M (Part A)	- 50	PR-1560-M (Part A)	-100	
EPON 1031	- 41	EPON 154	- 71	
Y-4086	- 1	MEK	-220	
MEK	- 50			
	<u>24 4-208.7</u>		<u>2414-210</u>	
PR-1058	-100	PR-1058	-200	
PR-1560-M (Part A)	- 40	PR-1560-M (Part A)	- 50	
EPON 1031	- 34	EPON 154	- 34	
Y-4086	- 1	Sylkem 90	- 8.7	
MEK	- 35	MEK	-160	
	<u>2414-208.8</u>		<u>2414-210.1</u>	
PR-1058	-100	PR-1058	-200	
PR-1560-M (Part A)	- 30	PR-1560-M (Part A)	-100	
EPON 1031	- 26	EPON 154	- 57	
Y-4086	- 1	Sylkem 90	- 14	
MEK	- 30	MEK	-200	
	<u>2414-209</u>		<u>2414-211</u>	
PR-1058	-200	PR-1058	-200	
PR-1560-M (Part A)	- 50	PR-1560-M (Part A)	- 50	
EPON 1031	- 42	EPON 154	- 16	
MEK	-160	EPON 1031	- 30	
		MEK	-170	

<u>2414-211.1</u>		<u>2414-213</u>	
PR-1058	-200	PR-1058	-200
PR-1560-M (Part A)	- 50	PR-1560-M (Part A)	-100
EPON 154	- 14.7	EPON 1031	- 50
EPON 1031	- 27.5	MEK	-180
Sylkem 90	- 4.3		
MEK	-150	<u>2414-213.1</u>	
		PR-1058	-200
<u>2414-212</u>		PR-1560-M (Part A)	-100
PR-1058	-100	EPON 1031	- 33
PR-1560-M (Part A)	- 50	MEK	-150
Y-4086	- 1.5		
		<u>2414-213.2</u>	
<u>2414-212.1</u>		PR-1058	-200
PR-1058	-100	PR-1560-M (Part A)	-100
PR-1560-M (Part A)	- 65	EPON 1031	- 67
Y-4086	- 1.65	MEK	-190
		<u>2414-213.3</u>	
<u>2414-212.2</u>		PR-1058	-200
PR-1058	-100	PR-1560-M (Part A)	-100
PR-1560-M (Part A)	- 50	EPON 1031	- 80
Y-4086	- 4.5	MEK	-200
		<u>2414-213.4</u>	
<u>2414-212.3</u>		PR-1058	-200
PR-1058	-100	PR-1560-M (Part A)	- 67
PR-1560-M (Part A)	- 65	EPON 1031	- 50
Y-4086	- 4.95	MEK	-150

<u>2414-213.5</u>		<u>2414-213.3</u>	
PR-1058	-200	PR-1058	-200
PR-1560-M (Part A)	- 67	PR-1560-M (Part A)	- 50
EPON 1031	- 33	EPON 1031	- 33
MEK	-140	MEK	-130

<u>2414-214</u>		<u>2414-215.4</u>	
PR-1058	-200	PR-1058	-200
PR-1560-M (Part A)	- 30	PR-1560-M (Part A)	- 50
Epoxide 207	- 12.3	EPON 1031	- 67
MEK	-100	MEK	-170

<u>2414-215</u>		<u>2414-215.5</u>	
PR-1058	-200	PR-1058	-200
PR-1560-M (Part A)	- 67	PR-1560-M (Part A)	- 50
EPON 1031	- 67	EPON 1031	- 80
MEK	-170	MEK	-180

<u>2414-215.1</u>		<u>2414-216</u>	
PR-1058	-200	PR-1058	-200
PR-1560-M (Part A)	- 67	NIAX 560	- 90
EPON 1031	- 80	MEK	-190
MEK	-190		

<u>2414-215.2</u>		<u>2414-216.1</u>	
PR-1058	-200	PR-1058	-200
PR-1560-M (Part A)	- 50	NIAX 560	- 80
EPON 1031	- 50	MEK	-190
MEK	-150		

2414-216.2

PR-1058 - 80

PR-1560-M (Part A) - 40

NIAX 560 -160

MEK -200

2414-216.3

PR-1058 - 80

PR-1560-M (Part A) - 40

NIAX 560 -144

MEK -200

2414-217.1

PR-1058 -100

PR-1560-M (Part A) - 50

2414-217.4

PR-1560-M (Part A) -100

Talc - 65

2414-217.5

PR-1058 -200

2414-217.4 -165

2414-217.6

PR-1058 -200

PR-1560-M (Part A) -100

Talc - 65

Y-4522 - 15

2414-217.51

PR-1058 -200

2414-217.4 -165

Y-4086 - 10

2414-218

PR-1058 -200

NIAX 520 - 37

MEK -130

2414-218.1

PR-1058 -200

NIAX 520 - 29

MEK -130

2414-218.2

PR-1058 -120

PR-1560-M (Part A) - 60

NIAX 520 -100

MEK -190

2414-218.3

PR-1058 -120

PR-1560-M (Part A) - 60

NIAX 520 - 89

MEK -180

	<u>2414.219</u>			<u>2414-221.1</u>	
PR-1058	-200		PR-1058	-200	
Sylkem 90	- 3		EPON 1031	- 10	
MEK	-100		MEK	-105	
			DMP 30	- 0.1	
	<u>2414-219.1</u>			<u>2414-221.2</u>	
PR-1058	-200		PR-1058	-200	
PR-1560-M (Part A)	- 30		EPON 1031	- 5	
Sylkem 90	- 7		MEK	-100	
MEK	-110		DMP 30	- 0.1	
	<u>2414-219.2</u>			<u>2414-221.3</u>	
PR-1560-M (Part A)	-200		PR-1058	-200	
Sylkem 90	- 30		PR-1560-M (Part A)	-130	
MEK	-110		EPON 1031	- 5	
	<u>2414-220</u>		MEK	- 60	
PR-1560-M (Part A)	-200		DMP 30	- 0.1	
Hooker Hydroxy Prepolymer	- 29			<u>2414-221.4</u>	
MEK	-100		PR-1058	-200	
DMP 30	- 0.1		PR-1560-M (Part A)	-100	
	<u>2414-221</u>		EPON 1031	- 5	
PR-1058	-200		MEK	-150	
EPON 1031	- 15		DMP 30	- 0.1	
MEK	-100				
DMP 30	- 0.1				

<u>2414-221.5</u>		<u>2414-222.3</u>	
PR-1058	-200	PR-1058	-200
PR-1560-M (Part A)	- 60	PR-1560-M (Part A)	-150
EPON 1031	- 5	Y-4086	- 14
MEK	-120	MEK	-170
DMP 30	- 0.1	DMP 30	- 0.1

<u>2414-222</u>		<u>2414-222.4</u>	
PR-1058	-200	PR-1058	-200
PR-1560-M (Part A)	- 20	PR-1560-M (Part A)	-170
EPON 1031	- 5	Y-4086	- 14.8
MEK	-100	MEK	-180
DMP 30	- 0.1	DMP 30	- 0.1

<u>2414-222.1</u>		<u>2414-223</u>	
PR-1058	-200	PR-1560-M (Part A)	-200
PR-1560-M (Part A)	-130	EPON 1031	- 25
Y-4086	- 13.2	MEK	-100
MEK	-160	DMP 30	- 0.1
DMP 30	- 0.1		

<u>2414-222.2</u>		<u>2414-223.1</u>	
PR-1058	-200	PR-1560-M (Part A)	-200
PR-1560-M (Part A)	-130	EPON 154	- 18
Y-4086	- 16.5	MEK	-100
MEK	-160	DMP 30	- 0.1
DMP 30	- 0.1		

2414-223.2

PR-1560-M (Part A)	-200
Sylkem 90	- 19
MEK	-100
DMP 30	- 0.1

2414-223.3

PR-1560-M (Part A)	-200
Epoxide 207	- 9
MEK	-100
DMP 30	- 0.1

2414-224

PR-1560-M (Part A)	-200
EPOXOL 55B40	- 50
MEK	-130

2414-225

PR-1560-M (Part A)	-200
PR-1058	- 50
EPOXOL 55B40	- 55
MEK	-150

2414-226

PR-1058	-200
NIAX 560	- 40
MEK	-140

2414-226.1

PR-1058	-200
NIAX 560	- 20
MEK	-120

2414-227

PR-1560-M (Part A)	-100
NIAX 560	- 90
MEK	-190

2414-227.1

PR-1560-M (Part A)	-100
NIAX 560	- 60
MEK	-160

2414-228

PR-1058	-200
NIAX 520	- 20
MEK	-120

2414-228.1

PR-1058	-200
NIAX 520	- 10
MEK	-110

2414-229

PR-1560-M (Part A)	-200
NIAX 520	- 80
MEK	-180

<u>2414-229,1</u>		<u>2414-231,2</u>	
PR-1560-M (Part A)	-200	F84	- 50
NIAX 520	- 40	PR-1560-M (Part A)	-100
MEK	-140	PR-1566 (Part B)	-120
		MEK	-160
<u>2414-230</u>		<u>2414-232</u>	
PR-1560-M (Part A)	-164	PR-1560-M (Part A)	-154
PR-1566 (Part B)	-100	PR-1566 (Part B)	-120
EPON 1031	- 5.3	PR-1415	- 20
MEK	-130	MEK	-150
DMP 30	- 0.1	DMP 30	- 0.1
<u>2414-231</u>		<u>2414-232,1</u>	
PR-1560-M (Part A)	-164	PR-1560-M (Part A)	-100
PR-1566 (Part B)	-100	EPONOL 55B40	- 43
MTBN	- 28	MEK	-195
MEK	-150		
DMP 30	- 0.1	<u>2414-232,2</u>	
<u>2414-231,1</u>		PR-1560-M (Part A)	-100
F84	- 50	EPONOL 55B40	- 58
PR-1560-M (Part A)	-100	MEK	-260
PR-1566 (Part B)	-160	<u>2414-232,3</u>	
MEK	-180	PR-1560-M (Part A)	-100
		PR-1058	- 15
		EPONOL 55B40	- 15
		MEK	-175

<u>2414-232.4</u>		<u>2414-234</u>	
PR-1560-M (Part A)	-100	PR-1560-M (Part A)	-200
PR-1058	- 40	EPONOL 55B40	- 50
EPONOL 55B40	- 60	Mixed Solvent	-180
MEK	-270		
<u>2414-232.5</u>		<u>2414-234.1</u>	
E196	- 50	PR-1560-M (Part A)	-200
PR-1560-M (Part A)	-100	EPONOL 55B40	- 75
PR-1566 (Part B)	-160	Mixed Solvent	-220
MEK	-180		
<u>2414-232.6</u>		<u>2414-234.2</u>	
E196	- 50	PR-1560-M (Part A)	-200
PR-1560-M (Part A)	-100	EPONOL 55B40	-100
PR-1566 (Part B)	-120	Mixed Solvent	-250
MEK	-160		
<u>2414-232.7</u>		<u>2414-234.3</u>	
PR-1560-M (Part A)	-200	PR-1560-M (Part A)	-200
EPONOL 55B40	- 29	EPONOL 55B40	-129
MEK	-230	Mixed Solvent	-240
<u>2414-233</u>		<u>2414-234.4</u>	
PR-1560-M (Part A)	-100	EPONOL 55B40	-143
EPONOL 55B40	-200	PR-1560-M (Part A)	- 15
MEK	-230	Mixed Solvent	-150
<u>2414-234.5</u>		<u>2414-234.5</u>	
PR-1560-M (Part A)	-100	EPONOL 55B40	-143
EPONOL 55B40	-200	PR-1058	-100
MEK	-230	Mixed Solvent	-150

<u>2414-234.6</u>		<u>2414-235.3</u>	
EPOCRYL E-11	- 61.5	PR-1058	-200
PR-1560-M (Part A)	-200	PR-1560-M (Part A)	-100
MEK	-200	Y-4522	- 15

<u>2414-234.7</u>		<u>2414-235.4</u>	
EPOCRYL E-11	-123	PR-1058	-200
PR-1560-M (Part A)	-200	PR-1560-M (Part A)	-100
MEK	-300	A-153	- 7

<u>2414-235</u>		<u>2414-235.5</u>	
PR-1058	-200	PR-1058	-200
PR-1560-M (Part A)	-100	PR-1560-M (Part A)	-100
Y-4522	- 5	A-153	- 16
MEK	-150		

<u>2414-235.1</u>		<u>2414-236</u>	
PR-1058	-200	E196	-200
PR-1560-M (Part A)	-100	EPOCRYL E-11	- 15
Y-4522	- 10	MEK	-110
MEK	-150		

<u>2414-235.2</u>		<u>2414-236.1</u>	
PR-1058	-200	E196	-200
PR-1560-M (Part A)	-100	EPOCRYL E-11	- 50
Y-4522	- 20	MEK	-150
MEK	-150		

<u>2414-237</u>		<u>2414-238,4</u>	
EPOCRYL E-11	-100	NACCONATE H12	-100
PR-1560-M (Part A)	-200	EPOCRYL E-11	- 19
Y-4522	- 18	MEK	-120
MEK	-200		
DMP 30	- 0.25	<u>2414-239</u>	
		PR-1560-M (Part A)	-200
<u>2414-238</u>		Diphenyl Oxide NOVOLAC	- 67
NACCONATE H12	-100	MEK	-130
PR-1566 (Part B)	-150	DMP 30	- 4
MEK	-175		
<u>2414-238.1</u>		<u>2414-240</u>	
NACCONATE H12	-100	PR-1058	-200
PR-1566 (Part B)	- 80	PR-1560-M (Part A)	-200
MEK	-140	Y-4086	- 10
<u>2414-238.2</u>		<u>2414-240.1</u>	
NACCONATE H12	-100	PR-1058	-200
EPONOL 55B40	-103	PR-1560-M (Part A)	-200
Mixed Solvent	-200	Y-4522	- 10
<u>2414-238.3</u>		<u>2414-240.2</u>	
NACCONATE H12	-100	PR-1058	-200
EPONOL 55B40	- 57	PR-1560-M (Part A)	-200
Mixed Solvents	-150	A-153	- 10

<u>2414-241</u>		<u>2414-243</u>	
PR-1058	-200	Unithane 100 CA	-200
PR-1560-M (Part A)	-100	PR-1560-M (Part A)	-100
Adduct of MTBN-APD	- 10	MEK	-100

<u>2414-241.1</u>		<u>2414-243.1</u>	
PR-1058	-200	Unithane 100 CA	-200
PR-1560-M (Part A)	-100	PR-1560-M (Part A)	-200
Adduct of MTBN-APD	- 20	MEK	- 50

<u>2414-241.2</u>		<u>2414-243.2</u>	
PR-1058	-200	Unithane 100 CA	-200
PR-1560-M (Part A)	-200	PR-1560-M (Part A)	-100
Adduct of MTBN-APD	- 10	PR-1058	- 50
		MEK	-175

<u>2414-241.3</u>		<u>2414-243.3</u>	
PR-1058	-200	Unithane 100 CA	-200
PR-1560-M (Part A)	-200	PR-1560-M (Part A)	-200
Adduct of MTBN-APD	- 20	PR-1058	-200
		MEK	- 80

<u>2414-242</u>		<u>2414-244</u>	
PR-1560-M (Part A)	-200	PR-1058	-200
Desmodur N	-100	PR-1560-M (Part A)	-100

<u>2414-242.1</u>			
PR-1560-M (Part A)	-200	MTBN	- 10
Desmodur N	-200	2414-413.2	- 10

	<u>2414-244.1</u>			<u>2414-245.5</u>	
PR-1058		-200	PR-1058		-200
PR-1560-M (Part A)		-100	DI		- 70
MTBN		- 10		<u>2414-300.1</u>	
2414-413.2		- 10	MTBN		-100
	<u>2414-245</u>		Sylkem 90		- 21
PR-1058		-200	MEK		-150
Mondur MR		- 25	DMP 50		- 1
MEK		- 27		<u>2414-300.2</u>	
	<u>2414-245.1</u>		MTBN		-100
PR-1058		-200	PR-1560-M (Part A)		- 32
Mondur MR		- 12	MEK		-150
MEK		- 15		<u>2414-300.3</u>	
	<u>2414-245.2</u>		MTBN		-100
PR-1058		-200	PAGE		- 17
MDI		- 50	MEK		-150
	<u>2414-245.3</u>		DMP 50		- 1
PR-1058		-200		<u>2414-300.4</u>	
MDI		- 26	MTBN		-100
	<u>2414-245.4</u>		PR-1560-M (Part A)		- 16
PR-1058		-200	PAGE		- 8
NACCONATE H12		- 50	MEK		-150

	<u>2414-300.5</u>		<u>2414-302</u>	
MTBN	-100	PR-1058	-200	
PR-1560-M (Part A)	- 6	PR-1560-M (Part A)	-100	
PAGE	- 7	MTBN	- 40	
Sylkem 90	- 3	MEK	-200	
MEK	-150	Pyridine	- 0.4	
	<u>2414-301</u>		<u>2414-302.1</u>	
PR-1058	-200	PR-1058	-200	
MTBN	- 40	PR-1560-M (Part A)	-100	
MEK	-150	MTBN	- 20	
Pyridine	- 0.4	MEK	-180	
	<u>2414-301.1</u>	Pyridine	- 0.2	
			<u>2414-302.2</u>	
PR-1058	-200	PR-1058	-200	
MTBN	- 20	PR-1560-M (Part A)	-100	
MEK	-150	MTBN	- 30	
Pyridine	- 0.4	Y-4086	- 4	
	<u>2414-302.2</u>	MEK	-190	
PR-1058	-200	Pyridine	- 0.5	
MTBN	- 30			
Y-4086	- 4		<u>2414-303</u>	
MEK	-150	PR-1058	-200	
Pyridine	- 0.4	MTBN	- 20	
		EPON 1031	- 40	
		MEK	-180	

<u>2414-303.1</u>		<u>2414-304</u>	
PR-1058	-200	MTBN	-200
MTBN	- 40	PR-1560-M (Part A)	-100
EPON 1031	- 20	Monochlorobenzene	-150
MEK	-180	Pyridine	- 0.4
<u>2414-303.2</u>		<u>2414-305</u>	
PR-1058	-200	EPOCRYL E-11	-100
PR-1560-M (Part A)	-100	MTBN	- 10
MTBN	- 5	PR-1560-M (Part A)	-200
EPON 1031	- 5	Mixed Solvent	-120
MEK	-170	DMP 30	- 0.125
<u>2414-303.3</u>		<u>2414-306</u>	
PR-1058	-200	MTBN	-200
PR-1560-M (Part A)	-100	PR-1560-M (Part A)	-100
MTBN	- 10	Y-4522	- 8
EPON 1031	- 10	MEK	-150
MEK	-180	DMP 30	- 0.125
<u>2414-303.4</u>		<u>2414-306.1</u>	
PR-1058	-200	MTBN	-200
PR-1560-M (Part A)	-100	PR-1560-M (Part A)	-100
MTBN	- 10	Y-4522	- 15
EPON 1031	- 20	MEK	-150
MEK	-180	DMP 30	- 0.125

	<u>2414-307</u>		<u>2414-308.1</u>	
MTBN	-100	CTBNX	-100	
EPON 154	- 20.9	PR-1560-M (Part A)	- 50	
MEK	-230	MEK	- 80	
DMP 30	- 1.3			
			<u>2414-400</u>	
	<u>2414-307.1</u>	PR-1566 (Part B)	-200	
MTBN	-100	PR-1560-M (Part A)	-100	
EPON 154	- 25	Pyridine	- 0.25	
MEK	-230			
DMP 30	- 1.4		<u>2414-401</u>	
		Diphenyl Oxide NOVOLAC	-100	
	<u>2414-307.2</u>	PR-1560-M (Part A)	-115	
MTBN	-100	MEK	-150	
EPON 154	- 24.1			
MEK	-230		<u>2414-401.1</u>	
DMP 30	- 1.45	Diphenyl Oxide NOVOLAC	-100	
		PR-1560-M (Part A)	-120	
	<u>2414-307.3</u>	Sylkem 90	- 5	
MTBN	-100	MEK	-160	
EPON 154	- 26.3			
MEK	-230		<u>2414-401.2</u>	
DMP 30	- 1.58	Diphenyl Oxide NOVOLAC	-100	
		PR-1560-M (Part A)	- 94	
	<u>2414-308</u>	PR-1058	- 82	
CTBNX	-100	MEK	-230	
PR-1560-M (Part A)	- 75			
MEK	-100			

2414-401.3

Diphenyl Oxide NOVOLAC	-100
PR-1560-M (Part A)	-133
LP-32	- 10
MEK	-180

2414-401.4

Diphenyl Oxide NOVOLAC	- 50
PR-1560-M (Part A)	-134
LP-32	- 50
MEK	-170

2414-401.5

Diphenyl Oxide NOVOLAC	- 50
PR-1560-M (Part A)	-144
LP-32	- 50
PR-1058	- 10
MEK	-250

2414-401.6

Diphenyl Oxide NOVOLAC	-100
PR-1560-M (Part A)	-141
LP-32	- 10
Sylkem 90	- 5
MEK	-250

2414-402

Adduct of A-1100 and Y-4086	- 92
Isopropanol	- 78
EPON 1031	- 42
Dibutyltin dilaurate	- 0.25

2414-403

Diphenyl Oxide NOVOLAC	-100
EPON 1031	- 86
MEK	-180
DMP 30	- 0.28

2414-403.1

Diphenyl Oxide NOVOLAC	-100
EPON 1031	- 95
MEK	-190
DMP 30	- 0.28

2414-403.2

Diphenyl Oxide NOVOLAC	-100
EPON 1031	- 80
PR-1058	- 29
MEK	-200

2414-403.3

Diphenyl Oxide NOVOLAC -100
EPON 1031 - 80
PR-1058 - 36
MEK -200

2414-406

PR-1710 (Part B) -200
PR-1560-M (Part A) -100
MIBK -100

2414-404

PR-1566 (Part B) -100
Diphenyl Oxide NOVOLAC - 10.8
PR-1058 -200
MEK -150

2414-407

PR-1710 (Part B) -200
PR-1560-M (Part A) - 50
MIBK -120

2414-404.1

PR-1566 (Part B) -100
Diphenyl Oxide NOVOLAC - 13.5
PR-1058 -200
MEK -150

2414-405

CTBNX - 77
PR-1058 -200
PR-1560-M (Part A) - 42.7
MEK -180

<u>2414-408</u>		<u>2414-413</u>	
PR-1710 (Part B)	-157	PR-1058	-240
Versamid 415	- 20	Y-4086	- 7.2
MIBK	-210		
		<u>2414-413.1</u>	
<u>2414-409</u>		PR-1560-M (Part A)	-150
EPOCXYL E-11	-200	Y-4522	- 97
MSK	-200		
		<u>2414-413.2</u>	
U.V. Source (2200 Angstroms)	-	PR-1560-M (Part A)	-150
		Y-4522	- 32
<u>2414-410</u>			
Viton B (18.2% MIBK Solution)	-215	<u>2414-414</u>	
NACCONATE H12	- 43	PR-1710 (Part B)	-200
MIBK	-130	Mondur HX	- 50
Maglite D	- 3.5	MIBK	-160
		<u>2414-414.1</u>	
<u>2414-411</u>		PR-1710 (Part B)	-200
Viton B (18.2% MIBK Solution)	-215	Mondur HX	- 25
NACCONATE H12	- 43	MIBK	-160
MIBK	-200		
Maglite D	- 3.5	<u>2414-415</u>	
		PR-1710 (Part B)	-200
<u>2414-412</u>		Desmodur N	- 25
Viton B (18.2% MIBK Solution)	-215	MIBK	-160
NACCONATE H12	- 43		
PR-1560-M (Part A)	- 16		
MIBK	-260		

<u>2414-415.1</u>		<u>2414-417.3</u>	
PR-1710 (Part B)	-200	Viton LM (33% MIBK Solution)	-200
Desmodur N	- 25	PR-1058	- 25
MIBK	-160	PR-1560-M (Part A)	- 75
<u>2414-416</u>		Y-4522	- 8
PR-1710 (Part B)	-200	<u>2414-417.4</u>	
MIBK	-140	Viton LM (33% MIBK Solution)	-200
A-1100	- 5	PR-1560-M (Part A)	-100
<u>2414-417</u>		<u>2414-417.5</u>	
Viton LM (33% MIBK Solution)	-200	Viton LM (33% MIBK Solution)	-200
PR-1560-M (Part A)	-100	PR-1560-M (Part A)	- 50
Y-4522	- 15	<u>2414-417.6</u>	
<u>2414-417.1</u>		Viton A (20% MIBK Solution)	-200
Viton LM (33% MIBK Solution)	-300	PR-1560-M (Part A)	-100
PR-1560-M (Part A)	-100	MIBK	-100
Y-4522	- 15	MT Carbon Black	- 10
<u>2414-417.2</u>		MgO	- 6
Viton B (18.2% MIBK Solution)	-215		
PR-1560-M (Part A)	-100		
MIBK	-100		
Y-4522	- 15		

2414-417.7

Viton A (20% MIBK Solution)	-200
FR-1560-H (Part A)	- 50
MIBK	-120
MT Carbon Black	- 10
MgO	- 6

2414-417.11

Viton A (20% MIBK Solution)	-200
Desmodur N	- 50
MIBK	-185
MT Carbon Black	- 10
MgO	- 6

2414-417.8

Viton A (20% MIBK Solution)	-200
Versamid 415	- 26
MIBK	-270
MT Carbon Black	- 10
MgO	- 6

2414-417.12

Viton A (20% MIBK Solution)	-200
Desmodur N	- 25
MIBK	-160
MT Carbon Black	- 10
MgO	- 6

2414-417.9

Viton A (20% MIBK Solution)	-200
Mondur HX	- 50
MIBK	-185
MT Carbon Black	- 10
MgO	- 6

2414-417.13

Viton A (20% MIBK Solution)	-200
A-1100	- 5
MIBK	-140
MT Carbon Black	- 10
MgO	- 6

2414-417.10

Viton A (20% MIBK Solution)	-200
Mondur HX	- 25
MIBK	-160
MT Carbon Black	- 10
MgO	- 6

2414-417.14

Viton A (20% MIBK Solution)	-200
NACCONATE H12	- 50
MIBK	-140
MT Carbon Black	- 10
MgO	- 6

<u>2414-418</u>		<u>2414-418,4</u>	
Viton A (20% MIBK Solution)	-200	Viton A (20% MIBK Solution)	-200
PR-1560-M (Part A)	- 50	PR-1560-M (Part A)	- 50
MIBK	-100	PR-1058	- 50
<u>2414-418.1</u>		Y-4522	- 2.5
Viton A (20% MIBK Solution)	-200	MIBK	-150
PR-1560-M (Part A)	- 50	<u>2414-418.5</u>	
MIBK	-100	Viton A (20% MIBK Solution)	-200
Y-4522	- 2.5	PR-1560-M (Part A)	- 50
<u>2414-418.2</u>		PR-1058	- 25
Viton A (20% MIBK Solution)	-200	Y-4522	- 2.5
PR-1560-M (Part A)	- 50	MIBK	-125
PR-1058	- 50	<u>2414-418.6</u>	
MIBK	-150	Viton A (20% MIBK Solution)	-200
<u>2414-418.3</u>		PR-1560-M (Part A)	- 55
Viton A (20% MIBK Solution)	-200	2414-418.2	- 10
PR-1560-M (Part A)	- 50	MIBK	-144
PR-1058	- 25	<u>2414-418.7</u>	
MIBK	-125	Viton A (20% MIBK Solution)	-200
		PR-1560-M (Part A)	- 55
		2414-418.2	- 20
		MIBK	-150

2414-418.8

Viton A (20% MIBK Solution)	-200
PR-1560-M (Part A)	-140
2414-413.2	- 10
MIBK	-130

2414-418.13

Viton LM (30% MIBK Solution)	-134
PR-1560-M (Part A)	-150
Maglite D	- 6
MIBK	- 90

2414-418.9

Viton A (20% MIBK Solution)	-200
PR-1560-M (Part A)	-140
2414-413.2	- 10
MIBK	-130
Talc	- 25

2414-418.14

Viton LM (30% MIBK Solution)	-134
PR-1560-M (Part A)	-150
Maglite D	- 6
MIBK	- 90
Talc	- 25

2414-418.11

Viton A (20% MIBK Solution)	-200
PR-1560-M (Part A)	-150
MIBK	-130
Maglite D	- 6

2414-418.15

Viton A (20% MIBK Solution)	-200
PR-1560-M (Part A)	-200
Maglite D	- 6
Talc	- 25
MIBK	-100

2414-418.12

Viton A (20% MIBK Solution)	-200
PR-1560-M (Part A)	-150
MIBK	-130
Maglite D	- 6
Talc	- 25

2414-418.16

Viton A (20% MIBK Solution)	-200
Mondur MR	-100
Maglite D	- 6
Talc	- 25
MIBK	-100

<u>2414-418.17</u>		<u>2414-418.21</u>	
Viton B (20% MIBK Solution)	-200	Viton A (20% MIBK Solution)	-200
PR-1560-M (Part A)	-200	Mondur MR	-150
Maglite D	- 6	Maglite D	- 6
Talc	- 25	Talc	- 25
MIBK	-200	MIBK	-300
<u>2414-418.18</u>		<u>2414-418.22</u>	
Viton B (20% MIBK Solution)	-200	Viton A (20% MIBK Solution)	-200
Mondur MR	-100	Mondur KX	-300
Maglite D	- 6	Maglite D	- 6
Talc	- 25	Talc	- 25
MIBK	-300	MIBK	-150
<u>2414-418.19</u>		<u>2414-418.23</u>	
Viton A (20% MIBK Solution)	-200	Viton LM (30% MIBK Solution)	-200
Mondur MR	-100	PR-1560-M (Part A)	-200
Maglite D	- 6	PR-1058	-100
Talc	- 25	Maglite D	- 9
MIBK	-200	Talc	- 25
<u>2414-418.20</u>		MIBK	-150
Viton A (20% MIBK Solution)	-200	<u>2414-418.24</u>	
PR-1560-M (Part A)	-300	PR-1057	-100
Maglite D	- 6	PR-1058	-100
Talc	- 25	PR-1560-M (Part A)	-100
MIBK	-150	Chlorobenzene	- 50

<u>2414-418.25</u>		<u>2414-418.29</u>	
Viton A (20% MIBK Solution)	-200	PR-1057	-150
PR-1560-M (Part A)	-300	PR-1058	- 70
Maglite Y	- 6	PR-1560-M (Part A)	-100
MIBK	-100	Chlorobenzene	- 45

<u>2414-418.26</u>		<u>2414-418.30</u>	
Viton A (20% MIBK Solution)	-200	PR-1057	-170
PR-1560-M (Part A)	-200	PR-1058	- 30
Maglite Y	- 6	PR-1560-M (Part A)	-100
MIBK	- 50	Chlorobenzene	- 35

<u>2414-418.27</u>		<u>2414-418.31</u>	
Viton B (20% MIBK Solution)	-200	Viton A (20% MIBK Solution)	-200
PR-1560-M (Part A)	-300	DDI	- 50
Maglite Y	- 6	MIBK	- 50
MIBK	-100	MT Carbon Black	- 10
		MgO	- 6

<u>2414-418.28</u>		<u>2414-418.32</u>	
Viton B (20% MIBK Solution)	-200	Viton A (20% MIBK Solution)	-200
PR-1560-M (Part A)	-200	DDI	- 50
Maglite Y	- 6	MIBK	- 50
MIBK	-120	MgO	- 6

	<u>2414-419</u>			<u>2414-420.3</u>	
PR-1422		-127	MTBN		-100
Toluene		-290	PR-1560-M (Part A)		-300
	<u>2414-419.1</u>		2414-413.2		- 10
PR-1440		-127	MEK		- 25
Toluene		-294		<u>2414-420.4</u>	
	<u>2414-419.2</u>		MTBN		-100
PR-1057		-200	PR-1560-M (Part A)		-200
PR-1560-M (Part A)		-100	2414-413.2		- 10
Chlorobenzene		-100	MEK		- 50
	<u>2414-420</u>			<u>2414-420.5</u>	
MTBN		-100	MTBN		-100
PR-1560-M (Part A)		-600	PR-1560-M (Part A)		-100
2414-413.2		- 10	2414-413.2		- 10
	<u>2414-420.1</u>		MEK		- 50
MTBN		-100		<u>2414-420.8</u>	
PR-1560-M (Part A)		-500	PR-1057		-200
2414-413.2		- 10	Mondur MR		- 12
	<u>2414-420.2</u>		Chlorobenzene		- 64
MTBN		-100		<u>2414-420.9</u>	
PR-1560-M (Part A)		-400	PR-1057		-200
2414-413.2		- 10	MDI		- 26
			Chlorobenzene		- 50

2414-422

Viton B (20% MIBK Solution)	-200
MIBK	-200
Trioctylphosphine	- 5
PR-1560-M (Part A)	-100

2414-422.4

Viton B (20% MIBK Solution)	-200
PR-1560-M (Part A)	-200
MIBK	-200
Trioctylphosphine	- 10

2414-422.1

Viton B (20% MIBK Solution)	-200
PR-1560-M (Part A)	-100
MIBK	-200
Trioctylphosphine	- 10

2414-422.5

Viton B (20% MIBK Solution)	-200
PR-1560-M (Part A)	- 20
MIBK	-105
Trioctylphosphine	- 10

2414-422.2

Viton B (20% MIBK Solution)	-200
PR-1560-M (Part A)	- 50
MIBK	-100
Trioctylphosphine	- 5

2414-422.6

Viton B (20% MIBK Solution)	-200
PR-1560-M (Part A)	-100
MIBK	-300
Trioctylphosphine	- 10

2414-422.3

Viton B (20% MIBK Solution)	-200
PR-1560-M (Part A)	- 50
MIBK	-100
Trioctylphosphine	- 10

2414-422.7

Viton B (20% MIBK Solution)	-200
PR-1560-M (Part A)	- 30
MIBK	-100
Trioctylphosphine	- 10

	<u>2414-422.8</u>		<u>2414-424</u>	
Viton B (20% MIBK Solution)	-200	PR-1057		-200
PR-1560-M (Part A)	- 10	DDI		-100
MIBK	-100	MIBK		-100
Trioctylphosphine	- 10		<u>2414-425</u>	
	<u>2414-422.9</u>	PR-1057		-100
Viton B (20% MIBK Solution)	-200	Cellosolve acetate		-100
PR-1560-M (Part A)	- 40		<u>2414-425.1</u>	
MIBK	- 95	PR-1057		-100
	<u>2414-423.3</u>	Cellosolve acetate		-100
Hycar 1022 (10% MIBK Solution)	-200	Talc		- 75
PR-1560-M (Part A)	-200		<u>2414-425.2</u>	
MIBK	- 50	PR-1057		-100
	<u>2414-423.4</u>	Cellosolve acetate		-100
Hycar 1022 (10% MIBK Solution)	-180	Talc		- 75
PR-1560-M (Part A)	-220	Organometallic catalyst		- 0.16
MIBK	- 50		<u>2414-425.3</u>	
	<u>2414-423.5</u>	PR-1057		-200
Hycar 1022 (10% MIBK Solution)	-150	Cellosolve acetate		-100
PR-1560-M (Part A)	-250	2414-217.4		- 35
MIBK	-100		<u>2414-425.4</u>	
		PR-1057		-200
		Cellosolve acetate		-100
		Talc		- 75
		2414-217.4		- 35

<u>2414-425.5</u>		<u>2414-426.5</u>	
PR-1057	-220	PR-1057	-300
PR-1560-M (Part A)	- 80	Cellosolve acetate	-150
Chlorobenzene	-100	Organometallic catalyst	- 0.45
		PR-1560-M (Part A)	- 60
<u>2414-425.6</u>		<u>2414-426.6</u>	
PR-1057	-220	PR-1057	-300
PR-1560-M (Part A)	- 80	Cellosolve acetate	-150
Cellosolve acetate	-100	PR-1560-M (Part A)	- 30
<u>2414-425.7</u>		<u>2414-426.7</u>	
PR-1057	-200	PR-1057	-300
2414-217.4	-105	Cellosolve acetate	-150
Cellosolve acetate	- 75	PR-1560-M (Part A)	- 60
<u>2414-425.8</u>		<u>2414-427</u>	
PR-1057	-220	Hycar 1022 (10% MIBK Solution)	-200
PR-1560-M (Part A)	- 80	PR-1560-M (Part A)	-110
Cellosolve acetate	-100	MIBK	- 55
Urethane catalyst	- 1		
<u>2414-426.4</u>		<u>2414-427.1</u>	
PR-1057	-300	Hycar 1022 (10% MIBK Solution)	-200
Cellosolve acetate	-150	PR-1560-M (Part A)	- 94
Organometallic catalyst	- 0.45	MIBK	- 55
PR-1560-M (Part A)	- 30		

2414-427.3

Hycar 1022 (10% MIBK Solution)	-200
PR-1560-M (Part A)	- 65
MIBK	- 40

2414-427.3

Hycar 1022 (10% MIBK Solution)	-200
PR-1560-M (Part A)	- 47
MIBK	- 28

2414-428

PR-1057 (Pigmented with Cr ₂ O ₃)	-280
PR-1560-M (Part A)	- 40

2414-428.1

PR-1057 (Pigmented with Cr ₂ O ₃)	-300
PR-1560-M (Part A)	- 20

2414-428.2

PR-1057 (Pigmented with Cr ₂ O ₃)	-250
PR-1560-M (Part A)	- 70

2414-428.3

PR-1057 (Pigmented with Cr ₂ O ₃)	-100
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2414-428.4

PR-1057 (Pigmented with Cr ₂ O ₃)	-100
Organometallic catalyst	- 0.08

2414-428.5

PR-1057 (Pigmented with Cr ₂ O ₃)	-200
PR-1560-M (Part A)	-100

2414-501

PR-1057	-200
PR-1560-M (Part A)	-100
Chlorobenzene	-100

2414-501.1

PR-1057	-200
PR-1560-M (Part A)	-100
Y-4522	- 5
Chlorobenzene	-100

2414-501.2

PR-1057	-200
PR-1560-M (Part A)	-100
Chlorobenzene	-100
Pyridine	- 1

<u>2414-501.3</u>		<u>2414-501.8</u>	
PR-1057	-200	PR-1057	-200
PR-1560-M (Part A)	-100	PR-1560-M (Part A)	-100
Y-4922	- 20	Chlorobenzene	-100
Chlorobenzene	-100	Trioctylphosphine	- 5
Pyridine	- 1		
<u>2414-501.4</u>		<u>2414-501.9</u>	
PR-1057	-220	PR-1057	-200
PR-1560-M (Part A)	- 80	PR-1560-M (Part A)	-100
Cellosolve acetate	-100	Chlorobenzene	-100
		Trioctylphosphine	- 10
<u>2414-501.5</u>		<u>2414-501.10</u>	
PR-1057	-240	PR-1057	-200
PR-1560-M (Part A)	- 60	PR-1560-M (Part A)	-100
Chlorobenzene	-100	Chlorobenzene	-100
		Trioctylphosphine	- 15
<u>2414-501.6</u>		<u>2414-501.11</u>	
PR-1057	-180	PR-1057	-200
PR-1560-M (Part A)	-120	PR-1560-M (Part A)	-100
Chlorobenzene	-100	Chlorobenzene	-100
		Trioctylphosphine	- 20
<u>2414-501.7</u>		<u>2414-501.12</u>	
PR-1057	-160	PR-1057	-200
PR-1560-M (Part A)	-140	PR-1560-M (Part A)	-100
Chlorobenzene	-100	Chlorobenzene	-100

	<u>2414-505</u>		<u>2414-520.1</u>	
PR-1057	-100	PR-1560-M (Part A)	-200	
Chlorobenzene	- 50	PR-1058	-100	
	<u>2414-505.1</u>	EPONOL 55B40	- 50	
PR-1057	-100	Mixed Solvent	-120	
Y-4522	- 5	Y-4522	- 10	
Chlorobenzene	- 50			<u>2414-520.2</u>
	<u>2414-505.2</u>	PR-1560-M (Part A)	-200	
PR-1057	-100	PR-1058	-100	
PR-1560-M (Part A)	- 50	EPONOL 55B40	- 25	
Chlorobenzene	- 50	Mixed Solvent	- 70	
Talc	- 60	Y-4522	- 10	
	<u>2414-505.3</u>			<u>2414-520.3</u>
PR-1057	-100	PR-1560-M (Part A)	-200	
PR-1560-M (Part A)	- 50	PR-1058	-125	
Chlorobenzene	- 50	EPONOL 55B40	- 50	
Y-4522	- 3	Mixed Solvent	-150	
Talc	- 60	Y-4522	- 10	
	<u>2414-520</u>			<u>2414-520.4</u>
PR-1560-M (Part A)	-200	PR-1560-M (Part A)	-200	
PR-1058	- 50	PR-1058	-125	
EPONOL 55B40	- 55	EPONOL 55B40	- 25	
Mixed Solvent	-120	Mixed Solvent	-100	
		Y-4522	- 10	

2414-520.5

PR-1560-M (Part A)	-200
PR-1058	- 60
EPONOL 55B40	- 40
Mixed Solvent	-110
Y-4522	- 5

2414-520.6

PR-1560-M (Part A)	-200
PR-1058	- 40
EPONOL 55B40	- 40
Mixed Solvent	-100
Y-4522	- 5

2414-520.7

PR-1560-M (Part A)	-200
PR-1058	- 60
EPONOL 55B40	- 20
Mixed Solvent	-110
Y-4522	- 5

2414-520.8

PR-1560-M (Part A)	-200
PR-1058	- 40
EPONOL 55B40	- 20
Mixed Solvent	-100
Y-4522	- 5

2414-520.9

PR-1560-M (Part A)	-200
EPONOL 55/PRICO Resin	- 50
Mixed Solvent	-100

2414-520.10

PR-1560-M (Part A)	-200
EPONOL 55/PRICO Resin	- 25
Mixed Solvent	- 80

2414-521

PR-1058	-200
PR-1560-M (Part A)	-100
Talc	- 65
2414-413.1	- 12

2414-521.1

PR-1058	-200
PR-1560-M (Part A)	-100
Talc	- 65
2414-413.1	- 36

2414-522

PR-1058	-200
PR-1560-M (Part A)	-100
Talc	- 65
2414-413.2	- 12

2414-522,1

PR-1058	-200
PR-1560-M (Part A)	-100
Talc	- 65
2414-413.2	- 36

2414-523,1

PR-1057	-200
PR-1560-M (Part A)	-100
Chlorobenzene	-100

APPENDIX I

TABLE 2 - SCREENING TEST DATA

COLUMN HEADINGS

- 3.3.9 Resistance to Water
MIL-C-27725A
- 3.3.10 Resistance to Salt Water and Fuel
MIL-C-27725A
- 3.3.13 Resistance to Iron Chloride
MIL-C-27725A
- 3.3.20 Resistance to Simulated Microbial Byproducts
MIL-C-27725A

QUALIFICATION TEST CODING KEY

- P - Pass
- F - Fail
- a - Blistering
- b - Pin Point Penetration
- c - Film Decomposition
- d - Loss of Adhesion
- e - Underfilm Corrosion

APPENDIX I

TABLE 2 - SCREENING TEST DATA

	3.3.9	3.3.13	3.3.10	3.3.20
2414-5	F,a,d	F,a,b,e	F,a,d	F,a,b,e
2414-6	F,a,d	F,a,b,e	P	F,a,b,e
2414-8	F,a	F,a,b	F,a	F,a,b,e
2414-10	F,a,d	F,a,e	F,a	F,a,b,e
2414-17	F,a,d	F,a,b,e	F,a,d	F,a,b,e
2414-100.1	F,a,d	F,e	F,d	P
2414-100.2	F,a,d	F,b,e	F,d	P
2414-100.3	F,a,d	F,b,e	F,d	P
2414-100.4	F,a,d	F,b,e	F,d	P
2414-100.5	F,a,d	F,b,e	F,d	P
2414-100.6	F,a,d	F,b,e	F,d	F,a,d
2414-101	F,a,d	F,a,c,e	F,d	F,b,c,e
2414-102	F,a,d	F,b,c,e	F,d	F,b,c,e
2414-103	F,a,d	F,b,c,e	F,d	F,b,c,e
2414-104	F,a,d	F,b,c,e	F,d	F,b,c,e
2414-105	F,a,d	F,b,c,e	F,d	F,b,c,e
2414-106	F,a,d	F,b	F,d	F,b
2414-107	F,a,d	F,b,c,e	F,d	F,b,c,e
2414-108	F,a,d	F,b,e	F,d	F,b,e
2414-109	F,a,d	F,b,e	F,d	F,b
2414-200	F,a,d	F,c	F,d	F,c
2414-200.1	F,a,d	F,c	F,d	F,c
2414-200.2	F,a,d	F,a,b	P	F,a,b,e
2414-201	F,a,d	F,c	F,d	F,c
2414-201.1	F,a,d	F,a,b	F,d	F,a,b
2414-202	F,a,d	F,c	F,d	F,c
2414-202.1	F,a,d	F,c	F,d	F,c
2414-203	F,a,d	F,c	F,d	F,c
2414-203.1	F,a,d	F,a,b,e	F,d	F,a,b,d,e
2414-204.1	P	F,a,b,e	P	F,b,e
2414-204.2	F,a,d	F,a,b,e	P	F,b,e
2414-204.3	F,a,d	F,a,b,e	F,a	F,b,e
2414-205.1	P	F,a,b,e	P	F,b,e
2414-205.2	P	F,b,e	P	F,b,e
2414-205.3	P	F,b,e	P	F,b,e
2414-205.4	P	F,b,e	P	F,b,e
2414-206.1	F,a,d	P	P	P
2414-206.2	F,a,d	P	P	P
2414-206.3	F,a,d	P	P	P
2414-206.4	F,a,d	P	P	P
2414-207	F,a	F,a,b,e	P	F,b,c,e
2414-207.1	F,a	F,a,b,e	P	F,a,c,e
2414-208.1	F,a,d	F,a,b,e	P	F,a
2414-208.2	F,a,d	F,a,b,e	P	F,a
2414-208.3	F,d	F,a,b,e	P	F,a
2414-208.4	F,d	F,a,b,e	P	F,a

	3.3.9	3.3.13	3.3.10	3.3.20
2414-208.5	F,d	F,a,b,e	P	F,a
2414-208.6	P	F,a,b,e	P	F,a
2414-208.7	F,a,d	F,a,b,e	P	F,a
2414-208.8	F,c	F,a,b,e	P	F,a
2414-209	F,a	F,b,c,e	P	F,a,b,e
2414-209.1	F,a	F,b,c,e	P	F,b,c,e
2414-210	F,a	F,b,c,e	P	F,b,c,e
2414-210.1	F,a	F,b,c,e	P	F,b,c,e
2414-211	F,a	F,b,c,e	P	F,b,c,e
2414-211.1	F,a	F,b,c,e	P	F,b,c,e
2414-212	F,a	P	P	F,a
2414-212.1	F,a	P	P	F,a
2414-212.2	P	P	P	F,a
2414-212.3	P	F,a	P	F,a
2414-213	F,a	F,a,b	P	F,a
2414-213.1	F,a	F,a,b	P	F,a
2414-213.2	F,a	F,a,b	P	F,a
2414-213.3	F,a	F,a,b	P	F,a
2414-213.4	F,a	F,a,b	P	F,a
2414-213.5	F,a	F,a,b	P	F,a
2414-214	F,a,d	F,a,b	P	F,a,b
2414-215	F,a	F,a,b	P	F,a,e
2414-215.1	F,a	F,a,b	P	F,a,b,e
2414-215.2	F,a	F,a	P	F,a,b,e
2414-215.3	F,a	F,a,b	P	F,a
2414-215.4	F,a,d	F,a,b	P	F,a,b,e
2414-215.5	F,a,d	F,a,b	P	F,a,b,e
2414-216	F,a,d	F,a,b,e	F,a	F,a,c,e
2414-216.1	F,a,d	F,a,b,c	F,a	F,a,c,e
2414-216.2	F,a,d	F,a,b,c	F,a	F,a,c,e
2414-216.3	F,a,d	F,a,b,e	F,a	F,a,c,e
2414-217.1	P	P	P	P
2414-217.4	-	-	-	-(no tests run)
2414-217.5	P	P	P	P
2414-217.6	P	P	P	P
2414-217.51	P	P	P	F,d
2414-218	F,a,d	F,a,b,e	F,a	F,a,c,e
2414-218.1	F,a,d	F,a,b,e	F,a	F,a,c,e
2414-218.2	F,a,d	F,a,b,e	F,a	F,a,c,e
2414-218.3	F,a,d	F,a,b	F,a	F,a,c,e
2414-219	P	F,a,b	P	F,a,b
2414-219.1	F,a	F,b	P	F,a
2414-219.2	P	F,a,b,e	P	F,a,b,e
2414-220	P	F,a,b,e	P	F,a,b,e
2414-221	F,a,d	F,a	P	F,a,b,e
2414-221.1	P	F,a,b	P	F,a,b
2414-221.2	F,a	F,a,b	F,a	F,a,b
2414-221.3	F,a,d	F,a,b	F,a	F,a
2414-221.4	F,a,d	F,a,b,e	F,a	P
2414-221.5	F,a	F,b	P	F,a
2414-222	F,a,d	F,a	P	F,a
2414-222.1	F,a,d	F,a,b,e	P	F,a

	3.3.9	3.3.13	3.3.10	3.3.20
2414-222.2	F,a,d	F,a,b,e	P	F,a
2414-222.3	F,a	F,a,b,e	P	F,a
2414-222.4	F,a	F,a,b,e	P	F,a
2414-223	F,a	F,a,b,e	P	P
2414-223.1	F,a	F,a,b,e	P	F,a
2414-223.2	P	F,a,c,e	P	F,b
2414-223.3	P	F,a,c,e	P	F,a,b,e
2414-224	F,a	F,a	P	P
2414-225	P	P	P	F,a
2414-226	F,a,d	F,a,b	F,a,d	F,a,b,e
2414-226.1	F,a,d	F,a,b	F,d	F,a,b,e
2414-227	F,a,d	F,a,c,e	F,a,d	F,a,b,e
2414-227.1	F,a,d	F,a,b,e	F,d	F,a,b
2414-228	F,a,d	F,a,b	F,d	F,a,b,c
2414-228.1	F,a,d	F,a,b	F,d	F,a,b,c
2414-229	F,a,d	F,a,b	F,d	F,a,c
2414-229.1	F,a,d	F,a,b,e	F,d	F,a,e
2414-230	F,a,d	F,a	F,d	F,a
2414-231	F,a,d	F,a	F,d	F,a
2414-231.1	F,a,d	F,b	F,a	F,a
2414-231.2	F,a,d	P	F,a	F,a
2414-232	F,a,d	F,a	F,d	F,a
2414-232.1	F,a	P	P	F,a
2414-232.2	F,a	F,b	P	F,a,b
2414-232.3	P	F,b	P	F,a,b
2414-232.4	F,a	P	P	F,a
2414-232.5	F,a,d	F,a,b	F,d	F,a
2414-232.6	F,a,d	F,a,b	F,d	F,a
2414-232.7	P	F,b	P	P
2414-233	P	F,a,b	P	F,a
2414-234	F,a	F,a,b	P	F,a
2414-234.1	F,a	F,b	P	F,a
2414-234.2	F,a	F,a	P	F,a
2414-234.3	F,a	F,a	F,a	F,a
2414-234.4	F,a	F,a	F,a	F,a,b
2414-234.5	F,a	F,a	F,a	F,a,b,e
2414-234.6	F,a,d	F,a,b	F,d	F,a,b
2414-234.7	F,a,d	F,a,b,e	F,d	F,a,b,e
2414-235	P	F,a,b,e	P	F,a,b
2414-235.1	P	F,a,b,e	P	F,a,b,e
2414-235.2	P	F,a,b,e	P	F,a,b
2414-235.3	P	P	P	F,a
2414-235.4	F,a	P	P	F,a,d
2414-235.5	F,a	P	P	F,a,d
2414-236	F,a,d	F,a,b,e	F,a	F,c
2414-236.1	F,a,d	F,c	F,a	F,c
2414-237	F,a	F,a,b	P	F,a,b,e
2414-238	P	F,b	P	F,a
2414-238.1	F,a	F,a,b	P	F,a
2414-238.2	F,a,d	F,b	F,a	F,a
2414-238.3	F,a,d	F,a	F,a	F,a

	3.3.9	3.3.13	3.3.10	3.3.20
2414-238.A	P	F,a,b,e	P	F,c
2414-239	F,a	F,a,b,e	P	F,b,e
2414-240	P	P	P	F,a
2414-240.1	P	P	P	F,a
2414-240.2	F,a	F,a	P	F,a
2414-241	F,a,d	F,a	F,d	F,a
2414-241.1	F,a,d	F,a	F,d	F,a
2414-241.2	F,a,d	F,a	F,d	F,a
2414-241.3	F,a,d	F,a	F,d	F,a
2414-242	F,a,d	F,a,b	F,a	F,a
2414-242.1	F,a	F,a	P	F,a
2414-243	P	P	P	F,a
2414-243.1	F,d	P	P	F,a
2414-243.2	P	P	P	F,a,b,e
2414-243.3	P	P	P	F,a,b,e
2414-244	F,a,d	F,a,e	F,a	F,a,b,e
2414-244.1	F,a,d	F,a,b,e	F,a	F,a,b,e
2414-245	F,a	F,a,b,e	P	F,a,b,e
2414-245.1	F,a,d	F,a,b,e	F,d	F,a,b,e
2414-245.2	F,a	F,a	P	F,a
2414-245.3	F,a	F,a,b,e	P	F,a,b,e
2414-245.4	F,a,d	F,a,b	P	F,a,b
2414-245.5	F,a	F,a,b	P	F,a,b
2414-300.1	F,a,d	F,a,b,e	P	F,a,b,e
2414-300.2	F,a,d	F,a,b,e	P	F,e
2414-300.3	F,a	F,a,b,e	P	F,b,c,e
2414-300.4	F,a,d	F,a,b,e	P	F,b,e
2414-300.5	F,a,d	F,a,b	P	F,b,e
2414-301	F,a	F,a	P	F,a,b
2414-301.1	F,a	F,a,b	P	F,a,b,e
2414-301.2	P	F,a	P	F,a
2414-302	P	F,a,b,e	P	F,a
2414-302.1	F,a	F,a,b,e	P	F,a,b
2414-302.2	F,a	F,a,b,e	P	F,a,b
2414-303	F,a	F,b,c,e	P	F,a,b,e
2414-303.1	F,a	F,a,b,e	P	F,a,b
2414-303.2	F,a	F,a,b	P	F,a,b
2414-303.3	F,a	F,a,b,e	P	F,a,b,e
2414-303.4	P	F,b	P	F,a,b,e
2414-304	F,a,d	P	P	F,a
2414-305	F,a,d	F,a	F,a,d	F,a,e
2414-306	F,a,d	P	P	F,a
2414-306.1	F,a,d	P	P	F,a
2414-307	F,d	F,b,c,e	F,d	F,c,e
2414-307.1	F,d	F,b,c,e	F,d	F,c,e
2414-307.2	F,d	F,b,c,e	F,d	F,c,e
2414-307.3	F,d	F,b,c,e	F,d	F,c,e
2414-308	F,a,d	F,a	P	F,a
2414-308.1	F,a,d	F,a	P	F,a
2414-400	P	P	P	P
2414-401	P	F,b,e	P	F,b,e

	3.3.9	3.3.13	3.3.10	3.3.20
2414-401.1	P	F,b,e	P	F,b,e
2414-401.2	P	F,b,c,e	P	F,b,c,e
2414-401.3	P	F,b,c,e	P	F,b,c,e
2414-401.4	F,a	F,b,c,e	P	F,b,c,e
2414-401.5	F,a	F,b,c,e	P	F,b,c,e
2414-401.6	F,a	F,b,c,e	P	F,b,c,e
2414-402	F,a	F,b,c,e	F,a	F,b,c,e
2414-403	P	F,b,c,e	P	F,b,c,e
2414-403.1	P	F,b	P	F,b,c,e
2414-403.2	P	F,a,b,e	P	F,b,c,e
2414-403.3	P	F,b,c,e	P	F,b,c,e
2414-404	P	F,a	P	F,a,b,e
2414-404.1	P	F,a	P	F,a,b,e
2414-405	F,a,d	F,a	F,a	F,a
2414-406	P	P	P	P
2414-407	P	P	P	P
2414-408	F,d	F,d	P	F,d
2414-409	F,a,d	F,c	F,a,d	F,c
2414-410	F,d	F,b,e	P	F,b,c,e
2414-411	F,d	F,c	P	F,b,c,e
2414-412	P	F,b,e	P	F,b,c,e
2414-413	P	P	P	F,a
2414-413.1	P	F,a	P	F,a
2414-413.2	P	P	P	F,a
2414-414	F,d	P	P	P
2414-414.1	F,d	P	P	P
2414-415	F,d	F,e	P	P
2414-415.1	F,d	F,e	P	F,a
2414-416	F,d	F,c,d	F,d	F,a,c,d
2414-417	P	F,e	P	F,e
2414-417.1	P	F,e	P	F,e
2414-417.2	P	F,e	P	F,e
2414-417.3	P	F,e	P	F,e
2414-417.4	P	F,e	P	F,e
2414-417.5	P	F,e	P	F,e
2414-417.6	P	P	P	P
2414-417.7	P	P	P	P
2414-417.8	F,d	F,d,e	P	F,d,e
2414-417.9	F,d	P	F,d	P
2414-417.10	F,d	P	F,d	P
2414-417.11	F,d	F,e	P	P
2414-417.12	F,d	F,d	P	F,a
2414-417.13	F,d	F,c,d	F,d	F,a,c,d
2414-417.14	F,d	F,d	F,d	F,a,c,d
2414-418	F,d	F,e	F,d	F,e
2414-418.1	P	F,e	P	F,e
2414-418.2	P	F,b,e	P	F,b,e
2414-418.3	P	F,b,e	P	F,b,e
2414-418.4	P	F,b,e	P	F,b,e
2414-418.5	P	F,b,e	P	F,b,e

	3.3.9	3.3.13	3.3.10	3.3.20
2414-418.6	P	F,b,e	P	F,b,c,e
2414-418.7	P	F,b,e	P	F,b,e
2414-418.8	P	F,b,e	P	F,b,e
2414-418.9	F	F,b,e	P	F,b,e
2414-418.11	F,d	F,b,e	F,d	F,b,e
2414-418.12	F,d	F,b,e	F,d	F,b,e
2414-418.13	F,d	F,b,e	F,d,e	F,b,e
2414-418.14	F,d	F,b,e	F,d	F,b,e
2414-418.15	F,d	F,b,e	F,d	F,b,e
2414-418.16	F,a,d	F,b,e	F,d	F,b,c,e
2414-418.17	F,d	F,b,e	F,d	F,b,e
2414-418.18	F,d	F,b,e	F,d	F,b,e
2414-418.19	F,d	F,b,e	F,d	F,b,e
2414-418.20	P	F,b,e	P	F,d,e
2414-418.21	F,a,d	F,b,e	F,d	F,d,e
2414-418.22	F,a,d	F,b,c,e	F	F,b,e
2414-418.23	P	F,b,e	F	F,b,c,e
2414-418.24	P	F,a,b,e	P	F,a,b
2414-418.25	F,d	F,a,c,e	P	F,a,b,e
2414-418.26	P	F,a,c,e	P	F,b,e
2414-418.27	F,d	F,a,b,e	P	F,b,e
2414-418.28	F,d	F,a,b,e	P	F,b,e
2414-418.29	P	F,a	P	F,a,e
2414-418.30	P	F,a	P	F,a
2414-418.31	P	F,e	P	F,e
2414-418.32	P	F,e	P	F,e
2414-419	F,c	F,c,e	P	F,c,e
2414-419.1	F,c	F,c,e	P	F,c,e
2414-419.2	P	P	P	P
2414-420	F,a,d	F,a,b,e	F,a	F,a,b,e
2414-420.1	F,a,d	F,a,b,e	F,a	F,a,b,e
2414-420.2	F,a,d	F,a,b	P	F,a,b
2414-420.3	F,a,d	F,a,b	P	F,a,b
2414-420.4	F,a,d	F,a	P	F,a
2414-420.5	F,a,d	F,a	P	F,a
2414-420.8	F,a,d	F,b	F,d	F,a,b,e
2414-420.9	F,a,d	F,b	F,d	F,a,b,e
2414-422	P	F,b	P	F,b,e
2414-422.1	P	F,b,e	P	F,b,e
2414-422.2	F,d	F,b	P	F,b,e
2414-422.3	F,a,d	P	F,a	F,b,e
2414-422.4	F,a	F,b,e	P	F,b,e
2414-422.5	F,d	F,b	P	F,b,e
2414-422.6	F,d	F,b,e	P	F,b,e
2414-422.7	F,a,d	F,a	F,a	F,a,b,e
2414-422.8	F,a,d	F,a	F,a	F,b,e
2414-422.9	F,d	F,b,e	P	F,b,e
2414-423.3	F,a	F,a,b,e	F,a,b,d	F,a,b,e
2414-423.4	F,a	F,a,b	F,b,d	F,a,b,e
2414-423.5	F,a	F,a,b,e	F,b	F,a,b,e
2414-424	F,a	P	P	F,b,e

	3.3.9	3.3.13	3.3.10	3.3.20
2414-425	P	P	F	F,a,b
2414-425.1	P	P	P	F,a,b
2414-425.2	P	P	P	F,a,b
2414-425.3	P	P	P	P
2414-425.4	P	P	P	P
2414-425.5	P	P	P	P
2414-425.6	P	P	P	P
2414-425.7	P	P	P	P
2414-425.8	P	P	P	P
2414-426.4	F,a	F,a	P	F,a
2414-426.5	F,a	F,a	P	F,a
2414-426.6	F,a	F,a	P	F,a
2414-426.7	F,a	F,a	P	F,a
2414-427	P	F,a,b,e	P	F,b,e
2414-427.1	P	F,a,b,e	P	F,b,e
2414-427.2	P	F,a,b,e	P	F,b,e
2414-427.3	F,d	F,a,b,e	P	F,a,b,c
2414-428	P	F,a	P	P
2414-428.1	P	F,a	P	P
2414-428.2	P	F,a	P	P
2414-428.3	P	F,b,e	P	F,e
2414-428.4	P	F,b,e	P	F,e
2414-428.5	P	F,b,e	P	F,b,e
2414-501	P	P	P	P
2414-501.1	P	P	P	P
2414-501.2	P	F,a	P	P
2414-501.3	P	F,a	P	F,a
2414-501.4	P	P	P	P
2414-501.5	P	P	P	P
2414-501.6	P	P	P	P
2414-501.7	P	P	P	P
2414-501.8	F,a	P	F,a	F,a
2414-501.9	F,a,d	P	F,a,d	F,a
2414-501.10	P	P	F,a,d	F,a
2414-501.11	F,a,d	P	F,a,d	F,a
2414-501.12	P	P	P	P
2414-505	F,a	F,b	P	F,a,b,e
2414-505.1		F,b	P	F,a,b,e
2414-505.2	F,a	F,b	P	F,b,e
2414-505.3	F,a	P	P	F,b
2414-520	P	P	P	F,a
2414-520.1	P	P	P	F,a
2414-520.2	P	P	P	F,a
2414-520.3	F,a	P	P	F,a,e
2414-520.4	F,a	P	P	F,a,e
2414-520.5	F,a,d	F,b,e	F,d	F,e
2414-520.6	F,a	F,b,e	F,d	F,e
2414-520.7	F,a	F,b,e	F,d	F,e
2414-520.8	F,a	F,b,e	F,d	F,a,e
2414-520.9	F,a,d	P	P	F,a
2414-520.10	F,a,d	P	P	F,a,e

	3.3.9	3.3.13	3.3.10	3.3.20
2414-521	P	F,a	P	F,a
2414-521.1	P	F,a	P	F,a
2414-522	P	F,a	P	F,a
2414-522.1	P	F,a	P	F,a
2414-523.1	P	P	P	P

APPENDIX I

TABLE 3

Test Report of One-Package Surface Coating 2414-501.4
 to Specification MIL-C-27725A Amendment 2
 as modified (Section IV B)

<u>Paragraph</u>	<u>Property</u>	<u>Requirements</u>	<u>Results</u>
3.1	Qualification	Not pertinent	
3.2	Materials	The two-part requirement is waived.	
3.2.1	Appearance	Conform to spec.	Passes test
3.2.2	Toxic products and formulations	Conform to spec.	No known severely toxic ingredients are contained in formula 2414-501.4
3.2.2.1	Toxicity certification	Not pertinent at this time.	
3.3	Properties		
3.3.1	Application properties and surface appearance	Conform to spec.	Meets requirement
3.3.2	Color	Conform to spec.	Meets requirement
3.3.3	Weight per gallon	Within + 5% of qualification sample.	Meets requirement
3.3.4	Nonvolatile content	>35%	42%
3.3.5	Viscosity	10-20 sec.	20 sec.
3.3.6	Application time	Not applicable	
3.3.7	Drying time	4 hours	2 hours
3.3.8	Cure time	14 days @ std. cond. or 2 days @ std. cond. plus 24 hrs. @ 120° F.	Meets requirement

<u>Paragraph</u>	<u>Property</u>	<u>Requirements</u>	<u>Results</u>
3.3.9	Resistance to water	Conform to spec.	Passes test
3.3.10	Resistance to salt water and fuel	Conform to spec.	Passes test
3.3.11	Resistance to engine oil	Conform to spec.	Passes test
3.3.12	Resistance to hydraulic fluid	Conform to spec.	Passes test
3.3.13	Resistance to iron chloride	Conform to spec.	Passes test
3.3.14	Fuel contamination	Conform to spec.	Not performed
3.3.15	Low temperature flexibility	Conform to spec.	Passes test
3.3.16	Sealing compound compatibility		
3.3.16.1	Sealing compound to coating material	Not applicable	
3.3.16.2	Coating material to sealing compound	Conform to spec.	Meets requirement
3.3.17	Material compatibility	Not applicable	
3.3.18	Accelerated storage stability	14 days @ 120° F.	Passes test
3.3.19	Repairability	Conforms to spec.	Meets requirement
3.3.20	Resistance to simulated microbial byproducts	Conforms to spec.	Passes test
3.3.21	Free diisocyanate content	≤ 0.45%	0.25%

APPENDIX II

FIGURES

Specimen identification includes formulation number and test exposure, reference MIL-C-27725A.



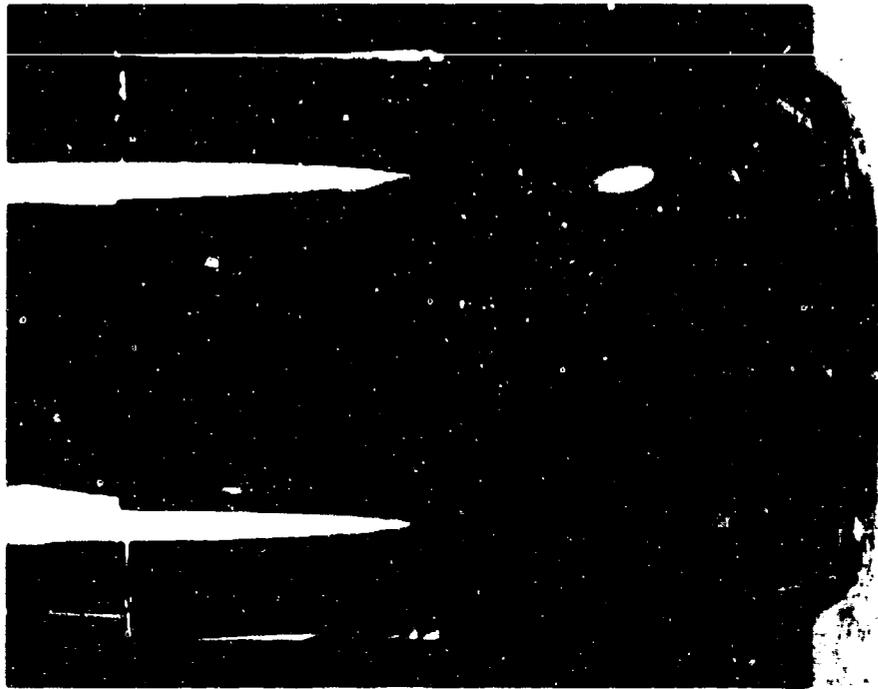
Formula: 2414-419
Exposure: 5% acetic acid/JRF,
5 days at 140° F
3.3.20 of MIL-C-27725A

Formula: 2414-419.1
Exposure: 5% acetic acid/JRF,
5 days at 140° F
3.3.20 of MIL-C-27725A

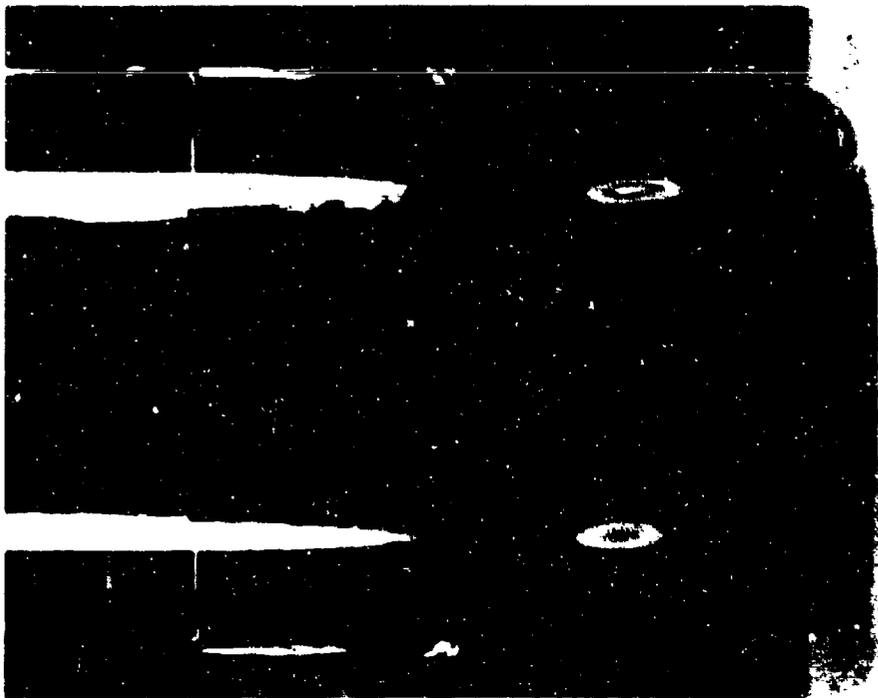
Formula: 2414-419
Exposure: 0.5% iron chloride,
10 days at 140° F
3.3.13 of MIL-C-27725A

Formula: 2414-419.1
Exposure: 0.5% iron chloride,
10 days at 140° F
3.3.13 of MIL-C-27725A

Figure 1

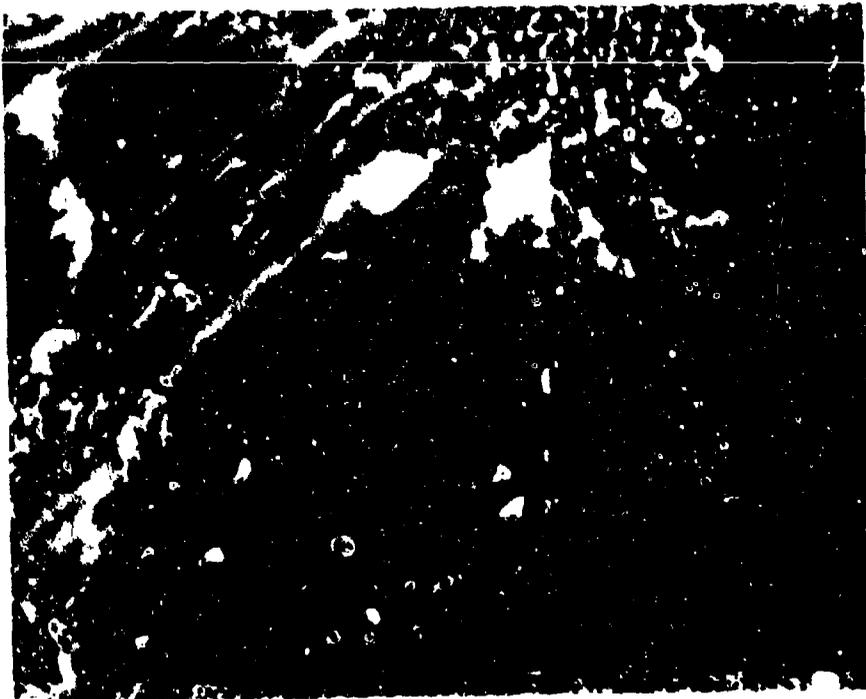


Formula: 2414-407
Exposure: 5% acetic acid/JRF,
5 days at 140° F
3.3.20 of MIL-C-27725A

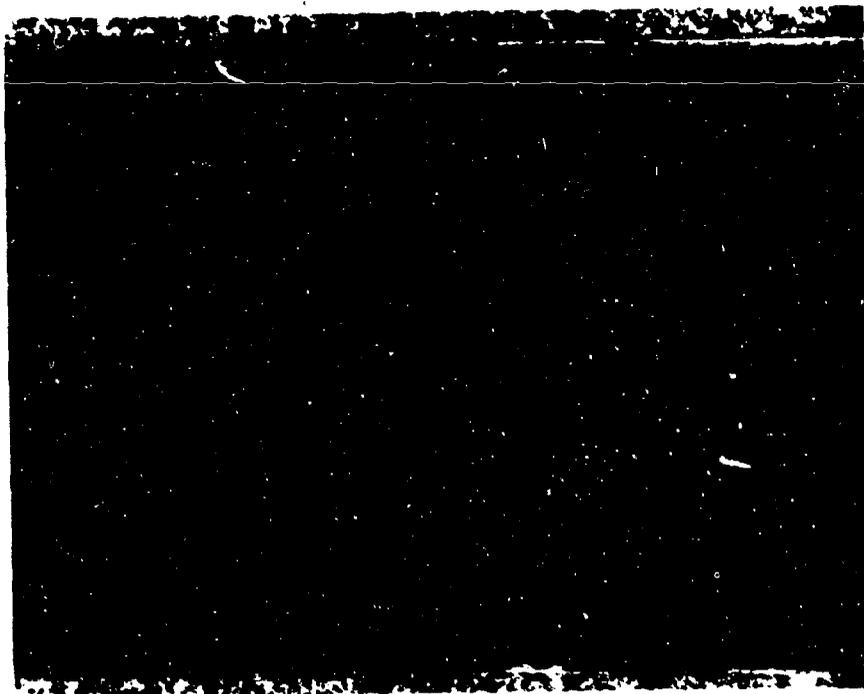


Formula: 2414-406
Exposure: 5% acetic acid/JRF,
5 days at 140° F
3.3.20 of MIL-C-27725A

Figure 2

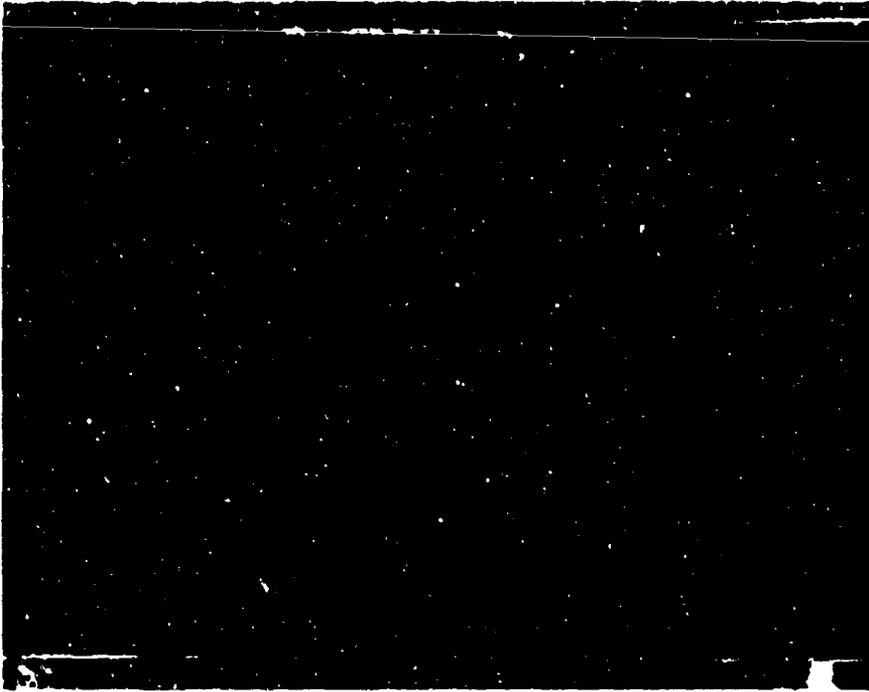


Formula: 2414-415.1
Exposure: 5% acetic acid/JRF,
5 days at 140° F
3.3.20 of MIL-C-27725A

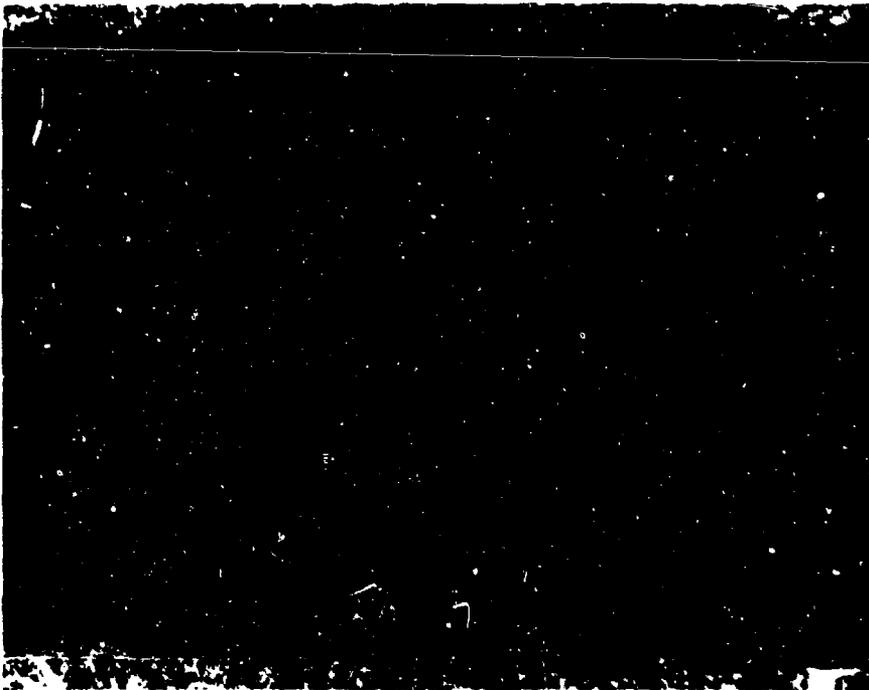


Formula: 2414-414
Exposure: 5% acetic acid/JRF,
5 days at 140° F
3.3.20 of MIL-C-27725A

Figure 3

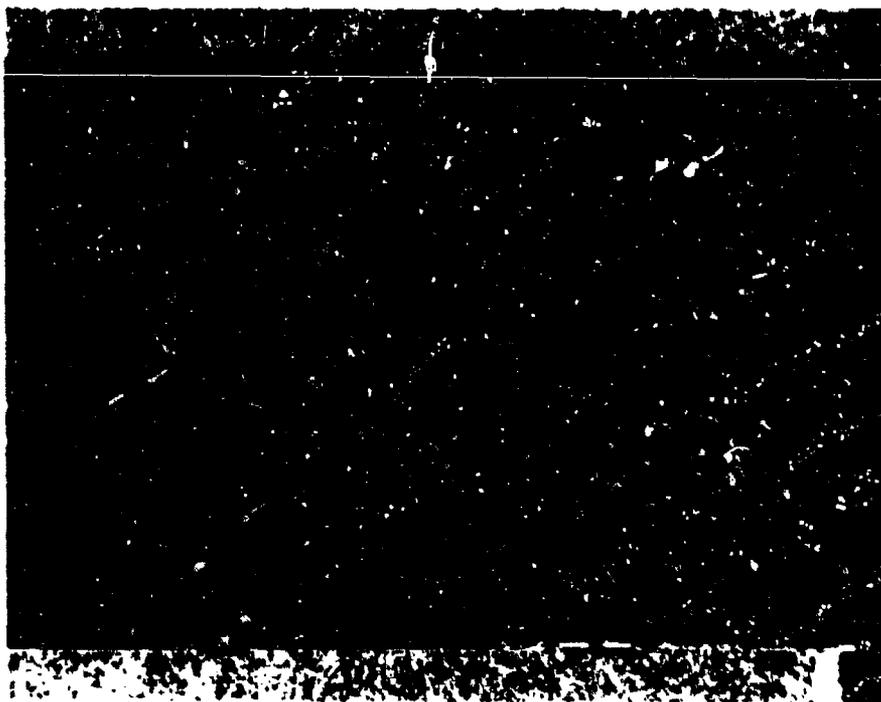


Formula: 2414-415.1
Exposure: 0.5% iron chloride,
10 days at 140- F
3.3.13 of MIL-C-27725A

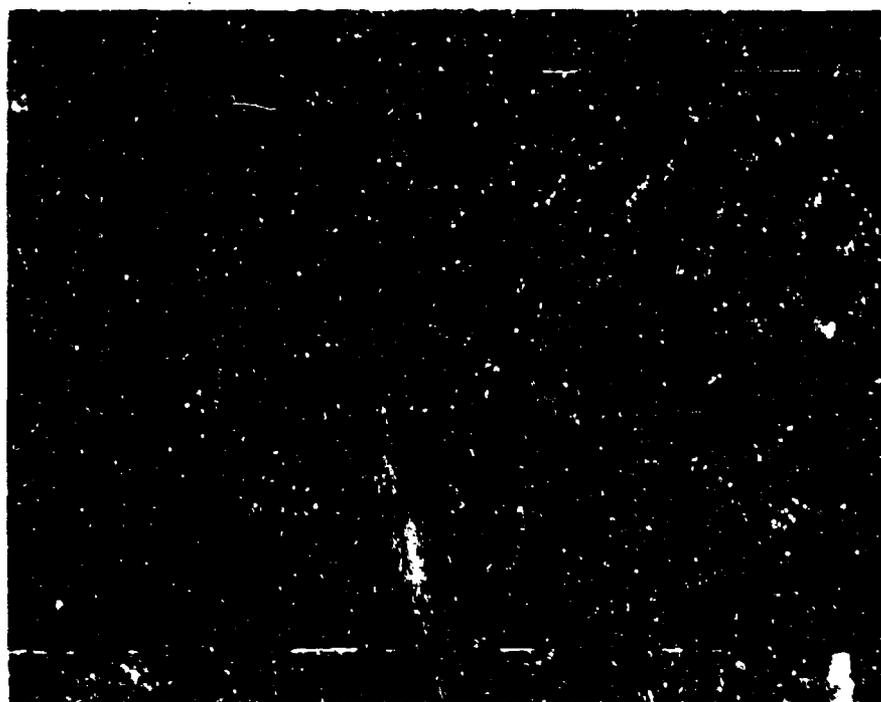


Formula: 2414-414
Exposure: 0.5% iron chloride,
10 days at 140- F
3.3.13 of MIL-C-27725A

Figure 4

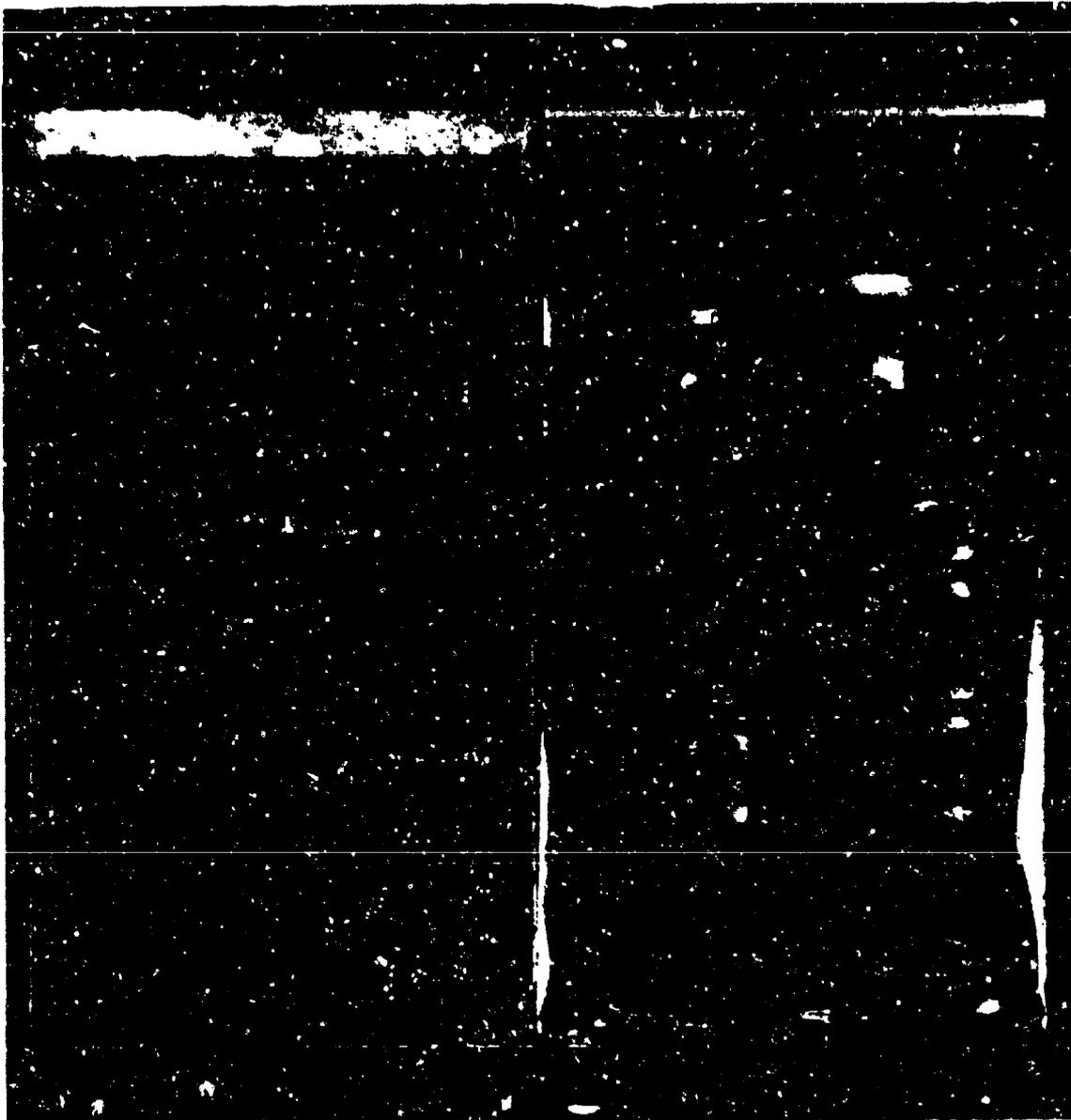


Formula: 2414-418.31
Exposure: 5% acetic acid: JRF,
5 days at 140° F
3.3.29 of MIL-C-27725A



Formula: 2414-418.31
Exposure: 0.5% iron chloride,
10 days at 140° F
3.3.13 of MIL-C-27725A

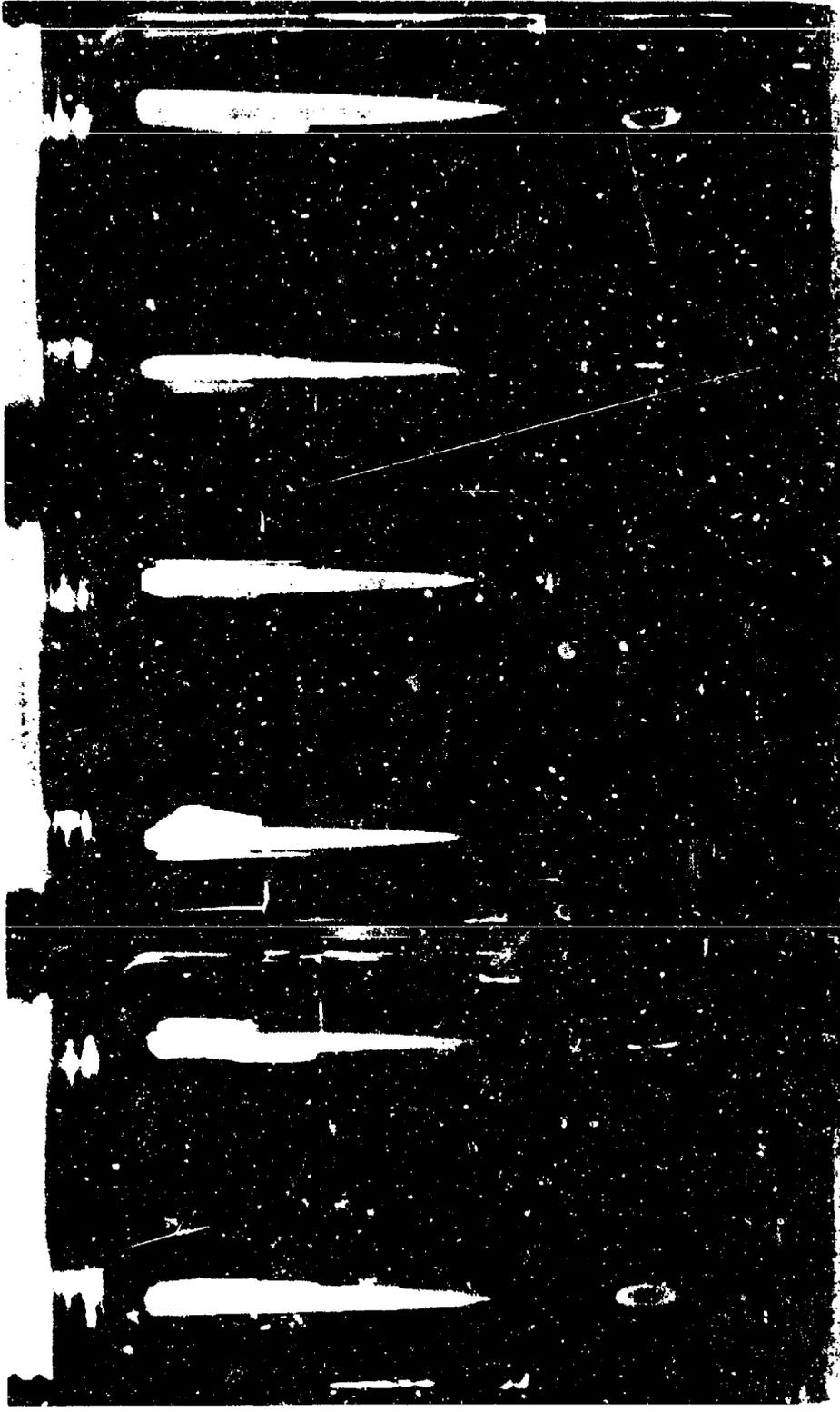
Figure 5



Formula: 2414-406
Exposure: 0.5% iron chloride,
10 days at 140° F
3.3.13 of MIL-C-27725A

Formula: 2414-408
Exposure: 0.5% iron chloride,
10 days at 140° F
3.3.13 of MIL-C-27725A

Figure 6



Formula: 2414-406
Exposure: 5% acetic acid/JRF,
5 days at 140° F
3.3.20 of MIL-C-27725A

Formula: 2414-407
Exposure: 5% acetic acid/JRF,
5 days at 140° F
3.3.20 of MIL-C-27725A

Formula: 2414-408
Exposure: 5% acetic acid/JRF,
5 days at 140° F
3.3.20 of MIL-C-27725A

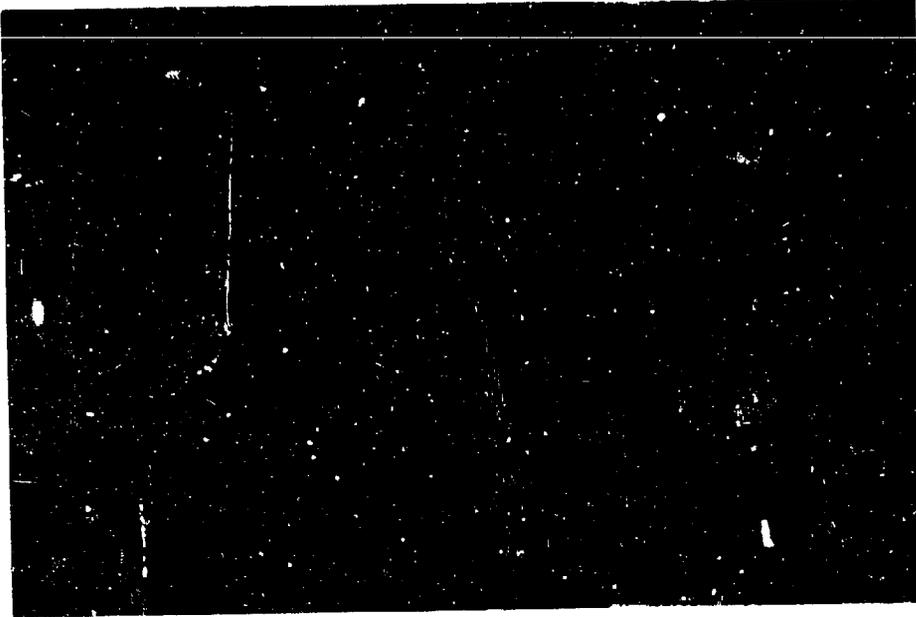
Figure 7



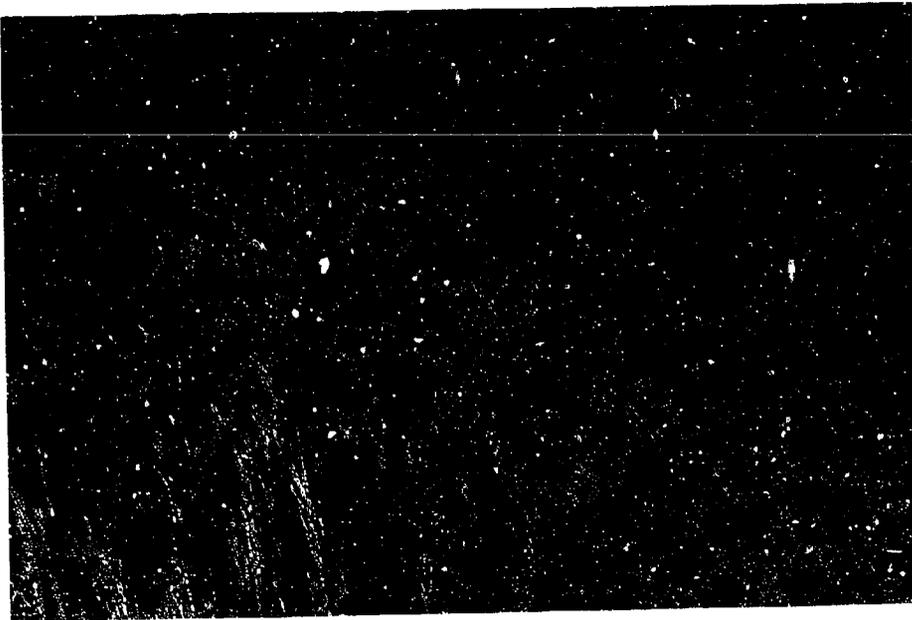
Formula: 2414-416
Exposure: 5% acetic acid/JRF,
5 days at 140° F
3.3.C3 of MIL-C-27725A

Formula: 2414-416
Exposure: 0.5% iron chloride,
10 days at 140° F
3.3.13 of MIL-C-27725A

Figure 8

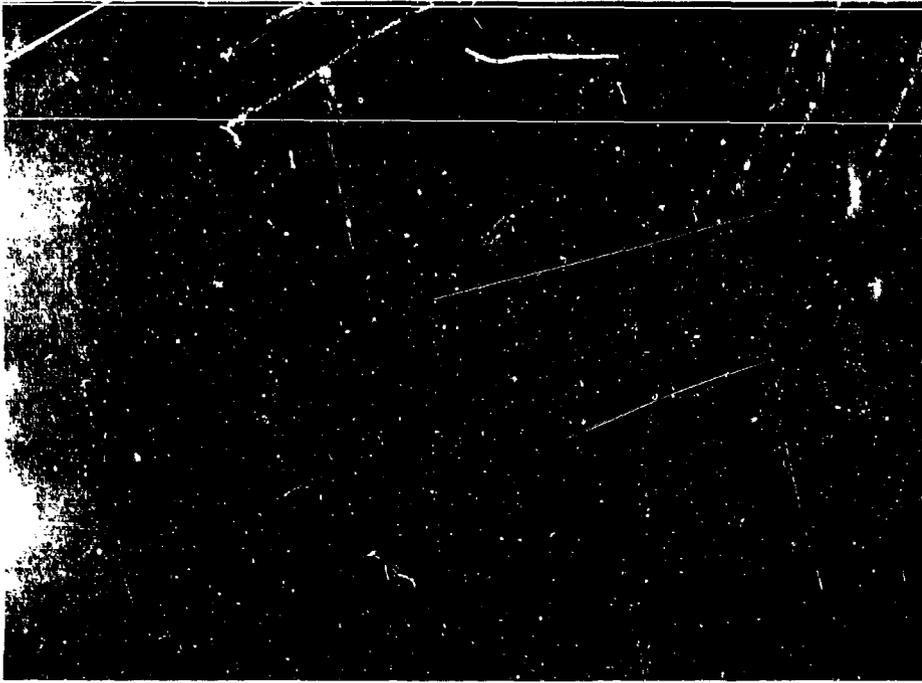


Formula: 2414-417.14
Exposure: 5% acetic acid/JRF,
5 days at 140° F
3.3.20 of MIL-C-27725A

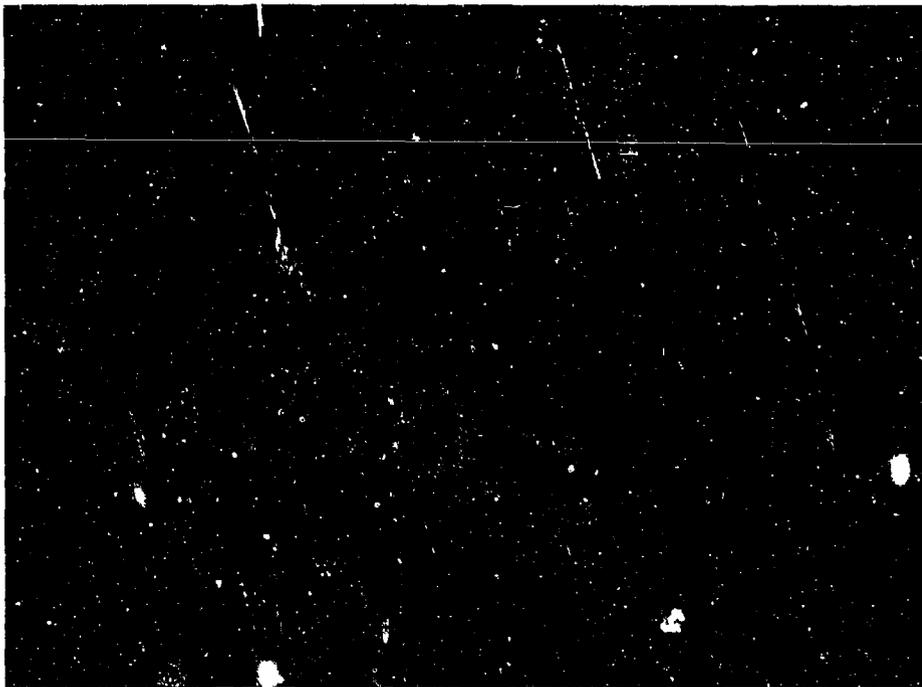


Formula: 2414-417.14
Exposure: 0.5% iron chloride,
10 days at 140° F
3.3.13 of MIL-C-27725A

Figure 9

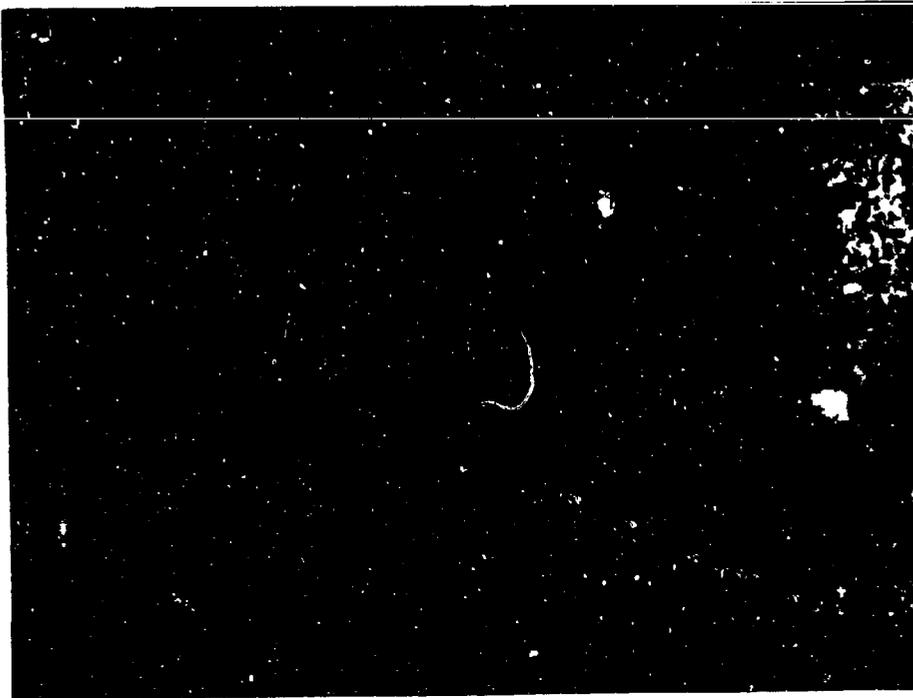


Formula: 2414-418
Exposure: 5% acetic acid/JRF,
5 days at 140° F
3.3.20 of MIL-C-27725A

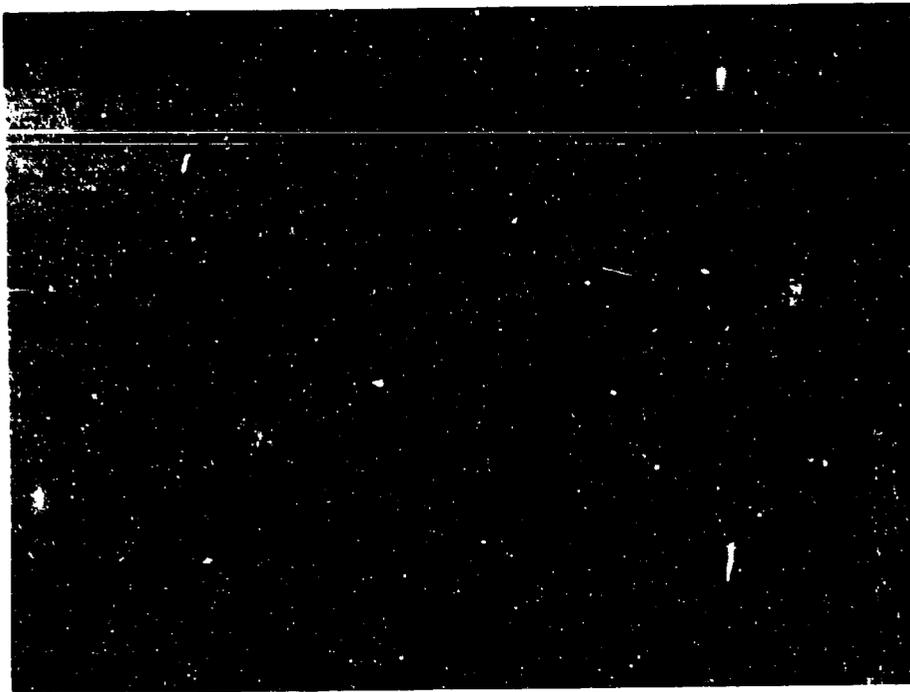


Formula: 2414-417.4
Exposure: 5% acetic acid/JRF,
5 days at 140° F
3.3.20 of MIL-C-27725A

Figure 10

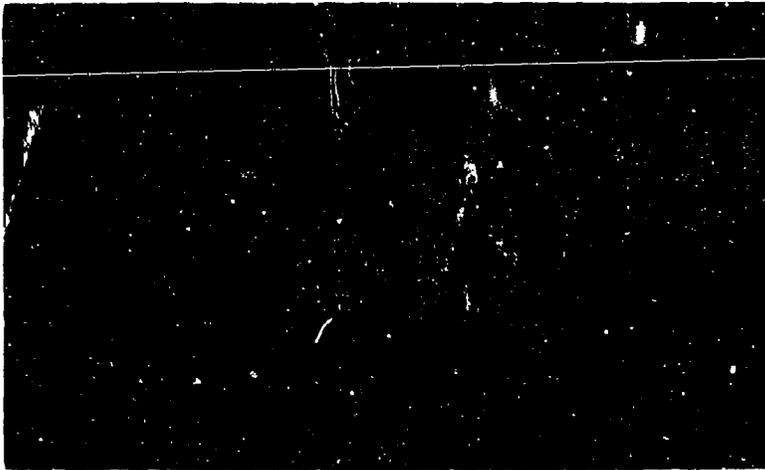


Formula: 2414-418.26
Exposure: 5% acetic acid/JRF,
5 days at 140° F
3.3.20 of MIL-C-27725A

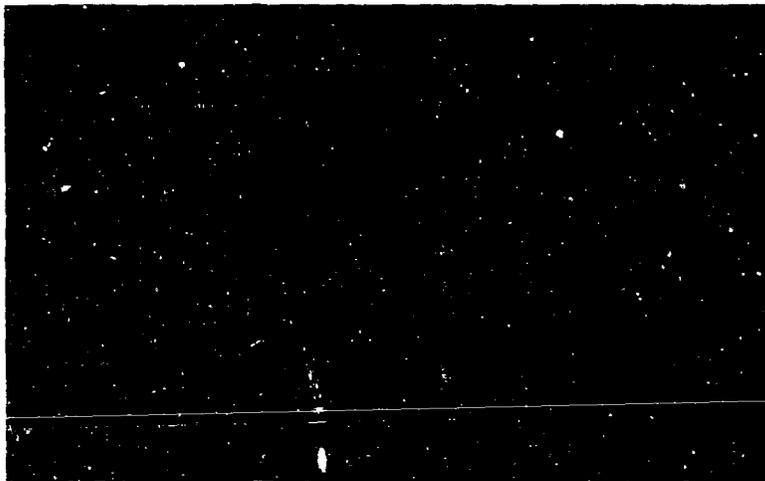


Formula: 2414-418.13
Exposure: 5% acetic acid/JRF,
5 days at 140° F
3.3.20 of MIL-C-27725A

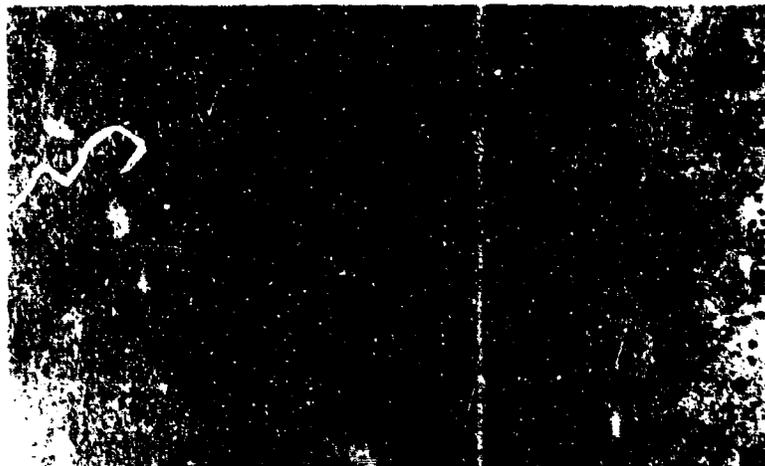
Figure 11



Formula: 2414-418.22
Exposure: 5% acetic acid/JRF,
5 days at 140° F
3.3.20 of MIL-C-27725A

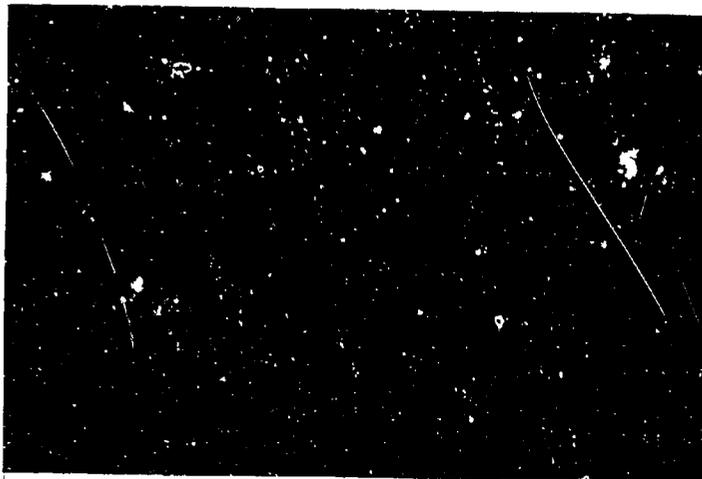


Formula: 2414-418.18
Exposure: 5% acetic acid/JRF,
5 days at 140° F
3.3.20 of MIL-C-27725A

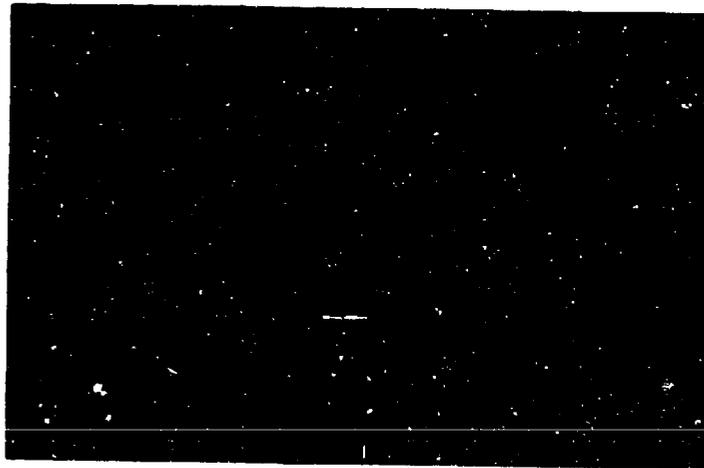


Formula: 2414-410
Exposure: 5% acetic acid/JRF,
5 days at 140° F
3.3.20 of MIL-C-27725A

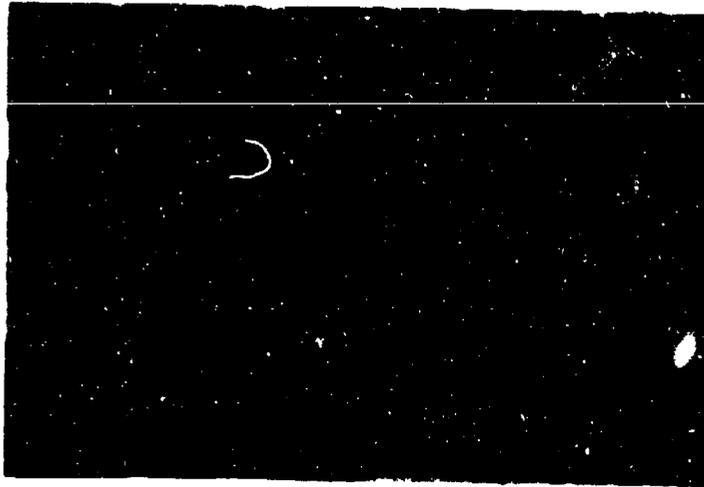
Figure 12



Formula: 2414-410
Exposure: 0.5% iron chloride,
10 days at 140° F
3.3.13 of MIL-C-27725A

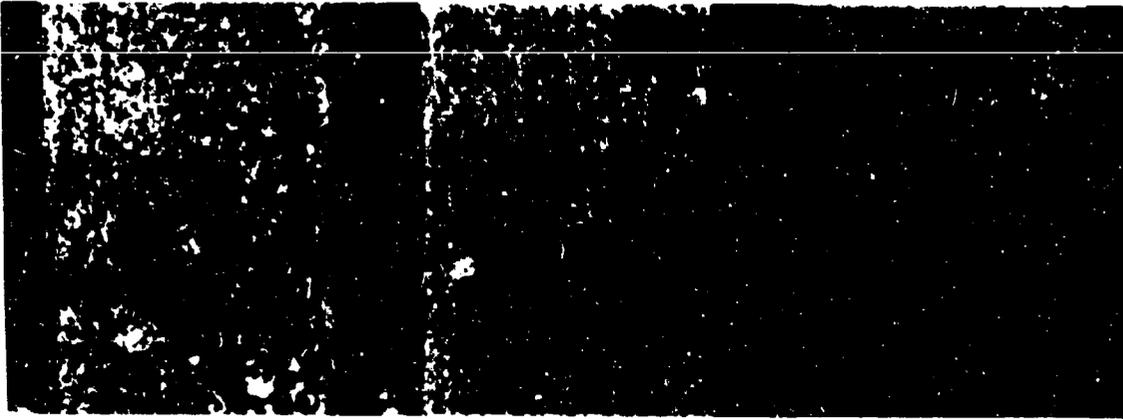


Formula: 2414-418.18
Exposure: 0.5% iron chloride,
10 days at 140° F
3.3.13 of MIL-C-27725A



Formula: 2414-418.22
Exposure: 0.5% iron chloride,
10 days at 140° F
3.3.13 of MIL-C-27725A

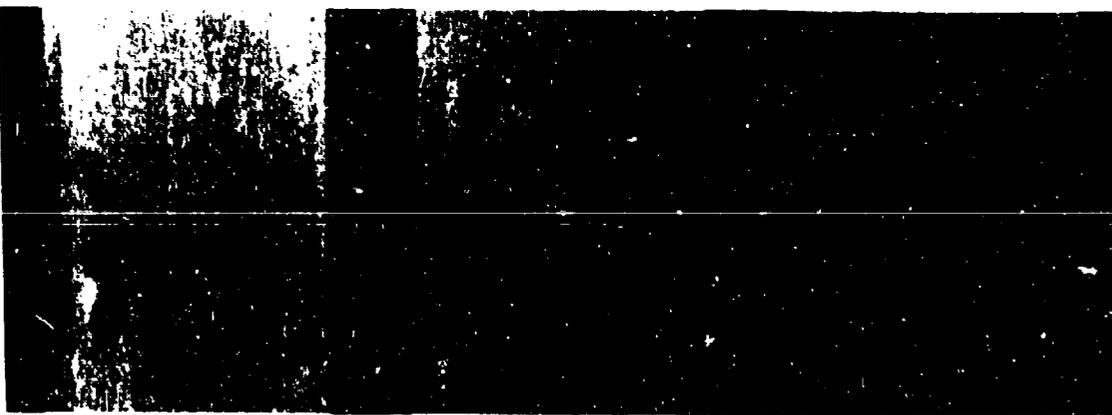
Figure 13



Formula: 2414-420
Exposure: 0.5% iron chloride,
10 days at 140° F
3.3.13 of MIL-C-27725A

Formula: 2414-420.1
Exposure: 0.5% iron chloride,
10 days at 140° F
3.3.13 of MIL-C-27725A

Formula: 2414-420.2
Exposure: 0.5% iron chloride,
10 days at 140° F
3.3.13 of MIL-C-27725A

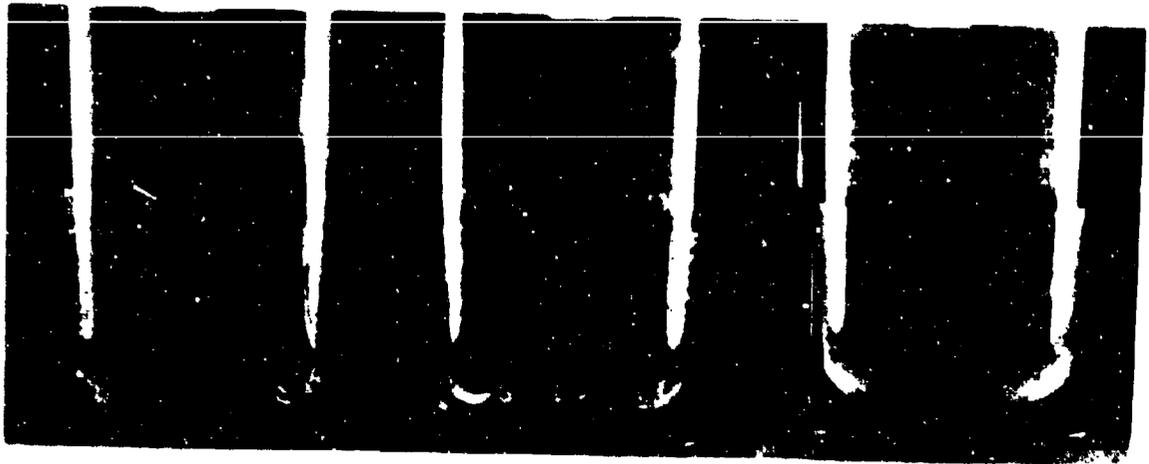


Formula: 2414-420.3
Exposure: 0.5% iron chloride,
10 days at 140° F
3.3.13 of MIL-C-27725A

Formula: 2414-420.4
Exposure: 0.5% iron chloride,
10 days at 140° F
3.3.13 of MIL-C-27725A

Formula: 2414-420.5
Exposure: 0.5% iron chloride,
10 days at 140° F
3.3.13 of MIL-C-27725A

Figure 14



Formula: 2414-420
Exposure: 5% acetic acid/JRF,
5 days at 140° F
3.3.20 of MIL-C-27725A

Formula: 2414-420.1
Exposure: 5% acetic acid/JRF,
5 days at 140° F
3.3.20 of MIL-C-27725A

Formula: 2414-420.2
Exposure: 5% acetic acid/JRF,
5 days at 140° F
3.3.20 of MIL-C-27725A



Formula: 2414-420.3
Exposure: 5% acetic acid/JRF,
5 days at 140° F
3.3.20 of MIL-C-27725A

Formula: 2414-420.4
Exposure: 5% acetic acid/JRF,
5 days at 140° F
3.3.20 of MIL-C-27725A

Formula: 2414-420.5
Exposure: 5% acetic acid/JRF,
5 days at 140° F
3.3.20 of MIL-C-27725A

Figure 15



Formula: 2414-200.2
Exposure: 5% acetic acid/JRF,
5 days at 140° F
3.3.20 of MIL-C-27725A

Formula: 2414-204.1
Exposure: 5% acetic acid/JRF,
5 days at 140° F
3.3.20 of MIL-C-27725A

Formula: 2414-204.2
Exposure: 5% acetic acid/JRF,
5 days at 140° F
3.3.20 of MIL-C-27725A

Formula: 2414-204.3
Exposure: 5% acetic acid/JRF,
5 days at 140° F
3.3.20 of MIL-C-27725A

Figure 16



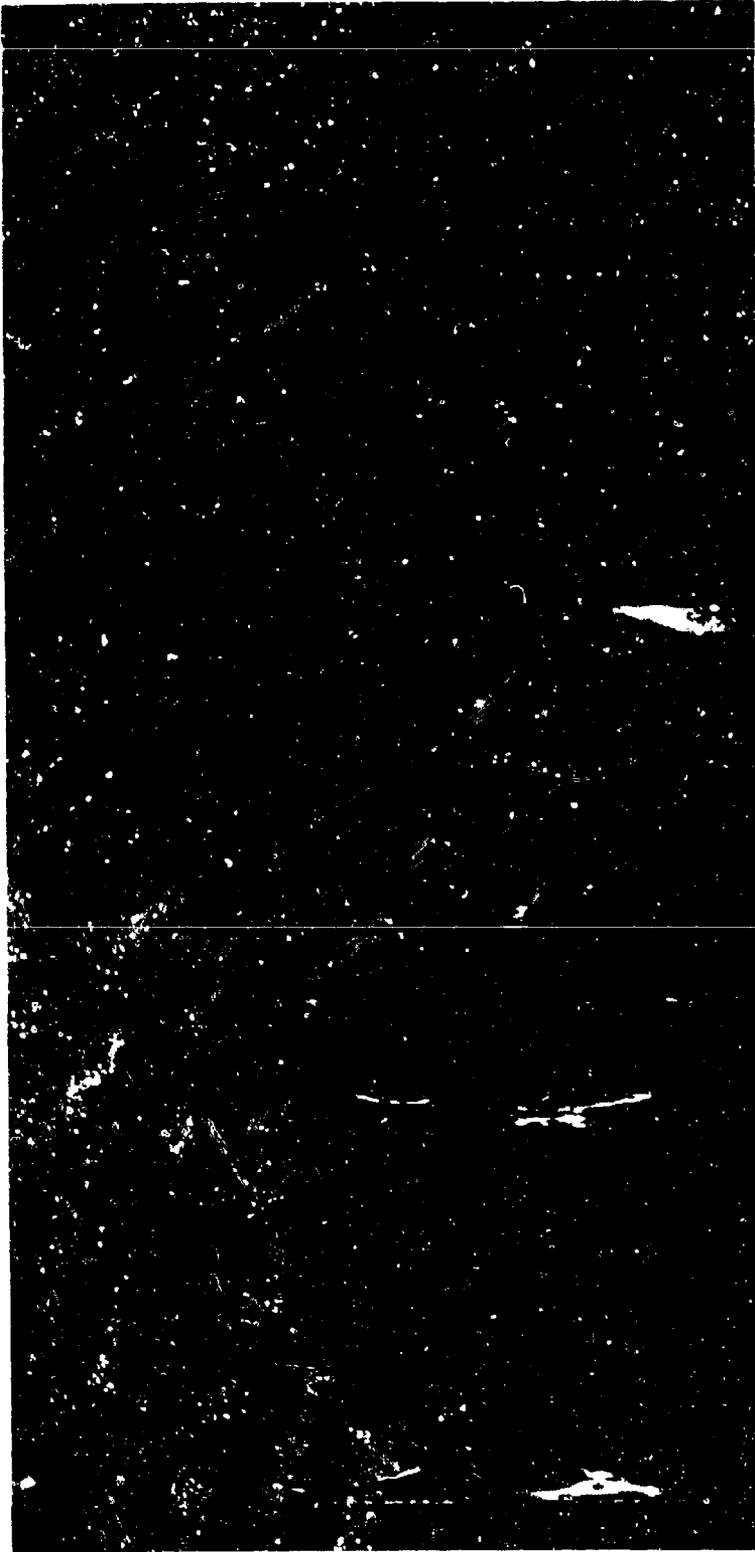
Formula: 2414-200.2
Exposure: 0.5% iron chloride,
10 days at 140°F
3.3.13 of MIL-C-27725A

Formula: 2414-204.1
Exposure: 0.5% iron chloride,
10 days at 140°F
3.3.13 of MIL-C-27725A

Formula: 2414-204.2
Exposure: 0.5% iron chloride,
10 days at 140°F
3.3.13 of MIL-C-27725A

Formula: 2414-204.3
Exposure: 0.5% iron chloride,
10 days at 140°F
3.3.13 of MIL-C-27725A

Figure 16 - Concluded

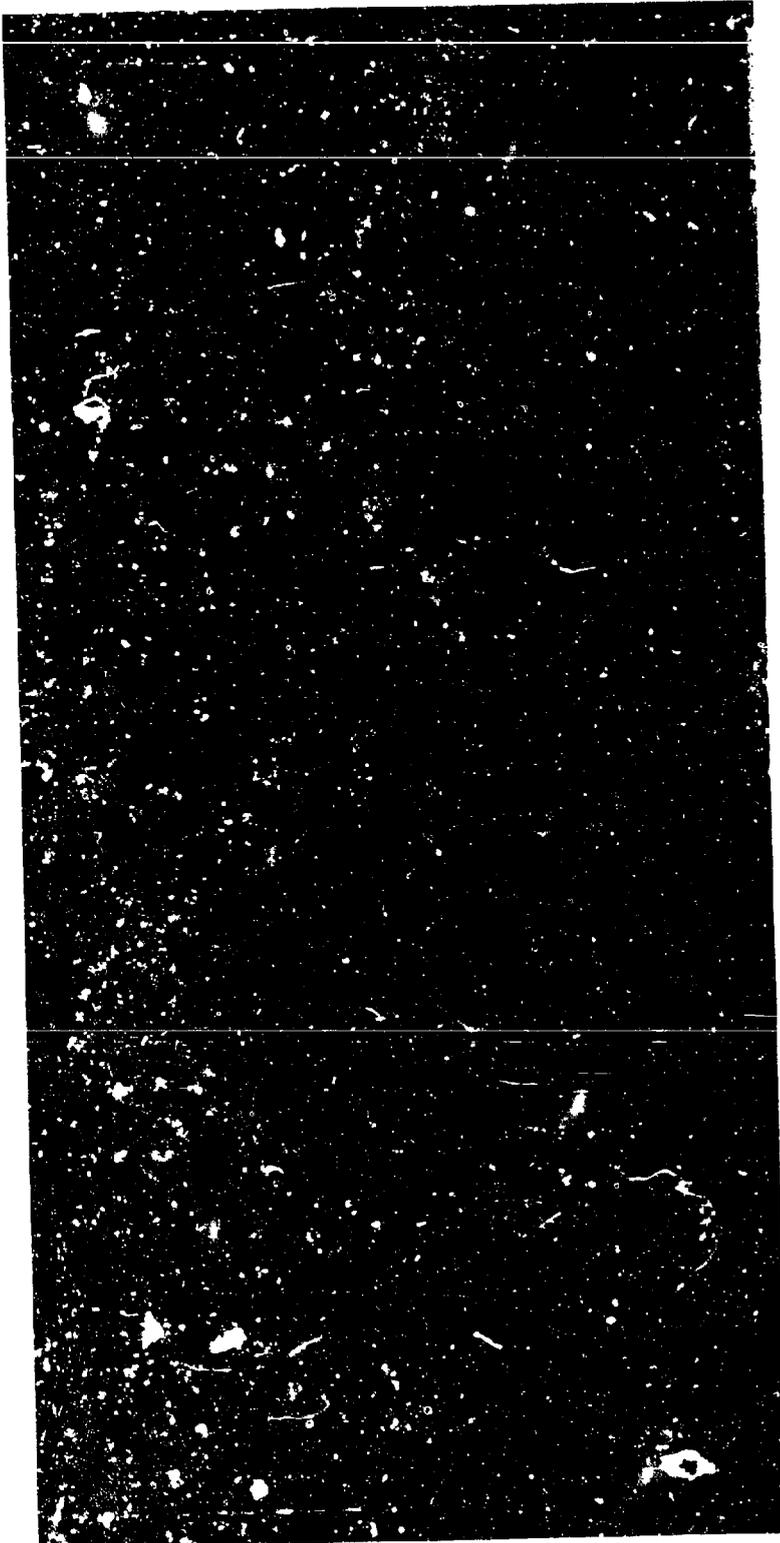


Formula: 2414-206.1
Exposure: 5% acetic acid JRF,
5 days at 140° F
3.3.20 of MIL-C-27725A

Formula: 2414-212.2
Exposure: 5% acetic acid JRF,
5 days at 140° F
3.3.20 of MIL-C-27725A

Formula: 2414-112.3
Exposure: 5% acetic acid JRF,
5 days at 140° F
3.3.20 of MIL-C-27725A

Figure 17



Formula: 2414-206.1
Exposure: 0.5% iron chloride,
10 days at 140° F
3.3.13 of MIL-C-27725A

Formula: 2414-212.2
Exposure: 0.5% iron chloride,
10 days at 140° F
3.3.13 of MIL-C-27725A

Formula: 2414-212.3
Exposure: 0.5% iron chloride,
10 days at 140° F
3.3.13 of MIL-C-27725A

Figure 18

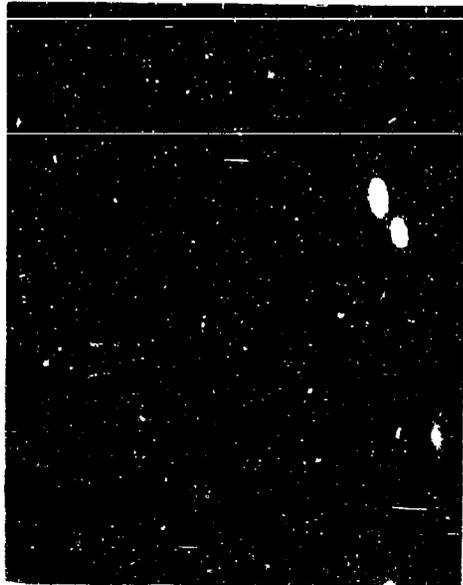


Formula: 2414-217.6
Exposure: 5% acetic acid/JRF,
5 days at 140° F
3.3.20 of MIL-C-27725A

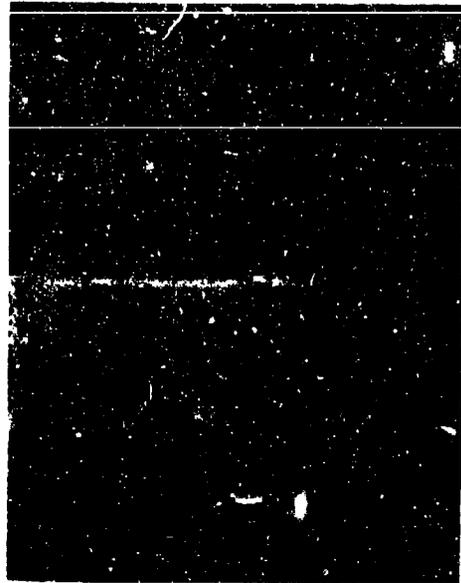
Formula: 2414-217.6
Exposure: 0.5% iron chloride,
10 days at 140° C
3.3.13 of MIL-C-27725A

Formula: 2414-217.6
Exposure: Distilled water,
30 days at 140° F
3.3.9 of MIL-C-27725A

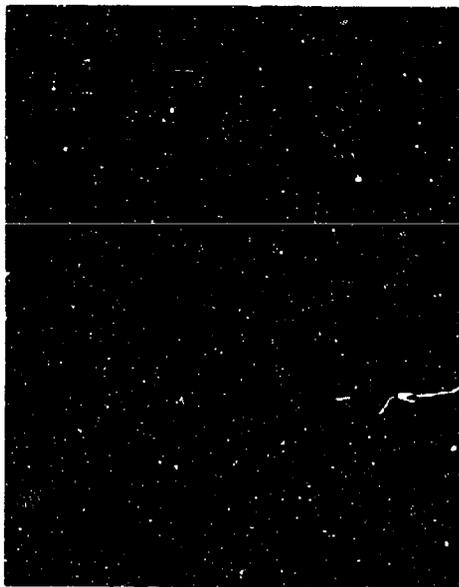
Figure 18



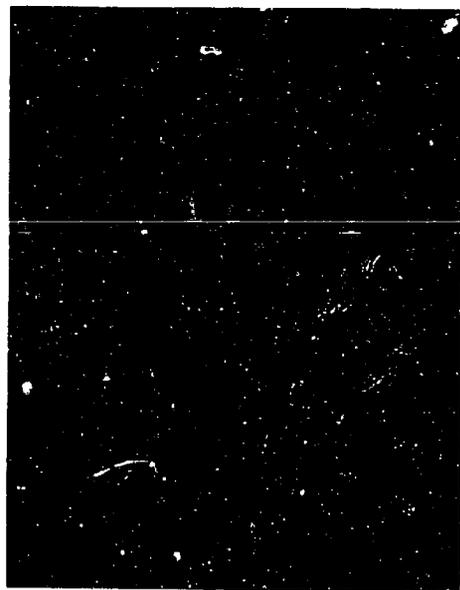
Formula: 2414-217.1
Exposure: 5% acetic acid/JRF,
5 days at 140° F
3.3.20 of MIL-C-27725A



Formula: 2414-245.5
Exposure: 5% acetic acid/JRF,
5 days at 140° F
3.3.20 of MIL-C-27725A

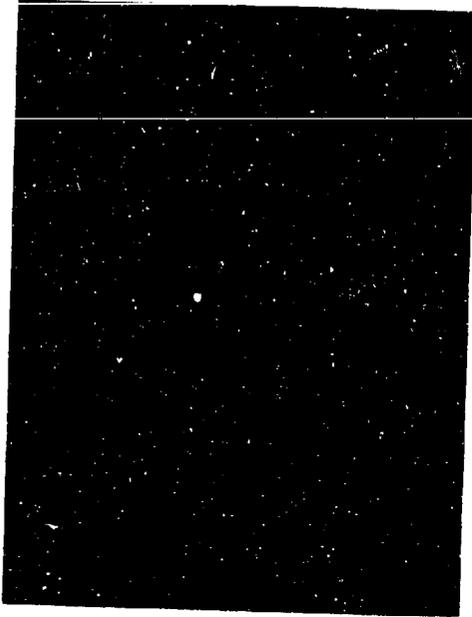


Formula: 2414-245.2
Exposure: 5% acetic acid/JRF,
5 days at 140° F
3.3.20 of MIL-C-27725A

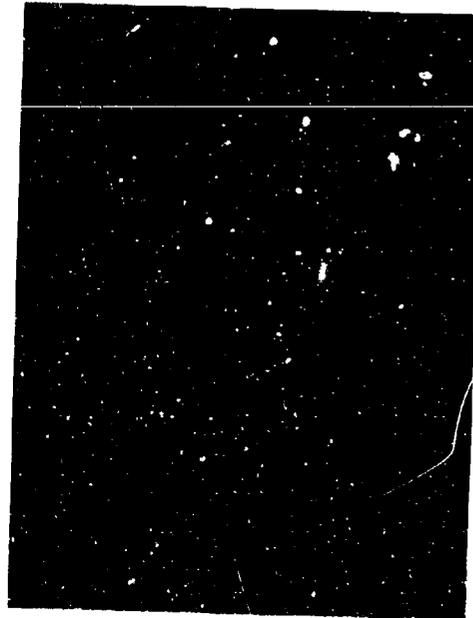


Formula: 2414-245.3
Exposure: 5% acetic acid/JRF,
5 days at 140° F
3.3.20 of MIL-C-27725A

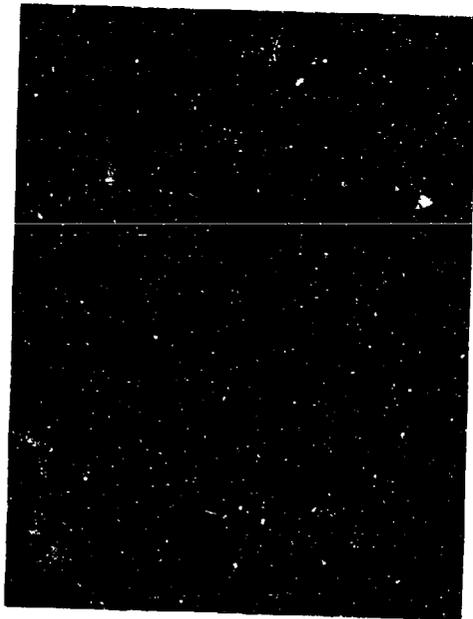
Figure 20



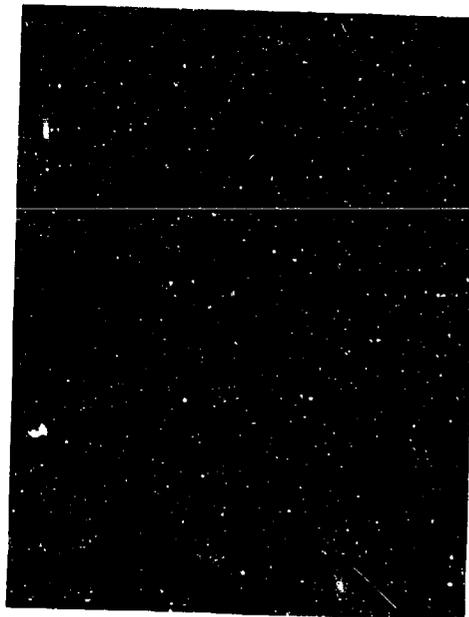
Formula: 2414-217.1
Exposure: 5% acetic acid/JRF,
5 days at 140° F
3.3.20 of MIL-C-27725A



Formula: 2414-245.4
Exposure: 5% acetic acid/JRF,
5 days at 140° F
3.3.20 of MIL-C-27725A

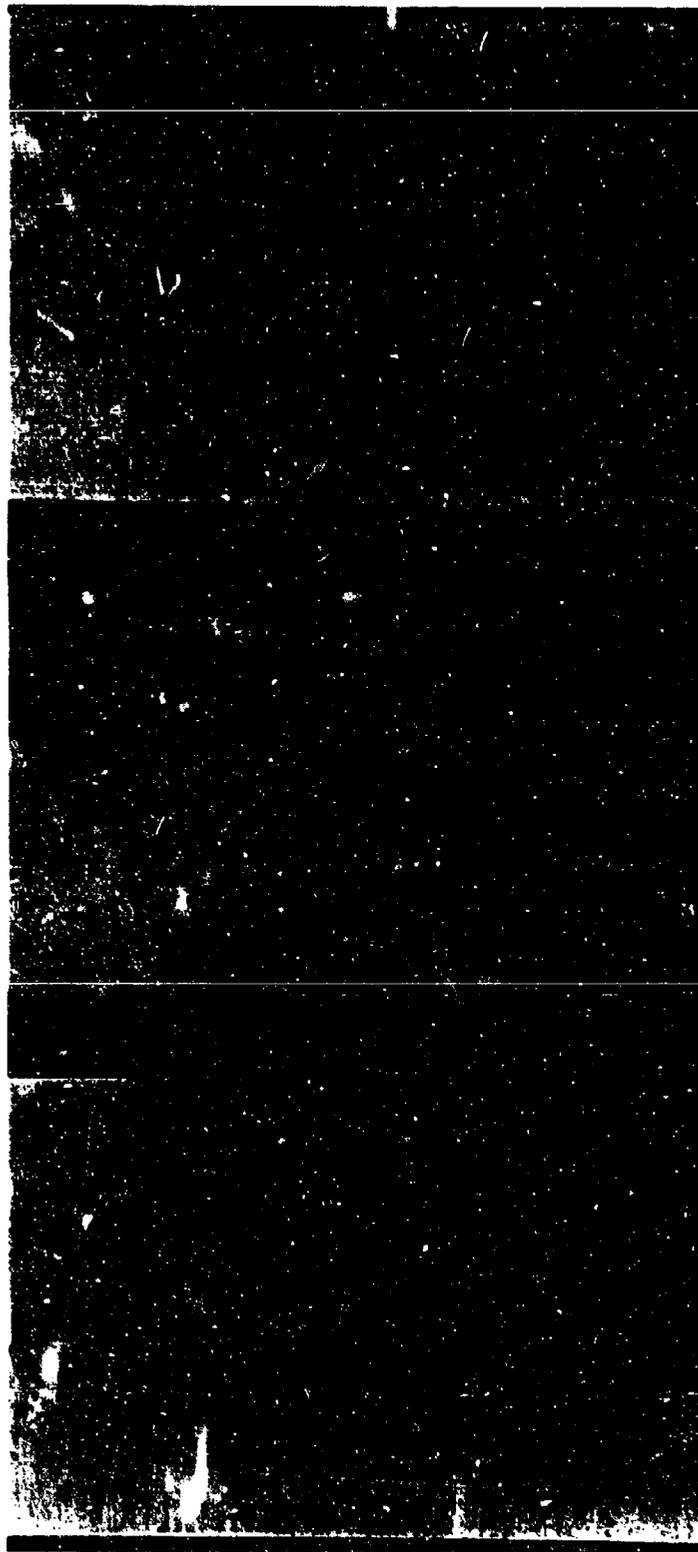


Formula: 2414-245
Exposure: 5% acetic acid/JRF,
5 days at 140° F
3.3.20 of MIL-C-27725A



Formula: 2414-245.1
Exposure: 5% acetic acid/JRF,
5 days at 140° F
3.3.20 of MIL-C-27725A

Figure 21



Formula: 2414-217.1
Exposure: 5% acetic acid/JRF,
5 days at 140° F
3.3.20 of MIL-C-27725A

Formula: 2414-418.2A
Exposure: 5% acetic acid/JRF,
5 days at 140° F
3.3.20 of MIL-C-27725A

Formula: 2414-419.2
Exposure: 5% acetic acid/JRF,
5 days at 140° F
3.3.20 of MIL-C-27725A

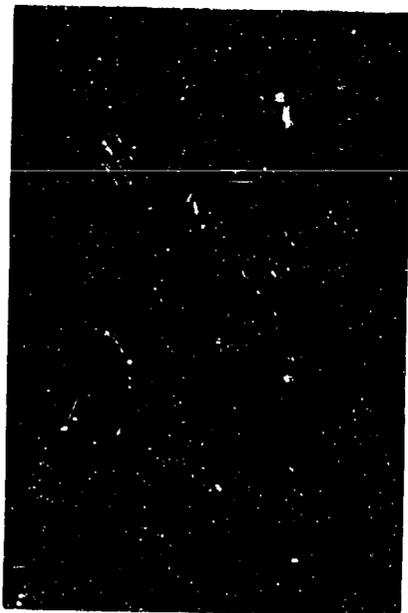
Figure 22



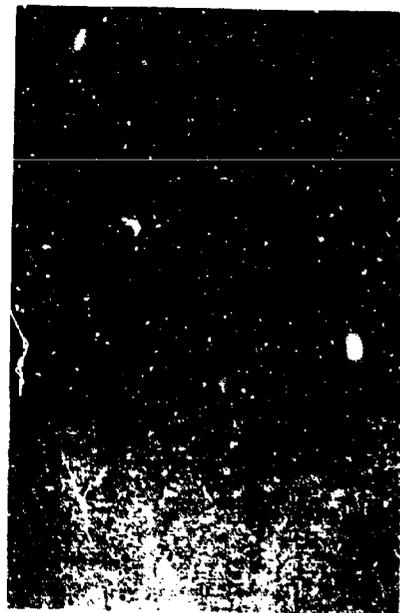
Formula: 2414-217.1
Exposure: 5% acetic acid/JRF,
5 days at 140° F
3.3.20 of MIL-C-27725A



Formula: 2414-420.8
Exposure: 5% acetic acid/JRF,
5 days at 140° F
3.3.20 of MIL-C-27725A

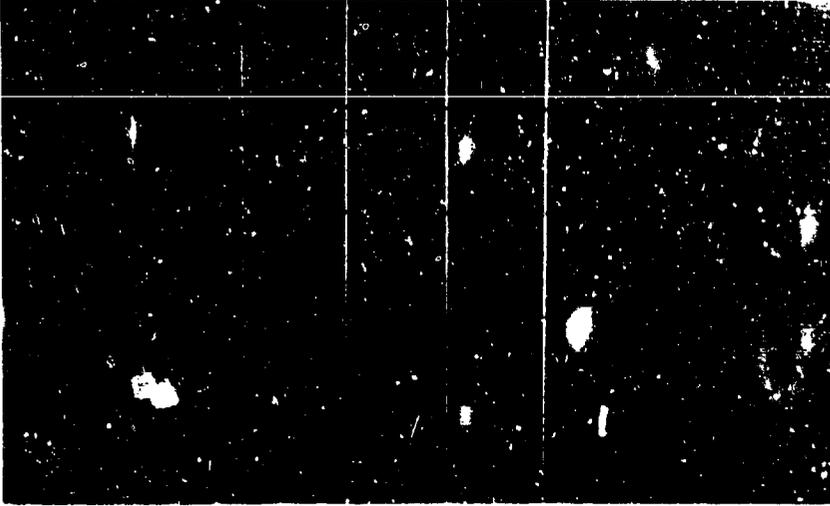


Formula: 2414-420.9
Exposure: 5% acetic acid/JRF,
5 days at 140° F
3.3.20 of MIL-C-27725A

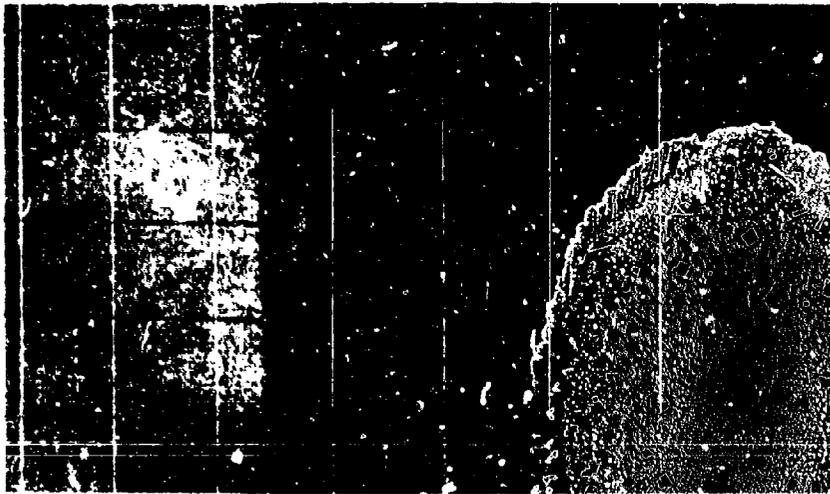


Formula: 2414-424
Exposure: 5% acetic acid/JRF,
5 days at 140° F
3.3.20 of MIL-C-27725A

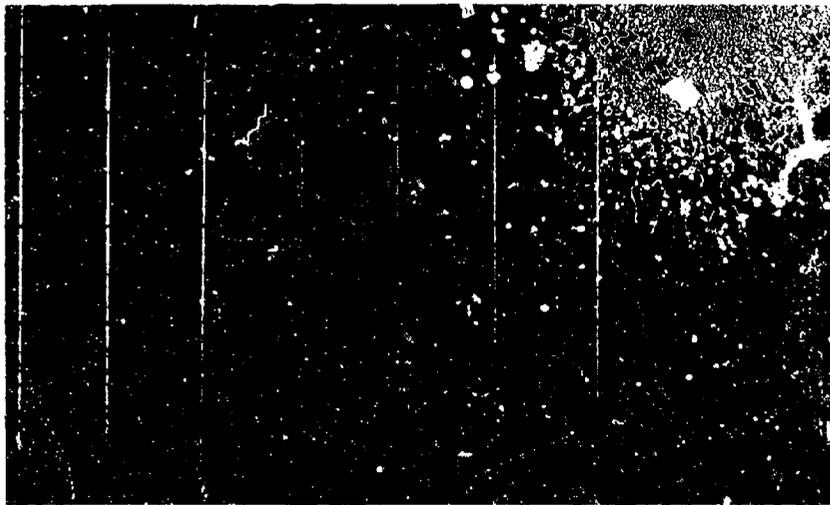
Figure 23



Formula: 2414-425.2
Exposure: 5% acetic acid /JRF,
5 days at 140° F
3.3.20 of MIL-C-27725A



Formula: 2414-425.1
Exposure: 5% acetic acid /JRF,
5 days at 140° F
3.3.20 of MIL-C-27725A

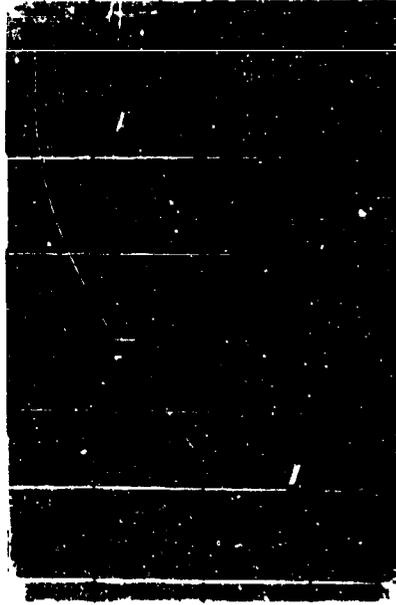


Formula: 2414-425
Exposure: 5% acetic acid /JRF,
5 days at 140° F
3.3.20 of MIL-C-27725A

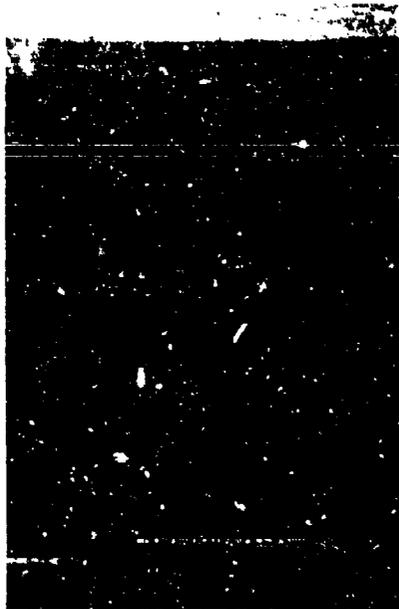
Figure 24



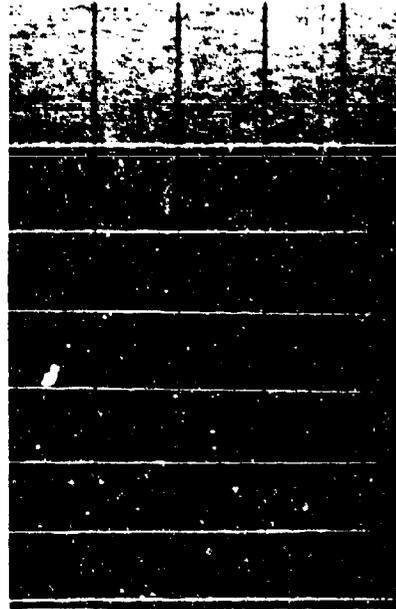
Formula: 2414-501.4
Exposure: Distilled water,
30 days at 140° F
3.3.9 of MIL-C-27725A



Formula: 2414-501.4
Exposure: 3% salt water JRF,
30 days at 140° F
3.3.10 of MIL-C-27725A



Formula: 2414-501.4
Exposure: 0.5% iron chloride,
10 days at 140° F
3.3.13 of MIL-C-27725A



Formula: 2414-501.4
Exposure: 5% acetic acid JRF,
5 days at 140° F
3.3.20 of MIL-C-27725A

Figure 25



Steam cleaning aircraft integral fuel tanks coated with formula 2414-501.4

Figure 26



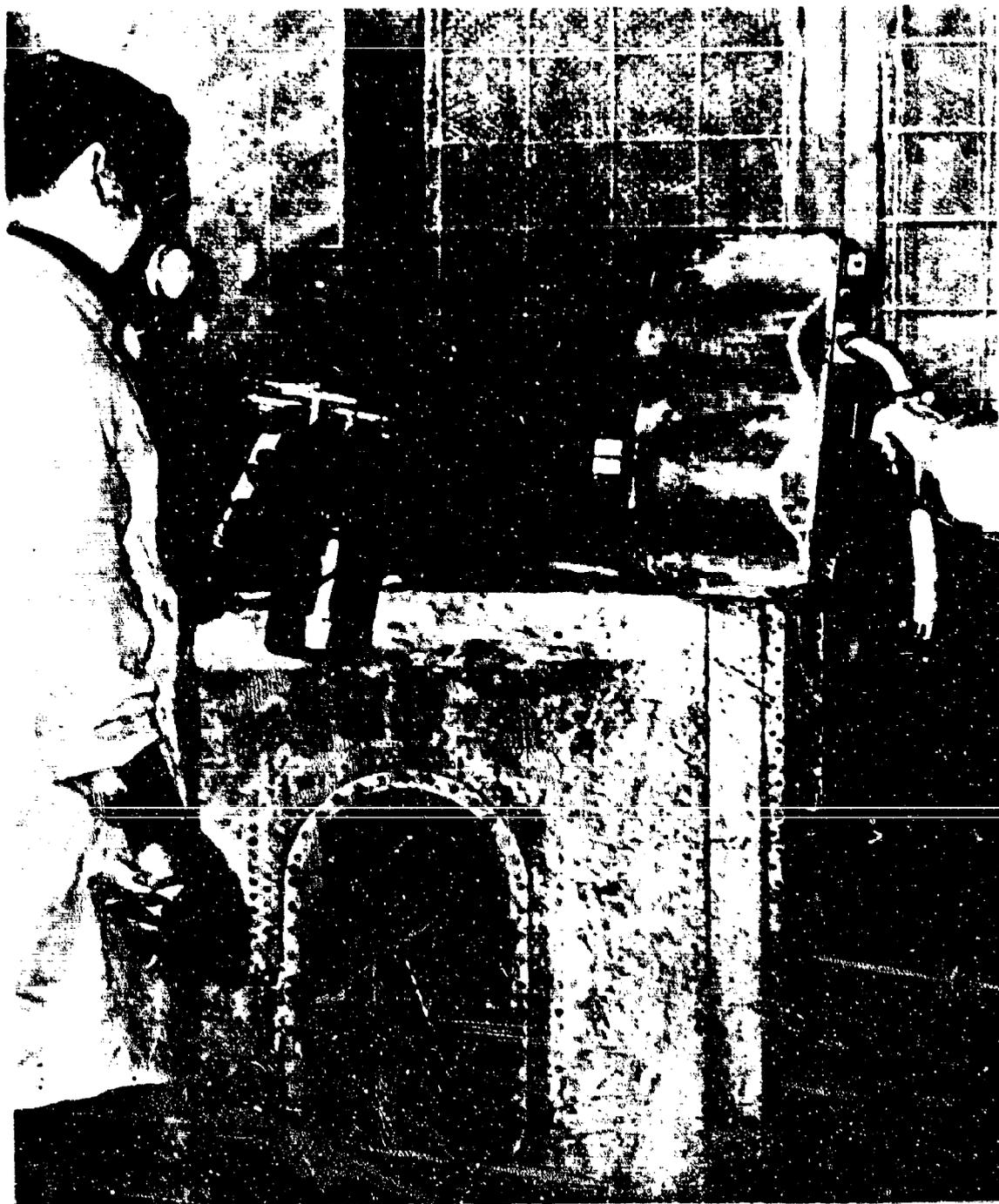
Effect of alkaline steam cleaning detergent on alodined 7075 T6 aluminum test panel.

Figure 27



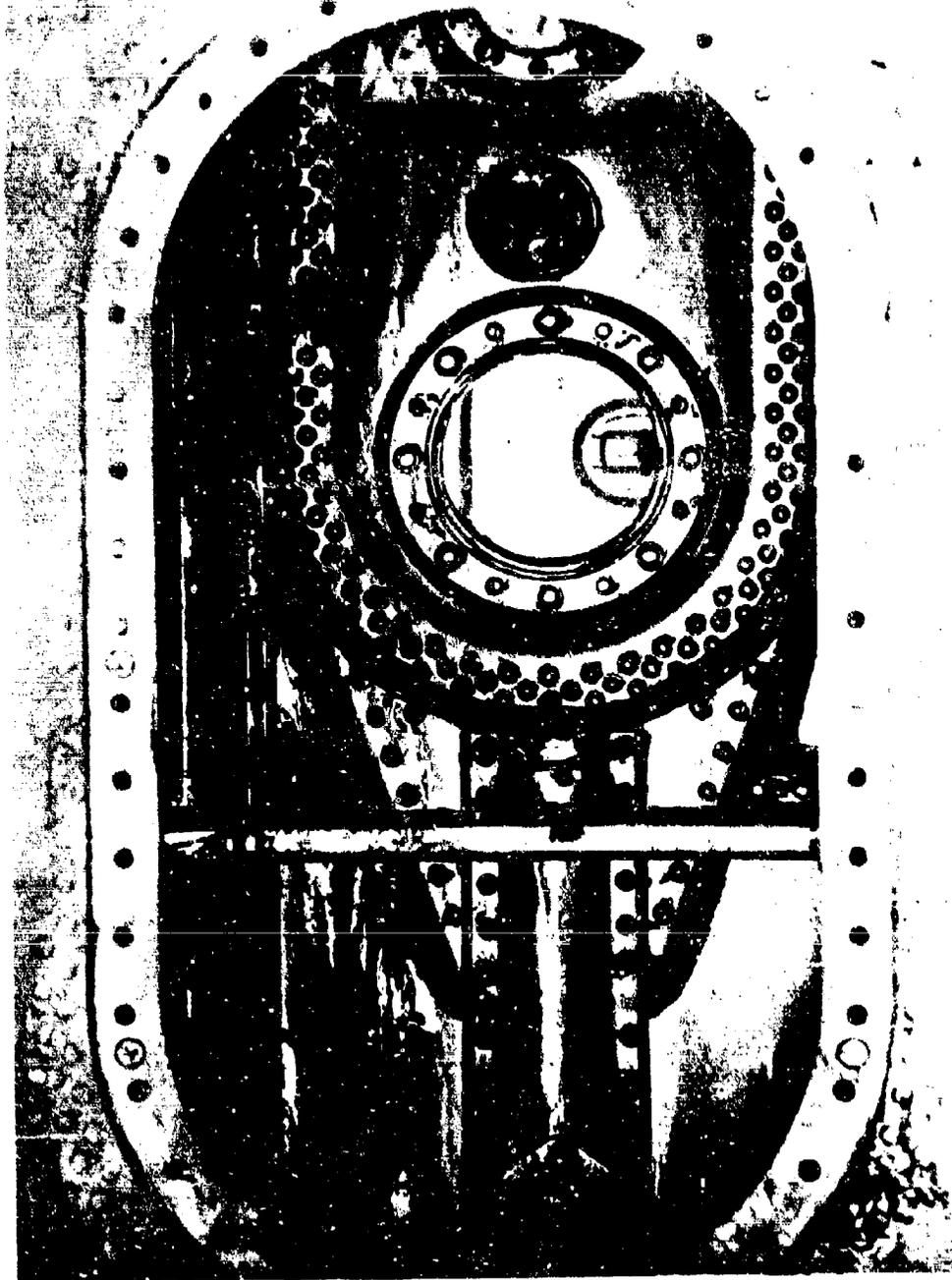
Spray application of coating formula 2414-501.4 to integral fuel tanks.

Figure 28



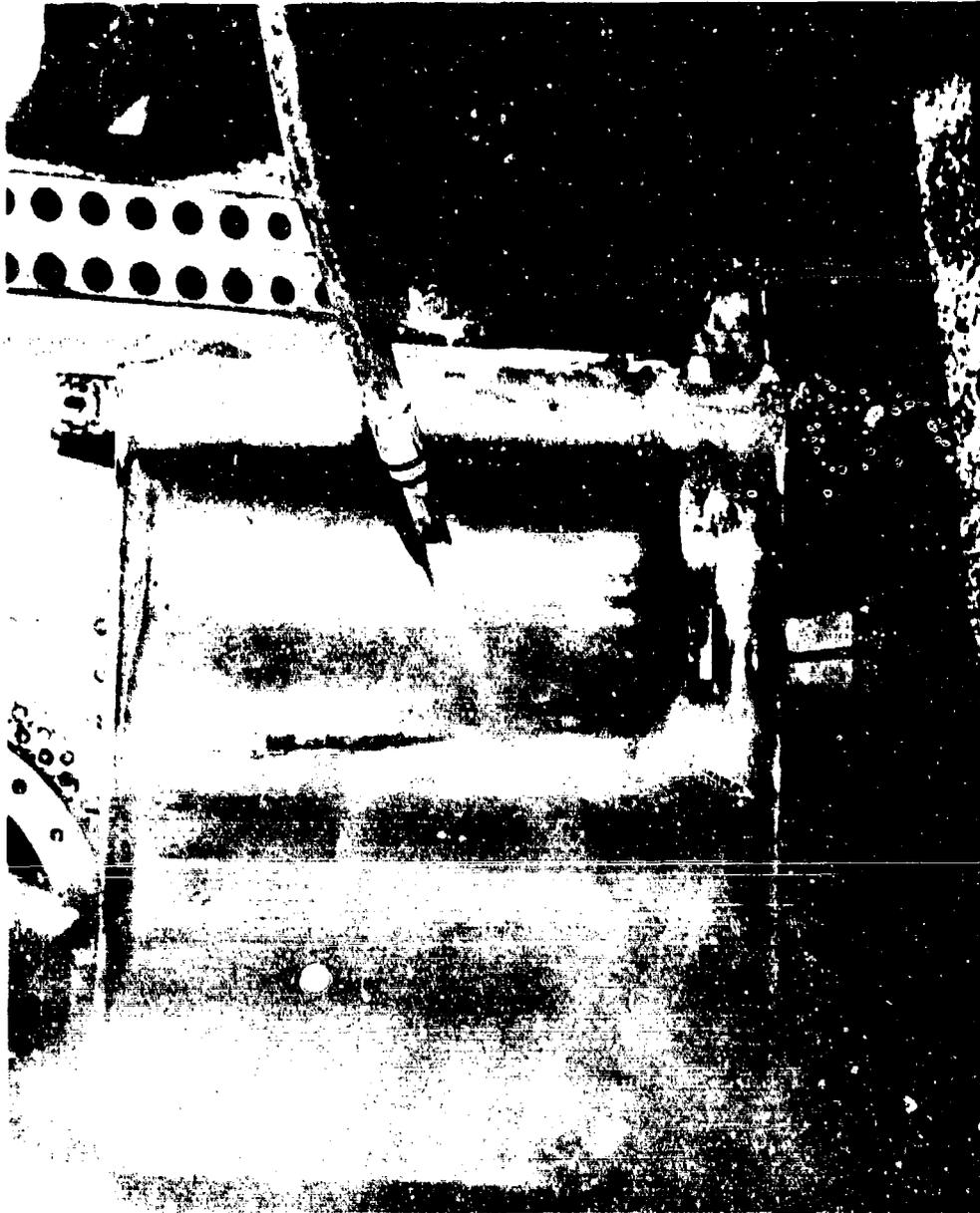
Spray application of coating formula 2414-561.4 to integral fuel tank component parts.

Figure 29



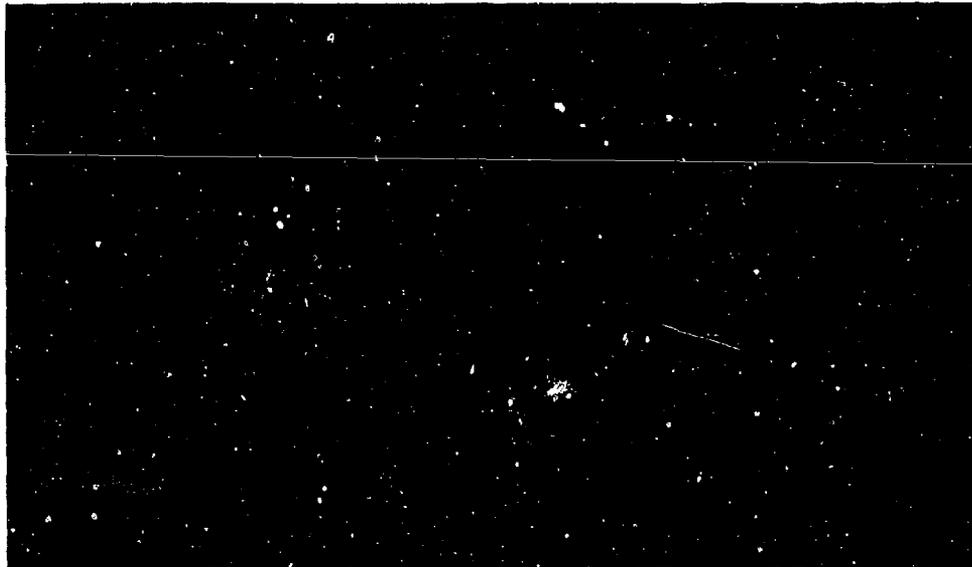
Inner view of spray-coated integral fuel tank.

Figure 30



Steam cleaning of coated integral fuel tank component.

Figure 31

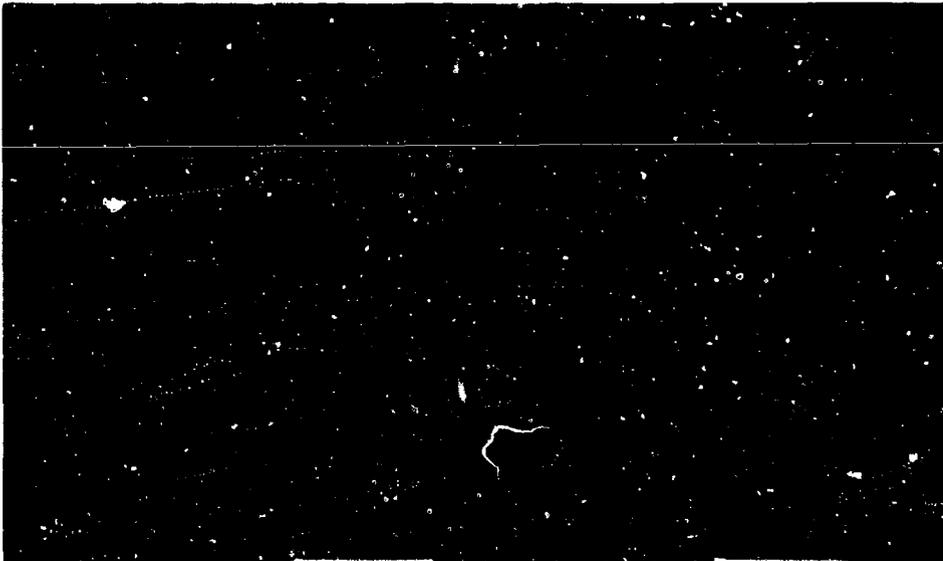


Specification test of formula 2414-501.4
Exposure: Distilled water,
30 days at 140° F
Type I, 4.7.9 of MIL-C-27725A

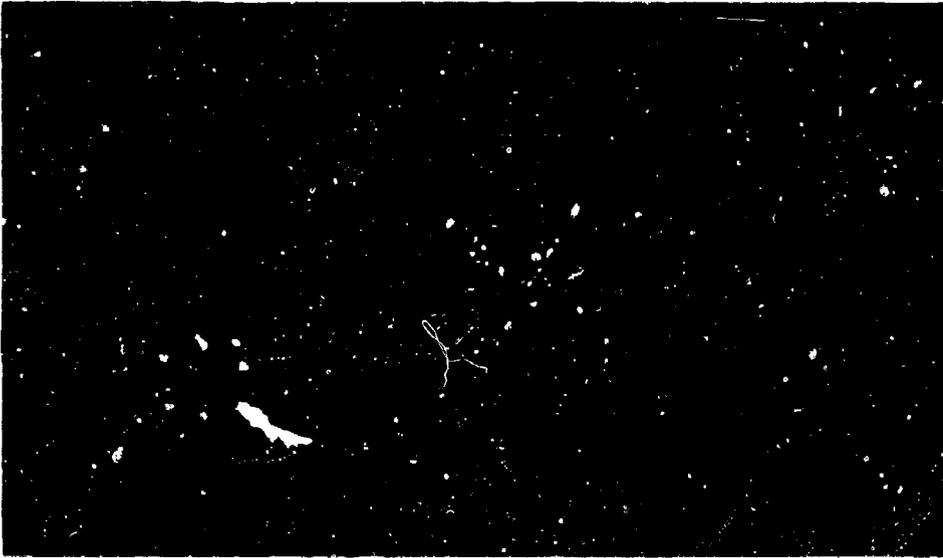


Specification test of formula 2414-501.4
Exposure: Distilled water,
30 days at 140° F
Type II, 4.7.9 of MIL-C-27725A

Figure 32

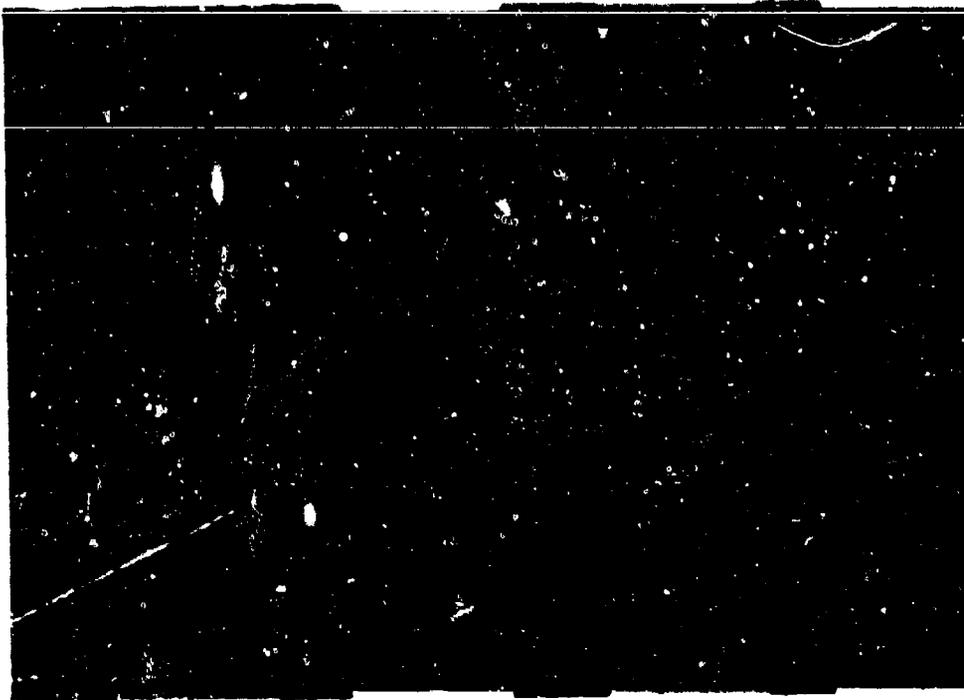


Specification test of formula 2414-501.4
Exposure: 3% salt water/JRF,
30 days at 140° F
Type I, 4.7.10 of MIL-C-27725A

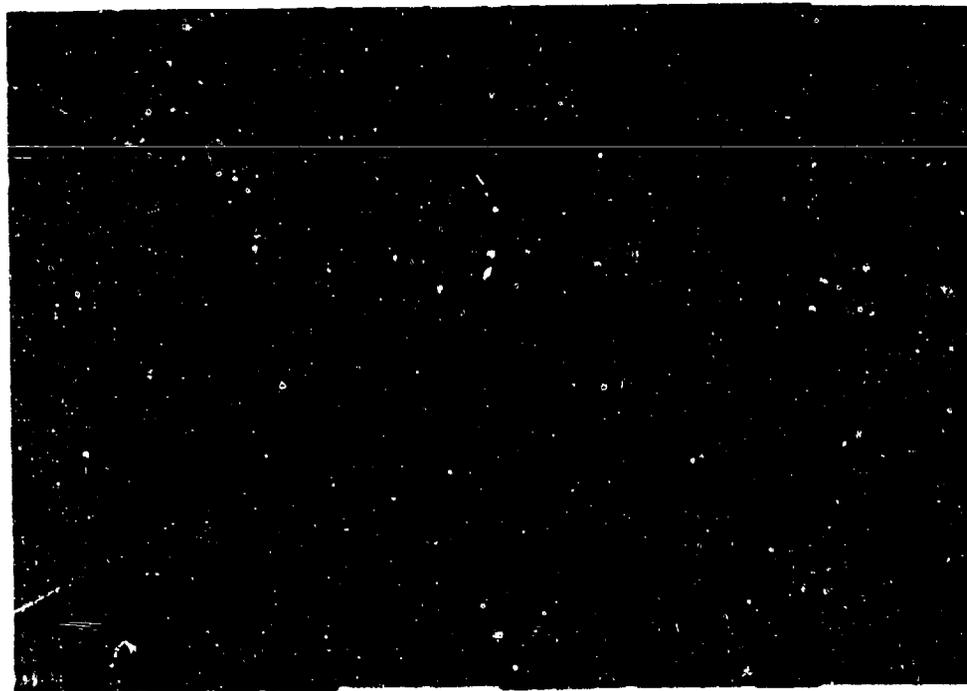


Specification test of formula 2414-501.4
Exposure: 3% salt water/JRF,
30 days at 140° F
Type II, 4.7.10 of MIL-C-27725A

Figure 33

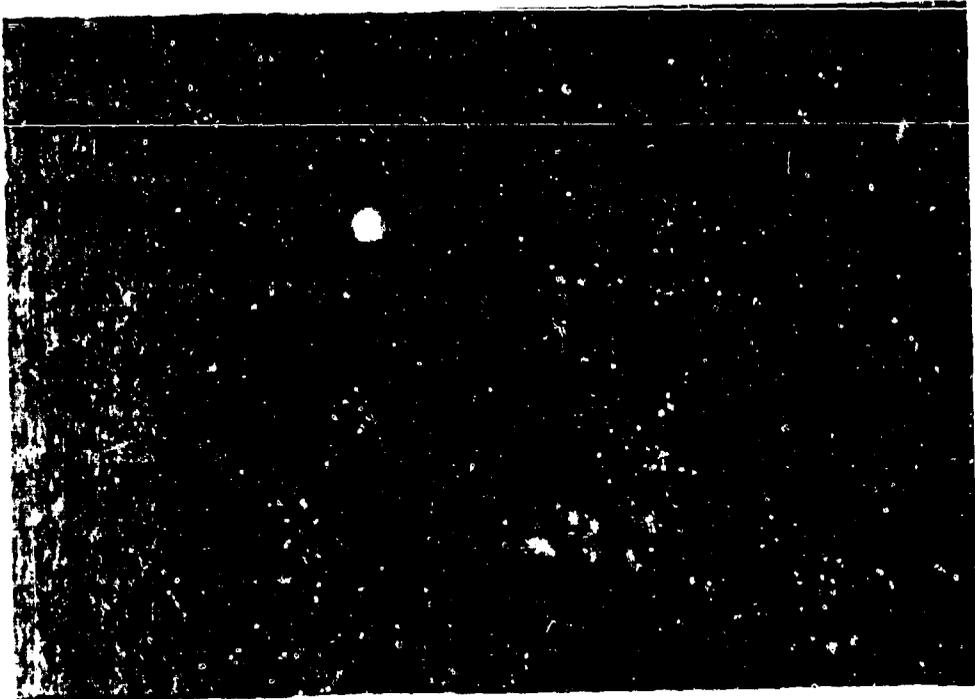


Specification test of formula 2414-501.A
Exposure: Engine Oil,
14 days at 250° F
Type II, 4.7.11 of MIL-C-27725A

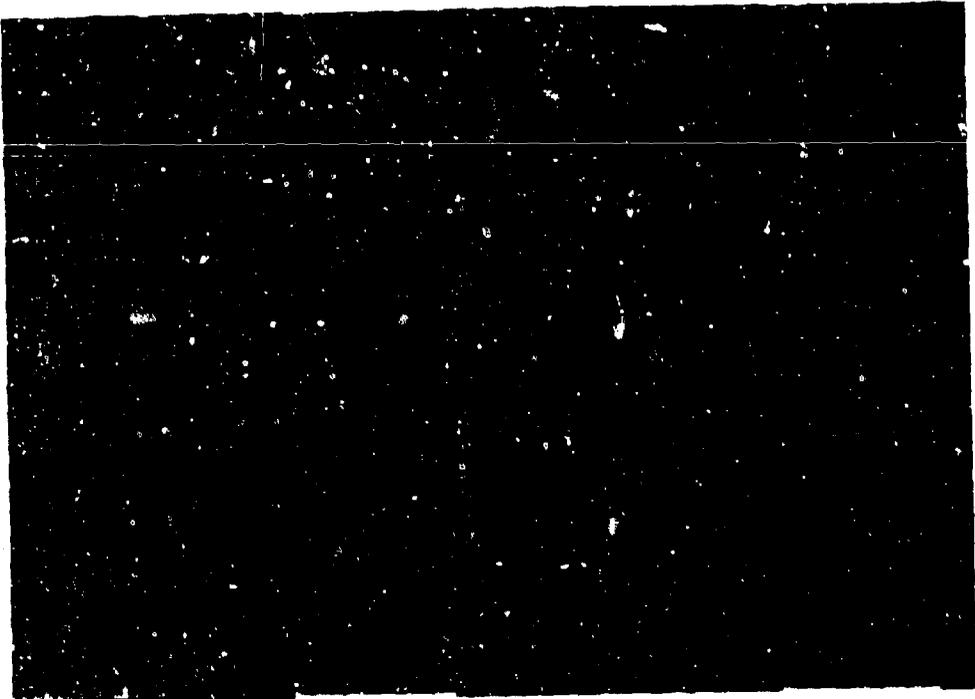


Specification test of formula 2414-501.A
Exposure: Engine Oil,
14 days at 250° F
Type I, 4.7.11 of MIL-C-27725A

Figure 34



Specification test of formula 2414-501.4
Exposure: Hydraulic fluid,
14 days at 180° F
Type II, 4.7.12 of MIL-C-27725A



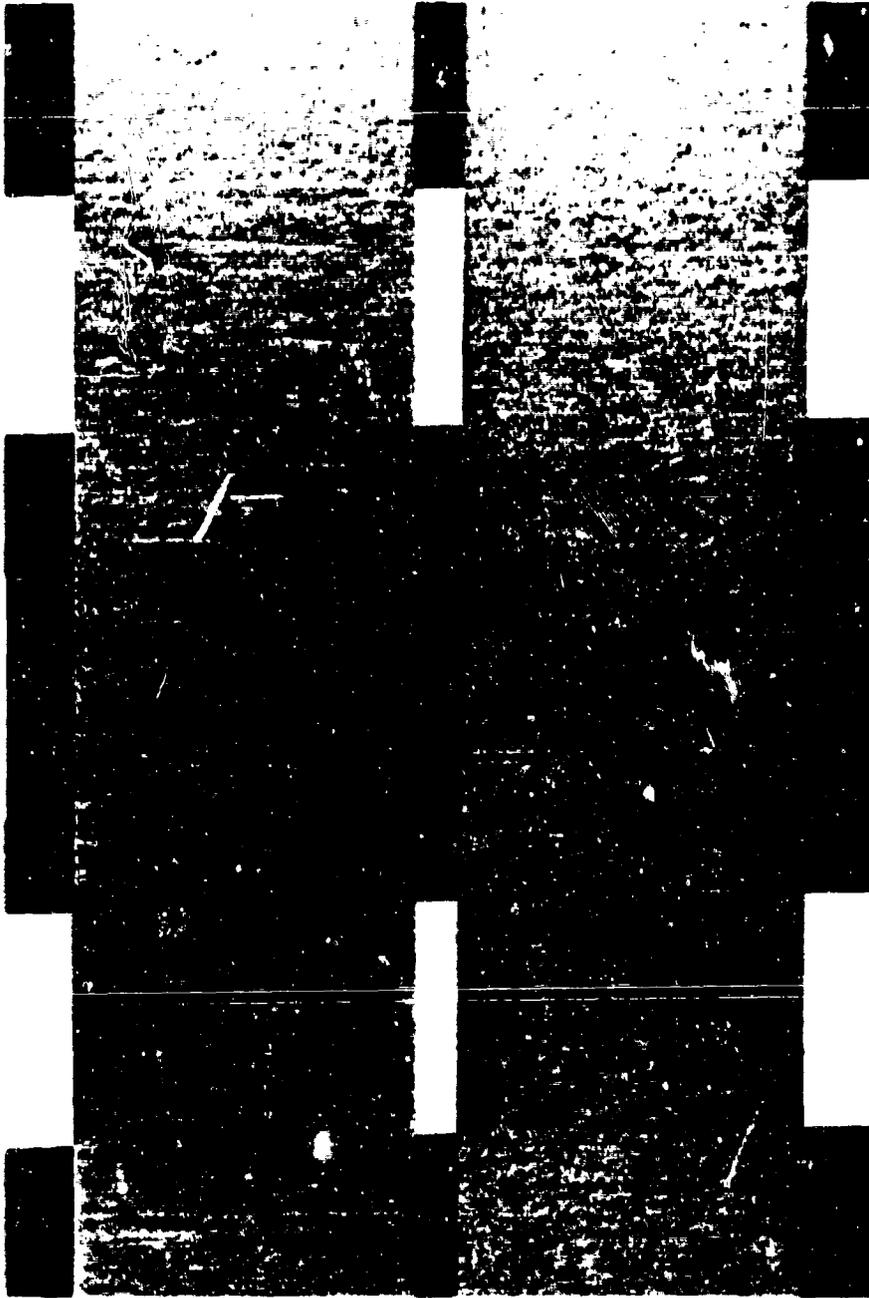
Specification test of formula 2414-501.4
Exposure: Hydraulic fluid,
14 days at 180° F
Type I, 4.7.12 of MIL-C-27725A

Figure 35



Specification test of formula 2414-501.4
Exposure: 0.5% iron chloride,
10 days at 140° F
4.7.13.1 of MIL-C-27725A

Figure 36



Specification test of formula 2414-501.4
Low temperature flexibility test
4.7.15 of MIL-C-27725A

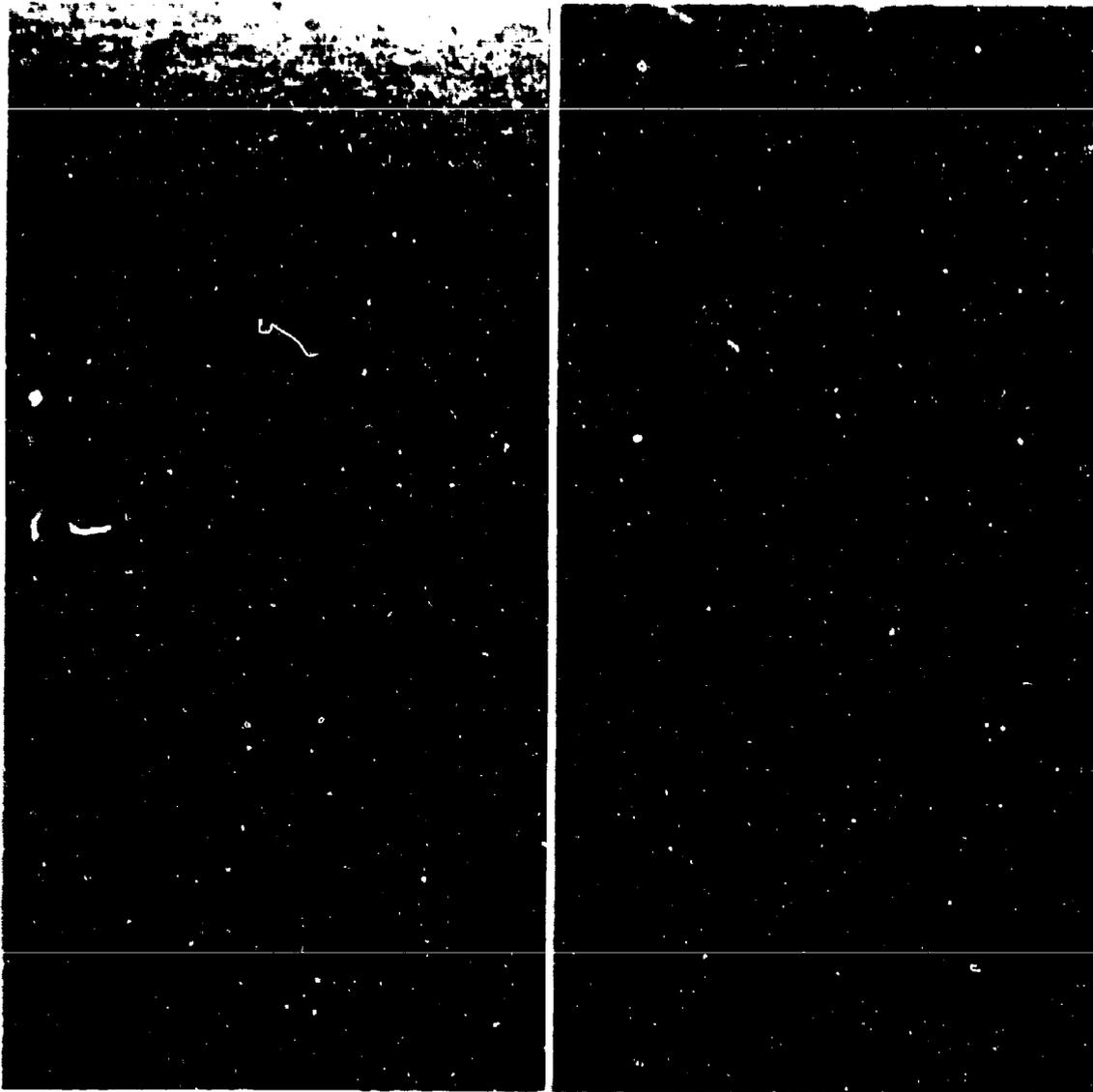
Figure 37



Specification test of formula 2414-501.4
Coating material to sealing compound
compatibility
Type I, 4.7.16.2 of MIL-C-27725A

Specification test of formula 2414-501.4
Coating material to sealing compound
compatibility
Type II, 4.7.16.2 of MIL-C-27725A

Figure 38



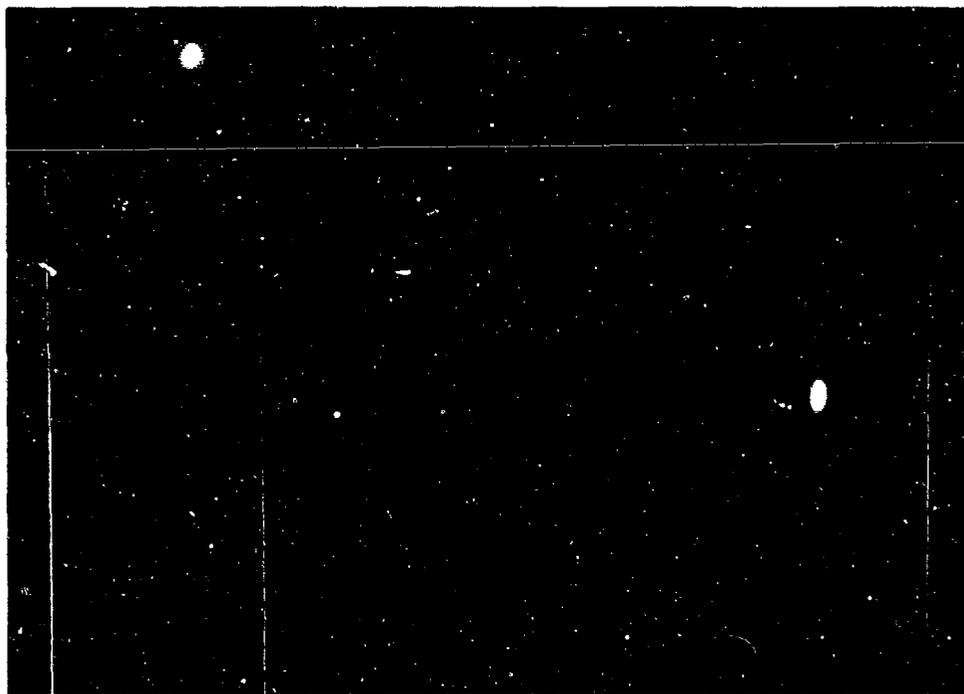
Specification test of formula 2414-501.4
Material reparability test
Type I, 4.7.19 of MIL-C-27725A

Specification test of formula 2414-501.4
Material reparability test
Type II, 4.7.19 of MIL-C-27725A

Figure 39

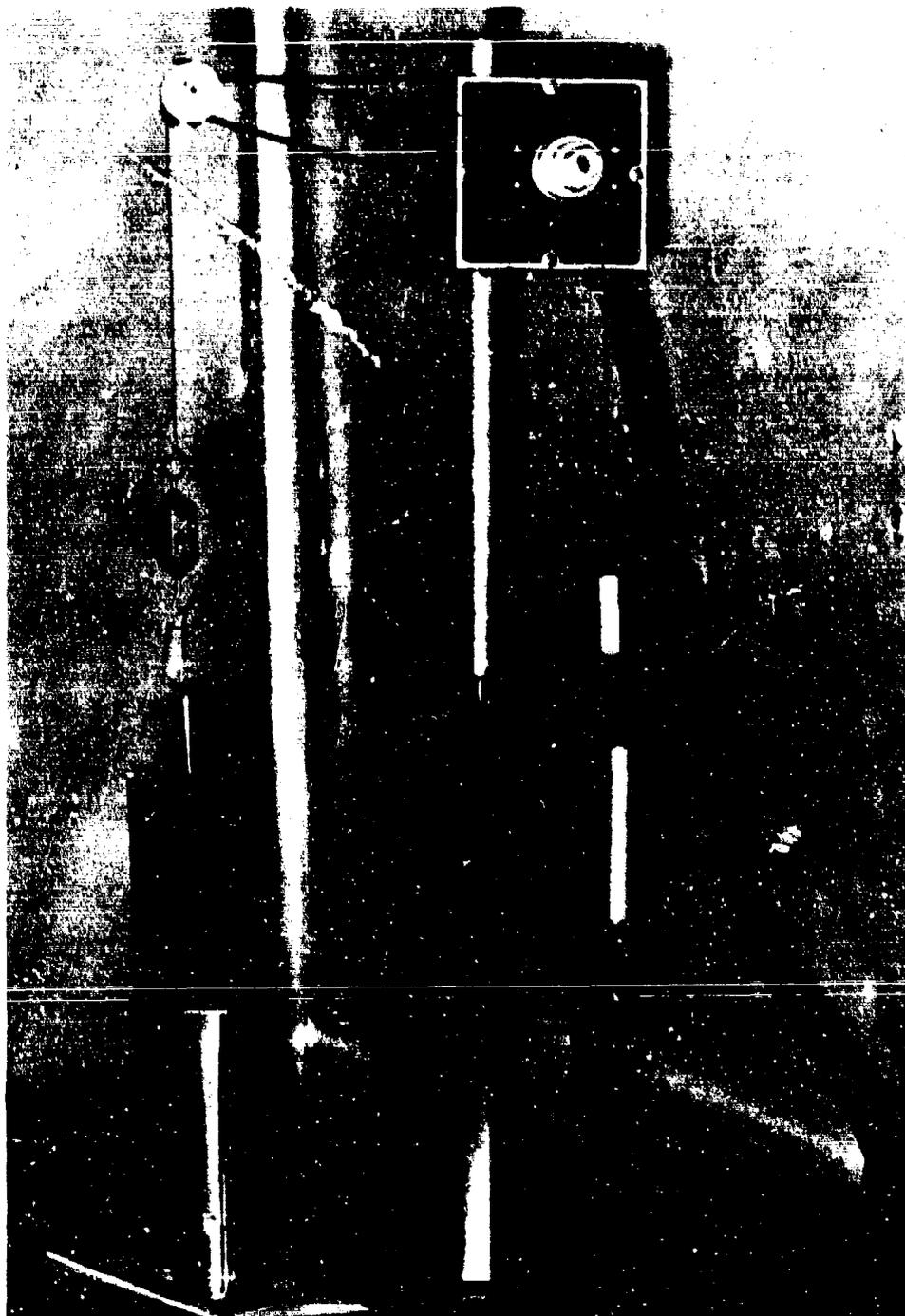


Specification test of formula 2414-501.4
Exposure: 5% acetic acid/JRF,
5 days at 140° F
Unscored panel, 4.7.20 of MIL-C-27725A



Specification test of formula 2414-501.4
Exposure: 5% acetic acid/JRF,
5 days at 140° F
Scored panel showing tape adhesion
test scribes
4.7.20 of MIL-C-27725A

Figure 40



Fisher-Payne dip-coating apparatus

Figure 41

APPENDIX III

EXPERIMENTAL PROCEDURES

Specimen preparation as well as the four environmental screening tests were conducted as described in MIL-C-27725A (USAF).

Surface coating formulations were studied on two types of aluminum surfaces.

- A. Type I, bare aluminum alloy 7075-T6, conforming to specification QQ-A-250/12, with chemical treatment in accordance with MIL-C-5541.
- B. Type II, bare aluminum alloy 7075-T6, conforming to specification QQ-A-250/12, with chemical treatment in accordance with Type II of MIL-A-8625.

The aluminum panels were cleaned with the following multicomponent solvent, reference Table II of MIL-C-27725A:

<u>Ingredient</u>	<u>Specification</u>	<u>% by Volume</u>
Aromatic petroleum naphtha	TT-N-97, Type I, Grade B	50
Ethyl acetate	TT-E-751	20
Methyl ethyl ketone	TT-M-261	20
Isopropyl alcohol	MIL-F-5566	10

The surface coatings were applied on 3" x 6" x 0.040" Types I and II aluminum panels, using a Fisher-Payne dip-coating apparatus at a constant withdrawal speed of four inches per minute. (See Figure 41). Prior to environmental testing, all coated panels were cured for 14 days at 75± 5°F. and 50± 10% relative humidity.

The four environmental screening tests drawn from MIL-C-27725A, which were employed as a means of evaluating candidate coating formulations, are listed below:

- A. Paragraph 4.7.9 - Resistance to water
- B. Paragraph 4.7.10 - Resistance to salt water and fuel
- C. Paragraph 4.7.13 - Resistance to iron chloride
- D. Paragraph 4.7.20 - Resistance to simulated microbial byproducts.

APPENDIX IV

MATERIALS

<u>Trademark or Designation</u>	<u>Description</u>	<u>Supplier</u>
A-153	Phenyltriethoxysilane	Union Carbide
A-1100	Gamma-aminopropyltriethoxysilane	Union Carbide
APD	2-Ethyl, 2-allylpropanediol-1,3	Aldrich Chemical Co.
Carbon Black	Carbon pigment	Baker Chemical Co.
CA	Cellosolve acetate	Braun Chemical
CB	Chlorobenzene	Braun Chemical
Cr ₂ O ₃	Chromium oxide	Baker Chemical Co.
DCB	Dichlorobenzene	Braun Chemical
DDI	Aliphatic diisocyanate	General Mills
Desmodur N	Aliphatic polyisocyanate	Mobay Chemical Co.
DMP 30	2,4,6-Tridimethylaminomethyl phenol	Rohm and Haas
ET 395-1300	Diphenyl oxide NOVOLAC	Dow Chemical Co.
E-196	Isocyanate terminated prepolymer	Mobay Chemical Co.
E-42AP7/V66KP16	Two-part epoxy coating	Sherwin Williams
EPOCRYL E-11	Unsaturated polyol	Shell Chemical Co.
EPON 1031	Solid epoxide resin	Shell Chemical Co.
EPON 154	Liquid epoxide resin	Shell Chemical Co.
EPONOL 53	Bisphenol A:epichlorohydrin copolymer	Shell Chemical Co.
EPONOL 55	Bisphenol A:epichlorohydrin copolymer	Shell Chemical Co.
EPOXIDE 207	Solid epoxide resin	Union Carbide
F-84	Isocyanate terminated prepolymer	Mobay Chemical Co.
Hycar CTBNX	Carboxyl terminated polybutadiene: acrylonitrile copolymer	E. F. Goodrich
Hycar MTBN	Mercaptan terminated polybutadiene: acrylonitrile copolymer	B. F. Goodrich
Hycar 1022	Polybutadiene:acrylonitrile copolymer	B. F. Goodrich
Hooker Prepolymer	Hydroxy terminated, fluorinated adipate-isophthlate prepolymer	Hooker Chemical
LP-52	Polysulfide prepolymer	Thiokol Co.
Maglite D	Magnesium oxide	Merck & Co.
Maglite Y	Magnesium oxide	Merck & Co.
MEK	Methyl ethyl ketone	American Mineral Spirits
MDI	p,p'-methylene diphenylisocyanate	Mobay Chemical Co.
Mondur HX	Hexamethylene diisocyanate	Mobay Chemical Co.
Mondur MR	Polyaromatic isocyanate	Mobay Chemical Co.
NACCCONATE H12	Aliphatic diisocyanate	Allied Chemical
NIAX 520	Polyester polyol	Union Carbide
NIAX 560	Polyester polyol	Union Carbide
Nycote 7-11	Nylon solvent solution	Nycote Labs

PAGE	Polyallylglycidyl ether	Shell Chemical Co.
PR-1057	One-part polyurethane coating	Products Research & Chemical Corp.
PR-1058	One-part polyurethane coating	Products Research & Chemical Corp.
PR-1422	Dichromate cured polysulfide sealant	Products Research & Chemical Corp.
PR-1440	Manganese cured polysulfide sealant	Products Research & Chemical Corp.
PR-1560-M (Part A)	Isocyanate adduct (activator for two-part urethane coating)	Products Research & Chemical Corp.
PR-1566 (Part B)	Base for two-part urethane coating	Products Research & Chemical Corp.
PR-1710 (Part B)	Fluoroelastomer	Products Research & Chemical Corp.
Shell H-3	Ketimine	Shell Chemical Co.
Sylkem 90	1,3-bis (3-glycidoxy propyl)-tetramethyl disiloxane	Dow Corning
Q 94-007	One-part fluorosilicone	Dow Corning
Spengel DV-1180	One-part polyurethane coating	Spencer Kellogg
Talc	Aluminum silicates	Baker Chemical
TDI	Toluene diisocyanate	Monsanto Chemical
TOP	Trioctylphosphine	Carlisle Chemical
Unithane 100 CA	One-part urethane coating	Thiokol Chemical
Urethane Catalyst	Metalorganic	Products Research & Chemical Corp.
Versamid 415	Polyamide	General Mills
Viton A	Fluoroelastomer	DuPont Co.
Viton B	Fluoroelastomer	DuPont Co.
Viton LM	Fluoroelastomer	DuPont Co.
Y-4086	Epoxy silane	Union Carbide
Y-4522	Mercaptosilane	Union Carbide
Z-6030	Methacryloxypropyl trimethoxysilane	Dow Corning
Z-6040	Glycidoxypropyl trimethoxysilane	Dow Corning

UNCLASSIFIED
Security Classification

18. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Corrosion-resistant Coating One-package Integral Fuel Tanks Protection Polysulfide Polyurathane Fluoroelastomer MIL-C-27725						

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