FINAL REPORT

Demonstration/Validation of Tertiary Butyl Acetate (TBAC) for Hand Wipe Cleaning Applications

ESTCP Project WP-200616

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Army Research Laboratory

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Tertiary Butyl Acetate, TBAC, VOC, exempt, solvent, cleaner, paint gun, paint thinning, hand wipe

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List of Acronyms

ACGIH	American Conference of Governmental Industrial Hygienists
AMRDEC	Aviation & Missile Research & Development Engineering Center
AQMD	Air Quality Management District
AR	Army Regulation
ARL	Army Research Lab
ASTM	American Society for Testing and Materials
BCF	Bio Concentration Factor
CAA	Clean Air Act
CARB	California Air Resource Board
CARC	Chemical Agent Resistant Coating
CCAD	Corpus Christi Army Depot
CERCLA	Comprehensive Environmental Response Compensation & Liability Act
CFC	Chlorofluorocarbon
CFR	Code of Federal Regulations
CHPPM	Center for Health and Preventive Medicine - Army
CNS	Central Nervous System
DENIX	Defense Environmental Network an Information Exchange
DLA	Defense Logistics Agency
DLSME	Defense Land Systems & Miscellaneous Equipment
DoD	Department of Defense
DMWR	Depot Maintenance Work Requirement
ECAM	Environmental Cost Analysis Methodology
EPA	Environmental Protection Agency
ESTCP	Environmental Security Technology Certification Program
GC	Gas Chromatography
GOCO	Government Owned Contractor Operated
GWC	Global Warming Potential
HAP	Hazardous Air Pollutant
HAZMAT	Hazardous Material
HCFC	Hydrochloroflourocarbon
IARC	International Agency for Research of Cancer
JS3WG	Joint Service Solvent Substitution Working Group
KB	Kauri-Butanol
MCLB	Marine Corp Logistics Base
MEC	Maintenance Engineering Call
MEK	Methyl ethyl ketone
MEO	Maintenance Engineering Order
MS	Mass Spectrometry
MSDS	Material Safety Data Sheet
NADEP	Naval Aviation Depot
NAVSEA	Naval Sea Systems Command
NDE	Non-destructive Evaluation
NSY	Naval Shipyard
NESHAP	National Emission Standard for Hazardous Air Pollutants

NFESC	Naval Facilities Engineering Service Center
NNSY	Norfolk Naval Shipyard
NTP	National Toxicology Program
ODC	Ozone Depleting Compound
ODS	Ozone Depleting Compound
OEHHA	Office of Environmental Health Hazard Assessment
OEM	Original Equipment Manufacturer
PCBTF	Parachlorobenzotrifouride
PEL	Permissible Exposure Limit
PPE	Personal Protective Equipment
PSNY	Puget Sound Naval Shipyard
SARA	Superfund Amendments Reauthorization Act
SCAQMD	South Coast Air Quality Management District
SERDP	Strategic Environmental Research and Development Program
SIP	State Implementation Program
SNAP	Significant New Alternatives Program
SPOTA	Sustainable Painting Operations for the Total Army
TBA	Tertiary-butyl alcohol or t-butanol
TBAC	*tertiary*-Butyl acetate (CH3COOC(CH3)3)
TCL	Target Chemical List
VOC	Volatile Organic Compound
VOHAP	Volatile Organic Hazardous Air Pollutant

Acknowledgements

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Abstract

Traditionally, vehicle, equipment, aircraft, and ship maintenance operations utilize organic solvents containing hazardous air pollutants (HAP), such as MIL-PRF-680, xylene, and methyl ethyl ketone (MEK), to remove dirt, grease, soot, paint debris, and burned-on carbon from various parts. Tertiary butyl acetate (TBAC), a HAP-Free and volatile organic compound (VOC) exempt solvent, can enable the Department of Defense (DoD) to demonstrate compliance with NESHAP and VOC regulations without performing the extensive record keeping required when using HAP and VOC containing solvents. The objective of this project is to demonstrate the efficacy and to validate the economic and process impact of TBAC in DoD solvent applications as a replacement for HAP and VOC containing solvents.

TBAC has been evaluated for cleaning applications in several process lines. Based on the process parameters developed in the laboratory evaluation and bench scale testing, full scale demonstration programs were performed at three sites, one each from the Army, Navy and Marine Corp. The demonstration sites were Corpus Christi Army Depot (CCAD), Norfolk Naval Shipyard, and Marine Corp Logistics Base Albany, GA (MCLB). These demonstrations showed that TBAC can replace the currently used solvents in some applications. Furthermore, cost analysis shows that such replacements are economically feasible.

1. Introduction

1.1 Background

Traditionally, vehicle, equipment, aircraft, and ship maintenance operations have utilized organic solvents containing Hazardous Air Pollutant(s) (HAP) and Volatile Organic Compounds (VOC), such as MIL-PRF-680, xylene, and methyl ethyl ketone (MEK), to remove dirt, grease, soot, and burned-on carbon from various parts. These solvents are used in various applications, which include hand wipe, vapor degreasing, immersion, and flush cleaning. The MIL-PRF-680 is a petroleum distillate based solvent with a VOC content of ~800 g/l. In an effort to meet local regulations, the Department of Defense (DoD) has increasingly come to rely on aqueous-alkaline cleaners for industrial cleaning operations. These latter cleaners provide substantial environmental benefits, but they can have materials compatibility issues including; corrosion, flash rusting, and hydrogen embrittlement of some metals surfaces such as copper, magnesium and silver plated steel. Due to these and other problems, MIL-PRF-680 and other VOC/HAP cleaners continue to be used throughout DoD for surface preparation, paint equipment clean up, and general parts cleaning. Due to environmental concerns of MIL-PRF-680 and performance concerns of aqueous-alkaline cleaners, it is desirable to test and implement a new class of organic solvents. This new class of solvents 1) do not contribute to emission of VOCs, 2) are HAP free, and 3) meet DoD material compatibility and performance criteria.

The Strategic Environmental Research and Development Program (SERDP) Special Study on Solvent Issues Related to National Emission Standard for Hazardous Air Pollutants (NESHAPs) identified that the largest contribution of HAPs at DoD facilities stems from hand wipe cleaning with solvents. The 2001 Environmental Program Requirements (EPR) Database showed that 73 installations are involved in 104 projects, which release hazardous pollutants due to certain products used in manufacture and maintenance of military equipment. More specifically these projects involve the process of cleaning and degreasing for painting, depainting, surface coating, and pretreatment for plating processes. The products being used in these processes include hydrocarbon-based solvents that contribute considerable amounts of HAPs and VOCs. New environmental regulations being put in place that greatly reduce the amount of HAPs and VOCs that can be released into the environment are the current drivers for this project. With these new regulations DoD's ability to properly maintain its tactical systems is being put into question. The cost of compliance with continued use of current technologies could be reduced significantly with the implementation of "greener" technologies that do not require supplemental equipment or as much paper work. A baseline assessment was conducted in 2002 as part of the Army Sustainable Painting Operations for the Total Army (SPOTA) effort. The Assessments Report discussed the baseline activities that were completed, presented the findings, and provided a general assessment of the solvent usage by the Army. In 2002, the Army used more than 46,000 gallons of HAP-containing solvents that contained almost 215,000 pounds of organic HAPs. A similar effort by the Navy Volatile Organic Hazardous Air Pollutant (VOHAP) Solvent Elimination Program revealed that the Navy used more than 200,000 lbs of HAP containing solvents.

In recent years, concerns over the upper atmosphere ozone layer, ground level photochemical smog and worker health have made traditional solvent cleaning products and processes

increasingly regulated and expensive. The Clean Air Act (CAA) Amendments of 1990 requires states with ozone problems to reduce VOC pollution. Upper atmosphere ozone-depleting chlorinated solvents, particularly, are now subject to strict environmental regulations. Under the Montreal Protocol, production of 1,1,1 TCA and CFC-113 have been prohibited since January 1, 1996, and other ozone-depleting substances are also scheduled for phase out. The 1994 National Emission Standards for Hazardous Air Pollutants (NESHAP) place emission and operating standards on the use of cleaners containing one or more of the chemicals contained in the EPA list of hazardous air pollutants. The states are required to implement these EPA promulgated regulations and each state submits a State Implementation Plan (SIP) to the EPA, describing how the regulations will be enforced within that state. SIPs differ from state to state, but all must comply with the core requirements of the U.S. EPA.

The U.S. Environmental Protection Agency (EPA) intends to promulgate a new NESHAP that will affect operations that are conducted by the DoD at military installations. The NEHSAP, "Defense Land Systems and Miscellaneous Equipment" (DLSME), the proposal date is listed as late in 2007; however, the review and implementation of area source rules has taken priority of the EPA resources and the proposal date may slip. The CAA Services Committee is also discussing alternative compliance methods with the DLSME rule writer. This may include a formal commitment by DoD to continue to reduce HAP emissions in lieu of a NESHAP. The DoD expects its impact to be great. The new DLSME NESHAP will be focused specifically on organic finishing processes. A coating is defined as an organic material applied to a substrate that forms and leaves behind a continuous solid film to provide decorative, protective, or other functional performance whether intended to be temporary or permanent. The EPA is expected to regulate categories of surface coatings similar to SPOTA technology areas. These may include Primers, Topcoats, Solvents, De-Painting Materials and possibly a category for General Use Coatings. This position is subject to change at any time before the rule is made effective, which should occur in the next two years. Examples of possible impacts include (but are not limited to): affecting combat/mission readiness because operations must undergo extensive and costly changes to implement controls, significant cost increases in cleaning and painting operations due to the record keeping requirements of the NESHAPs, and/or increasing fines due to noncompliance. Exceptions to this rule will be those operations already regulated under the Aerospace or Shipbuilding NESHAPs.

Regulating the use of solvents related to painting operations is difficult because there are so many different applications (i.e., thinning paint, preparing surfaces, flushing paint lines, etc.). This would create confusion in writing and enforcing the rule, because regulated facilities would have to somehow prove how the HAP solvents are used. The EPA invited representatives from the DoD to propose different ideas for regulating solvents, resulting in more than 30 suggestions. The DoD will choose several of these for further development and continue to work with the EPA to develop a compliance plan that works for all parties involved. The Army has proposed the following emission limits for solvents: all solvent use related to painting operations must be HAP-free unless a HAP-containing product is specified in a government standardization document (i.e., specification, technical manual, depot maintenance work requirement, etc.). As a corollary, the DoD will commit to funding research and development of HAP-free solvents and implementing those that are demonstrated to meet performance requirements. HAP-free will be defined as levels not required to be reported on a Material Safety Data Sheet (MSDS), which are less than 1% for any non-carcinogen HAP and less than 0.1% for any carcinogen HAP. Demonstrating compliance with these emission limits could be a problem. Installations could

easily prove that a HAP solvent is required by a certain document, but they could not prove that they are only using the HAP solvent for that specific application.

This project addresses each of the services environmental quality requirements: Navy: 2.1.01.g Control/Reduce Emissions from Coatings, Stripping, and Cleaning Operations (high priority), 2.1.01.q Control of VOC and HAP Emissions (high priority) and 3.11.03.a Non-VOC/Ozone Depleting Substance (ODS) Solvents and Cleaning Systems for Aircraft/Weapon and Shipboard/Shore Applications (high priority); Air Force: Need 1232 Avoid requirement for additional facility upgrades to meet the VOC/HAP standard; Army A (3.1.a): Alternative Products in Cleaning and Degreasing Processes, and SPOTA.

1.2 Objectives of the Demonstration

The objective of the proposed effort is to demonstrate the efficacy and validate the economic and process impact of TBAC solvent in DoD solvent applications as a replacement for HAP and VOC solvents. Traditionally, vehicle, equipment, aircraft, and ship maintenance operations utilize organic solvents containing HAP(s), such as MIL-PRF-680, xylene, and MEK, to remove dirt, grease, soot, and burned-on carbon from various parts. The DoD Services Clean Air Steering Committee and it's workgroups have established a bottom line goal for DoD to stop using HAP solvents. The implementation of HAP free, environmentally friendly solvents for cleaning will reduce HAP and VOC emissions, improve worker health and safety and significantly reduce the record keeping burden associated with demonstrating compliance with the NESHAP regulations.

Recent developments have modified the NESHAP compliance options. The EPA delisted MEK as a HAP. This has eliminated much of the acute pressure to find alternatives for operations currently using MEK based cleaners; however, MEK is still a VOC, so although this may provide an option in select cases there will not be a wholesale switch over to MEK. The Joint Service Solvent Substitution Working Group (JS3WG) has committed to the demonstration of HAP and VOC free solutions. The Army Solvent Substitution Working Group (ASSWG) has been working with the preparing technical POCs to address the issue of MIL-PRF-680 and HAPs. New language has been added to MIL-PRF-680 such that products governed by the requirement be HAP-free. This change in language will reduce the HAP containing product use of DoD and allow all operations currently using a MIL-PRF-680 product to demonstrate compliance without any changes in procedures. The applications that were selected for this demonstration do not currently use MIL-PRF-680 products. These changes; however, have released some of the regulatory pressure and have added greater emphasis on this demonstration to show both performance and economic return.

Based on the process parameters developed in the laboratory evaluation and bench scale testing, full scale dem/val programs were initiated at three sites, one each from the Army, Navy and Marine Corp. The demonstration sites are Corpus Christi Army Depot (CCAD), Norfolk Naval Shipyard, and Marine Corp Logistics Base Albany, GA (MCLB).

CCAD investigated the use of TBAC as a pre-paint tack wipe solvent as a solvent conforming to Type MIL-T-81772 thinner. The manufacturing processes involve an existing hand wipe

cleaning activity chosen for demonstrating the effectiveness of TBAC as a hand wipe cleaning replacement. The current method of cleaning the component / part involves the use of hand wiping with a dry lint free cloth moistened with the current cleaning solvent as described in the DMWR. The component parts are required to be completely cleaned and visually inspected before proceeding through the manufacturing process.

The Navy evaluated TBAC as a replacement for T10 Thinner for paint gun cleaning. The Navy conducted a dem/val of this process at Norfolk Naval Shipyard (NNSY). The paint clean up uses approximately 54,000 pounds of T10 thinner across the four shipyards. T10 thinner does not have any governing documents and is primarily governed by shop practices. The demonstration tests for TBAC were conducted with the actual equipment typically used to apply paint at a Naval Sea Systems (NAVSEA) Shipyard. A typical two-part epoxy paint was used as the test material. The paint was prepared according to the manufacturer's specifications. The paint was held or used for a time that is consistent with the time required for a typical paint operation. The aged paint was pumped through the paint application equipment before the demonstration tests are performed. The ability of the solvent to clean wet paint from application equipment was evaluated

Maintenance Center, MCLB, Albany evaluated the use of TBAC for paint clean up, as an alternative to the flushing medium currently employed on paint application components and as a paint thinner to replace MIL-T-81772 (75% Methyl Ethyl Ketone).

1.3 Regulatory Drivers

In recent years, concerns over the ozone layer, photochemical smog and worker health have made traditional solvent cleaning products and processes increasingly regulated and expensive. The CAA Amendments of 1990 requires states with ozone problems to reduce VOC pollution -- a primary precursor to ozone. Ozone-depleting chlorinated solvents, particularly, are now subject to strict environmental requirements. Under the Montreal Protocol, production of 1,1,1 TCA and CFC-113 have been prohibited since January 1, 1996, and other ozone-depleting substances are also scheduled for phase out. The 1994 NESHAPs place emission and operating standards on the use of cleaners containing one or more of the chemicals contained in the EPA list of hazardous air pollutants. The states are required to implement these EPA promulgated regulations and each state submits a SIP to the EPA, describing how the regulations will be enforced within that state. SIPs differ from state to state, but all must comply with the core requirements of the U.S. EPA.

The EPA intends to promulgate a new NESHAP that will affect operations that are conducted by the DoD at military installations. The DLSME NEHSAPis expected to be proposed soon. The DoD expects its impact to be great. The new DLSME NESHAP will be focused specifically on organic finishing processes. A coating is defined as an organic material applied to a substrate that forms and leaves behind a continuous solid film to provide decorative, protective, or other functional performance whether intended to be temporary or permanent. The EPA is expected to regulate categories of surface coatings similar to SPOTA technology areas. These may include Primers, Topcoats, Solvents, De-Painting Materials and possibly a category for General Use Coatings. This position is subject to change at any time before the rule is made effective, which

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Regulating the use of solvents related to painting operations is difficult because there are so many different applications (i.e., thinning paint, preparing surfaces, flushing paint lines, etc.). This would create confusion in writing and enforcing the rule, because regulated facilities would have to somehow prove how the HAP solvents are used. The EPA invited representatives from the DoD to propose different ideas for regulating solvents, resulting in more than 30 suggestions. The DoD will choose several of these for further development. The Army has proposed the following emission limits for solvents: all solvent use related to painting operations must be HAP-free unless a HAP-containing product is specified in a government standardization document (i.e., specification, technical manual, depot maintenance work requirement, etc.). As a corollary, the DoD will commit to funding research and development of HAP-free solvents and implementing those that are demonstrated to meet performance requirements. HAP-free will be defined as levels not required to be reported on a MSDS, which are less than 1% for any non-carcinogen HAP and less than 0.1% for any carcinogen HAP. Demonstrating compliance with these emission limits could be a problem. Installations could easily prove that a HAP solvent is required by a certain document, but they could not prove that they are only using the HAP solvent for that specific application.

There had been concern that some states might not implement the EPA VOC exemption. In particular there was concern about the California Air Resources Board (CARB) who voiced concerns to the EPA in 2000 about the potential toxicity of TBAC. Air Quality Management Districts (AQMDs) and individual counties regulate point sources in California. In particular, AQMDs such as the South Coast Air Quality Management District (SCAQMD) regulate HAP and VOC emissions from degreasing and hand-wipe cleaning applications and facilities where these operations take place. SCAQMD prohibits the use of class II VOC exempt compounds in cleaners. VOC-exempt compounds are placed in class II if they are known or suspected to have adverse health or environmental impacts or if insufficient information is available to make that determination. TBAC has not been classified by SCAQMD but the toxicity concerns raised by the California Office of Environmental Health Hazard Assessment (OEHHA) in the CARB draft assessment report may prompt the District to place TBAC with class II exempt compounds such as PERC at least until the health concerns raised by OEHHA are addressed. The project team has been in coordination with government and industry experts to assess the status of the implementation of the TBAC exemption. The status of the state TBAC VOC exemption process as of January, 2007 is shown in Figure 1. This issue has a limited impact on the implementation plan since the most of the states have implemented the VOC exemption.

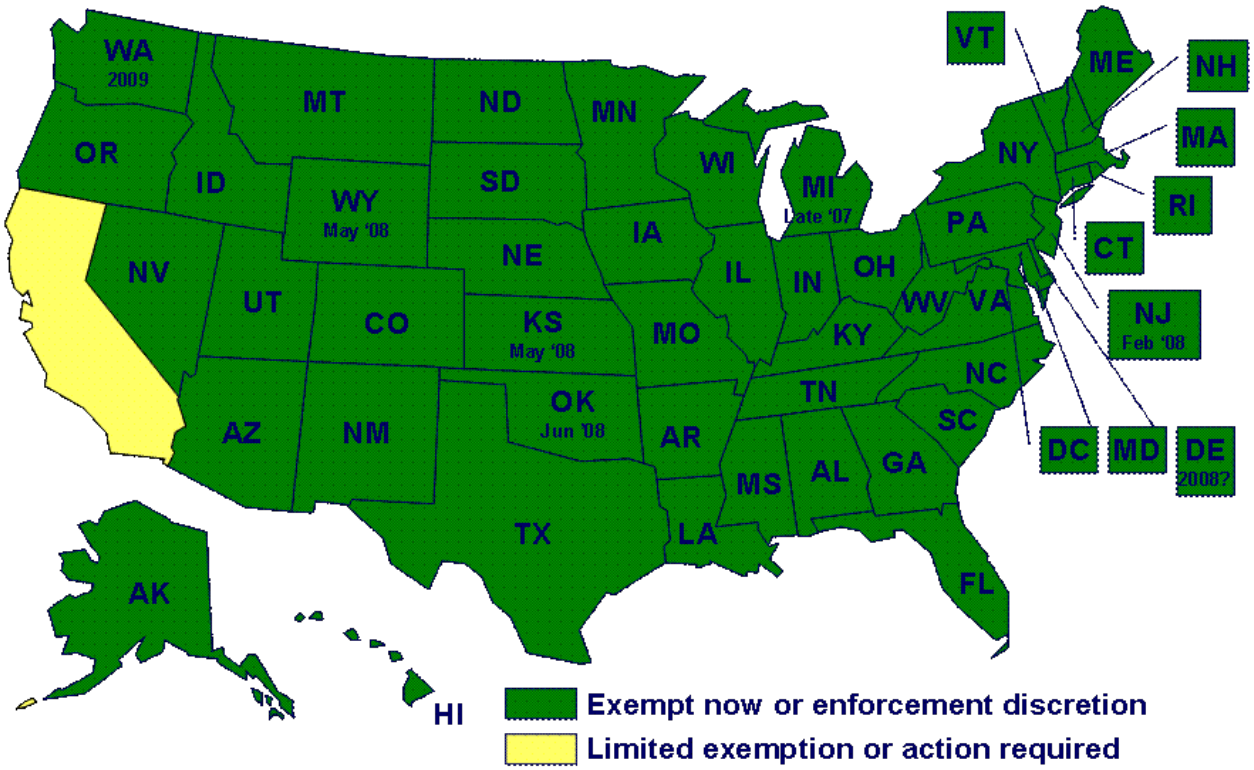

Figure 1.1 Status state TBAC VOC exemption process

This project addresses each of the services environmental quality requirements: Navy: 2.1.01.g Control/Reduce Emissions from Coatings, Stripping, and Cleaning Operations (high priority), 2.1.01.q Control of VOC and HAP Emissions (high priority) and 3.11.03.a Non-VOC/ODS Solvents and Cleaning Systems for Aircraft/Weapon and Shipboard/Shore Applications (high priority); Air Force: Need 1232 Avoid requirement for additional facility upgrades to meet the VOC/HAP standard; Army A (3.1.a): Alternative Products in Cleaning and Degreasing Processes, and SPOTA.

1.4 Stakeholder/End-User Issues

Ester compounds, like TBAC, typically have a fairly strong odor and there may be some worker resistance. However, test evaluation of TBAC with assemblers at Raytheon found the odor to be acceptable (Elias, W.G., Real life applications with environmentally compliant solvents for electronics, *Proceedings Nepcon West 2000*, Anaheim CA). CCAD Solvent Performance Test Evaluation of alternative Hand-wipe Solvents (Laboratory Report 2005000601 dated 29 October 2004) states that there should not be user issues related to work environment. Furthermore, studies at Eastern Michigan University and San Diego State University show that the odor detection threshhold TBAC is 4-5 times lower than n-Butyl Acetate (n-BuAc) (a solvent commonly used in Chemical Agent Resistant coating (CARC) paints) and is less objectionable. The odor compatibility of TBAC was evaluated using worker surveys during the demonstrations.

The drying characteristics of TBAC including drying time and residues are critical performance criteria for TBAC as a drop in replacement for existing solvents. These properties were evaluated in the laboratory test plan. Preliminary investigations by third party labs and users at

CCAD and Naval Air Depot (NADEP) JAX indicate that the drying characteristics (i.e. drying time, non-volatile residue) of TBAC are acceptable for existing process schedules. The drying time of TBAC was evaluated during the demonstration of the paint thinning as part of the demonstrations at MCLB Albany and hand wipe cleaning at CCAD. The Navy paint equipment clean up application does not have a drying time performance objective.

The impact of TBAC on the overall coating process was evaluated. The impact of cleaning with TBAC on coating integrity was evaluated per the requirements of ADS-61A-PRF, "Aeronautical Design Standard Performance Specification for Army Aircraft Cleaners, Aqueous and Solvent". Coating adhesion and sealant peel strength are included in the laboratory test plan. The NNSY demonstration evaluated the affect of TBAC on paint quality by painting with the demonstration paint equipment and evaluating coating quality per documented paint application procedures.

TBAC has a flash point of 40°F. It is a flammable liquid as defined under Superfund Amendments of Reauthorization Act (SARA) Title III, section 311/312 hazard category but is not subject to the reporting requirements of SARA Title III, section 313. The flashpoint of TBAC was a consideration in the selection of the demonstration applications. Applications were selected where flammability was not a primary consideration or where the flashpoint of TBAC did not change the flammability classification of the process.

For TBAC to be qualified as an alternative to current solvents in the cleaning process, it must meet all the requirements of those processes, including all environmental, occupational safety, and health, chemical properties, materials compatibility and performance requirements. For those successful dem/val tests, TBAC could be substituted for the current solvents in the cleaning process steps of similar coating application operations DoD maintenance facilities and depots.

2. Technology Description

2.1 Technology Development and Application

TBAC (CAS 540-88-5) is a natural gas-derived ester solvent originally developed in the 1950's by Texaco as a fuel additive to improve cetane and reduce harmful exhaust emissions. However, it was never commercialized for that purpose. Until recently, it had found limited commercial use as a pharmaceutical intermediate. In 1997, Lyondell Chemical (then ARCO Chemical) identified TBAC as a chemical with negligible photochemical reactivity and petitioned the US EPA to add it to their list of VOC exempt compounds.

This exemption request was granted in 2004. TBAC is also not a HAP, ozone depleter, greenhouse gas, particulate matter precursor, or SARA 313 chemical. TBAC is inherently biodegradable, has low bioaccumulation potential (BCF <5), low tendency to partition to water and soil, and low toxicity. TBAC is also SNAP-approved as a replacement for ozone depleting chloroflourocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs) in cleaning and other applications.

TBAC can be used in coatings, inks, adhesives and for cleaning, paint thinning and cleanup, and adhesive residue removal where these flammable solvents and blends (e.g. T-10 thinner) are

currently being used. It can also be used instead of toluene, xylene, MEK, and other esters to reduce the HAP and VOC content of CARC paints without negatively affecting cost or performance.

TBAC is also a potential replacement for acetone, methyl acetate, and PCBTF (para-chlorobenzotrifluoride or Oxsol 100), three VOC-exempt solvents used in cleanup and CARC paints. Acetone and methyl acetate have very low flash points and TBAC provides an additional margin of safety and can reduce solvent usage because of its lower evaporation rate. PCBTF is relatively expensive and very dense, has an unpleasant odor, and is not as good a viscosity reducer as TBAC. TBAC can reduce procurement costs, solvent usage, and potential soil and water contamination issues compared to PCBTF.

TBAC is currently produced by Lyondell Chemical Company under the tradename TBAc™ Solvent in Houston, TX. It is available in drums, isocontainers and tank trucks, directly from Lyondell or from several national and regional distributors including Ashland, Brenntag, Chemcentral, and Univar.

TBAc™ Solvent has low water content and meets urethane grade specifications for use in two-component urethane coatings. It is stable indefinitely under normal storage conditions in unopened, factory-sealed containers. It is resistant to oxidation, hydrolysis and aminolysis, three common decomposition pathways for other ester solvents such as methyl-, ethyl-, propyl- and n-butyl acetates.

Table 2-1 Key Physical Properties Comparison

PROPERTY	TEST	TBAC[1]	Toluene	Acetone	MEK	Xylenes	T-10 (blend)
CAS number	none	540-88-5	108-88-3	67-64-1	78-93-3	1330-20-7	71-36-3 1330-20-7 110-43-0 100-41-4
Flash Point, °F(°C)	ASTM D-56	40°(4°)	40°(4°)	-4°(-20°)	40°(4°)	80°(27°)	80°(27°)
Kauri-Butanol Value	ASTM D-1133	114	105	NA	NA	98	
Physical Form	Appearance	Clear Liquid	Clear Liquid	Clear Liquid	Clear Liquid	Clear Liquid	Clear Liquid
Specific Gravity @ 68°F	ASTM D-1298	0.87	0.86	0.79	0.81	0.86	0.83
Vapor Pressure, mm Hg @ 68°F	ASTM D-2879	34	22	180	78	5	4.3 6.6 2.1 7.1
VOC status	US EPA definition	exempt	VOC	exempt	VOC	VOC	VOC

HAP listed	US EPA definition	no	yes	no	no	yes	Yes
Evaporation Rate	n-butyl acetate = 1.0	2.78	2.24	7.7	6.0	0.70	<1
OSHA PEL, ppm	None	200	200	1000	200	NA	50 100 50 100
Cost, $/gal	Purchasing records	8.0	7.5	12.8	17.9		8.4

Note 1. Appendix A & B contain the TBAC MSDS and a technical data sheet for TBAC, respectively.

2.2 Previous Testing of the Technology

Environmental Impact and Fate - The environmental impact of TBAC has been more thoroughly evaluated than many of the solvents it is designed to replace. Appendix C contains a technical data sheet summarizing the environmental aspects of TBAC. TBAC is a volatile solvent with low water solubility (0.3 wt %). In its anticipated uses as an industrial solvent, it is expected to be released predominantly into the atmosphere via evaporation from industrial products and operations. No significant releases to water or soil are anticipated so impacts to aquatic organisms and sediment are also expected to be negligible. Nonetheless, if TBAC were to be released to water or soil, the majority would also evaporate and the rest would biodegrade. TBAC is inherently biodegradable, has low aquatic toxicity, and does not bioaccumulate (BCF < 5).

Fugacity models (EQC) show that it will remain almost exclusively (98.8%) airborne when released to air and has little tendency to partition to water and soil. Photochemical reactivity studies using three state-of–the-art atmospheric computer models and a detailed photoproduct study show that TBAC has negligible tendency to form ozone. It produces about half as much ozone as ethane under all atmospheric scenarios, and 20 to 50 times less ozone than toluene and xylene, respectively. Ozone and particulate matter are criteria pollutants and lung irritants and have been linked to premature deaths and respiratory ailments such as asthma. Replacing these solvents by TBAC in products and operations will result in an almost quantitative reduction in ozone formation.

TBAC is also not expected to contribute to particulate matter (PM10 and PM2.5) formation, global warming, and stratospheric ozone depletion according to leading experts in the field. Consequently, using TBAC instead of VOCs, HAPs or ozone depleters will have a significant beneficial impact on the environment and on human health.

Toxicity Studies – The toxicity of TBAC has been tested on laboratory rats, mice, guinea pigs and rabbits and shown to be low. It's rat oral LD50 (4.5g/kg/day) toxicity is lower than that of table salt and its inhalation LC50 for 6 hours of exposure is approximately 4,200 ppm. TBAC is not a skin sensitizer but is a mild eye and skin irritant. Exposure to 200-300 ppm causes mild

irritation to the eyes and nose and exposure to 3,300 ppm causes severe extreme irritation to the eyes and nose.

The TBAC odor threshold (50% detection limit is about 10 ppb) is about five times higher than n-butyl acetate (2 ppb). The 50% ocular detection threshold (onset of eye irritation) for TBAC is over four orders of magnitude higher (250 ppm) and 67% higher than that of n-Butyl acetate. Its odor is also less objectionable than n-butyl acetate, with a more fruity (blueberry or camphor-like) character. This indicates that TBAC has excellent warning properties and is less irritating, objectionable or detectable than n-BuAc, a common component of paints and coatings.

Pharmacokinetic studies show that inhaled TBAC is rapidly metabolized to TBA (Tertiary butyl alcohol / t-butanol) and acetic acid, a component of vinegar and the citric acid cycle. These metabolites are rapidly and efficiently excreted via the urinary pathway. TBA, being an alcohol, is a CNS (central nervous system) depressant and overexposure to TBAC can lead to alcohol intoxication. Symptoms such as headache and motor impairment usually disappear rapidly after exposure and radiolabeling studies in rats show that less than 1% is retained in the body after 48 hours.

TBAC and its TBA metabolite have been shown to be non-mutagenic by a battery of in-vivo and in-vitro tests. TBAC has not been tested for chronic toxicity but its TBA metabolite has. TBA causes small but statistically significant increases in naturally occurring tumors in rats and mice when ingested a very high doses for extended periods. These tumors are not believed to be relevant to human carcinogenicity as they occur by metabolic pathways that do not occur in humans (α-2u in rat kidneys) or to which humans are much less susceptible (chronic progressive nephropathy and mice thyroid tumors).

Furthermore, the levels of TBAC required to produce enough TBA to cause these weak chronic effects in rodents exceeded the lethal dose for TBAC. It is, therefore, extremely unlikely that TBA and TBAC are non-threshold carcinogens and that workers or the population could be exposed to enough TBAC to cause a carcinogenic response, even under worst case occupational exposure scenarios.

Consistent with this analysis, the National Toxicology Program (NTP) has concluded that these tumors do not present clear evidence of carcinogenicity in animals and the American Conference of Governmental Industrial Hygienists (ACGIH) and International Agency for Research on Cancer (IARC) have concluded that TBA is not classifiable as a human carcinogen.

Testing in Industrial Solvent-borne Coatings, Inks, Adhesives, Thinners and Cleaners –

TBAC has been extensively tested as a solvent for coatings, adhesives, inks, and cleaners. It solubilizes a broad range of resins and soils. Test results can be found at www.TBAC.com.

Coatings - Solvent-based coatings come in two basic forms, thermoplastic (lacquers) and thermosetting (enamels). Both forms contain solvents, resins, additives, and optionally, pigments. The role of the solvents is to reduce the viscosity of the coating components so they can be more easily manufactured, stored, transported, and applied to the substrate. Solvents are

also commonly used to further reduce the viscosity before the application (thinning) and to clean application equipment (paint cleanup).

The type and number of solvents used depends on a number of variables including the coating components, the substrate, and the application process and conditions. For a solvent to be effective, it must readily dissolve the resin and evaporate rapidly after application of the coating. It must also not react with the coating components, especially the reactive components of a thermosetting coating such as two-component urethanes or epoxies.

TBAC has been shown to be an effective viscosity reducer for a broad range of coating resins. It is suitable for use with most resin systems and, unlike other solvents, does not readily react with amine or isocyanate crosslinkers or strong acid catalysts. It can, therefore, be used in most solvent-based coatings systems.

TBAC is a urethane grade solvent supplied with a low water content. It can therefore be used to thin two-component urethane and epoxy CARC coatings as well as alkyds enamels. Isotron Corporation has proceeded to PHASE II development of advanced CARC coatings based on TBAC. This Navy-sponsored project aims to develop a single-pack, zero-VOC CARC coating for the Marine Corps.

Cleaners – Solvent based cleaners for handwipe and cold-cleaning applications must effectively cut a variety of greases, fluxes and soils and leave no residue. They should also have low surface tension to wet the surface and evaporate quickly. TBAC is a very effective degreaser for a variety of industrial greases as well as rosin flux.

Its performance compared to common cleaning solvents was summarized in a recent article in Process Cleaning Magazine. TBAC has also been subjected to a battery of corrosion tests to determine its suitability for aircraft maintenance and cleaning. TBAC is also less aggressive than acetone on certain plastics (PS, ABS, SAN, acrylics) and elastomeric materials.

Previous work on hand wipe cleaning by Raytheon indicated that TBAC exhibited comparable cleaning efficacy with MEK and Methyl Propyl Ketone (MPK). The purpose of the effort was to evaluate MPK and tertiary-Butyl Acetate as potential drop-in replacements for MEK in cleaning aluminum and composite substrates of common contaminates (**Tertiary Butyl Acetate: A Potential VOC Exempt Solvent for Hand Wipe Cleaning and Coatings Applications** presented at Solvent Substitution Workshop, James E. Foreman, Raytheon Systems Company, 9/15/1999)

NAVAIR has been working on alternatives for P-D-680 under the W2210 Pollution Abatement Ashore Program. Cleaning efficiency tests conducted by NAVAIR indicate that TBAC has a cleaning efficiency slightly better than P-D-680, Type II (soil: baked on grease at 220^0F for 2 hrs). Performance testing (paint adhesion, cleaning ability) was conducted at NADEP JAX with regard to testing TBAC to the Fed Spec P-W-2981 Wipe Solvents, Exempt and Non-Exempt. (**Alternative Substitution for P-D-680** presented W2210 Pollution Abatement Ashore Program IPR, El Sayed Arafat, NAVAIR 4.9.7.2, 7/18/2005)

CCAD Laboratory Report 200500601, **Solvent Performance Test Evaluation of Alternative hand-Wipe Solvents**, investigated a total twelve solvents with the objective of determining an effective and acceptable alternative hand wipe solvent to TCE and MEK. The properties evaluated were removal of partially dried primers, Teflon sleeve cleaning performance, honeycomb panel solvent retention, bond cleaning on single lap shear specimens. TBAC was recommended for further study

Other uses – TBAC has also been tested as a solvent for inks and ink cleanup and adhesives.

2.3 Factors Affecting Cost and Performance

TBAC is a pound per pound replacement for most hydrocarbon and oxygenated solvents. It is less dense than halogenated solvents and is, therefore, more cost effective. For example, PCBTF, another exempt solvent, costs approximately twice as much as TBAC, is a less effective viscosity reducer, and its density is 55% greater. Replacing PCBTF with TBAC would result in at least a three-fold decrease in solvent costs.

TBAC is a versatile solvent that can be used in a variety of applications including paint thinning and cleanup, cold cleaning, hand wipe cleaning, ink and adhesive residue cleanup. This versatility may allow DoD facilities to purchase and store bulk quantities of the solvent at its maintenance sites, thereby reducing procurement costs.

Operations that use large quantities of the solvent may also be able to recover it, further reducing emissions and procurement costs. TBAC emissions can be recovered on carbon beds and purified on or off-site for reuse. This technology has been demonstrated on a small scale by Waterlink and is currently being implemented at a large sealant and gasket manufacturing facility where it is replacing toluene..

Facilities that currently incinerate their VOC emissions may also be able to reduce or eliminate the cost of running the thermal oxidizers and reduce their NOx emissions at the same time by using TBAC. Facilities that are major HAP or VOC sources may be redefined and their reporting requirements lessened.

TBAC is not a HAP, VOC, SARA 313, Prop 65 or Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) chemical. Using it instead of other solvents may help reduce Environment, Health and Safety (EH&S) administrative costs, exceedance fees, and other regulatory expenses. Its very low health and environmental impact make it unlikely to be strictly regulated in the future, thereby avoiding future reformulation costs as well.

As a cleaning solvent, TBAC has characteristics similar to the traditional solvents this project seeks to replace, like MEK and PERC (Tetrachloroethylene). The same factors that affect the performance of these solvents will impact the performance of TBAC. Factors include temperature, humidity and type of soil to be removed.

2.4 Advantages and Limitations of the Technology

TBAC offers DoD depot and maintenance facilities with the opportunity to reduce their reliance on HAP and VOC solvents in their maintenance operations. Potential advantages of the technology include:

Reduction or elimination of VOC and HAP emissions

- Reduction in procurement costs through bulk purchasing and solvent recycling
- Reduction in compliance and EH&S costs
- Reduction in energy costs associated with thermal oxidizers
- Reduction in solvent emissions and costs through recycling of TBAC

However, TBAC is a flammable, odorous solvent, and overexposure to it could have detrimental health effects, such as alcohol intoxication and eye and respiratory irritation. Its use should be limited to applications where flammability and worker overexposure is properly managed through the use of engineering controls and proper worker personal protective equipment.

Appendix D – Health and Safety Plan addresses health and safety concerns specific to the use of TBAC as part of cleaning and coating operations. The procedures and practices addressed in this appendix are those that will be the most commonly encountered and used for this demonstration project.

3. Demonstration Design

Three independent demonstration sites participated in the effort. Each demonstration site looked at different application(s) in order to maximize the implementation potential of this effort. The laboratory/bench evaluation requirements for the three demonstration sites were consolidated to take advantage of overlapping requirements. The Laboratory Test Protocol is included in Appendix E.

3.1 Corpus Christi Army Depot Demonstration

CCAD has demonstrated two applications as described below.

3.1.1 UH-60 Flight Controls Mixer Shaft

This application addresses cleaning of the shaft which is part of the UH-60 Flight Controls Mixer Assembly depicted in Figure 3.1 and shown separately in Figure 3.2. Table 3.1 describes the details of the process and demonstration part. Currently, a hand wipe cleaning procedure moistened with the solvent acetone is used to remove light grease, dust and dirt from the shaft before it is used for assembly of the UH-60 Flight Controls Mixer.

Table 3.1 Flight controls Mixer Shaft Cleaning

Facility	Industrial Operation	Part	Part Number / Component	Contamination	Current Hand Wipe Solvent
AVIM	Assembly of UH-60 Flight Controls Mixer	Shaft, chrome plated	70400-02155-103	Light grease, dust, dirt	Acetone

Figure 3.1 UH-60 Flight Controls Mixer

Figure 3. 2 S haft Part no. 70400-02155-103

A single shaft was selected and cleaned for establishing a baseline comparison using the existing solvent acetone. Following the establishment of the baseline for comparison, the demonstration consisted of three separate tests with three separate but identical parts (Figure 3.3).

The procedure for each test required a standard lint-free dry cloth moistened with TBAC to clean the entire surface area of the shaft. After each cleaning procedure the shaft was visually inspected and performance criteria results were discussed with the mechanic performing the demonstration (Figure 3.4). The performance data obtained from each demonstration was manually recorded.

Figure 3.3 Three parts tested

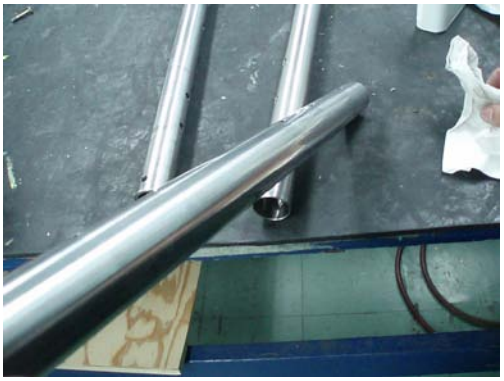

Figure 3. 4 Inspection after cleaning

3.1.2 UH-60 Aircraft Fuselage

A second production process demonstration selected for testing is the hand-wipe solvent cleaning of the UH-60 fuselage tub (Figure 3.5) and other fuselage panels (Figures 3.6 and 3.7) during initial cleaning after pre-shop analysis (PSA) dis-assembly. The tub is primed and is contaminated with grease, oil, dirt and lubricants. In addition the tub stringers contain adhesive residue that is used to bond the floor boards. The other panels tested are also primed and contaminated with grease, oils, dirt and lubricants. Table 3.2 describes the details of the current process and selected aircraft for demonstration. Currently, a hand wipe moistened with the solvent Toluene is used to clean and remove the contaminants before it proceeds to the next production operation.

Table 3.2 UH-60 Fuselage Tub Cleaning

Facility	Industrial Operation	Part / Component	Part Number	Contamination	Current Hand Wipe Solvent
Aircraft Cleaning WC 554A0	UH-60 Aircraft Cleaning	Fuselage cabin/tub & panels	UH-60 Aircraft Tail# 80-23440	grease, oils, adhesive residue, dirt, lubricants	Toluene

Figure 3.5 Fuselage tub Figure 3.6 Canted bulkhead Figure 3.7 Roof panel

An area measuring approximately one square foot of the various areas chosen for cleaning were tested by first creating a baseline cleaning with Toluene followed by a cleaning of an equal area with TBAC. All the tests were performed on one UH-60 aircraft identified as tail number (SN) 80-23440.

The procedure for each test required a standard lint-free dry cloth moistened with TBAC to clean the surface area selected. After each cleaning procedure the area was visually inspected and performance criteria results were discussed with the operator performing the demonstration. The performance data obtained from each demonstration was manually recorded.

3.2 Norfolk Naval Shipyard Demonstration Design

The Naval Sea Systems Command (NAVSEA) is seeking an alternative solvent for cleaning two-part epoxy spray paint equipment. The NAVSEA Solvent Substitution Project identified T-10 Thinner as the most widely used solvent with human and environmental risks at NAVSEA facilities. T-10 Thinner was determined to be commonly used at NAVSEA facilities to clean two-part epoxy paints from paint spray pumps. The replacement of T-10 Thinner with a safer alternative offers the opportunity for significant reduction in risk and the environmental footprint of the process.

T-10 Thinner poses risks to workers due to the relatively high toxicity of its ingredients, and due to its high flammability. Also, T-10 Thinner poses risks to the environment due to the presence of EPA regulated hazardous air pollutants (HAPs) and volatile organic compounds (VOCs). Finally, T-10 Thinner contains chemicals that are listed on the NAVSEA Target Chemical List (TCL). The TCL identifies chemicals that NAVSEA has designated as targets for Pollution Prevention (P2) efforts. Therefore, it is desirable to replace T-10 Thinner with a safer solvent.

A safe and effective solvent for cleaning two-part epoxy paints from spray paint equipment would significantly improve cleaning operations at NAVSEA facilities. The identification of a safe and effective alternative solvent would allow replacing a traditional, undesirable solvent. The uses of the traditional T-10 Thinner must be considered when selecting an appropriate substitute. A substitute solvent must meet several basic criteria related to the paint cleaning operations. The solvent must:

1. Be effective for applications where T-10 Thinner is used.
2. Reduce risks to workers.
3. Reduce environmental risks.
4. Be cost effective.
5. Be easily useable by workers with basic training.
6. Not damage spray paint equipment.
7. Not interfere with the performance or the level of protection provided by paints.

The characteristics of both TBAC and T-10 Thinner were determined by a properties study, lab tests, and demonstration tests to obtain results that are reliable, repeatable, and quantitative. The evaluation of TBAC required the identification of baseline performance. T-10 Thinner was used as a basis for the identification of baseline performance because its widespread use allows for a comparison with well-known performance characteristics. The characteristics of T-10 Thinner were therefore applied as representative baseline performance. The characteristics of TBAC were compared to the baseline performance to determine whether TBAC is a potential alternative solvent. The determination of whether TBAC is a potential alternative solvent applies to replacing T-10 Thinner as well as to replacing other solvents that are unacceptable or undesirable human health and environmental risks.

Demonstration tests were planned and completed to characterize the performance of TBAC for cleaning paints in field conditions. The demonstration tests were necessary to obtain quantitative information on the performance of TBAC so that a comparison could be made with baselines.

There were three main goals of the demonstration tests. First, the demonstration tests were intended to document the effectiveness of the solvents for cleaning two-part epoxy paint from spray paint equipment during field conditions. Second, the tests were intended to document the affect of the solvents on spray paint equipment during field operations; including the solvent affects on pumps, guns, and transfer lines. Third, the tests were intended to document the affect of the solvents on paint performance during field operations. Table 3.3 provides the intended demonstration test objectives and gives the methods for achieving the test objectives.

Table 3.3 – Demonstration Test Objectives

Objectives	Tests	Expected Results
Cleaning effectiveness of TBAC	• Quantity of paint removed during one cleaning cycle • Quantity of solvent required • Paint equipment inspection • Time to Clean Point	• Relative effectiveness of alternative solvents • Effectiveness compared to current operations • Residual paint • Cleaning Time
TBAC affect on paint performance	• Paint adhesion (ADS-61A-PRF & FED-STD-141)	• Change in paint performance
TBAC affect on equipment operation	• Observed equipment performance over test cycles • Observed condition of equipment at end of test cycles	• Change in observed equipment performance • Change in observed equipment condition (damage, deformation)

A demonstration test plan was prepared to identify baseline performance and to obtain performance data for TBAC during field conditions. The demonstration tests were planned to obtain baseline performance criteria for the traditional solvent – T-10 Thinner – used to clean paint spray pumps. Also, the tests were planned to obtain performance data on TBAC for the same field conditions. The field tests were planned to provide results that represented typical field operations that were repeatable so that the performance to the test products could be fairly compared. The equipment used for the demonstration tests, the personnel that performed the tests and the facility where the tests were performed were the same as those used for actual painting operations. However, actual painting and equipment cleaning practices had to be modified to ensure reliable and comparable data was obtained from the demonstration tests. The *Norfolk Naval Shipyard Alternative Solvents Demonstration/Validation Plan* (Reference 3 in Appendix G) was prepared for the demonstration tests. Figure 3.8 provides an overview of the demonstration plan.

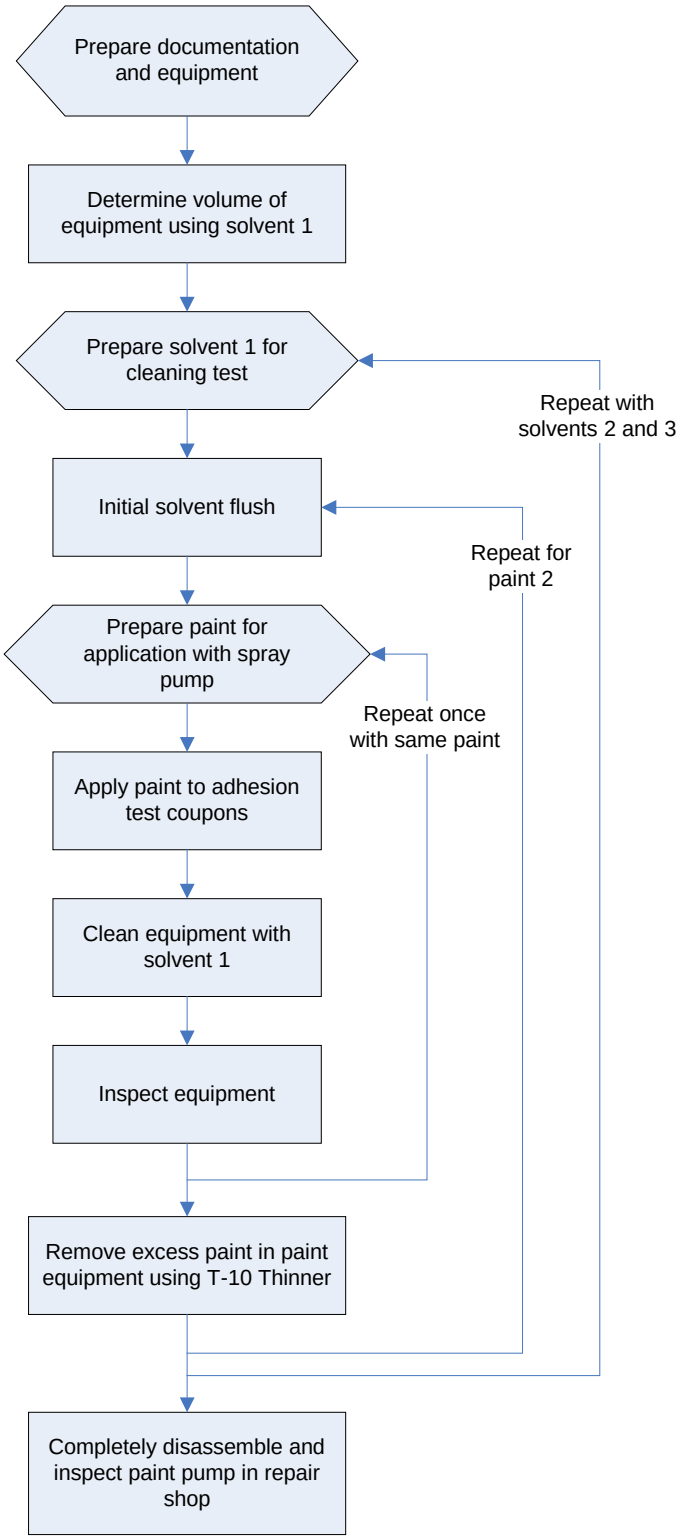

Figure 3.8 – Demonstration Test Plan Flowchart

Norfolk Naval Shipyard (NNSY) was selected as the preferred location to perform the demonstration tests. The history of painting operations, the types of paints and solvents used, the available facilities, the available equipment, and the skilled and knowledgeable personnel were

reasons NNSY was selected. NNSY commonly applied two-part epoxy paints as normal operations. Also, facility personnel were experienced in applying the paints and in cleaning spray paint equipment with solvents such as T-10 Thinner. Finally, the NNSY facilities supported the performance of the demonstration tests under controlled conditions. The Demonstration Tests were conducted at NNSY from 11-14 September 2007.

3.3 USMC Maintenance Center Albany Demonstration Design

Maintenance Center, MCLB, Albany evaluated the use of TBAC as a medium in the Fluidics Plural Paint mixers for paint flushing and application, as an alternative to the medium currently employed on paint application components and as a paint thinner to replace MIL-T-81772 (75% Methyl Ethyl Ketone). Replacement of MIL-T-81772 would constitute an annual cost savings of $108,000 from our total HAZMAT waste stream. A dramatic savings in operational and labor (>5%) was not anticipated; however, a significant reduction in our overall HAZMAT footprint and VOC emissions was anticipated.

This evaluation was accomplished by conducting comparison testing of approved Tertiary-Butyl Acetate (TBAC – CAS No. 540-88-5) products as an alternative to current products (T-10 Thinner, MIL-C-81702) used in processes for paint thinning and paint detritus clean up. This testing focussed on dry times, cleanup efficiency, compatibility with current coatings, and worker acceptance.

4. Performance Assessment

4.1 Performance Criteria

The TBAC ESTCP working group assembled general performance criteria that represented common criteria. In some cases different substrates were of interest for the individual demonstrations so the test matrix was expanded to cover a spectrum of materials.

Performance criteria are included in Table 4-1.

Table 4-1: Performance Criteria

Performance Criteria	Description	Primary or Secondary
Environmental, Occupational Safety and Health	**Toxicity** – Shall have no adverse effect on human health when used as intended.	Primary
	Flammability – Shall not increase hazard category of the operation.	Primary (CCAD)
	Volatile Organic Compounds – Shall contain less than 50 g/l VOC, be VOC exempt, or a SCAQMD certified clean air	Primary (CCAD) Secondary (NAVSEA/MCLB)

Performance Criteria	Description	Primary or Secondary
	solvent.	
	Hazardous Air Pollutants (HAPs) – Shall be HAP-free.	Primary
	ODC – Shall not be an ODC.	Primary
	Global Warming Compounds – Shall not be a GWC.	Primary (CCAD) Secondary (NAVSEA/MCLB)
Chemical Properties	**Nonvolatile Residue** – Shall not have a nonvolatile residue greater than 2.5 mg/100mL.	Secondary
	Appearance – Shall be clear and free from suspended matter and undissolved water when observed at ambient conditions.	Secondary
	Viscosity – Criteria shall be established based on baseline testing.	Secondary (NAVSEA)
	Flash Point – Shall meet safety standards for given application.	Secondary (NAVSEA)
Performance - Surface Cleaning	**Soil Cleaning per MIL-PRF-680A –** Shall not have a relative solvency of less than 85 percent (MIL-PRF-680A).	Secondary
	Sealant Adhesion – Shall not cause the sealing compound to have minimum peel strength of less than 20 pounds force per inch (lb_f/in.) after a seven (7) day exposure in jet reference fluid. There shall also be 100 percent cohesive failure of the sealant during testing.	Secondary (CCAD)
	Paint Adhesion – Shall not cause the primer coating to peel away from the substrate from any test panels after immersion in de-ionized water for 24 hours.	Secondary (CCAD)
	Fluorescent Penetrant Inspection – Shall not impede the identification of known cracks and the intensity of the cracks should be brighter or equal to the control using	Secondary (CCAD)

Performance Criteria	Description	Primary or Secondary
	Fluorescent Penetration Inspection.	
	Water Break – Water break free for any surface cleaned with the manufacturer's suggested working concentration of the cleaning compound shall be greater than one (1) minute	Secondary (NAVSEA)
	Kauri Butanol Number – for reference only - $\geq$ 27 (Secondary Criteria)	Secondary (NAVSEA)
	Cleaning Efficiency – Shall meet or exceed the cleaning efficiency of the current cleaner.	Secondary (NAVSEA)
	Adhesive Bonding - Shall not cause lower percentage of bondline cohesive failure compared to the baseline surface cleaner or solvent.	Secondary (CCAD)
Performance – Surface Effects	**Effects on Painted Surfaces** - Shall not cause streaking, discoloration, blistering or a permanent decrease in film hardness of more than one (1) pencil hardness level on any painted surfaces.	Secondary
Performance - Storage	**Low Temperature Stability** – shall be such that the cleaning compound returns to its original homogeneous condition after exposure to extreme environments	Secondary
Materials Compatibility - Metals	**Total Immersion Corrosion** – Shall not cause any indication of staining, etching, pitting, or localized attack; nor shall weight change exceed allowable limits.	Secondary
Materials Compatibility – Plastics, Elastomers, Sealants	**Effects on Polysulfide Sealants** – Shall not change the durometer hardness (Shore A) of polysulfide sealants more than 5 units	Secondary
	Effects on Rubber - shall not change the tensile strength +/- 15%, elongation +/- 20% or Shore A hardness +/- 7 of the rubber material	Secondary
	Effects on Elastomers, Plastics, and Flourocarbons – Shall meet or exceed the	Primary (NAVSEA)

Performance Criteria	Description	Primary or Secondary
	performance of the current cleaner/solvent	
Hazardous Materials Reduction	The reduction in traditional solvent use will also reduce the amount of VOCs, and HAPs entering the environment.	Secondary
Process Waste	As with the current solvents used, the spent demonstration solvent may be contaminated with bearing cleaning agents, dissolved greases, oils, preservatives and contaminants. This process waste will be disposed of as hazardous waste through existing hazardous waste contracts.	Secondary
Reliability	The demonstration solvent must be chemically compatible with materials and chemicals that are part of the process during which the demonstration solvent is used. The demonstration solvent must be chemically compatible and perform effectively with all materials that are normally found in these processes.	Primary (CCAD)
Cost/Safety/ Environmental factors	The demonstration solvent must not require significant capital investment. Use of the demonstration solvent will not require additional manpower or additional skills. No adverse change in safety requirements or PPE	Primary (CCAD/MCLB) Primary (MCLB) Primary (CCAD/MCLB)
Ease of Use	The demonstration solvent must not significantly affect the process parameters. The demonstration solvent shall be chemically compatible with current equipment including current parts washers, recirculation pumps and seals, and filtration systems.	Primary (CCAD/MCLB) Primary (CCAD/MCLB)
Operation of Paint Equipment after Solvent Use	No adverse impact on the operation of the paint equipment after thinning operation No adverse effect on equipment operation; no decrease in equipment functionality or	Primary (MCLB) Primary (NAVSEA)

Performance Criteria	Description	Primary or Secondary
	operation for at least 96 hours after cleaning.	
Time Required to Thin	The time required to thin the paint formulation shall be ≤ the time required to thin using the current solvent	Primary (MCLB)
Versatility	The demonstration solvent is particularly suitable for non-attainment areas (VOC exempt or low VOC's).	Primary (CCAD)
Confirmed IARC carcinogen	Total quantity of chemicals in the solvent that are confirmed IARC carcinogens shall be less than 0.1%.	Primary (NAVSEA)
Probable IARC carcinogen	Total quantity of chemicals in the solvent that are probable IARC carcinogens shall be less than 0.1%.	Primary (NAVSEA)
Possible IARC carcinogen	Total quantity of chemicals in the solvent that are possible IARC carcinogens should be less than 0.1%.	Secondary (NAVSEA)
PEL	The OSHA PEL should be greater than 100 ppm.	Secondary (NAVSEA)
NAVSEA Target Chemical List prohibited chemical	Total quantity of chemicals in the solvent that are TCL prohibited chemicals shall be less than 0.1%.	Primary (NAVSEA)
Cleaning time	Time required to clean paint application equipment < current solvent cleaning time based on the determinations of the painter	Secondary (NAVSEA)
Quantity of solvent used	Quantity of solvent required in gallons< quantity of current solvent required in gallons f or a single cleaning operation	Primary (MCLB) Secondary (NAVSEA)
Quantity of Paint Removed	Quantity of paint removed > quantity removed with the current solvent for the same time period	Secondary (NAVSEA)
Applicable military standards for the performance of coatings	No adverse effect on coating applied after use of alternative cleaner according to the criteria in applicable military standards; the quality of applied paint shall be equal to or better than the quality of paint after the equipment is cleaned with the current solvent.	Primary (NAVSEA)
Effective cleaning of painted aircraft surfaces	Pass test ASTM F502-93 Part 7.3.1 Pass test ASTM F502-93 Part 7.3.2	Primary (CCAD) Primary (CCAD)
Drying time	Acceptable drying time without affecting production	Primary (CCAD)

Performance Criteria	Description	Primary or Secondary
	Drying time ≤ drying time with current solvent	Primary (MCLB)
Production time	Acceptable to production -	Primary (CCAD)
Odor Compatibility	Satisfactory odor per worker/observer survey	Primary (CCAD)
Time Required to Thin	Time required to thin the paint formulation with TBAC ≤ time required to thin using current solvent	Primary (MCLB)
Efficiency of meeting and maintaining viscosity requirements	Quantity of solvent required to obtain and maintain the required viscosity ≤ quantity required of current solvent	Primary (MCLB)

4.2 Performance Confirmation Methods

The objective of the proposed effort is to demonstrate the efficacy and validate the economic and process impact of TBAC solvent in DOD solvent applications as a replacement for HAP and VOC solvents. The implementation of HAP free environmentally friendly solvents for cleaning will reduce HAP and VOC emissions, improve worker health and safety and significantly reduce the record keeping burden associated with demonstrating compliance with the NESHAP regulations. The substitute solvent, TBAC, is expected to require minimal changes to equipment, operating procedures, or personnel protective equipment. In addition, the replacement solvent must perform as well or better than the current solvent.

To validate the suitability of TBAC as a replacement depends on the results of the environmental, occupational and safety and health, chemical properties, materials compatibility and performance tests, as well as the actual demonstration/validation of the TBAC product in the cleaning processes. All aspects of the demonstration must be satisfied in order to claim that the demonstration is a success. The overall success of the demonstration will be measured against these criteria. A Quality Assurance Plan (Appendix E) was developed to ensure that the data collected during this demonstration project is of sufficient quality to fulfill the project objectives.

In addition, testing was performed evaluating both the current and the alternative solvents. These data will be used to formulate an opinion as to the success of the demonstration portion of this effort.

Table 4-2 provides the expected performance, performance confirmation methods and performance results for the demonstration. More detailed laboratory test results are given in Appendices F, G and H.

Table 4-2. Expected and Actual Performance and Performance Confirmation Methods

Performance Criteria	Expected Performance (pre-demo)	Performance Confirmation Method	Actual Performance (post-demo)
PRIMARY CRITERIA (Performance Objectives – Quantitative)			
Environmental, Occupational Safety and Health	**Toxicity** –no adverse effect **Volatile Organic Compounds** – exempt **Hazardous Air Pollutants (HAPs)** – Shall be HAP-free.	Army – CHPPM Regulation 40-5 Exempt Definition – EPA List	Pass Pass Pass
Performance – Effective Cleaning of Painted Aircraft Surfaces	**Effects on Painted Surfaces -** Not cause streaking, discoloration, blistering or a permanent decrease in film hardness > 1 pencil hardness Topcoat Primer MIL-PRF-22750 MIL-PRF-23377 MIL-PRF-46168 Type IV MIL-PRF-23377 MIL-PRF-85285 Type I MIL-PRF-23377 MIL-P-14105 MIL-PRF-23377 MIL-DTL-64159 MIL-P-53022 MIL-C-53039 MIL-P-53022	ASTM F-502 ADS-61A-PRF	All Pass
Materials Compatibility – Plastics, Elastomers, Sealants	**Effects on Elastomers, Plastics, and Fluorocarbons** - Shall meet or exceed the performance of the current cleaner/solvent as defined by shall not change the tensile strength,	ASTM D-471 except sections 13 14 & 16	

Performance Criteria	Expected Performance (pre-demo)	Performance Confirmation Method	Actual Performance (post-demo)
	elongation, or hardness of the material more than the baseline cleaner/solvent <u>Materials</u> Delrin (ASTM D 6778) Polyethylene (ASTM D 1248) PTFE (ASTM D 3294) Viton (ASTM D 6909) Nylon (ASTM D 4066) Polypropylene (ASTM D 4101) Polyurethane (ASTM D 5476) Leather		 Pass Pass Pass Fail Pass Pass Pass Fail
Operation of paint equipment after cleaning	No adverse effect on equipment operation; no decrease in equipment functionality or operation for at least 96 hours after cleaning. No adverse impact on the operation of the paint equipment after thinning operation	Operating experience	Fail
Quantity of solvent used	Quantity of solvent required ≤ quantity of current solvent required for a single thinning operation	Process recordkeeping	Pass
Drying Time	Drying time ≤ drying time with current solvent	Process recordkeeping	Fail
Efficiency of meeting & maintaining viscosity	Quantity of solvent required to obtain the required viscosity ≤ quantity required of current solvent	Process recordkeeping	Pass
Time Required to Thin	Time required to thin ≤ time required to thin with	Process recordkeeping	Pass

Performance Criteria	Expected Performance (pre-demo)	Performance Confirmation Method	Actual Performance (post-demo)
	current solvent		
PRIMARY CRITERIA (Performance Objectives – Qualitative)			
Effectiveness	Perform comparable to the current solvent No adverse impact on process due to residue left on surfaces	Operating experience Operating experience	Pass & Fail Application dependent Pass & Fail Application dependent
Reliability	Chemically compatible with materials and chemicals that are part of the process	Visual inspection of components after processing	Pass (except Viton)
Ease of Use	Not significantly affect the process parameters. Chemically compatible with current equipment	Operating experience Maintenance record	Fail
Cost/Safety/ Environmental Factors	Does not require significant capital investment Does not require additional manpower or additional skills. No adverse change in safety requirements or PPE	Operating Experience Operating Experience Operating Experience	Pass
Versatility	Meet or exceed the current solvent product Suitable for non-attainment areas (VOC exempt).	Operating experience	Pass
Confirmed IARC carcinogen	Total quantity of chemicals in the solvent that are confirmed IARC carcinogens shall be less than 0.1%.	Source data or GC/MS	Pass

Performance Criteria	**Expected Performance (pre-demo)**	**Performance Confirmation Method**	**Actual Performance (post-demo)**
Probable IARC carcinogen	Total quantity of chemicals in the solvent that are probable IARC carcinogens shall be less than 0.1%.	Source data or GC/MS	Pass
NAVSEA Target Chemical List prohibited chemical	Total quantity of chemicals in the solvent that are NAVSEA TCL prohibited chemicals shall be less than 0.1%.	Source data or GC/MS	Pass
Applicable military standards for the performance of coatings	No adverse effect on coating applied after use of alternative cleaner according to the criteria in applicable military standards; the quality of applied paint shall be equal to or better than the quality of paint after the equipment is cleaned with the current solvent.	ADS-61A-PRF 4.5.19	Pass
Odor Compatibility	Odor is satisfactory to workers	Worker/observer survey	Pass & Fail Application dependent, relative to current cleaner
Drying Time	Drying time is acceptable and does not adversely affect production		Pass & Fail Application dependent
SECONDARY CRITERIA (Performance Objectives – Quantitative)			

Performance Criteria	Expected Performance (pre-demo)	Performance Confirmation Method	Actual Performance (post-demo)
Chemical Properties	**Nonvolatile Residue** – < 2.5 mg/100mL.	ASTM D 1353 (Procedure 2)	Pass
	Appearance –Clear/Free from suspended matter and undissolved water	Visual Inspection	Pass
	Viscosity – Criteria shall be established on baseline testing.	ASTM D445	0.7 cSt
	Flash Point – Shall exceed the flashpoint of the current solvent and meet safety standards for given application.	ASTM D-93	<39°C
Performance - Surface Cleaning	**Soil Cleaning per MIL-PRF-680A –**relative solvency ≥ baseline solvent	MIL-PRF-680A	96%
	Sealant Adhesion – minimum peel strength ≥ 20 lb_f/in & 100 percent cohesive failure	ADS-61A-PRF 4.5.17	
	MIL-P-23377		Pass
	MIL-P-85582		Fail
	Paint Adhesion –no primer coating peeling, MIL-C-85285 topcoat on all	ADS-61A-PRF 4.5.19	
	AL 2024 T3 bare(anodized per MIL-A-8625, Type I; w/ MIL-P-23377 primer		Pass
	AL 2024 T3 clad(conversion coated per MIL-C-5541, w/ MIL-P-23377 primer		Pass
	AL 2024 T3 bare(anodized		Fail

Performance Criteria	Expected Performance (pre-demo)	Performance Confirmation Method	Actual Performance (post-demo)
	per MIL-A-8625, Type I; w/ MIL-P-85582 primer AL 2024 T3 clad(conversion coated per MIL-C-5541, w/ MIL-P-85582 primer		Pass
	Fluorescent Penetrant Inspection – No negative impact on detection	ADS-61A-PRF 4.5.20	Pass
	Water Break – ≥ 1 min	ASTM-F22-02	Fail
	Kari Butanol Number – ≥ 27	ASTM D 1133	Pass
	Cleaning Efficiency – Meet or exceed cleaning efficiency of current cleaner	P-W-2891 Para 4.5.5	<20 seconds
	Adhesive Bonding – bond strength and cohesive failure ≥ baseline cleaner,	ADS-61A-PRF 4.5.18	Fail
Performance - Storage	**Temperature Stability** – original homogeneous condition after exposure to extreme environments.	Visual Inspection	Pass
Materials Compatibility - Metals	**Total Immersion Corrosion** – none Material Mg (AZ 31B-H24, SAE AMS 4377) Al (AMS-QQ-A-250/6 H321, 5083) Al (7075-T6) Ti (AMS 4911, 6AL-4V) Steel (AMS 5046, grade 1020)	ASTM F-483	All Pass

Performance Criteria	Expected Performance (pre-demo)	Performance Confirmation Method	Actual Performance (post-demo)
	Steel (4340) AM-355 CRT PH 13-8 Mo Maraging C-250 Zinc (ASTM B 852) Brass (ASTM B 121, C35600) Steel (ASTM A 36) Cadmium (A-A-51126) Al (2024-T3, QQ-A-250/4) Steel (1020, Cd plated, QQ-P-416) 304 Stainless steel (ASTM A 666) Chrome plated steel (ASTM A 263) Nickel plated steel (ASTM A 265) Zinc plated steel (ASTM A 153) Carbon steel (ASTM A 36) 4140 alloy steel (ASTM A 29) Al (6061, ASTM B 209)		
Materials Compatibility – Plastics, Elastomers, Sealants	**Effects on Polysulfide Sealants** – No change ± 5 Shore A units **Effects on Rubber** - no change: tensile strength > +/- 15%, elongation > +/- 20% or Shore A hardness > +/- 7 Rubber type 217/3B 3217/2B RW Compression 0149 compound 10 L compound P-12 compound 0235	ADS-61A-prf 4.5.13 ASTM D-471	Pass Fail Pass Pass Pass Pass Pass Pass

Performance Criteria	Expected Performance (pre-demo)	Performance Confirmation Method	Actual Performance (post-demo)
	14A compound 0135		Fail Fail
Possible IARC carcinogen	Total quantity of chemicals in the solvent that are possible IARC carcinogens should be less than 0.1%.	Source data or GC/MS	Pass
PEL	The OSHA PEL should be greater than 100 ppm.	Defined by OSHA	Pass
Quantity of Paint Removed	Quantity of paint removed ≥ quantity removed with the current solvent for the same time period	Lab analysis of solvents after cleaning	Pass
Cleaning time	Time required to clean paint application equipment ≤ current solvent cleaning time based on the determinations of the painter	Operating experience	Fail
Quantity of solvent used	Quantity of solvent required in gallons≤ quantity of current solvent required in gallons for a single cleaning operation	Process recordkeeping	Pass
SECONDARY CRITERIA (Performance Objectives – Qualitative)			
Hazardous Materials Reduction	Reduction in traditional solvent use	Process recordkeeping	Pass

4.3 Data Analysis, Interpretation and Evaluation

The Corpus Christi Army Depot, Norfolk Naval Shipyard, and USMC Maintenance Center Albany demonstration results and analyses are presented below. More complete analyses are given in Appendices F, G and H.

4.3.1 Corpus Christi Army Depot Demonstration

4.3.1.1 UH-60 Flight Controls Mixer Shaft

In each of three tests, TBAC performed satisfactory against all criteria except in two categories. After hand wiping the shaft with TBAC, visual inspection revealed a slight residue that required additional wiping with a dry cloth. The residue remaining after wiping the shaft with TBAC caused the wipe test to fail in meeting the performance criteria for "drying time" and "performance effectiveness". The results of these two categories should not be considered a show stopper for considering TBAC as an acceptable substitution in this application. TBAC was successful at removing all contaminants equal to the current solvent acetone. However, there would be an additional step required of wiping the shaft with a dry cloth in the current procedure to achieve an equal surface finish. The impact on production due to the low number of shafts processed per month and the short time required performing an extra wipe would be minimal.

4.3.1.2 UH-60 Aircraft Fuselage

In all of the tests for the tub and panels for removing grease, oil, dirt and lubricants, TBAC performed satisfactory against all criteria except in one category "odor compatibility". TBAC was noticed by the operator and observers to have a significantly stronger odor. In the tests to remove adhesive residue, TBAC did not perform satisfactory in the category "effectiveness". TBAC caused the adhesive residue to swell and become gummy but would not completely dissolve the adhesive residue. Toluene performed more effectively at removing adhesive residue. The effectiveness of TBAC at removing grease, oil, dirt and lubricants in all tests suggests TBAC will be effective as a general degreasing solvent. The removal of adhesive residue will eventually be a non-factor through the use of the newer silicone adhesive tapes being specified for use in installing floor boards that can be removed without any solvents.

4.3.2 Norfolk Naval Shipyard Demonstration

4.3.2.1 Solvent Cleaning Effectiveness

Bench scale tests and field demonstration tests were performed to evaluate cleaning effectiveness of TBAC on commonly used paints. There was a difference between the lab bench test and the demonstration test cleaning test results. The lab bench-scale tests indicate that TBAC may be almost as effective as the baseline T-10 Thinner for cleaning Intergard 264 and Amercoat 235 from test coupons. The lab cleaning tests also indicate that TBAC may take a little longer than the baseline cleaner to clean the paints from those coupons. TBAC cleans Intergard 264 more effectively then it cleans Amercoat 235. Standardized, controlled, and repeatable lab tests provide good evidence that TBAC may be used to effectively and efficiently clean Amercoat 235 and Intergard 264 from coupons.

Demonstration tests generally indicate that TBAC is not as effective as the baseline cleaner for cleaning Amercoat 235 and Intergard 264 from paint spray pumps. The painter observed that neither TBAC nor the baseline cleaned Intergard 264 when five gallon quantities of the solvents

were used. In addition, TBAC cleans Amercoat 235 more effectively than it cleans Intergard 264. Finally, the painter observed that TBAC took longer then the baseline cleaner to clean Amercoat 235 from spray paint equipment. However, it was concluded in Reference 5 in Appendix that if TBAC was used in the Standard Shop Practice for Cleaning Paint Equipment (5 gallons recirculated) it would adequately clean Amercoat 235 from the spray paint equipment.

The differences in test results between the laboratory bench test and the D/V test indicates that laboratory testing may or may not be a good representation of the cleaning environment of a closed paint gun system in the field. This reinforces the importance of field demonstrations and indicates that future evaluations need to be careful about using lab testing only to qualify a cleaner for this application.

Generally, the cleaning effectiveness conclusions are:

- TBAC may be used to clean Amercoat 235 from spray paint equipment. However, TBAC may take a little longer than the baseline cleaner to clean that paint from the spray paint equipment. It is not possible to accurately determine the additional time that would be required to clean equipment with TBAC in actual operations due to differences between the lab tests, D/V tests, and actual cleaning operations.
- Based on the differing results between lab bench tests and demonstration tests, it is uncertain whether TBAC would adequately and effectively clean Intergard 264 from spray paint equipment. However, the baseline cleaner did not adequately clean Intergard 264 in demonstration tests either.

4.3.2.2 Solvent Affect on Paint Performance

It is important to determine whether the alternative solvent TBAC has any impact on the performance of paints. The use of TBAC may affect the performance of paints if significant quantities are mixed with paints before the paints are applied. Affects on the performance of paints may occur after spray paint equipment has been cleaned and when the first portion of a batch of paint is applied. It is unlikely that the performance of paints will be affected as a batch of paint is applied and the concentrations of residual solvents in the spray paint equipment decrease.

Paint adhesion tests were conducted on 26 September 2007 as part of the demonstration tests to evaluate the affect of TBAC and the baseline T-10 Thinner and on the performance of the two-part epoxy paints. The spray paint equipment was cleaned with the test solvents. The solvents then were discharged from the equipment as the test paints were drawn into the equipment. The test paints then were applied to primed test coupons. One test coupon was used for each paint/solvent cleaning test cycle. The FED-STD-141 Test Method No. 6301 “Adhesion (Wet) Tape Test” was used to evaluate the performance of the tested paints.

The paint adhesion test results indicate that there is no detrimental affect on paint performance due to the use of either TBAC or the baseline solvent. The failure of the primer in the C2/TBAC/Intergard 264 test is attributed to the failure of the primer that was used for the test coupon.

4.3.2.3 Solvent Compatibility with Equipment

Solvent compatibility with paint spray pumps was evaluated in lab tests and in field demonstration tests. Lab tests on solvent compatibility evaluated the affects of TBAC and the baseline T-10 Thinner on metallic and on non-metallic constituents in paint spray pumps. Overall results are:

Great care should be used to minimize or prevent contact of TBAC or the baseline T-10 Thinner with Viton®. Reference 4 in Appendix G states that Viton® should not come into contact with TBAC. The effects of the baseline T-10 Thinner on Viton® are reported to be less than the effects of TBAC.

- TBAC may be used with PTFE and T-10 Thinner should perform adequately. Reference 4 states that TBAC had no adverse reactions on Teflon®.
- TBAC performed better than the baseline T-10 Thinner on all tests for compatibility with polyurethane.

TBAC performed better on polypropylene than the baseline T-10 Thinner on all but the Tensile Strength at Break Point test.
TBAC is better than the baseline T-10 Thinner on its effects on Nylon. Laboratory compatibility tests indicated TBAC should not cause equipment problems with its use. T-10 Thinner did not cause adverse effects on the materials tested and should not affect equipment with continued use.

- Leather that is used as a packing material should perform at least as well with TBAC as it does with the baseline T-10 Thinner.

TBAC is better than the baseline T-10 Thinner with polyethylene.
TBAC is better than the baseline T-10 Thinner with Delrin (acetal). There was no definite corrosion for any of the tested metals with TBAC or the baseline T-10 Thinner. The TBAC may be used in the paint application pumps without corrosion consequences.
There were no reported detrimental affects on the materials used in the paint application spray pump.
The laboratory test results and to a lesser extent demonstration test results indicates that TBAC meets or exceeds the baseline performance of T-10 Thinner for compatibility with paint spray pumps.

4.3.3 USMC Maintenance Center Albany Demonstration

Testing was conducted at the Marine Corps Logistics Base Albany, GA, Paint Booth No. SC-9

One Amphibious Assault Vehicle (AAV) hull constructed of 5083 and 5086 aluminum was used for the demonstration. The AAV hull had been depainted and blasted with Almondite garnett. Oxidation was removed with Chemetal Oakite Gard acid. The hull was prepared prior to the application of the primer coat by the application of an ordnance wash primer process (DoD-P-15328D, Type I).

The wash primer was mixed in accordance with the technical data sheet and was applied using conventional application equipment.

The AAV hull was coated using MIL-P-53022, Type II as the primer. The mix concentration was in accordance with tech data sheet. The unit was set to provide mix ratio:1/2 cup of TBAc

Thinner per quart of primer. No induction time was required due to static mix tube capability of fluidics machines.

The viscosity was sampled three times using a No. 4 Ford Cup and the measurements were averaged to 26.1.

The primer was applied at a rate of 4-5 mils wet with conventional guns from plural mixing equipment using .055 needles (JGA 510 DeVilbus). At the completion of primer application the vehicle was delivered to the oven for the drying cycle at 130° F.

Upon completion of painting operations the application equipment is normally flushed through the lines to the guns with T-10. The catalyst side pump is flushed exclusively with xylene. For this test TBAC was used for both due to the tendency for catalyst to crystallize if it comes into contact with water (T-10 has hydroscopic properties). TBAC was chosen due for its non-hydroscopic nature. The TBAC performance described by the painters was not as effective as the xylene that is normally used on the catalyst side. The TBAC left a noted residue.

During external cleaning of the guns, a difference in solvency (90% of T-10 usage is for cleanup) was observed. The TBAC tended to gel and coagulate more than the T-10. This could ultimately result in clogged equipment, advanced failure rates, and increased maintenance requirements.

TBAC had a slightly higher viscosity compared with an equal amount of thinner. Painters preferred application with TBAC and commented that it had improved flow characteristics. The paint (primer) was inspected numerous times and there is no visible indication there is an issue with compatibility. for either thinner

The painters acknowledged that the TBAC (when used as an alternative thinner to T-10) seemed to have improved flow characteristics. Painters commented that the TBAC was smoother and “layed” down better with a better stand-off distance but also commented that the TBAC had a stronger odor.

T-10 thinner is not used in topcoat application with the exception of clean-up. No comparison testing was conducted in this phase of paint application between T-10 and TBAC.

The general consensus from the painters is that the TBAC actually performed as good or better as a paint thinner. Application seemed to be slightly improved and the vehicle seemed to dry quicker.

Cleaning and flushing operations constitute approximately 90% of our T-10 and xylene usage totals. As with the results identified in Phase I, the TBAC did not seem to have the same solvency effect as the T-10(or the xylene). It tended to gel and coagulate and gummed up the plural paint equipment resulting in extended efforts to flush and clean the equipment. This equipment is very sensitive to gelling and hardening and can result in significant down time. This would result in the depot incurring additional maintenance and replacement costs.

As a result of the Phase I and Phase II testing the maintenance center is unlikely to utilize TBAC as an alternative to either T-10 thinner or xylene.

5. Cost Assessment

5.1 Cost Reporting

TBAC, a HAP-Free and VOC exempt solvent, can enable the DoD to demonstrate compliance with NESHAP and VOC regulations without performing the extensive record keeping. The cost of compliance with the NESHAP record-keeping requirement varies across the DoD; however, the estimated annualized compliance costs in the Army are $75M for the DLSME NESHAP alone. Based on current usage data, 45% of the Army's HAP emissions are from solvent usage. This project will use cost benefit analysis to estimate the economic benefit of the implementation of TBAC as hand wipe solvent.

The applications being investigated for this demonstration will utilize TBAC as a drop in replacement for existing products. The only cost associated with implementation would be the difference in solvent costs and any necessary replacement of pump seals and filtration system seals and elements for product compatibility (this requirement depends on materials compatibility tests results). Complete and accurate records will be kept of all costs associated with the conversion from the current solvent to the proposed TBAC product.

<u>TBAC failed several CCAD requirements and was not as good as currently used acetone. The testing at USMC Albany showed a compatibility problem with the paint gun components. As a result, only the Norfolk Naval Shipyard may replace its currently used T-10 thinner with TBAC. Accordingly, the cost analysis will be specific to this likely use.</u>

5.2 Cost Analysis

Basic cost information was gathered to support the evaluation of potential alternative solvents. The operating costs for TBAC and the baseline T-10 Thinner are expected to be similar because they will be used in a similar way. There may be some differences in operations due to variations in effectiveness of the solvents, but these differences are not expected to have a significant impact on the operating costs. Also, it is assumed that the waste disposal costs are similar for all of the potential alternative solvents.

5.2.1 Operating Costs

The cost of cleaning paint application pumps with T-10 Thinner at NNSY was evaluated to obtain a baseline annual cost for equipment cleaning operations.

5.2.1.1 T-10 Thinner Annual Operating Cost

<u>Material Cost</u>

The average annual T-10 Thinner cost is based on 3518 gallons of solvent used per year.

- Cost of T-10 Thinner based on 5 gal quantity: $10.52/gal

- Annual cost of solvent: 3518 gal*($10.52/gal) = $37,000

The cost for a gallon of T-10 Thinner was found to be $10.52/gallon in 2007 when it was purchased for demonstration tests at NNSY. The quantity of T-10 Thinner used per year was determined by a site visit and investigation at NNSY in May 2005.

Labor Costs

The total elapsed time to complete the Standard Shop Practice for Cleaning spray paint equipment one time is 20 minutes. The labor cost per hour was reported to be $76.98 in Reference 6 in Appendix G, *T-10 Thinner Replacement Project, Mid-Project Status Report* dated 12/30/05.
Assuming a 5.0% annual rate for inflation, the labor cost per hour is $80.80 at the end of 2006.
Therefore, the annual labor cost may be calculated as follows.

- Number of annual cleaning events: (3518 gal/year)/(5 gal/event) = 703.6 events/year
- Annual labor hours: 704 events/year*(1/3 man-hours/event) = 235 hours/year
- Annual labor costs: 235 hrs/yr*$80.80/hr = $19,000/year

Cost of Waste Disposal
The annual cost of waste solvent disposal is based on the assumption that all used T-10 Thinner is sent to a disposal facility. The average annual quantity of T-10 Thinner that is sent to disposal is 3518 gal. The disposal costs for a gallon of waste were reported to be $3.05 in Reference 6. Assuming a 5.0% annual rate for inflation, the disposal cost is $3.20 at the end of 2006.

- Cost of waste disposal: 3518 gal*$3.20= $11,300

Recycling Cost

See Section 5.2.2 on Cost Benefits of Recycling below.

Environmental/OSH Costs

There are costs associated with environmental compliance and health and safety compliance. Environmental costs include the cost for preparing and maintaining required permits. Health and safety costs include the costs for the HAZCOM Program, the safety program, and the workman's comp program. These costs could not be determined in the facility investigations that took place in 2005. A more detailed investigation is necessary to determine these costs.

PPE Equipment

There are costs associated with protecting workers from potential detrimental affects of the chemicals and the affects of operations. Costs for basic protective equipment are listed below.

Respirator: $19.95 each x 1/yr = $19.95
Vapor cartridge: $14.95 each x 1/5 events x 704 events/yr = $2100.

Tyvek Suit: $9.95 each x 1/5 events x 704 events/yr = $1400.
Protective Sleeve: $2.95 each x 1/event x 704 events/yr = $2100.
Nitrile Gloves: $3.95/pair x 1 pair/event x 704 events/yr = $2780.
Ear Muffs: $29.95 each x 1/year = $29.95
Ear Plugs: .99/pr x 1 pair/5 events x 704 events/yr = $140.
Goggles: $3.95 each x 1/year = $3.95
Spray Sock: $3.95 each x 1/event x 704 events/yr = $2780.
Wipes: $55.39/box of 15 x 4/event x 704 events/yr = $10,400
Total PPE Cost = $21,800.

Total annual cost for operations that use T-10 Thinner: $37,000 + $19,000 + $11,300 + $21,800 = $89,100

5.2.1.2 TBAC Cost

Material Cost: The cost for TBAC is $9.59/gal when purchased in 55 gal quantities. It is expected that this solvent is recyclable by distillation and that recycling should significantly mitigate the product cost.

Labor Costs:

- Based on D/V test results, labor costs may be a little higher for cleaning operations that use TBAC for removing Amercoat 235.
- Based on the D/V Test results, labor costs could be significantly higher for cleaning operations that use TBAC to remove Intergard 264.
- Based on laboratory bench test results, there would be no additional labor costs for cleaning operations that use TBAC to clean Intergard 264.
- Based on laboratory bench test results, labor costs would be up to 33% higher for cleaning operations that use TBAC to clean Amercoat 235.
- The time presently needed to clean the spray paint equipment using T-10 Thinner is 20 minutes.
- Assuming 5 gallons of solvent used per cleaning operation and an average annual NNSY usage of 3518 gal (Reference 6 in Appendix G) then there are an average 704 cleaning operations per year at NNSY.
- For all the D/V cleaning tests TBAC averaged 11.8% less effective at cleaning Amercoat 235 or an increase of cleaning time of 2.4 minutes. This would be a cost of $3.20 per cleaning operation for an average annual cost increase of $2253 or approximately 28 hours of labor.
- Using a worst case D/V Time Paint Removal Efficiency of 32.6 less effective, this would be an increased cleaning time of 6.6 minutes. This would be a cost of $ 8.83 per cleaning operation for an average annual cost increase of $6216 or approximately 77 hours of labor.
- Using D/V data it is estimated that using TBAC will increase labor costs between $2300 and $6200 per year when cleaning Amercoat 235. Labor costs would be considerably higher for cleaning Intergard 264.

- Using Lab bench test data it is estimated that using TBAC will increase labor costs between $2750 and $4950 using TBAC to clean Intergard 264. However, there would be no increase labor costs when using TBAC to clean Amercoat 235.
- Overall, the cost increase for using TBAC to clean Intergard 264 and Amercoat 235 from the spray paint equipment is estimated to range between $0 and $6200 per year.
- D/V test cleaning times will always be more accurate because many variables are not accounted for in lab tests. Lab testing only accounts for the interaction between the cleaner and the soil not the impact of the cleaning process/environment (in this case a closed system under pressure), therefore, additional operational tests are recommended to obtain a more accurate basis for the increased labor costs for using TBAC.

Disposal Costs: The used TBAC would be classified as a hazardous waste due to the flashpoint of about 40F and due to the hazardous constituents in paints that are cleaned. Therefore the disposal costs remain the same as for the baseline T-10 Thinner.

Recycling Cost: See Section 5.2.2 on Cost Benefits of Recycling below.

ESH Costs: The environmental and safety costs are expected to be similar to the costs for the baseline T-10 Thinner. However, there is a potential cost savings because TBAC is a VOC exempt and HAP free solvent and there would be less reporting requirements.

PPE Costs: Both Amercoat 235 and Intergard 264 require full PPE Protection. Therefore, regardless of the solvent used to clean the equipment, there will be paint contained in that solvent and the paint MSDS is the overarching requirement. Therefore, the PPE is the same for both TBAC and T-10 Thinner.

5.2.2 Cost Benefits of Recycling

Recycling provides an opportunity to significantly reduce the cost of cleaning spray paint equipment. Significant cost reductions are possible due to reduced quantities of purchased solvents, and due to reduced quantities of waste solvents that require disposal. There are two recycling methods that may be used to recycle the solvents. The first method is distillation and the second method is settling/filtration. Distillation is probably most appropriate for certain types of solvents. Solvents that are good at dissolving epoxy resins, and solvents with a single ingredient or with ingredients that have similar boiling points are expected to be good candidates for distillation recycling. Also, solvents that are good at dissolving epoxy resins are good candidates for distillation recycling because the dissolved resins would remain suspended in solution for long periods of time and this would reduce the effectiveness of the settling/filtration recycling method.

TBAC is expected to be a good candidate for recycling by distillation because it is composed of a single ingredient and because dissolved paints are expected to remain in solution. It is advantageous to use a single ingredient solvent when there is the potential to lose some of the solvent due to evaporation or due to chemical reaction with the material being cleaned over time. The loss of one or more ingredients in larger proportions than the other ingredients would change the composition of a solvent over time and could affect the effectiveness of a solvent.

The process for recycling T-10 Thinner is expected to be similar to the distillation process that would be used to recycle TBAC. However, T-10 Thinner is expected to be more difficult to recycle than TBAC. T-10 Thinner is a multi-component solvent and the percentages of the different components are important to the performance of the solvent. Recycling this solvent may change the composition of the solvent due to reactions of the solvent ingredients with the paints, or due to evaporation of the more volatile components in the solvent. A change in the composition of T-10 Thinner is expected to affect the performance of this solvent; therefore, there may be difficulties in recycling this solvent.

5.2.3 Cost Analysis Results

Generally, product costs may be a significant part of the cost associated with cleaning spray paint equipment. The differences in product costs could result in significant differences in the costs of using the solvents over time. However, the resolution of several uncertainties could significantly alter this possibility. The most significant uncertainties are the ability to recycle TBAC and the labor associated with TBAC. These uncertainties could make the differences in product costs less significant.

There is the potential for significant cost savings over time if TBAC is recycled. Additional evaluation is required to determine the costs and benefits of recycling TBAC.

Material Costs: There is negligible difference in material costs between T-10 Thinner and TBAC.

Labor Costs*:* Overall, the cost increase for using TBAC to clean Intergard 264 and Amercoat 235 from the spray paint equipment is estimated to range between $0 and $4950 per year. Operational tests are recommended to obtain a more accurate basis for the increased labor costs for TBAC.

Disposal Costs: There are negligible cost differences between T-10 Thinner waste and TBAC waste.

ESH Costs: There would be less reporting requirements with TBAC then with T-10 Thinner, therefore the ESH costs would be less. However, it is difficult to accurately determine the magnitude those costs accurately.

Recycling Costs: TBAC may be easier to recycle then T-10 Thinner; therefore, the recycling costs may be lower. More than likely the same equipment would be used to recycle either solvent. The cost driver would then be the heat of vaporization, which would determine energy costs. However, there is no data on this. Additional evaluation is required to determine the actual cost benefit of recycling.

PPE Costs: PPE costs would be the same whether using T-10 Thinner or TBAC.

Total Costs: Material, disposal, and PPE costs are considered to be a wash. Therefore the total cost difference between using T-10 Thinner and TBAC would be dependent on the magnitude of

ESH cost savings when compared to possible operations labor increases, and the savings of recycling TBAC. These numbers are unavailable at the time of this report.

TBAC is evaluated as a drop in replacement and as a result there are no costs for installation of new equipment or modification of existing equipment. The use of TBAC is similar to the current cleaners so there is no reduction in man hours associated with the switch to TBAC. The qualification of a HAP free solvent will reduce overall costs primarily by reducing the projected regulatory compliance burden. New National Emission Standards for Hazardous Air Pollutants (NESHAP) usage tracking requirements will also significantly increase costs for regulated solvents. These costs can be avoided if a suitable HAP free solvent such as TBAC can be qualified.

T-10 thinner is a petroleum-derived and subject to continuing changes in the price of petroleum. In general, its cost will rise and fall with the worldwide cost of oil, refining markup and any supply/demand imbalances. The VOC exemption of TBAC is a recent development and the market is still under development. As the market expands and demand increases it is reasonable to assume that the per-unit-cost of the TBAC will decrease.

In summary, substitution of the TBAC for existing HAP and VOC products can be accomplished for the cost difference between the two products. To continue to use the current product will require installation of new vapor recovery and destruction equipment, with their associated operating and maintenance expenses, and new increased administration costs associated with NESHAP solvent usage reporting requirements.

6.0 Implementation Issues

6.1 Environmental Checklist

For these demonstrations, all cleaning was performed on the current cleaning line using the current solvent or the TBAC product. No additional operating permits were required for the performance period of the demonstration. At the conclusion of the demonstration, the on site environmental compliance procedures was used to manage the disposal of spent and unused TBAC product and any associated waste through existing hazardous waste contracts.

6.2 Other Regulatory Issues

Full-scale application of the technology demonstrated by this project does not require compliance with any additional regulations or procedures. Relevant demonstration results will be made available to the local environmental offices and the responsible weapon system managers. Demonstration results will also be included in the Joint Service Solvent Substitution Tracking System.

6.3 End-User/Original Equipment Manufacturer (OEM) Issues

A joint group led by the Army Research Lab (ARL) and the JS3WG and consisting of technical representatives from Naval Facilities Engineering Service Center (NFESC), Naval Facilities Engineering Command, Naval Air Systems Command (NAVAIR), U.S. Army Aberdeen Test Center, U.S. Army Tank Automotive Research, Development, and Engineering Center, Defense Logistics Agency (DLA), U.S. Army Aviation and Missile Command, Air Force Materials Command, MCLB Maintenance Center Albany and the NASA AP2 Office identified engineering performance and testing requirements for cleaning applications. The group represents a broad cross section of materiel developers, weapon system managers, R&D engineers and end users. This group reached consensus on test conditions and acceptance criteria to qualify alternatives against these critical technical and performance requirements. All of the efforts of this group have been coordinated with the extended membership of the JS3WG to ensure maximum participation and buy-in.

To reach potential DoD interested parties, ARL will present project results at the annual Cleaner, Safer Industrial Materials and Processes (CSIMP) Workshop, the Joint Service Environmental Management Conference (JSEM) and at other applicable conferences and in various DoD publications. ARL and NFESC will coordinate to utilize established mechanisms in place for supporting the transition of technologies to other DoD customers. These products include the preparation of environmental quality initiative fact sheets, the JS3 Database, Currents Magazine articles, Pollution Prevention Technical Library data sheets, tri-folds, user data packages, technical reports, technology implementation plans and a point of contact (POC) list of potential customers. Demonstration results will also be posted on the Defense Environmental Network & Information Exchange (DENIX). Potential non-DoD interests will be informed of the results of the project by submitting articles for publication in applicable trade publications and technical journals. Based on results of this demonstration, efforts may be made to identify potential technology-transfer candidates, both at government owned/contractor operated (GOCO) facilities and at facilities owned and operated by contractors doing work for DoD.

7.0 References

Military Standard – MIL-PRF-680A, “Performance Specification – Degreasing Solvent” dated 25 July 2003.
Military Standard – MIL-T-81772B, “Military Specification – Thinner, Aircraft Coating” dated 29 January 1986.
Military Standard – ADS-61A-PRF, “Aeronautical Design Standard Performance Specification for Army Aircraft Cleaners, Aqueous and Solvent”, dated 4 Feb 2002.
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Aircraft Maintenance Chemical Testing of TBAC. Lyondell Chemical Data Sheet, http://www.lyondell.com/html/products/techlit/2686.pdf
CCAD Laboratory Report 200500601 - Solvent Performance Test Evaluation of Alternative hand-Wipe Solvents
James E. Foreman, Raytheon Systems Company, “Tertiary Butyl Acetate: A Potential VOC Exempt Solvent for Hand Wipe Cleaning and Coatings Applications presented at Solvent Substitution Workshop”, September 1999
El Sayed Arafat, NAVAIR 4.9.7.2, “Alternative Substitution for P-D-680”, presented W2210 Pollution Abatement Ashore Program IPR, July 2005
Lyondell Chemical Presentation: http://www.lyondell.com/html/products/techlit/2992.pdf
Lyondell Chemical Presentation: http://www.lyondell.com/html/products/techlit/3007.pdf

8.0 Points of Contact

POINT OF CONTACT Name	ORGANIZATION Name Address	Phone/Fax/email	Role in Project
Wayne Ziegler	ARL Attn: AMSRL-RD-WM-MC APG, MD 21005-5069	(410) 306-0746 (voice) (410) 306-0829 wziegler@arl.army.mil	Principle Investigator
Tom Torres	NFESC 1100 23rd Avenue Port Hueneme, CA 93043-4370	(805) 982-1658 (voice) (805) 982-4832 (fax) tom.torres@navy.mil	Co-Principle Investigator
Greg Russell	Maintenance Directorate, Code L216 814 Radford Blvd., Suite 20329 Albany, GA 31707-0329	(229) 639-8072 gregory.russell.ctr@usmc.mil	Marine Corp Site Programmatic POC
Steve Allen	Maintenance Directorate, Code L216 814 Radford Blvd., Suite 20329 Albany, GA 31707-0329	(229) 639-6380 steven.allen@usmc.mil	Marine Corp Site Technical POC
Scott Howison	U.S. Army AMCOM G-4 (Logistics) Environmental Division AMSAM-EN-EV Building 111 Redstone Arsenal, AL 35898	Ph: (256) 876-6129 Fax: (256) 955-0749 Email: stephen.howison@redstone.army.mil	CCAD Site Programmatic POC
David Solis	U.S. Army AMCOM G-4 CCAD	361-961-2000 ext 408 david.solis3@us.army.mil	CCAD Site Technical POC

El Sayed Arafat	NAVAIR Materials Engineering Division 48066 Shaw Rd., Bldg. 2188 Patuxent River, MD 20670	301-342-8054 elsayed.Arafat@navy.mil	Technical POC
Ben Zlateff	NAVSEA 04RE (BAE Systems)	360 /396-7089 ZlateffBJ@kpt.nuwc.navy.mil	NAVSEA Technical/Programmatic POC
Tom Cook	NAVSEA 04RE	401/832-5853 CookTL@npt.nuwc.navy.mil	NAVSEA Programmatic POC
William Taylor	Attn:CSTE-DTC-AT-WC-M APG, MD 21005-5059	410-278-4461 whtaylor@atc.army.mil	Laboratory Testing
Matt Rothgeb	NASA AP2 Office Headquarters Bldg, Room 3481 Kennedy Space Center, FL 32899	321-867-8476 matthew.rothgeb-1@ksc.nasa.gov	NASA Liaison
Elizabeth Berman	Air Force Research Lab Pollution Prevention Team WPAFB, Ohio	(937) 656-5700 Elizabeth.Berman@wpafb.af.mil	AF Liaison
Dan Pourreau	Lyondell Chemical Co 3801 West Chester Pike Newtown Square, PA 19073-2387	610-359-6837 dan.pourreau@lyondell.com	

Appendix A Material Safety Data Sheet

LYONDELL

Material Safety Data Sheet

MSDS No.:	BE2458
Variant:	U.S.A.-EN
Version No:	1.6
Validation Date:	02/02/2005

TERT BUTYL ACETATE

SECTION 1: IDENTIFICATION

Product Name: TERT BUTYL ACETATE

Product Number: 000000000000499244

Internal ID: 353

Chemical Family: Organic Ester

CAS Number: 540-88-5

Chemical Name: Tert Butyl Acetate

Synonyms: Tertiary butyl Acetate; Acetic Acid, 1,1-Dimethylethyl ester; Acetic acid, tert-Butyl ester

Manufacturer
Lyondell Chemical Company
One Houston Center, Suite 700
1221 McKinney St.
P.O. Box 2583
Houston Texas 77252-2583

Business Contact
Customer Service 888 777-0232
Product Safety 800 700-0946

24 Hour Emergency Contact
CHEMTREC 800 424-9300
LYONDELL 800-245-4532

SECTION 2 : COMPOSITION/INFORMATION ON INGREDIENTS

Component Name	CAS #	EU Inventory	Concentration Wt.%*		Risk	Symbol
Tert-Butyl Acetate	540-88-5	208-760-7	99.5	<= 100.0	R11, R66	F
tert-Butyl Alcohol	75-65-0	200-889-7		<= 0.5	R11, R20	F, Xn

* Concentration of gaseous products or materials is given in Mole %

Compositions given are typical values not specifications.

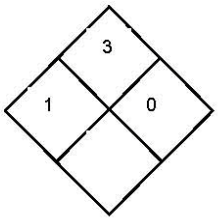
SECTION 3: HAZARD IDENTIFICATION

Emergency Overview
This material is HAZARDOUS by OSHA Hazard Communication definition.

Signal Word
WARNING.

Hazards
Skin irritant - defatting action. Eye irritant. CNS depressant. Highly flammable.

NFPA®



HMIS®

Health	1
Flammability	3
Reactivity	0

Physical State
Liquid.

Color
Clear, colorless.

Odor
Sweet odor.

Odor Threshold
No value available.

Potential Health Effects

Routes of Exposure
Inhalation Eye Skin.

Signs and Symptoms of Acute Exposure
See component summary.

- *Tert-Butyl Acetate 540-88-5*

Skin irritant. Slight eye irritant. Respiratory tract irritant. CNS depressant.

- *tert-Butyl Alcohol 75-65-0*

Moderate to severe eye irritant. Mildly irritating to the skin but not a skin sensitizer. Breathing mist or vapors may cause mucous membrane or upper respiratory tract irritation. Overexposure may cause coughing, shortness of breath, dizziness, central nervous system depression, intoxication and collapse. Ingestion would likely cause gastrointestinal tract irritation. May produce symptoms of nervous system depression including headache, dizziness, nausea, loss of sense of balance, drowsiness, and visual disturbances.

Skin
Contact may cause mild skin irritation. Repeated or prolonged skin contact may result in allergic dermatitis. No significant signs or symptoms indicative of any health hazard are expected to occur as a result of skin absorption exposure.

Inhalation
Not expected to present a significant inhalation hazard under anticipated conditions of normal use.

Eye
May cause minor eye irritation.

Ingestion
Not a likely route of exposure. Low toxicity. Not expected to be an ingestion hazard. May cause nausea.

Chronic Health Effects

See component summary.

- *Tert-Butyl Acetate 540-88-5*

No appropriate human or animal data are available on the chronic health effects from prolonged or repeated exposure to this material.

- *tert-Butyl Alcohol 75-65-0*

Prolonged or repeated breathing of high concentrations may cause symptoms of central nervous system depression. May cause dermatitis by defatting the skin from prolonged or repeated contact. This material has been shown to induce tumors in laboratory animals. These findings are not likely relevant to humans. May be toxic to the developing embryo and fetus.

Conditions Aggravated by Exposure
This material or its emissions may affect the central nervous system (CNS) and/or aggravate pre-existing CNS disorders. Skin contact may aggravate an existing dermatitis. This material or its emissions may aggravate pre-existing eye disease.

SECTION 4: FIRST AID MEASURES

General
After adequate first aid, no further treatment is required unless symptoms reappear.

Skin
Remove contaminated clothing as needed. Wash skin thoroughly with mild soap and water. Flush with lukewarm water for 15 minutes. If sticky, use waterless cleaner first. Seek medical attention if ill effect or irritation develops.

Inhalation
If overcome by exposure, remove victim to fresh air immediately. Give oxygen or artificial respiration as needed. Call a physician.

Eye
Thoroughly flush the eyes with large amounts of clean low-pressure water for at least 15 minutes, occasionally lifting the upper and lower eyelids. If irritation persists, seek medical attention.

Ingestion
If large quantity swallowed, give lukewarm water (pint/ 1/2 litre) if victim completely conscious/alert. Do not induce vomiting. Risk of damage to lungs exceeds poisoning risk. Obtain emergency medical attention.

Note to Physician
Treat symptomatically. Treatment of overexposure should be directed at the control of symptoms and the clinical condition of the patient.

SECTION 5: FIRE FIGHTING MEASURES

Flammable Properties

Classification
OSHA/NFPA Class IB Flammable Liquid.

Flash Point:
~ 4.4 °C (39.92 °F) (Closed Cup)

Auto-Ignition Temperature
~ 517.8 °C (964.04 °F)

Lower Flammable Limit
~ 1.26 vol%

Upper Flammable Limit

~ 6.88 vol%

Extinguishing Media

Suitable: SMALL FIRE: Use dry chemicals, CO2, water spray or alcohol-resistant foam. LARGE FIRE: Use water spray, water fog or alcohol-resistant foam.

Unsuitable: Do not use solid water stream/may spread fire.

Protection of Firefighters

Protective Equipment/Clothing: Wear positive pressure self-contained breathing apparatus (SCBA). Structural firefighters protective clothing will only provide limited protection.

Fire Fighting Guidance: Releases flammable vapors below normal ambient temperatures. When mixed with air and exposed to ignition source, vapors can burn in open or explode if confined. Flammable vapors may be heavier than air and travel long distances along the ground before igniting and flashing back to vapor source. Move containers from fire area if you can do it without risk. Fight fire from maximum distance or use unmanned hose holders or monitor nozzles. Cool containers with flooding quantities of water until well after fire is out. Withdraw immediately in case of rising sound from venting safety devices or discoloration of tank. Always stay away from tanks engulfed in fire. For massive fire, use unmanned hose holders or monitor nozzles; if this is impossible, withdraw from area and let fire burn.

Hazardous Combustion Products: No Data Available.

SECTION 6: ACCIDENTAL RELEASE MEASURES

Release Response
Extremely flammable. Eliminate all sources of ignition. All equipment used when handling this product must be grounded. Do not touch or walk through spilled material. Stop leak if you can do it without risk. Prevent entry into waterways, sewers, basements or confined areas. A vapor suppressing foam may be used to reduce vapors. Absorb or cover with dry earth, sand or other non-combustible material and transfer to containers. Use clean non-sparking tools to collect absorbed material. Dike large spills and place materials in salvage containers. Water spray may reduce vapor; but may not prevent ignition in closed spaces.

SECTION 7: HANDLING AND STORAGE

Handling
Use only non-sparking tools. Extinguish all ignition sources. Carefully vent any internal pressure before removing closure. Containers must be properly grounded before beginning transfer. Handle empty containers with care; vapor/residue may be flammable. All equipment must conform to applicable electrical code. This material may attack some forms of plastics, rubbers, and coatings. Isolate, vent, drain, wash and purge systems or equipment before maintenance or repair. Check atmosphere for explosiveness and oxygen deficiencies. Wear recommended personal protective equipment. Observe precautions pertaining to confined space entry.

Storage
Store closed drums with bung in up position. Store only in tightly closed, properly vented containers away from heat, sparks, open flame and strong oxidizing agents. Containers must be properly grounded before beginning transfer. This material may attack some forms of plastics, rubbers, and coatings. Consult supplier(s) of these materials for specific recommendations. Steel drums are recomended for packaging.

SECTION 8: EXPOSURE CONTROLS AND PERSONAL PROTECTION

Engineering Controls
Both local exhaust and good general room ventilation must be provided not only to control exposure but also to prevent formation of flammable mixtures.

Personal Protection
Inhalation A respiratory protection program that meets OSHA's 29 CFR 1910.134 or ANSI Z88.2 requirements must be

followed whenever workplace conditions warrant respirator use.

Skin Wear chemical resistant gloves such as: Butyl rubber. Nitrile. or Teflon. Depending on the conditions of use, protective gloves, apron, boots, head and face protection should be worn. The equipment must be cleaned thoroughly after each use.

Eye Use splash goggles when eye contact due to splashing or spraying liquid is possible.

Additional Remarks

Selection of appropriate personal protective equipment should be based on an evaluation of the performance characteristics of the protective equipment relative to the task(s) to be performed, conditions present, duration of use, and the hazards and/or potential hazards that may be encountered during use. Emergency eye wash fountains and safety showers should be available in the immediate vicinity of any potential exposure. Use good personal hygiene practices. Wash hands before eating, drinking, smoking, or using toilet facilities. Wash clothing frequently.

Occupational Exposure Limits

Component Name	Source / Date	Value	Type	Notation
Tert-Butyl Acetate	US (ACGIH) / 2003	200 ppm	8 HRS/TWA	No
	US (OSHA) / 2001	200 ppm 950 mg/m3	8 HRS/TWA	No
tert-Butyl Alcohol	US (ACGIH)	100 ppm	8 HRS/TWA	No
	US (OSHA)	100 ppm	8 HRS/TWA	No

SECTION 9: PHYSICAL AND CHEMICAL PROPERTIES

Appearance: Liquid. Clear, colorless.

Odor: Sweet odor.

Odor Threshold: No value available.

pH: 6 - 7

Boiling Point/Boiling Range: ~ 98 °C (208.4 °F) @ 760 mm Hg

Freezing Point/Melting Point: -62 °C (-79.6 °F)

Flash Point: ~ 4.4 °C (39.92 °F) (Closed Cup)

Auto-ignition: ~ 517.8 °C (964.04 °F)

Flammability: OSHA/NFPA Class IB Flammable Liquid.

Lower Flammable Limit: ~ 1.26 vol%

Upper Flammable Limit: ~ 6.88 vol%

Explosive Properties: No Data Available.

Oxidizing Properties: No Data Available.

Vapor Pressure: ~ 34 mm Hg @ 25 °C (77 °F)

Evaporation Rate: ~ 2.8 (butyl acetate = 1)

Relative Density: ~ 0.862 @ 25 °C (77 °F)

Relative Vapor Density: No Data Available.

Viscosity: < 1 mPa.s @ 25 °C (77 °F)

Solubility (Water): ~ 0.9% (at 77°F/25°C)

Partition Coefficient (Kow): No Data Available.

Additional Physical and Chemical Properties: Additional properties may be listed in Sections 3 and 5.

SECTION 10: STABILITY AND REACTIVITY

Chemical Stability
Stable.

Conditions to Avoid
Heat, sparks, open flame, other ignition sources, and oxidizing conditions.

Substances to Avoid
Plastics. Acids. Alkalies. Nitrates. Strong oxidizing agents.

Decomposition Products
Carbon monoxide. Carbon dioxide and water.

Hazardous Polymerization
Not expected to occur.

Reactions with Air and Water
Not expected to occur.

SECTION 11: TOXICOLOGICAL INFORMATION

PRODUCT INFORMATION

Product Summary
No additional toxicology information is available for this material. See component summary.

COMPONENT INFORMATION

- *Tert-Butyl Acetate 540-88-5*

Acute Toxicity - Lethal Doses

LC50 (Inhl)	Rat	> 4000 PPM	6 HOURS
LD50 (Oral)	Rat	4500 MG/KG	
LD50 (Skin)	Rabbit	> 2000 MG/KG	

Repeated Dose Toxicity

Exposure of rats to tertiary-butyl acetate 6 hrs/day, 5 days/week at 1643 ppm caused liver toxicity and unsteady gait at the end of each exposure. Kidney toxicity was seen in males at 120, 430, and 1643 ppm.

- *tert-Butyl Alcohol 75-65-0*

Acute Toxicity - Lethal Doses

LC50 (Inhl)	Rat	> 14,100 PPM	4 HOURS
LD50 (Oral)	Rat	2,733 MG/KG BWT	
LD50 (Skin)	Rabbit	> 2000 MG/KG BWT	

Irritation

Skin May be irritating to the skin. No significant signs or symptoms indicative of any health hazard are expected to occur as a result of skin absorption exposure. Not expected to be a sensitizer.

Eye Neat liquid may produce moderate to severe, reversible eye irritation. Washing the eyes after 30 seconds did not significantly reduce the irritation.

Target Organ Effects

Skin. Eye. Respiratory system. Central nervous system.

Repeated Dose Toxicity

Subchronic and chronic administration of t-butanol in the drinking water of male rats at concentrations of 1.25 mg/ml (estimated at 90 mg/kg bwt and higher) resulted in kidney pathology. The kidney pathology is mediated through the a-2u-globulin mode of action. In male and female rats that received 90 mg/kg bwt and higher t-butanol, there was an increase in the severity of chronic progressive nephropathy, a disease not relevant for humans. In male and female mice at concentrations in drinking water of 10 mg/ml (~1000 mg/kg bwt), an increased incidence of thyroid follicular cell hyperplasia was observed, and at ~2000 mg/kg bwt, the mice exhibited an increased inflammation of the urinary bladder resulting in hyperplasia.

Reproductive Effects

T-butanol had no effect on fertility in a one-generation screening study. At maternally toxic doses (1000 mg/kg bwt), there were fewer live pups per litter and lower birth weight, which continued throughout lactation. No adverse effects on testes and ovary structure were seen in rats that received repeated high oral doses (up to 8200 mg/kg bwt).

Developmental Effects

Results from studies in pregnant rats and mice indicate that t-butanol is not teratogenic but at high oral doses (1000 mg/kg bwt) produces embryo/fetotoxicity and developmental delay.

Genetic Toxicity

Negative for genotoxicity both in vitro and in vivo tests.

Carcinogenicity

In a drinking water study, t-butanol induced benign kidney tumors in male rats via an a-2u-globulin mode of action, a tumor mechanism not relevant to humans. In female mice, there was an increased incidence of benign thyroid tumors. t-Butanol is not classified as to carcinogenicity by OSHA, NTP, IARC or EPA.

SECTION 12: ECOLOGICAL INFORMATION

PRODUCT INFORMATION

Ecotoxicity

No additional information available.

Acute toxicity to fish
LC50 / 96 HOURS fathead minnow 327 mg/l

Environmental Fate and Pathway

No Data Available.

Persistance and Degradability
Biodegradation: No data available.
Bioaccumulation: Low water solubility and high volatility indicate that bioaccumulation in aquatic systems is unlikely.

COMPONENT INFORMATION

- *Tert-Butyl Acetate 540-88-5*

Ecotoxicity

No additional information available.

Acute toxicity to fish
LC50 / 96 HOURS fathead minnow 327 mg/l

Environmental Fate and Pathway

No data available.

- *tert-Butyl Alcohol 75-65-0*

Ecotoxicity

This material is expected to be non-hazardous to aquatic species.

Acute toxicity to fish
LC50 / 96 HOUR fathead minnow > 961 mg/l

Acute toxicity to aquatic invertebrates
EC50 / 48 HOUR waterflea. 5,504 mg/l

Toxicity to aquatic plants
EC50 / green algae. > 976 mg/l
Summary: growth inhibition

Toxicity to microorganisms
EC50 / bacteria. 11,263 mg/l

EC0 / bacteria. 13,560 mg/l

EC10 / 18 HOUR bacteria. 2,050 mg/l

Chronic toxicity to fish

Summary: No Data Available.

Chronic toxicity to aquatic invertebrates

Summary: No Data Available.

Environmental Fate and Pathway

The product is volatile and will partition to air. Degraded in the atmosphere by reaction with photochemically produced hydroxyl radicals with an estimated half life ranging from 2.5 days to 25 days.

Persistance and Degradability
Stability in Water: Not expected to volatilize from surface waters. Not likely to adsorb to suspended solids and sediment in water.

Stability in Soil: Expected to have high mobility in soils. Volatilization from dry soil surfaces is expected. Volatilization from moist soil surfaces is expected to be an important fate process of this material.

Biodegradation: This material is expected to be inherently biodegradable.

Bioaccumulation: BCF < 5 This material is not expected to bioaccumulate.

SECTION 13: DISPOSAL CONSIDERATIONS

Contaminated product, soil, water, container residues and spill cleanup materials containing allyl alcohol are hazardous wastes. Comply with applicable federal, state, and local regulations.

SECTION 14: TRANSPORT INFORMATION

Special Requirements
If you reformulate or further process this material, you should consider re-evaluation of the regulatory status of the components listed in the composition section of this sheet, based on final composition of your product.

Proper Shipping Name	Butyl acetates
ID No.	UN1123
Hazard Class	3
PG	II

SECTION 15: REGULATORY INFORMATION

Regulatory Status

Country	Inventory	
Australia	AICS	X
Canada	DSL	X
Canada	NDSL	
China	IECS	C
European Union	EINECS	X
European Union	ELINCS	
European Union	NLP	
Japan	ENCS	X
Korea	ECL	X
Philippines	PICCS	X
United States	TSCA	X

X = All components are included or are otherwise exempt from inclusion on this inventory.

C = Contact Lyondell/Equistar by e-mail at product.safety@lyondell.com or product.safety@equistarchem.com for additional information.

Tertiary butyl acetate was excluded from the Federal definition of a VOC (40 C.F.R. § 51.100(s)(5)) by the U.S. Environmental Protection Agency on November 29, 2004 (69 FR 69304). State and local definitions may vary. If identified components of this product are listed under the TSCA 12(b) Export Notification rule, they will be listed below.

SARA 302/304

This material contains a component(s) with known CAS numbers classified as hazardous substances subject to the reporting of CERCLA (40 CFR 302) and/or to the release reporting requirements of SARA (Section 302) based on reportable quantities (RQs).

Component	RQ
tert-Butyl Acetate / 540-88-5.	5,000 lbs

SARA 311/312

Based upon available information, this material is classified as the following health and/or physical hazards according to Section 311 & 312:

Fire Hazard.
Immediate (Acute) Health Hazard.

SARA 313

This material contains the following chemicals with known CAS numbers subject to the reporting requirements of SARA Title III, Section 313 and 40 CFR 372:

Component	Reporting Threshold
tert-Butyl Alcohol / CAS# 75-65-0	1.0%

State Reporting

This material is not known to contain any chemicals currently listed as carcinogens or reproductive toxins under California Proposition 65 at levels which would be subject to the proposition.

Massachusetts Substances List (MSL) - Hazardous substances on the MSL must be identified when present in materials at levels greater than state specified criterion. The criterion is: >= 1%. Components with CAS numbers present in this material at a level which could require reporting under the statute are:

- tert-Butyl Acetate / 540-88-5.

Hazardous Substances listed by the State of Pennsylvania must be identified when present in materials at levels greater than the state specified criterion. The criterion is >= 1%. Components with CAS numbers in this material at a level which could require reporting under the statute are:

- tert-Butyl Acetate / 540-88-5.

Environmentally Hazardous Substances listed by the State of Pennsylvania must be identified when present in materials at levels greater than the state specified criterion. The criterion is >= 1%. Components with CAS numbers in this material at a level which could require reporting under the statute are:

- tert-Butyl Acetate / 540-88-5.

SECTION 16: OTHER INFORMATION

Latest Revision(s)
Revised Section(s): 3 11 Date of Revision: 9 January 2002 Revised Section(s): 15 January 21 2005

DISCLAIMER OF RESPONSIBILITY

This document is generated for the purpose of distributing health, safety, and environmental data. It is not a specification sheet nor should any displayed data be construed as a specification. The information on this MSDS was obtained from sources which we believe are reliable. However, the information is provided without any warranty, expressed or implied, regarding its correctness. Some information presented and conclusions drawn herein are from sources other than direct test data on the substance itself. The conditions or methods of handling, storage, use and disposal of the product are beyond our control and may be beyond our knowledge. For this and other reasons, we do not assume responsibility and expressly disclaim liability for loss, damage, or expense arising out of or in any way connected with handling, storage, use, or disposal of this product. If the product is used as a component in another product, this MSDS information may not be applicable.

Numerical Data Presentation
The presentation of numerical data, such as that used for physical and chemical properties and toxicological values, is expressed using a comma (,) to separate digits into groups of three and a period (.) as the decimal marker. For example, 1,234.56 mg/kg = 1 234,56 mg/kg

Language Translations
The information presented in this document has been translated from English by a vendor Lyondell believes to be reliable. Lyondell and its vendor have made a good-faith effort to verify the accuracy of the translation, but assume no responsibility for any errors that may have occurred. Please refer to our web sites (www.lyondell.com and www.equistarchem.com) for the original document written in English.

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Appendix B Technical Data Sheet

LYONDELL

TECHNICAL DATA

TBAc™ Solvent (Tert-Butyl Acetate)
Physical Properties

CAS Number	540-88-5
Elemental Formula	$C_6H_{12}O_2$
Molecular Weight (g/mole)	116.16
Boiling Point (°C)	98
Melting Point (°C)	- 62
Flash Point (°F)	40
Vapor Pressure (mm Hg @ 25°C)	34
Evaporation Rate (vs n-BuAc = 1)	2.8
Density (g/ml @ 25°C) (lbs/gal)	0.867 (7.24)
Viscosity (cps @ 25°C)	<1
Surface Tension (dynes/cm^2)	22.4
Dielectric Constant (DIC @ 20 °C in cyclohexane)	1.94
Electrical Resistivity (megaOhms)	23.81
Solubility in Water (wt%)	0.3
Maximum Incremental Reactivity (MIR)	0.20g ozone/gTBAc
Hansen 3D Solubility Parameters, cgs	
Hansen D	6.97
Hansen P	1.66
Hansen H	2.91
Total Hansen	7.73
DOT Classification	Class 3 Flammable
NFPA & HMIS Ratings (H/F/R)	1/3/0
EPA VOC status	*final rule published11/29/04
OSHA PEL (ppm)	200
SARA 313 List	not listed
HAP's List	not listed
Cal Prop 65 List	not listed
Ozone Depleter	no
Acute Toxicity (LD50)	slight (4.5 gram/kg)
Eyes/skin Irritation	slight/slight
Carcinogen	not expected
Mutagen	no

*The U.S. EPA has published a rule excluding tertiary butyl acetate from the Federal definition of a VOC (40 C.F.R. § 51.100(s)(5); see also 69 FR 69304). State and local definitions may vary.

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Appendix C Technical Data Sheet – Environmental Aspects

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TECHNICAL DATA

TBAc™ Solvent (Tert-Butyl Acetate) Environmental Aspects

TBAc solvent, Lyondell Chemical Company's brand of tert-butyl acetate, CAS# 540-88-5, is a unique non-HAP (hazardous air pollutant), VOC (volatile organic compound)-exempt* organic solvent with versatile performance and negligible photochemical activity. It is suitable for use in coatings, inks, adhesives, and cleaners. It is a potential substitute for a variety of HAP solvents and VOCs such as toluene, xylene, MEK, and MIBK as well as ozone depleting solvents such as methyl chloroform and CFC-113.

Unless otherwise noted, the following environmental fate information was taken from the US National Library of Medicine's HSDB database[1] and the references contained therein.

Summary

Because of its high vapor pressure and low water solubility, tert-butyl acetate will degrade in the environment primarily by atmospheric oxidation.

If released to soil, tert-butyl acetate will rapidly leach out and volatilize. If released to water, the majority of tert-butyl acetate will volatilize within days and the rest will biodegrade within weeks. Aquatic adsorption and bio-concentration will, therefore, not be significant.

The atmospheric fate of tert-butyl acetate is well understood. In a typical atmosphere, it reacts with atmospheric OH radicals with a half-life of 26 days. In a polluted atmosphere, it oxidizes to acetic anhydride, acetone, and organic nitrates, which, in turn, ultimately oxidize to CO_2 and water.

Because of their high affinity for water, acetic anhydride and acetone will be efficiently removed via washout and, ultimately, biodegrade.

Tert-butyl acetate is negligibly photo-reactive, generating less than 70% the amount of ozone produced by ethane on a per gram basis. Tert-butyl acetate and its photoproducts also exist predominantly in the vapor phase in the atmosphere and are, therefore, not aerosol or particulate precursors.

Tert-butyl acetate does not contain halogens and cannot, therefore, deplete stratospheric ozone. Tert-butyl acetate also does not contain nitrogen or sulfur and will not contribute appreciably to acid rain in the form of nitric, halo, or sulfuric acids.

Atmospheric Fate

Aerosol Forming Potential - Tert-butyl acetate will exist almost entirely in the vapor-phase in the ambient atmosphere due to its high vapor pressure (34 mm Hg @25°C). Its photoproducts are also volatile and are not expected to generate aerosols of fine particulate matter ($PM_{2.5}$).[2]

Global Warming Potential - The half-life for the vapor-phase reaction of tert-butyl acetate with atmospheric hydroxyl radicals is about 26 days in an average atmosphere. Based on this short atmospheric lifetime, tert-butyl acetate is not expected to contribute significantly to global warming.[3]

Tert-butyl acetate is a member of the ester class of chemicals whose global warming potential was reviewed under SNAP and considered not to be of concern.[4]

Ozone Forming Potential – Tert-butyl acetate has a very low potential to form tropospheric ozone (smog). Product and smog chamber studies[5] have shown that tert-butyl acetate oxidizes to acetic anhydride (50%), acetone (20%), and organic nitrates (17-20%).

The maximum incremental reactivity (MIR) for tert-butyl acetate ranges between 40% and 70% of that of ethane and thereby meets the EPA's published criterion for "negligible photochemical reactivity."[6]

Ozone Depleting Potential - Tert-butyl acetate does not contain halogens and cannot, therefore, contribute to stratospheric ozone depletion. The USEPA has identified tert-butyl acetate and other esters as alternatives to ozone-depleting CFCs in solvent cleaning, aerosols, adhesives, coatings, and inks under the SNAP (Significant New Alternatives Policy).[7]

Acid Rain Forming Potential - Tert-butyl acetate also does not contain sulfur and cannot, therefore, form halo or sulfuric acids, two major contributors to acid rain formation. Since it does not contain nitrogen, its maximum potential to form nitric acid is limited to the ~20% yield of organic nitrates formed in polluted atmospheres.

Acetic anhydride, tert-butyl acetate's principal atmospheric product, will hydrolyze to acetic acid and be washed out. Compared to nitric, halo, and sulfuric acids, acetic acid is a very weak acid and will not contribute appreciably to acid rain formation.

*The U.S. EPA has published a rule excluding tertiary butyl acetate from the Federal definition of a VOC (40 C.F.R. § 51.100(s)(5); see also 69 FR 69304).

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Aquatic Fate

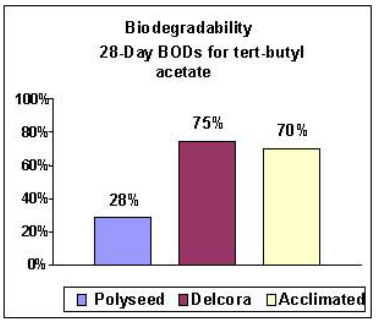
Volatilization - Most of the tert-butyl acetate released to water will volatilize within days and the rest will biodegrade within weeks. Based on a functional group estimation method, the Henry's Law Constant for tert-butyl acetate is calculated to be 3.3×10^{-4} atm•m^3/mole at 25°C. This value of Henry's Law constant suggests that volatilization from environmental bodies of water will be rapid.[1]

The volatilization half-life from a river one meter deep flowing 1 m/sec with a wind velocity of 3 m/sec is estimated to be 6.0 hours; the volatilization half-life from a similar river 10 meters deep is estimated to be 7.4 days.

Hydrolysis - The hydrolysis half-lives of tert-butyl acetate at pHs 7.0, 8.0, and 9.0 are about 135 years, 14.6 years, and 1.46 years, respectively, at 25°C. This indicates that hydrolysis will be important only in extremely alkaline environmental waters with pH values approaching 10 or higher.

Biodegradation - Tert-butyl acetate has been shown[8] to biodegrade in standard closed-bottle laboratory tests using acclimated and non-acclimated microorganisms. 28-day biological oxygen demand (BOD) expressed as % of chemical oxygen demand (COD) ranged from 28% with EPA-approved Polyseed to 75% with acclimated Delcora sludge typically found in Publicly-Owned Treatment Works (POTW) (see chart).

Chemicals with BOD greater than 60% of their COD are generally considered to be "readily biodegradable". Tert-butyl acetate is, therefore, either readily or inherently biodegradable, depending on the microorganisms present.



Bioconcentration - Based on a log Kow (octanol-water coefficient) of 1.38, the bio-concentration factor (BCF) for tert-butyl acetate can be estimated to be 6.6 by an EPA-recommended regression-derived equation. This BCF value suggests that tert-butyl acetate bio-concentration is not significant.[1]

Terrestrial Fate

Volatilization - Based on its high vapor pressure, tert-butyl acetate will evaporate relatively rapidly from wet or dry solid surfaces.[1]

Leaching – Residual tert-butyl acetate in moist soil will rapidly migrate to bodies of water. Based on a log Kow (octanol-water coefficient) of 1.38, the Koc value for tert-butyl acetate can be estimated to be 134 by a regression-derived equation. This Koc value indicates high soil mobility.[1]

Hydrolysis - Chemical hydrolysis of tert-butyl acetate in moist, very alkaline soils (pH 10 or higher) may be important, but hydrolysis in soils of pH 9 or lower will not occur to any appreciable extent.[1]

References:

1 Hazardous Substances Data Bank, Issue 98-2 (May 1998), U.S. National Library of Medicine.

2 Letter from Spyros Pandis, Elias Associate Professor of Chemical Engineering, Carnegie Mellon University, September 1998.

3 Don Wuebbles, Director Environmental Council, University of Illinois, Urbana-Champaign, Personal Communication, September 1998

4 Reba Rubinstein, EPA SNAP staff, personal communication, 08/24/98.

5 Tuazon, E. C.; Aschmann, S. M.; Atkinson, R.; Carter, W. P. L., J. Phys. Chem. A (1998), 102(13), 2316-2321.

6 EPA-453/R-94-066-A, March 1995 Report to Congress, p. 3-5, footnote 2.

7 40 CFR Parts 9 and 82, Protection of Stratospheric Ozone; Final Rule, Federal Register, Vol.59, No. 53

8 Unpublished report, Raytheon Environmental Services Laboratory, August 1998.

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Appendix D Health and Safety Plan

This appendix addresses health and safety concerns specific to the use of TBAC as part of cleaning and coating operations. These procedures and practices are not intended to serve as a substitute for common sense, or for safety practices and procedures recommended by equipment and material vendors and suppliers. This section cannot and does not present a comprehensive set of guidelines for such unusual or unforeseen conditions or circumstances that may arise from the use of chemicals and performing a cleaning process.

D.1 Definition of Hazards and Hazardous Areas

Hazards and the possibility of accidents are always present. Applicable hazards are discussed in the sections that follow.

D.1.l Chemical Hazards

For this demonstration, transferring of solvents between mixing/storage containers will be required. It is not expected that any other hazardous liquid or solid chemicals will be used. During solvent transfer operations, use of personnel protective equipment as specified by the safety plan of the applicable work site is required. In addition to the liquid solvents, hazardous fumes may also exist. Ensure compliance with all procedures defined in the SOP's.

D.1.2 Physical Hazards.

Physical injuries can be defined as cuts, bruises, broken bones, burns, or infections. Physical injuries can occur anywhere, e.g., in the course of handling objects; falls; machine failure or contact with machinery; or exposure to liquids. Physical injuries are usually caused by some action, lack of action, or defect that leads to an accident that in turn was brought about by failure to practice accepted safety procedures, unsafe personnel actions, or unsafe conditions. All physical injuries should be treated promptly by qualified personnel and documented appropriately as soon thereafter as practical. Corrective action should be considered for those injuries that can be prevented by physically modifying the condition that caused the injury. The types of physical hazards include:

- Mechanical hazards
- Poor walking/working surfaces
- Excessive noise
- Extreme temperatures
- Ergonomic hazards
- Electrical hazards

D.1.3 Electrical Hazards

The following fundamental electrical safety precautions should be followed at all times:

- Only qualified or authorized persons are allowed to work on any electrical equipment.
- Do not use any part of your body as a test circuit.
- Ground all electrical tools and equipment.
- Keep all electrical controls accessible and well marked. Access to potentially energized parts shall be restricted to qualified employees.
- Keep wires from becoming a tripping hazard.
- Never use metal ladders around electrical equipment.
- When there is a question about an electrical hazard, ask before you expose yourself to it.
- When working around electrical equipment, as with any other hazardous work environment, keep your mind on the hazard at all times.

D.1.4 Mechanical Hazards.

Ensure that the following requirements are in place and that these safe work practices are used when working around mechanical hazards:

- All moving mechanical parts must be guarded by a shield or other suitable safety device. These safety devices are designed to protect workers against accidental injury, but they are only useful when installed.
- All work should be adequately supervised to prevent accidents or injuries.
- No one will be allowed in the project work areas while under the influence of drugs or alcohol.
- No one will be allowed to work while his/her abilities are impaired by fatigue, illness, or other conditions that might make him/her susceptible to accidents or injury.
- All project workers should be familiar with the location and operation of all fire extinguishers, safety equipment, and building exits.
- Loose clothing, dangling ties, etc., should not be worn around any moving mechanical equipment.
- No mechanical equipment should be adjusted or repaired while in operation. Workers should not perform maintenance or repairs without specific instructions from the supervisor in charge.

D.1.5 Poor Walking/Working Surfaces.

Uneven or slippery surfaces, holes, protruding objects, and obstacles create a trip hazard, and contribute to poor working or walking surfaces. To control hazards relating to working and

walking surfaces:

- Survey the work area for uneven surfaces, protruding objects on which employees may bump their heads or body parts; slippery surfaces, holes, loose boards, protruding nails are common tripping hazards.
- Do not store objects in designated aisle ways or other areas where they may create a hazard.
- Clean up any spills of water or other material immediately. For spills of hazardous materials, refer to spill control guidance.
- Ensure that covers and/or guardrails are provided to protect personnel from open pits, tanks, vats, ditches, etc.
- Ensure that exits, aisles, stairways, doors, etc., are clear at all times.
- Maintain adequate lighting.
- Do not clutter area with unneeded or unused equipment, furniture, etc.
- Maintain adequate storage facilities for necessary safety equipment and personnel protective apparel.
- Follow proper housekeeping procedures.

D.1.6 Excessive Noise.

Depending on the loudness of the noise source and the duration of exposure, excessive noise may cause hearing damage. In addition, loud noises can startle workers, make them nervous or irritable, cause verbal warnings to go unheard, and contribute to an increase in accidents and mistakes.

Where average daily noise exposures are anticipated to be 84 dBA (decibels measures on the A-weighted scale) or greater for an 8 hour shift, protective hearing devices will be required.

Excessive noise exposure is not anticipated as a primary hazard for this demonstration project.

D.1.7 Extreme Temperatures

Extreme hot or cold working conditions can have an impact on the body and the ability to safely conduct work. Extreme work area temperatures are not anticipated for the course of this project.

D.1.8 Ergonomic Hazards

Ergonomic hazards may include repetitive motions, forceful exertions, awkward postures, vibration, and local contact stresses. Ergonomic hazards that may be encountered during the project include forceful exertions or awkward positions due to improper lifting or carrying of objects. Wherever feasible, mechanical lifting aids should be used. Hoists, powered trucks, or other devices appropriate for the task should be used. Where lifting is required, personnel should follow safe lifting techniques (e.g. lift objects with the use of leg muscles instead of the back) to reduce back injuries.

D.2 Protective Clothing and Equipment

A frequent cause of accidents is failure to use the proper safety equipment. OSHA requires safety equipment to be provided by management, and all employees should use it in accordance with established OSHA safety standards and inspect the protective equipment prior to each use.

Protective clothing and equipment may include:

- Safety glasses, goggles, or face shield
- Gloves
- Safety shoes
- Hard hat
- Coveralls
- Ear plugs or ear muffs

In addition to protective clothing, other types of safety equipment include:

- Emergency eyewashes and safety showers
- Fire extinguishers
- First aid kits
- Spill control materials

Each type of protective clothing and equipment is discussed in further detail in the following sections.

D.2.1 Protective Clothing

Personal protective clothing and equipment reduce the possibility of injury to personnel. Protective clothing is required to be available for specific hazards and jobs under OSHA standards. Personnel protective clothing must meet the requirements of the American National Standards Institute and must be used by appropriately trained employees. It is essential that all protective clothing be inspected for defects or damage before each use. Damaged personnel protective clothing and equipment must not be used.

<u>Eye and face protection</u> is required when there is a hazard from flying particles, liquid, or gaseous chemicals, or potentially injurious light radiation:

- Safety glasses with side shields - used when there is a hazard from flying particles.
- Goggles - used for liquid and gaseous chemical exposures, or dusty environments.

- Face shields - required when face protection is needed; should be worn over primary eye protection.

Hand protection is required for exposure from lacerations, abrasion, punctures, and thermal burns.

- Work gloves – leather work gloves provide protection against abrasions and cuts. Kevlar and similar materials provide greater cut resistance.

- Chemical resistant gloves - rubber gloves provide protection against many organic chemicals including solvents.

- Thermal gloves - used to provide protection when handling extremely hot or cold materials and parts.

Foot protection is required when working in areas where there is a danger of foot injuries due to falling or rolling objectives, objects piercing the feet, or electrical hazards.

- Safety shoes – protective toe footwear is required for working around heavy equipment. Non-sparking footwear is required in areas where there is a danger of explosion, and rubber boots are required in wet or damp work areas.

Head Protection is required when there is a possibility for injury to the head from falling objects. Protective helmets designed to reduce electrical shock are also available.

- Hard hats - required to provide head protection from impact and penetration from falling objects or flying objects and from limited electrical shocks or burns.

Body protection is used to protect the torso and other parts of the body from contact with mechanical or chemical irritants, or dirt.

- Apron - provide limited protection to the torso. May be a work apron, to protect against dust, dirt, etc.

- Coveralls - used to protect clothing from dirt, dust, etc.
- Miscellaneous items - kneepads are recommended for protection against bruises when the work requires kneeling for extended periods of time. Protective creams are recommended to protect the skin from contamination by oils, greases, paints, and dust.

- Clothing which is resistant to flash-flame shall be worn when there is possible exposure to electric arc flash. Avoid wearing man-made materials, i.e., polyester and nylon, as these materials are found to be a potential burn hazard.

The use of hearing protection and respiratory protection is not anticipated for this project unless any of the following conditions exist.

- Where average daily noise exposures are anticipated to be 84 dBA (decibels measures on the A-weighted scale) or greater for an 8 hour shift, protective hearing devices will be required.

- Hazardous fumes will exist during testing evolutions. Ensure that all solvent fumes are directed away and down wind from all project employees. If the testing is in a normally well-ventilated area, and respiratory protection is not normally required, nothing in the test sequence will require additional protection. If in doubt, consult the local health and safety supervisor.

D.2.2 Other Equipment.

Other types of equipment that may be necessary include emergency eyewash and safety showers, fire extinguishers, and first aid kits.

- Emergency eyewashes and safety showers - emergency-drenching facilities must be provided whenever there is a potential for exposure to corrosive chemicals. These facilities must be posted with a highly visible sign and located at accessible location requiring no more than 10 seconds to reach.
  - Know the location of the closest emergency eyewash and safety shower.
  - Do not block the access to eyewashes and showers.
  - Ensure that the units are maintained on a weekly basis.

- Fire extinguishers - extinguishers approved by the Underwriter's Laboratories are required in areas of fire hazard. Local fire protection officials may be asked to determine the kinds of fire hazards and types of extinguishers needed at the facility.
  - Know the location of the closest fire extinguisher.
  - Ensure that the extinguishers in the area are appropriate for the materials and chemicals being handled, and do not contribute to the fire hazard.
  - Know the means for summoning the fire department.

- First aid kits - first aid kits and posted first aid procedures for burns, poisons, bleeding, etc. should be on hand at all times. An emergency medical station should be available during normal working hours, and project employees should be aware of its location and operating hours. If employees are not currently trained in first aid, the outside clinic or hospital relied on for emergency first aid must be located so that medical treatment can be provided within fifteen minutes of the time of injury.
  - Know the location of the first aid kit.
  - Keep first aid training current.
  - Know the location and/or means for summoning emergency medical attention.
  - Post phone numbers for physicians and ambulance.

- Medical Facilities - All personnel must be aware of the route to the nearest hospital or emergency medical treatment facility.

Other tools used to complete the project must also be appropriately maintained and used. OSHA standards require management to make sure that proper tools, in good repair are available at all

times (even employee-owned tools). When personnel are working in areas where flammable or explosive gases exist, non-sparking tools must be used.

D.3 OSHA Standards

Operations personnel are subject to physical and bodily injury as are workers in all industries. However, the performance of cleaning operations has a low potential for accidents caused by the presence of gases and chemicals. Workers engaged in this project should be familiar with safety practices that pertain specifically to his/her job. Where indicated, the safety recommendations listed in Table F.1 should be implemented and enforced as required by OSHA.

Additional data may be found in the Code of Federal Regulations, Title 29. However, regulations are of little value unless supervisory personnel ensure compliance.

Table D.1: Applicable OSHA Standards

Subpart D	Walking-Working Surfaces:
1910.23	Guarding floor wall openings and holes.
Subpart E	Means of Egress
1910.36	General requirements
1910.37	Means of egress, general
Subpart G	Occupational Health and Environmental Control
1910.93	Air contaminants (gases, vapors, fumes, dusts, and mists)
1910.94	Ventilation
1910.95	Occupational noise exposure
Subpart H	Hazardous Materials
1910.101	Compressed gasses
Subpart I	Personnel Protective Equipment
1910.132	General requirements
1910.133	Eye and face protection
1910.134	Respiratory protection
1910.135	Occupational head protection
1910.136	Occupational foot protection
1910.137	Electrical Protective Equipment
Subpart J	General Environmental Controls
1910.144	Safety color code for marking physical hazards
1910.145	Specifics for accident protection signs and tags
1910.147	The Control of Hazardous Energy (Lockout/Tagout)
Subpart K	Medical and First Aid
1910.151	Medical services and first aid

Subpart L	Fire Protection
1910.157	Portable fire extinguishers
Subpart M	Compressed Gases and Compressed Air Equipment
1910.166	Inspection of compressed gas cylinders
Subpart N	Materials Handling and Storage
1910.179	Overhead and gantry cranes
Subpart O	Machinery and Machine Guarding
1910.212	General requirements for all machines
Subpart P	Hand- and Powered- Tools and Other Hand Held Equipment
1910.242	Hand- and portable-powered tools and equipment, general
Subpart S	Electrical
1910.331	Scope
1910.332	Training
1910.333	Selection and Use of Work Practices
1910.334	Use of Equipment
1910.335	Safeguards for Personnel Protection
1910.336	Definitions

Source: Chapter XVII, Title 29 Code of Federal Regulations, Part 1910, Occupational Safety and Health Standards, 01 July 1998.

Appendix E Lab Test Protocol

Demonstration/Validation of Tertiary Butyl Acetate (TBAC) for Hand Wipe Cleaning Applications
Project Number: 06 E-PP3-010/ WP-0616

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SECTION A.1. CLEANER EVALUATION

A.1.1 SAFETY, ENVIRONMENTAL and CHARACTERISTICS

A.1.1.1 Toxicity

Objective

The objective of this test was to obtain a toxicology clearance for the manufacturer's suggested working concentration of the product.

Criterion

The toxicity of the manufacturer's suggested working concentration of the product shall conform to AR 40-5 and shall have no adverse effects on the health of personnel or the environment when used properly and with the appropriate personal protection equipment (PPE).

Test Procedures

Toxicology clearance for any potentially hazardous product to be used by U.S. Army military personnel is granted or denied by CHPPM using the process in Army Regulation (AR) 40-5, Army Regulation, Medical Services, Preventive Medicine (ref 1.1-1). A toxicology clearance involves a toxicological evaluation of materials prior to introduction into the U.S. Army supply system. The Program Manager (PM) is responsible for identifying technically feasible materials and requesting a toxicology clearance for the use of those materials.

a. CHPPM toxicology evaluations require the following:

(1) Final chemical formulation (handled as proprietary if required).

(2) Identity and application of new solvent; identity of solvent being replaced, if applicable.

(3) Reports from manufacturers pertaining to use of the solvent in the commercial market and Material Safety Data Sheets (MSDSs).

(4) Available human and animal toxicity studies and epidemiological information.

b. A toxicity evaluation is performed and clearances are conditionally approved based on the solvent application or use condition.

A.1.1.2 Flash Point

Objective

The objective of this test is to determine the flash point characteristics of the manufacturer's suggested working concentration of the cleaning compound.

Criterion

There is no set criterion for the flash point of the products. The flash point of the manufacturer's suggested working concentration of the cleaning compound is for informational purposes to determine the type classification in MIL-PRF-680A and for evaluation for safety concerns.

Test Procedures

The flash point of the manufacturer's suggested working concentration of the cleaning compound is determined using the method outlined in American Society for Testing and Materials (ASTM) D-93, Standard Test Method for Flash Points by Pensky-Martens Closed Cup Tester.

a. The test apparatus is prepared, the samples are taken, and all cautionary statements in ASTM D-93 should be applied.

b. Test was performed using a GT Instruments, D93 tester.

c. Report the following information for each test performed:

(1) Summary of test methods and any deviations from the protocol.

(2) Identification of solution tested, concentration used and diluent used.

(3) Test conditions: temperature, exposure time and humidity.

(4) Identification of testing laboratory and responsible technical point of contact.

(5) Individual and average test results.

A.1.1.3 Non-volatile Residue

Objective

The objective of this test is to determine the nonvolatile residue (NVR) characteristics of the manufacturer's suggested working concentration of the cleaning compound.

Criterion

The nonvolatile residue of the manufacturer's suggested working concentration of the cleaning compound shall not be greater than that stated in the supporting test document below for each command.

		mg per 100 ml of solution
AMCOM	ADS-61-PRF, Type I	10
AMCOM	ADS-61-PRF, Type II	2.5

AMCOM	ADS-61-PRF, Type III	2.5
TACOM	Modified ADS-61-PRF, Type I	5-8
TACOM	Modified ADS-61-PRF, Type II	5-8
TACOM	Modified ADS-61-PRF, Type III	5-8
Non-specific	MIL-PRF-680, Type I	8
Non-specific	MIL-PRF-680, Type II	8
Non-specific	MIL-PRF-680, Type III	8
Non-specific	MIL-PRF-680, Type IV	8

Test Procedure

The non volatile residue characteristics of the manufacturer's suggested working concentration of the cleaning compound is determined according to ASTM D1353, Standard Test Method for Nonvolatile Matter in Volatile Solvents for Use in Paint, Varnish, Lacquer, and Related Products.

a. The products were tested as written in the ASTM D1353.

b. Measure 100ml of the product and place in an evaporating dish, place on a steam bath and evaporate to dryness.

c. The residue remaining in the dish is then weighed.

d. Nonvolatile residue determinations shall be made on three samples and the average shall be reported. If the two weights differ by more than 0.5% (absolute) the drying procedure shall be repeated.

e. Report the following information for each test performed:

(1) Summary of test methods and any deviations from the protocol.

(2) Identification of solution tested, concentration used and diluent used.

(3) Test conditions: temperature, exposure time and humidity.

(4) Identification of testing laboratory and responsible technical point of contact.

(5) Individual and average test results.

(6) Results of visual inspections, observations and discussion of specimen condition.

A.1.1.4 Appearance/Visual Inspection

Objective

The objective of this test is to determine the appearance of the manufacturer's suggested working concentration of the cleaning compound. Under visual inspection for the presence of contaminants under strong white light and for the absence of accumulation of lint fibers must perform better than base line T-10 thinner.

Criterion

The appearance of the manufacturer's suggested working concentration of the cleaning compound shall be free of separation or colloidal dispersion (Test Protocol).

Test Procedures

The appearance of the manufacturer's suggested working concentration of the cleaning compound is to be determined using a modified version of MIL-C-29602, paragraph 4.5.2.1 (app C, ref 2.1-4).

a. The package in which the manufacturer's suggested working concentration of the cleaning compound is delivered should remain undisturbed for a minimum of 48 hours at ambient conditions.

b.With minimal disturbance, the package is then opened.

c.The manufacturer's as received concentration of the cleaning compound is observed for separations or colloidal dispersions.

d.A uniform 1-liter sample is then taken (using calowasa) and placed into a clean glass jar with a screw-type lid.

e.The closed sample is allowed to sit undisturbed for 48 hours at ambient conditions.

f.With minimal disturbance, the sample is then observed for separations or colloidal dispersions. Appearance at this time should be photographically documented.

g.Report the following information for each test performed:

(1)Summary of test methods and any deviations from the protocol.

(2)Identification of solution tested, concentration used and diluent used.

(3)Test conditions: temperature, exposure time and humidity.

(4)Identification of testing laboratory and responsible technical point of contact.

(5)Results of visual inspections, observations and discussion of specimen condition.

(6)Photographic documentation of specimen conditions.

A.1.1.5 Viscosity

Objective

The objective of this test is to determine the viscosity of the manufacturer's suggested working concentration of the cleaner.

Criterion

The viscosity of the cleaning compound shall be acceptable for reaching into recessed areas and crevasses. The criterion shall be determined based on baseline testing of the current cleaning solvent.

Test Procedures

The viscosity of the alternative cleaning solution and the baseline solvent shall be determined using procedures outlines on ASTM D 445.

A.1.2 SURFACE CLEANING

A.1.2.1 Soil Cleaning per MIL-PRF-680A

Objective

The objective of this test is to determine the relative solvency or soil cleaning characteristics of the manufacturer's suggested working concentration of the cleaner.

Criterion

The manufacturer's suggested working concentration of the cleaning compound shall not have a relative solvency of less than 85 percent (MIL-PRF-680A).

Test Procedures

The soil cleaning of the manufacturer's suggested working concentration of the cleaning compound is to be determined using a test method developed by TACOM. MIL-PRF-680A, Performance Specification Degreasing Solvent, Appendix.

a. Three test specimens 1 by 1 by .04 in(25 by 25 by 1 mm), are made from steel, carbon, mild (ASTM-A-366, class 1, commercial bright finish).

b. The metal specimens are washed in toluene (CP, 99 percent) until free of any soils and greases.

c. The test specimens are dried with dry, clean air.

d. The test specimens are then weighed to the nearest 0.1 gram.

e. Approximately 0.4 gram of MIL-G-10924F grease, automotive, artillery is applied to the test specimen, covering both sides uniformly.

f. The test specimen is then placed into a beaker using a holder to prevent contact with the sides or bottom of the beaker.

g. The manufacturer's suggested working concentration of the cleaning compound is added to the beaker until the test coupon is completely immersed.

h. The beaker with the test specimens is partially immersed in an ultrasonic cleaner in such a manner that there is no mixing of the test cleaner and the liquid in the ultrasonic cleaner. The liquid in the ultrasonic cleaner is maintained at a water temperature of 50°C (122°F).

i. The test specimen is observed until all of the grease is removed and the time is recorded.

j. If grease still remains on the test specimen after 100 minutes, testing is terminated and the cleaning time is recorded as 100 minutes.

k. The test specimen is dried using dry, clean air.

l. The test specimen is weighed to the nearest 0.1 gram.

m. The steps in paragraphs a through l are repeated with the other two remaining specimens.

n. Calculate the cleaning power as follows:

Solvent cleaning power, % = ((100-A)/100) X 100

Where A is average time of three runs obtained from tests.

o. Report the following information for each test performed:

(1) Summary of test methods and any deviations from the protocol.

(2) Identification of solution tested, concentration used and diluent used.

(3) Test conditions: temperature, exposure time and humidity.

(4) Identification of testing laboratory and responsible technical point of contact.

(5) Individual and average test results.

(6) Results of visual inspections, observations and discussion of specimen condition.

(7) Photographic documentation if needed of specimen conditions (specifically any staining, evidence of general corrosion, etching, pitting or localized attack).

A.1.2.2 Sealant Adhesion

Objective

The objective of this test is to determine the effect the manufacturer's suggested working concentration of the cleaning compound has on the sealant peel strength.

Criterion

The manufacturer's suggested working concentration of the cleaning compound shall not cause the sealing compound to have a minimum peel strength of less than 20 pounds force per inch (lbf/in.) after a seven (7) day exposure in jet reference fluid. There shall also be 100 percent cohesive failure of the sealant during testing(Test Matrix).

Test Procedures

The effect the manufacturer's suggested working concentration of the cleaning compound has on sealant peel strength is determined by using a method presented in section 4.5.17 of ADS-61A-PRF.

a. Two sets of eight test panels, 15.24- by 7- by 0.1-cm (6- by 2.75- by 0.04-in.) aluminum 2024-T3, are prepared.

b. The primer MIL-P-23377 is applied to one set of panels and the primer MIL-P-85582 is applied to the other set.

c. Scuff sand the panels primed with MIL-P-85582 with abrasive mats conforming to AA-58054, Type I, Class 1, Grade A or equivalent.

d. A standardized contaminant mixture of two parts (by weight) of hydraulic fluid (MIL-H-83282) and one part (by weight) of lubricating grease (MIL-G-81322) and one-tenth part by weight carbon black is prepared.

e. The contaminant mixture is applied to all the test panels and baked for 2 hours at 54 ^{o}C (130 ^{o}F).

f. The test panels are cooled to ambient (room) temperature.

g. The gross contaminant is removed from the test panels with a clean dry cloth.

h. Four of each set of test panels are wiped four times with a clean cloth soaked with the manufacturer's suggested working concentration of the cleaning compound. The cleaning is accomplished by first removing excess contaminant with a clean cloth. Cleaning of the coupon is continued using a cloth soaked in the working concentration of the cleaner. The cloth is wiped across the coupon in one direction, folded to expose a clean area of cloth and repeated. The coupon shall be wiped four times. Clean the remaining panels of each set with MEK (ASTM D740), the control cleaner.

i. If the test cleaner is water based, the panels are then wiped clean with a clean cloth soaked in deionized water (ASTM D1193, Type IV) and allowed to dry thoroughly.

j. Coat at least 125 mm (5 inches) of the panels on one side with a 3 ± ½ mm (1/8 ± 1/64 inch) thickness of sealing compound per MIL-S-8802 Type II, Class B.

k. Impregnate a 70 x 300 mm (2 ¾ x 12 inch) strip of wire screen (20 to 40 mesh aluminum or Monel wire fabric) or cotton duck per CCC-C-419 Type III or equivalent with sealant, such that approximately 125 mm (5 inches) of one end is completely covered with sealant on both sides. Work the sealant well into the fabric.

l. Place the sealant-impregnated end of the fabric on the sealant-coated panel. Smooth the fabric down on the panel, taking care not to trap air beneath the fabric.

m. Apply an additional 1 mm (1/32 inch) thick coating of sealing compound over the fabric. Allow the sealant to fully cure, in accordance with manufacturer's recommendations.

n. Completely immerse the panels in jet reference fluid per AMS 2629 Type I at 60 ± 1°C (140 ± 2°F) for 7 days, using covered glass vessels.

o. Place the panels in jet reference fluid for 24 hours at ambient temperature.

p. Measure the sealant peel strength within 10 minutes after removal from the jet reference fluid.

(1) Cut two, 25 mm (1 inch) wide sections lengthwise through the fabric and sealing compound on each panel.

(2) In a suitable tensile testing machine, strip back the fabric at an angle of 180 degrees to the metal panel, using a rate of 50 mm/min (2 inches/min).

(3) During the peel strength testing, make three cuts at approximately 25 mm (1 inch) intervals through the sealing compound to the panel to attempt to promote adhesive failure. Do not cut the wire or cloth.

(4) Measure the numerical average of the peak loads. Do not include failures of the sealing compound to the fabric in the peel strength values.

(5) Determine the approximate percentage of cohesive/adhesive failures.

(6) If the control specimens that are prepared with methyl ethyl ketone do not meet the performance requirements of 20 lbs of force and 100% cohesive failure, repeat the procedure with a different batch of sealant.

q. Report the following information for each test performed:

(1) Summary of test methods and any deviations from the protocol.

(2) Specimen details: Type and dimensions of test specimen and number of replicates.

(3) Identification of solution tested, concentration used and diluent used.

(4) Test conditions: temperature, exposure time and humidity.

(5) Identification of testing laboratory and responsible technical point of contact.

(6) Individual and average test results.

(7) Results of visual inspections, observations and discussion of specimen condition.

(8) Photographic documentation of specimen conditions (specifically any staining, evidence of general corrosion, etching, pitting or localized attack).

A.1.2.3 Paint Adhesion

Objective

The objective of this test is to determine how the manufacturer's suggested working concentration of the cleaning compound effects paint adhesion.

Criterion

The manufacturer's suggested working concentration of the cleaning compound shall not cause the primer coating to peel away from the substrate from any test panels after immersion in distilled water for 24 hours (Test Matrix).

Test Procedures

The effects the manufacturer's suggested working concentration of the cleaning compound on paint adhesion is determined using the FED-STD-141, Test Method No.6301, Federal Test Method Standard for Paint, Varnish, Lacquer and Related Materials.

a. A set of six test panels, 4 by 4 by 0.25 in. (10 by 10 by 0.635 cm), are prepared from aluminum (2024-T3 bare) and anodized per MIL-A-8625, Type I.

b. A second set of six test panels, 10 by 10 by 0.635 cm, are prepared from aluminum (2024-T3 clad) with a conversion coat per MIL-C-5541, Class 3.

c. Both sets of test panels are dried for 24 hours at ambient (room) conditions.

d. Apply standardized contaminant mixture consisting of two parts by weight of hydraulic fluid (MIL-PRF-83282 or equivalent), one part by weight lubricating grease (MIL-PRF-81322 or equivalent), and one-tenth part by weight of carbon black, to test panels, bake for 2 hours at 55°C (130°F), and cool to room temperature.

e. Clean both sets of panels with the manufacturer's suggested working concentration of the cleaning compound. The cleaning is accomplished by first removing excess contaminant with a clean cloth. Cleaning of the coupon is continued using a cloth soaked in the working concentration of the cleaner. The cloth is wiped across the coupon in one direction, folded to expose a clean area of cloth and repeated. The coupon shall be wiped four times. Allow test panels to dry at ambient (room) conditions for 24 hours.

f. Three panels from each set are then painted with MIL-P-23377 primer and MIL-C-85285 topcoat (gloss white).

g. The other three panels from each set are painted with MIL-P-85582 primer and MIL-C-85285 topcoat, gloss white.

h. The painted panels are allowed to dry for seven days at ambient (room) conditions.

i. All of the test panels are immersed in deionized (ASTM D1193 Type IV) water for 24 hours.

j. The test specimen should then be removed from the water and wiped dry with a soft, clean cloth.

k. Within 1 minute of removal from the water, two parallel scratches, 2.54 cm (1 in.) apart, are made through the coatings to the metal with a stylus or small, sharp knife.

l. A 2.54-cm wide strip of masking tape is applied across the scratches. The masking tape used shall be a 1-inch wide strip of flat back paper tape having an average adhesion of 60 oz/in. and shall be 3M's, Scotch™,Code No. 250 or equivalent.

m. The tape should be pressed into the surface by rolling the tape with a rubber-covered roller eight times. The roller should weigh 4.5-lbs and have a surface durometer hardness value within the range of 70 to 80. The roller shall be approximately 3 ½ inches in diameter and 1 ¾ inches in width.

n. The tape is then removed with one quick motion.

o. If the tape removes any amount of paint, it should be photographically documented immediately upon termination of the test.

p. Report the following information for each test performed:

(1) Summary of test methods and any deviations from the protocol.

(2) Identification of solution tested, concentration used and diluent used.

(3) Test conditions: temperature, exposure time and humidity.

(4) Identification of testing laboratory and responsible technical point of contact.

(5) Individual and average test results.

(6) Results of visual inspections, observations and discussion of specimen condition.

(7) Photographic documentation, if needed, for specimen conditions.

A.1.2.4 Fluorescent Penetrant Inspection

Objective

The objective of this test is to determine the effect the manufacturer's suggested working concentration of the cleaning compound has on fluorescent penetrant inspection.

Criterion

The manufacturer's suggested working concentration of the cleaning compound shall not impede the identification of known cracks and the intensity of the cracks should be brighter or equal to the control using Fluorescent Penetration Inspection (ADS-61A-PRF).

Test Procedures

Fluorescent Penetration Inspection (FPI). The fluorescent penetration inspection characteristics of the manufacturer's suggested working concentration of the cleaning compound are determined by using the inspection method given in ADS-61-PRF, paragraph, 4.5.2.1.

a. For the purposes of evaluation, a Testing and Monitoring(TAM) and JAP(actual name of panel is unknown) panels were utilized. The TAM standard panel (Dubl-Chek P6M-5 TAM 146040 S/N 10242) consists of a Cr plated panel with 5, star crack patterns of decreasing sizes. For identification purposes designate the holes 1 through 5 from left to right with the hanging hole on the left edge of the panel. The JAP panels (89-610 STP

B30 B) was a Cr plated panel stressed to produce consistent cracking across the entire length.

b. Pre-clean the test specimen bars as follows: Hand wash with soapy water, e.g., Alconox solution. Rinse in hot tap water and wipe dry with clean cloth. Dip in methanol (0-M-232 Grade A) for fifteen minutes. Ultrasonically clean in perchloroethylene (ASTM D-4376 (app C, 102)), trichloroethylene (ASTM D-4080 (app C, ref 2.4-8)), or methyl ethyl ketone (TT-M-261) for thirty minutes. Check the bars under ultraviolet (black) light to ensure all previous penetrant has been removed from the bar surfaces/cracks. If penetrant remains, repeat above steps. Dry bars in oven at 55°C (130°F) for five minutes and allow to cool to room temperature.

c. A standard contaminant mixture should be made by combining two parts (by weight) of hydraulic fluid (MIL-H-83282) and one part (by weight) of lubricating grease (MIL-G-81322).

d. Apply the standardized contaminant mixture to the test bars as follows: Using a clean glass rod covering the fatigue crack, apply two drops of the contaminant to each bar, and evenly spread the contaminant over the surface of each bar in the area of the crack. Place the bars in a dry air-circulating oven for two hours at 55°C (130°F).

e. Wipe excess contaminant from the bars with clean cloths. Clean the bars with the candidate cleaner, using a cleaning/rinsing process that is recommended for the particular cleaner/application. Test at the intended use concentration and temperature. Report the cleaning/rinsing process, including the cleaner concentration, cleaning method, and processing time and temperature.

f. Place the bars in an oven at 55°C (130°F) for five minutes. Remove the bars from the oven and allow them to cool at room temperature for three minutes.

g. Penetrant inspect in accordance with ASTM E-1417 (app C, ref 2.4-9), ASTM E-165 (app C, ref 2.4-10), or ASTM E-1210 (app C, ref 2.4-11), using penetrant materials that are qualified per AMS 2644 (app C, ref 2.4-12). If classification is not known, use Type I (fluorescent dye), Method D (post emulsifiable, hydrophilic), and Level 3 (high) sensitivity, and Form A (dry powder) developer. Record the product names and classification of penetrant, emulsifier, and developer used.

h. Measure the fluorescent brightness intensity of the penetrant materials as follows: Calibrate, zero, and focus a suitable photometer/spotmeter (e.g., Photo Research Photomultiplier-Tube Optical Photometer (Model UBD, PR-1500 Spectra Spotmeter)). Place specimen bars under ultraviolet (black) light per ASTM E-1417, ASTM E-165, ASTM E-1219 (app C, ref 2.4-13) or ASTM E-1210. For each bar, measure the intensity value of the crack, indication and the background intensity value on the bar surface near the crack. Subtract the background reading value from the crack reading value to obtain the relative intensity of the crack indication. Record all measurements and observations. Take all measurements in similar sequence and minimize the amount of time between readings to ensure similar dwell times.

i. Repeat step b though g, but replace the candidate cleaner/process in step d with the control cleaning method (e.g., cleaning with methyl ethyl ketone (TT-M-261), or vapor degreasing with perchloroethylene (ASTM D-4376) or trichloroethylene (ASTM D-4080)).

j. Compare the brightness intensities obtained with the candidate and the control cleaners.

k. Repeat the procedure a minimum of three times each for the candidate cleaner and the control cleaner.

l. When all testing has been completed, clean specimen bars as described in step b to remove all residual penetrant inspection materials.

m. Report the following information for each test performed:

(1) Summary of test methods and any deviations from the protocol.

(2) Identification of solution tested, concentration used and diluent used.

(3) Test conditions: temperature, exposure time and humidity.

(4) Identification of testing laboratory and responsible technical point of contact.

(5) Individual and average test results.

(6) Results of visual inspections, observations and discussion of specimen condition.

A.1.2.5 Water Break

Objective

The objective of this test is to determine the water break free of the manufacturer's suggested working concentration of the cleaning compound.

Criterion

The water break free for any surface cleaned with the manufacturer's suggested working concentration of the cleaning compound shall be greater than one (1) minute (Test Matrix).

Test Procedures

The water break of the manufacturer's suggested working concentration of the cleaning compound is to be determined using a modified version of ASTM F-22.

a. A 4 by 4 by 0.25-in (10- by 10- by 1.0-cm) test coupon of aluminum 7075-T6 should be abraded and cleaned with a Scotch-Brite™ pad.

b. The test coupon is placed into a container of deionized water.

c. The test coupon is then removed vertically from the water.

d. The time it takes for the draining water layer to become a discontinuous film is determined.

e. The steps in paragraphs a through d are repeated until the time exceeds 1 minute.

f. The test coupon is then dried.

g. A standard contaminant mixture should be made by combining two parts (by weight) of hydraulic fluid (MIL-H-83282) and one part (by weight) of lubricating grease (MIL-G-81322).

h. The standardized mixture is applied to the test coupon and baked for 2 hours in an air-circulating oven at 54 ^{o}C (130 ^{o}F). The test coupon is allowed to cool to ambient temperature.

i. The test coupon is then cleaned with the manufacturer's suggested working concentration of the cleaning compound and allowed to air dry. The cleaning is accomplished by first removing excess contaminant with a clean cloth. Cleaning of the coupon is continued using a cloth soaked in the working concentration of the cleaner. The cloth is wiped across the coupon in one direction, folded to expose a clean area of cloth and repeated. The coupon shall be wiped four times.

j. The test coupon is then tested again for water break using the steps in paragraphs b through d

A.1.2.6 Kauri Butanol Number

Objective

The objective of this test is to determine the Kauri Butanl number for the manufacturer's suggested working concentration of the cleaner. The **Kauri-Butanol** test is a common cloud-point test for ranking hydrocarbon solvent strength. The kauri-butanol value (KB) of a solvent represents the maximum amount of that solvent that can be added to a stock solution of kauri resin (a fossil copal) in butyl alcohol without causing cloudiness. Since the alternative cleaner is not a hydrocarbon solvent this test will be executed for information purposes only.

Criterion

The Kauri Butanol number of the cleaning compound shall be equal to or greater than 27.

Test Procedures

The Kauri Butanol of the alternative cleaning solution and the baseline solvent shall be determined using procedures outlines on ASTM D 445.

A.1.2.7 Cleaning Efficiency

Objective

The objective of this test is to determine the cleaning efficiency characteristics of the manufacturer's suggested working concentration of the cleaner.

Criterion

The manufacturer's suggested working concentration of the cleaning compound shall meet or exceed the cleaning efficiency of the baseline cleaner.

Test Procedures

1. Test panel preparation. Prepare nine test panels, constructed from clad aluminum alloy 2024 (T3 temper) conforming to SAE-AMS-QQ-A-250/5, with dimensions of 6 by 3 by 0.025 inch (150 by 76 by 0.6 mm). Deoxidize the test panels by immersion for two minutes in corrosion removing compound conforming to SAE-AMS1640, type I, class 1. Upon removal, rinse the test panels with deionized water to obtain a water-break free surface. Allow test panels to air dry.

2. Test panel soiling. Each of three sets of three test panels shall be soiled with a different contaminant:

   a. Turbine engine lubricating oil conforming to MIL-PRF-23699
   b. Hydraulic fluid conforming to MIL-PRF-83282
   c. JP-5 jet fuel conforming to MIL-DTL-5624.

   Soil the test panels by evenly spreading 5 milliliters (mL) of each contaminant onto the surface of the test panel to be cleaned and coated with primer coating. Store the lubricating oil and hydraulic fluid contaminated test panels for 24 hours at 120 ±2 °F (49 ±1 °C). Air dry the jet fuel contaminated test panels 24 hours at room temperature.

3. Procedure. Clean the nine test panels as follows:

   a. Fold a wipe cloth, conforming to CCC-C-46, type I, class 7, or SAE-AMS3819, grade A, and initial dimensions of 9 by 9 in (228 by 228 mm), into a square of 4.5 by 4.5 in (114 mm by 114 mm).

   b. Soak the folded cloth with no more than 10 mL of test solvent.

   c. Wipe each test panel with one stroke in one direction, applying moderate manual pressure. Ensure that the contact area between the cloth and the test panel is saturated

with the test solvent. This procedure (a through c) shall not be repeated more than three times.

d. Allow to air dry for no more than one hour at ambient conditions.

e. Examine each test panel in accordance with ASTM-F22 for conformance to table I.

For the purpose of paint solvent cleaning effectiveness, the following procedure will be followed:

Supplement to ASTM G 122 - NAVSEA T-10 Thinner Replacement Project

The uses of large quantities of T-10 Thinner at Norfolk Navy Shipyards (NNSY) and Puget Sound Navy Shipyards (PSNS) are associated with the uses of large quantities of certain paints at these facilities. The paints that require large quantities of T-10 Thinner need to be tested with potential alternative solvents to ensure that one of the safer solvents does an adequate job of removing paints.

The following paints represent the most used brands of paint at NNSY that use T-10 Thinner. These paints need to be tested to evaluate the cleaning capabilities of the potential alternative solvents for different paint formulations.

Ameron, Amercoat 235, Gray
International Paint, Intergard 264, Gray

Laboratory tests are necessary to evaluate the effectiveness of solvents to clean the two part epoxy paints from paint application equipment. The laboratory test results will be used to identify the most promising alternative solvents. The laboratory tests are based on ASTM G 122 “Standard Test Method for Evaluating the Effectiveness of Cleaning Agents”. However, ASTM G 122 does not provide the level of detail necessary to perform the required paint cleaning tests. Therefore, this test plan is intended to serve as a supplement to the test procedure.

Test Coupon Preparation

Prepare test coupons as specified in MIL-DTL-24441C, Section 4.5.15.1 Preparation of panels. The test coupons shall have identical preparation to ensure that the characteristics are the same.
The test coupons shall have the same surface area to ensure consistency for all samples and to allow easy comparison of test results. The dimensions of the coupons may vary from the specifications provided in MIL-DTL-24441C to allow coupon use in available test apparatus. The coupon size (and the scale accuracy) should be adequate to allow detection of variations between new and cleaned coupons. The coupon size shall be recorded and consistent for all tests.

Weigh the test coupons with a scale with an accuracy of at least 0.1 mg.

Paint Sample Preparation

Prepare paint samples by mixing the proportion of hardener and base specified in the manufacturer’s directions. Prepare adequate quantities of paints to allow dipping the coupons in the paints.

Thoroughly mix by hand stirring with a spatula or paint paddle. Allow the paint to condition for one hour and for three hours before testing. Condition the paints at 73 F.

Solvent Preparation

Select test containers or beakers that are large enough to hold enough solvents to submerge the paint coupons and allow for possible complete paint removal on all coupons. Virgin solvent will be used at the start of each test sequence. The amount shall be consistent for all tests. Aberdeen Test Center will specify or document the container size and solvent quantities to set the baseline.

Maintain the solvents at 73° F before and during the tests.

Paint Sample Testing

Place the test coupons in the prepared paint samples so that the coupons are completely coated with paint. All test coupons for paint aged for a particular time should be dipped at the same time or in quick succession to prevent using paint that is aged for different lengths of time. Remove the coupons and allow the excess paint to drain off the coupons. The time that excess paint is allowed to drain should be the same for all test coupons. The holding time should be determined by checking to see how long paint continues to drip from a test coupon after it is removed from a batch of paint. Weigh the paint covered test coupons with a scale with an accuracy of at least 0.1 mg.

Prepare three paint covered test coupons for each cleaning time interval for paint aged a particular time. This will allow an evaluation of the variation of test results, and it will allow for preparation of an average test result for a particular cleaning interval. Table 1 provides the list of test coupons that need to be prepared to test one type of paint in two different solvents.

Include an unpainted test coupon in the process to act as a control for the painted coupons.

Insert the wet test coupons and the unpainted blank coupon in the solvent test containers until the coupons are completely submerged. Immediately begin ultrasonic cleaning of the submerged coupons and begin timing the cleaning operation.

Remove test coupons from each of the solvents at time intervals of 30 seconds, one minute, two minutes, and five minutes. Allow solvents to drip off of the test coupons after they are removed from the solvents. Do not rinse the test coupons. Dry the test coupons for a period of ten hours at ambient conditions 70° F. Ensure that all test coupons are allowed to dry for the same period before they are weighed. Weigh the test coupons with a scale with an accuracy of at least 0.1 mg.

Adjust the time periods for cleaning the test samples to be four equal divisions of the total time to removal if it is found that the specified time periods do not provide useful data on the rate of cleaning the test coupons.

Record observations on the conditions of the cleaned test coupons at the end of each cleaning time interval. Describe the percent of coupon covered if there is visible paint remaining on the cleaned test coupons.

Record visual observations on the time to total removal (TTR) required to clean test coupons. State the times visible paint has been cleaned from the test coupons if different then stated time intervals.

Table C.3-3 – Sample Matrix for Paint 1

Cleaning Time		Paint Conditioning Time	
		1 hr.	3 hrs
Solvent 1	30 sec.	Samples 1, 2, 3	Samples 13, 14, 15
	1 min.	Samples 4, 5, 6	Samples 16, 17, 18
	2 min.	Samples 7, 8, 9	Samples 19, 20, 21
	5 min.	Samples 10, 11, 12	Samples 22, 23, 24
	5 min.	Blank Coupon	
	TTR*	Samples 25, 26, 27	Samples 28, 29, 30
Solvent 2	30 sec.	Sample 31, 32, 33	Samples 34, 35, 36
	1 min.	Samples 37, 38, 39	Samples 40, 41, 42
	2 min.	Samples 43, 44, 45	Samples 46, 47, 48
	5 min.	Samples 49, 50, 51	Samples 52, 53, 54
	5 min.	Blank Coupon	
	TTR*	Samples 55, 56, 57	Samples 58, 59, 60

*TTR – Time to Total Removal of Paint

A.1.2.9 Adhesive Bonding

Objective

The objective of this test is to determine the effects on bonding of the manufacturer's suggested working concentration of the cleaning compound.

Criterion

The manufacturer's suggested working concentration of the cleaning compound shall not cause lower percentage of bondline cohesive failure compared to the baseline surface cleaner or solvent (Test Protocol).

Test Procedures

Adhesive bonding shall be verified by following the procedure described below using aluminum (7075-T6 bare), stainless steel (AM-355), titanium (6A1-4V), and nickel (electroformed)

substrates. The bonding surfaces of the test panels shall be activated using the appropriate surface preparations procedures described in the Appendix for the specific metal substrate type:

a. Cut a sufficient number of test panels of each substrate to provide a minimum of six specimens per cleaner for each of the two testing temperatures (i.e. minimum twelve test specimens per cleaner per substrate). Use panel thickness and dimensions that are appropriate to fabricate test specimens per ASTM D 3167. The flexible adherents shall be 0.063 mm (0.025 in.) and the rigid adherents shall be 1.63 mm (0.064 in.).

b. Prepare and apply the standard contaminant according to 4.5.1.

c. Remove the gross contaminant with a clean cloth.

d. Hand wipe the candidate-cleaner panel surfaces until visually clean with a clean cloth soaked with the candidate cleaner at the specified use concentration. For aqueous cleaners, hand wipe panels again with de-ionized water (ASTM D-1193, Type IV) until visual evidence of the cleaner is removed. Hand wipe the control-cleaner panel surfaces until visually clean with a clean cloth soaked with methyl ethyl ketone (ASTM D740).

e. Abrade the panel bonding surfaces with an orbital sander: 180 grit for aluminum, 120 grit for titanium, and 80 grit for stainless steel and nickel. Clean again per step d.

f. Fabricate test specimens per ASTM D 3167, using a paste adhesive (Dexter Hysol EA 9309.3NA or equivalent). Use shims or scrim cloth, if necessary, to control the bondline thickness to 5 – 10 mils. Cure the adhesive as recommended by its manufacturer. Record the bondline thickness and the adhesive cure conditions.

g. Perform floating roller peel tests in accordance with ASTM D3167 on a suitable testing machine (e.g., Instron or equivalent). Condition and test at least six (6) specimens for each testing temperature as follows: (1) Condition at 25°C (75°F)/ambient humidity for 24 hours minimum. Test at 25°C (75°F). (2) Condition at 80°C (180°F)/95% humidity environment for 30 days. Test at 80°C (180°F).

h. Examine/compare and record failure surface characteristics, particularly adhesive/cohesive failure modes. Record measured peel strength values and any pertinent observations or anomalies. Record the contaminants used, if other than the standard contaminant, and the cleaner concentration used (for aqueous cleaner).

A.1.3. STORAGE

A.1.3.1 Low Temperature Stability

<u>Objective</u>

The objective of this test is to determine the temperature stability of the manufacturer's suggested working concentration of the cleaning compound.

Criterion

The temperature stability of the manufacturer's suggested working concentration of the cleaning compound shall be such that the cleaning compound returns to its original homogeneous condition after exposure to extreme environments.

Test Procedures

The temperature stability of the manufacturer's as received concentration of the cleaning compound is determined using a modified version described in ADS-61A-PRF.

a. A 50-mL sample of the manufacturer's as received concentration of the cleaning compound is placed in a suitable, clean test tube.

b. The test tube is then cooled to 0° F(-17.8 C) for 1 hour.

c. The test tube is then placed in an air circulating oven for one hour at 120°F (48.9°C)

d. The steps in paragraph b and c are repeated four more times (a total of five cycles).

e. At the end of the fifth cycle, the test tube is inverted five times and left to stand at room temperature.

f. The manufacturer's as received concentration of the cleaning compound should then be observed for homogeneity or any changes noted from the original solutions. Appearance at this time should be photographically documented if needed.

g. Report the following information for each method:

(1) Summary of test methods and any deviations from the protocol.

(2) Identification of solution tested, concentration used and diluent used.

(3) Test conditions: temperature, exposure time and humidity.

(4) Identification of testing laboratory and responsible technical point of contact.

(5) Results of visual inspections, observations and discussion of specimen condition.

SECTION A.2. MATERIAL COMPATIBILITY TESTS

A.2.1 CORROSION

A.2.1.1 Total Immersion

Objective

The objective of this test is to determine the total immersion characteristics of the manufacturer's suggested working concentration of the cleaning compound.

Criterion

The manufacturer's suggested working concentration of the cleaning compound shall not show any indication of staining, etching, pitting, or localized attack on the test panels, or cause weight change to an average of three (3) test panels greater than that shown in Table 2.1.1 (Test Matrix). Two sets of criteria from two different performance specifications are shown in the table along with the test matrix criteria.

TABLE 2.1.1. ALLOY AND MAXIMUM AVERAGE WEIGHT LOSS

Material	**MIL-PRF-680A**	**ADS-61A-PRF** mg/cm^2/168 hr	**Test Matrix**
Magnesium (AZ31B-H24) [a]	.50	.70	
Aluminum 5083			.20
Aluminum 7075 T6		.49	
Titanium 4911	.10	.35	
Steel 1020	.25		
Steel 4340		.49	
AM355 CRT		.49	
PH 13-8 Mo		.49	
Maraging C-250		.49	
Zinc ASTM B852			1.50
Brass ASTM C35600			1.0
Steel A36			.2
Cadmium			1.5

[a] AMS 4377 surface treated in accordance with AMS-M-3171 Type III.

Test Procedures

The total immersion corrosion caused by the manufacturer's suggested working concentration of the cleaning compound is determined using ASTM F-483, Standard Test Method for Total Immersion Corrosion Test for Aircraft Maintenance Chemicals.

a. Four test specimens, 50.8 by 25.4 by 1.6 mm (2 by 1 by 0.06 in.) with a 3.2 mm (0.125 in.) diameter mounting hole suitably located at one end of the specimen, are prepared from the same sheet stock of each material in table 2.1.1.

b. Immerse the test specimens in a beaker of mineral spirits, Type II, conforming to ASTM-D-235 at room temperature. Using clean forceps to hold the test specimen, swab the surface of the individual specimens with a cotton swab.

c. Shake off the excess solvent. Separately immerse the test specimens several times in a beaker of methyl ethyl ketone (MEK). Shake off the excess MEK and dry in a low-temperature oven at 120 $\pm$ 5° C (248 $\pm$ 5° F) for 15 minutes. Remove to desiccator and cool to room temperature.

e. Identify each panel with Numbers 1, 2, 3, or 4. Each test specimen is then weighed to the nearest 0.1 mg.

f. A container of the manufacturer's suggested maximum use concentration of the cleaning compound is prepared for immersing the test specimens. The volume of the cleaner solution is related to the surface area of the test specimen immersed by 8 mL cleaner per 1-cm^2 test specimen. Take the total surface area of the specimens as 28.2 cm^2 (4.4 in^2).

g. Separate containers are used for each of the materials.

h. Testing should be conducted at 38 $\pm$ 3° C (100 $\pm$ 5° F).

i. Three test specimens of each material type are immersed into the cleaning product and allowed to soak for 24 hours. Maintain at the required temperature for the prescribed exposure period. The fourth test specimen is stored in a desiccator and used as the control specimen for the test.

j. After 24 hours, the test specimens are removed from the cleaning solution and rinsed under hot tap water (49 to 60 ^{o}C (120 to 140 ^{o}F)).

k. The test specimens are then rinsed in dionized water conforming to Specification D-1193, Type IV at ambient (room) temperature.

l. The test specimens are then rinsed with a stream of acetone, conforming to Specification D 329, from a wash bottle and oven dried at 120 ^{o}C (250 ^{o}F).

n. After drying, the test specimens are placed in a desiccator until cooled to ambient (room) temperature.

o. The test specimens are then individually weighed to the nearest 0.1 mg.

p. The following visual observations should be conducted on each test specimen in comparison to the unexposed control specimen:

(1) Discoloration, staining and dulling.

(2) Etching.

(3) Presence of accretions and relative amounts.

(4) Pitting.

(5) Presence of selective or localized attack.

q. The three test specimens are returned to the same container they were immersed in for the first 24 hour period for an additional 144 hours.

s. After a total of 168 hours, the steps in paragraphs j through p are repeated.

t. All test specimens should be photographically documented immediately upon completion of the test.

u. Report the following information for each test performed:

(1) Summary of test methods and any deviations from the protocol.

(2) Identification of sample material alloy(s), product temper and selection of thickness of material tested including reference to product specification.

(3) Specimen details: Type and dimensions of test specimen and number of replicates.

(4) Identification of solution tested, concentration used and diluent used.

(5) Test conditions: temperature, exposure time and humidity.

(6) Identification of testing laboratory and responsible technical point of contact.

(7) Individual and average test results.

(8) Results of visual inspections, observations and discussion of specimen condition.

(9) Photographic documentation of specimen conditions (specifically any staining, evidence of general corrosion, etching, pitting or localized attack).

A.2.2 SURFACES

A.2.2.1 Effects on Painted Surfaces

Objective

The objective of this test is to determine the effects on painted surfaces of the manufacturer's suggested working concentration of the cleaning compound.

Criterion

The manufacturer's suggested working concentration of the cleaning compound shall not cause streaking, discoloration, blistering or a permanent decrease in film hardness of more than one (1) pencil hardness level on any painted surfaces. (ADS 61A PRF).

Test Procedures

The effect of the manufacturer's suggested working concentration of the cleaning compound on the painted surfaces is determined using ASTM F-502, Standard Test Method for Effects of Cleaning and Chemical Maintenance Materials on Painted Aircraft Surfaces.

a. The 18 test panels of aluminum Alclad 7075-T6, 3 by 6 by 0.02 in.(76 by 152 by 0.5 mm) are prepared according to the procedure given in ASTM F-502.

b. All of the test panels are cleaned with acetone, dried, and abraded lightly with a fine aluminum oxide mat. The surface is then rinsed with distilled water.

c. All of the test panels are coated with a conversion coat conforming to MIL-C-81706, Class 1A, and allowed to dry.

d. On 12 test panels one coat of MIL-P-23377 (Type I, Class C) epoxy primer, 0.6 to 0.8 mil (0.010 to 0.015 mm) is applied.

e. The test panels are allowed to dry at ambient (room) conditions.

f. Each of the following coatings is to be applied to three test panels: (Aircraft green is the preferred color.)

   (1) MIL-C-22750 epoxy topcoat.

   (2) MIL-C-85285, Type I polyurethane, high-solids topcoat.

   (3) MIL-C-46168, Type IV aliphatic polyurethane, single-component topcoat.

   (4) MIL-P-14105 heat-resistant paint.

g. The coatings in paragraph f are to be applied as a mist coat and allowed to dry for 30 minutes in ambient (room) conditions.

h. An additional three coats of the coatings should be applied in 0.010 to 0.015mm applications and allowed a 1-hour drying time at ambient (room) conditions between each coat.

i On the remaining 6 panels, one coat of MIL-P-53022 (Type II) epoxy primer, 0.6 to 0.8 mil (0.010 to 0.015 mm) is applied.

j. The test panels are allowed to dry at ambient (room) conditions.

k. Each of the following coatings is to be applied to three test panels: (Aircraft green is the preferred color.)

(1) MIL-C-64159 epoxy topcoat.

(3) MIL-C-53039, Amendment 2 aliphatic polyurethane, single-component topcoat, CARC.

l. The coatings in paragraph f are to be applied as a mist coat and allowed to dry for 30 minutes in ambient (room) conditions.

m. An additional three coats of the coatings should be applied in 0.010 to 0.015mm applications and allowed a 1-hour drying time at ambient (room) conditions between each coat.

n. The test panels are allowed to dry for four days at ambient (room) conditions.

o. The test panels are then baked for 24 hours in a mechanical convection oven at 82 ^{o}C (180 ^{o}F) or allowed to air dry an additional 3-10 days at room temperature.

p. A set of drawing pencils is prepared as described in the ASTM.

(1) Strip the wood away from one end of each pencil approximately 3/8 in. without damaging the lead.

(2) Square the tip of the lead by holding the pencil in a vertical position and moving the lead back and forth over a very fine (180 to 320 grit) sandpaper.

(3) Square the tip of the lead after each trial.

q Place the test panels in a horizontal position in an oven maintained at 100 ± 5°F (38 ± 2°C).

r. Apply the test solution to approximately one half the area of each panel and allow to remain on the panels for 30 min.

s. Then remove the panels from the oven and rinse with distilled or deionized water and allow to air dry for 24 hours.

t. Examine for streaking, discoloration, or blistering of the finish.

u. Determine the hardness of the treated and untreated areas in the following manner:

(1) Hold pencils of decreasing hardness by hand at a 45º angle and push across the paint film with a firm uniform pressure until a pencil is found that will not cut the film but will leave a black mark on the surface, whereas the next hardest pencil will cut through the film without leaving a black mark.

(2) The hardness number of the pencil that cuts the film shall express film hardness.

(3) Make at least three determinations on both exposed and unexposed portions of the coated panel.

v. Perform procedure for each of 3 panels for each coating set.

w. The paint hardness is not allowed to differ by more than one pencil hardness unit for each of the same type of paint test panels.

x. Report the following information for each test performed:

(1) Summary of test methods and any deviations from the protocol.

(2) Identification of sample materials tested including reference to product specification.

(3) Specimen details: Type and dimensions of test specimen and number of replicates.

(4) Identification of solution tested, concentration used and diluent used.

(5) Test conditions: temperature, exposure time and humidity.

(6) Identification of testing laboratory and responsible technical point of contact.

(7) Individual and average test results.

(8) Results of visual inspections, observations and discussion of specimen condition.

(9) Photographic documentation, if needed, of specimen conditions (specifically any staining, blistering or localized attack).

A.2.2.2 Effects on Carbon/Epoxy Composites

<u>Objective</u>

The objective of this test is to determine the effect on carbon/epoxy composites of the manufacturer's suggested working concentration of the cleaning compound.

Criterion

The manufacturer's suggested working concentration of the cleaning compound shall not cause the composite test coupon to have an average interlaminar shear strength less than the baseline sample.

Test Procedures

a. A sheet of carbon/epoxy laminate with parallel fibers shall be prepared as specified by ASTM D 2344.

b. Immerse one set of specimens in the test solvent for 24 hours ± 2at 75 °F ± 5 (24 °C ± 3).

c. Immerse another set of specimens in the control cleaner for 24 hours ± 2 at 75 °F ± 5 (24 °C ± 3).

d. Retain the third set for dry controls.

e. Determine shear strengths of the immersed and dry specimens as specified by ASTM D 2344.

f. Compare the loss of interlaminar shear strength by immersion in the test cleaner with that of the control cleaner.

A.2.3 PLASTICS, RUBBER AND SEALANTS

A.2.3.1 Effects on Polysulfide Sealants

Objective

The objective of this test is to determine the effect on polysulfide sealant of the manufacturer's suggested working concentration of the cleaning compound.

Criterion

The manufacturer's suggested working concentration of the cleaning compound shall not change the durometer hardness (Shore A) of polysulfide sealants more than 5 units.

Test Procedures

The effect that the manufacturer's suggested working concentration of the cleaning compound has on polysulfide sealants is determined using ADS-61A-PRF, Aeronautical Design Standard, Performance Specification for Army Aircraft Cleaners, Aqueous and Solvent.

a. Two test specimens should be prepared from MIL-S-81733, Type II, and AMS-S-8802, Type II sealants sheet stock.

b. It is assumed that these materials do not have hardnesses that depend on humidity.

c. The sheet stock is made by mixing the sealants as specified by the manufacturer and pressing each into a 0.3175-cm (0.125-in.) thick sheet mold.

d. The sealant was cured using the standard cure of 14 days at 25° ± 3 ^{o}C at 50% relative humidity.

e. Test specimens are cut from the cured sheet stock. Specimens should have sufficient surface area for hardness testing before and after exposure to the test cleaning compound. Recommended specimen dimensions would be 2 x 2 in. (50 mm x 50 mm).

f. Test each specimen for Shore A hardness in accordance with ASTM D2240.

g. All testing is conducted at ambient (room) temperature.

h. Immerse the two test specimens from each sealant into the manufacturer's suggested working concentration of the cleaning compound.

i. The test specimens are allowed to soak for 30 minutes.

j. The test specimens are removed from the manufacturer's suggested working concentration of the cleaning compound and rinsed with cool tap water.

k. The test specimens are then tested for a Shore A hardness in accordance with ASTM D-2240-95 within 5 minutes of removal from the cleaning compound.

l. The cleaning compound shall not change the durometer hardness more than five units after exposure.

m. Report the following information for each test performed:

(1) Summary of test methods and any deviations from the protocol.

(2) Identification of sample material, selection of thickness of material tested including reference to product specification.

(3) Specimen details: Type and dimensions of test specimen and number of replicates.

(4) Identification of solution tested, concentration used and diluent used.

(5) Test conditions: temperature, exposure time and humidity.

(6) Identification of testing laboratory and responsible technical point of contact.

(7) Individual and average test results.

(8) Results of visual inspections, observations and discussion of specimen condition.

A.2.3.2 Effects on Rubber

Objective

The objective of this test is to evaluate the effect of the manufacturer's maximum recommended use concentration of the test cleaner on the mechanical properties of strength, elongation and hardness of the rubber compounds immersed in the cleaner.

Criterion

The manufacture's maximum recommended use concentration of the cleaning compound shall not change the tensile strength +/- 15%, elongation +/- 20% or Shore A hardness +/- 7 of the rubber material (Test Matrix).

Test Procedure

Compatibility of the manufacturer's maximum recommended use concentration of the cleaning solution with rubber is determined using ASTM D 471, Standard Test Method for Rubber Property – Effects of Liquids, section 15, Changes in Tensile Strength, Elongation and Hardness and ASTM D 412 Standard Test Methods for Vulcanized Rubber and Thermoplastic Elastomers-Tension.

a. Three test specimens and three control specimens should be prepared from each of the following rubbers, AMS 3217/2B, AMS 3217/3B and various formulas of MIL-DTL-45301.

b. The compounds of MIL-DTL-45301 are:

0235 from the M88 vehicle roadwheel
0135 from the M113, Bradley Fighting Vehicle and M109 vehicle trackblock wheel side
0149 from the Bradley Fighting Vehicle and M1 vehicle roadwheel
P12 from the M113 roadwheel
14A (T107 G/S) from the M88 vehicle trackblock ground side
10L (T107 W/S from the M88 and M60 vehicles trackblock wheel side
RW Compression from the Bradley Fighting Vehicle and M113 roadwheel

c. Prepare the specimens from flat vulcanized sheets 2.0 ± 0.1 mm (0.08 ± 0.004 in.) in thickness using Die C of ASTM D 412.

d. All material used for the baseline tensile strength, elongation and hardness as well as test specimens shall be from the same lot.

e. Measure the thickness and width of each tensile and elongation test specimen.

f. Using a Shore A durometer hardness tester, measure the hardness of each specimen by taking, at a minimum, 5 readings and record the average.

g. Place the specimens in a glass test tube, having an approximate outside diameter of 38 mm (1.5 in.) and an approximate overall length of 300 mm (12 in.) fitted loosely with a stopper. The stopper shall not contaminate the test liquid. Clean glass beads shall be used in the tube as a bumper and to separate the specimens.

h. Add enough of the test solution to the test tube to cover the specimen.

i. Test liquids shall not be reused.

j. Allow the test specimen to be immersed for a period of 2 hours at a temperature of 23ºC. Immersion tests shall be made in the absence of direct light.

k. At the end of the immersion period, remove the specimens from the test tubes and immediately take a minimum of 5 Shore A hardness readings and record the average.

l. The specimens are then allowed to air dry at 23º C 50% RH for 24 hours.

m. Determine the tensile strength and ultimate elongation in accordance with ASTM D 412, using the original un-immersed thickness or cross-sectional area. Shore A hardness readings are again taken as in paragraph i.

n. Calculate the change in properties as follows:

(1) Tensile strength based on the original unstretched cross-sectional area:

$$TS_0 = \frac{F}{A}$$

(2) To express tensile strength and ultimate elongation after immersion as a percentage change from the original properties, use the following formula:

$$\Delta P, \% = \frac{P_i - P_o}{P_o} X \cdot 100$$

(3) Calculate the hardness change after immersion in hardness units:

$$\Delta H = H_i - H_o$$

where:

TS_o = tensile stress based on original unstretched cross-sectional area

F = observed force,

A = original unstretched cross-sectional area of the test specimen before immersion,

ΔP = change in property (tensile strength and ultimate elongation) after immersion, %,

P_0 = original property before immersion,

P_i = property after immersion,

ΔH = hardness change after immersion, units,

H_0 = original hardness before immersion, units

H_i = hardness after immersion, units.

n. Report the following information for each test performed:

(1) Summary of test methods and any deviations from the protocol.

(2) Identification of sample materials and selection of thickness of material tested including reference to product specification.

(3) Specimen details: Type and dimensions of test specimen and number of replicates.

(4) Identification of solution tested, concentration used and diluent used.

(5) Test conditions: temperature, exposure time and humidity.

(6) Identification of testing laboratory and responsible technical point of contact.

(7) Individual and average test results.

(8) Results of visual inspections, observations and discussion of specimen condition.

(9) Photographic documentation, if needed, of specimen conditions.

A.2.3 Effects on Elastomers, Plastics, and Fluorocarbons

Objective

The objective of this test is to evaluate the effect of the manufacturer's maximum recommended use concentration of the test cleaner on the mechanical properties of strength, elongation and hardness of the elastomer, plastic, and fluorocarbon compounds immersed in the cleaner.

Criterion

The manufacture's maximum recommended use concentration of the cleaning compound shall not change the tensile strength +/- 15%, elongation +/- 20% or Shore A hardness +/- 7 of the elastomer, plastic, and fluorocarbon materials.

Test Procedure

Compatibility of the manufacturer's maximum recommended use concentration of the cleaning solution with rubber is determined using ASTM D 471, Standard Test Method for Rubber Property – Effects of Liquids, section 15, Changes in Tensile Strength, Elongation and Hardness and ASTM D 412 Standard Test Methods for Vulcanized Rubber and Thermoplastic Elastomers-Tension.

c. Three test specimens and three control specimens should be prepared from each of the elastomer, plastic, and fluorocarbon materials.

d. Prepare the specimens from flat vulcanized sheets 2.0 ± 0.1 mm (0.08 ± 0.004 in.) in thickness using Die C of ASTM D 412.

e. All material used for the baseline tensile strength, elongation and hardness as well as test specimens shall be from the same lot.

f. Measure the thickness and width of each tensile and elongation test specimen.

g. Using a Shore A durometer hardness tester, measure the hardness of each specimen by taking, at a minimum, 5 readings and record the average.

h. Place the specimens in a glass test tube, having an approximate outside diameter of 38 mm (1.5 in.) and an approximate overall length of 300 mm (12 in.) fitted loosely with a stopper. The stopper shall not contaminate the test liquid. Clean glass beads shall be used in the tube as a bumper and to separate the specimens.

i. Add enough of the test solution to the test tube to cover the specimen.

j. Test liquids shall not be reused.

k. Allow the test specimen to be immersed for a period of 2 hours at a temperature of 23ºC. Immersion tests shall be made in the absence of direct light.

l. At the end of the immersion period, remove the specimens from the test tubes and immediately take a minimum of 5 Shore A hardness readings and record the average.

m. The specimens are then allowed to air dry at 23º C 50% RH for 24 hours.

n. Determine the tensile strength and ultimate elongation in accordance with ASTM D 412, using the original un-immersed thickness or cross-sectional area. Shore A hardness readings are again taken as in paragraph i.

o. Calculate the change in properties as follows:

(1) Tensile strength based on the original unstretched cross-sectional area:

$$TS_0 = \frac{F}{A}$$

(2) To express tensile strength and ultimate elongation after immersion as a percentage change from the original properties, use the following formula:

$$\Delta P, \% = \frac{P_i - P_o}{P_o} X \cdot 100$$

(3) Calculate the hardness change after immersion in hardness units:

$$\Delta H = H_i - H_o$$

where:

TS_o = tensile stress based on original unstretched cross-sectional area

F = observed force,

A = original unstretched cross-sectional area of the test specimen before immersion,

ΔP = change in property (tensile strength and ultimate elongation) after immersion, %,

P_0 = original property before immersion,

P_i = property after immersion,

ΔH = hardness change after immersion, units,

H_0 = original hardness before immersion, units

H_i = hardness after immersion, units.

p. Report the following information for each test performed:

(1) Summary of test methods and any deviations from the protocol.

(2) Identification of sample materials and selection of thickness of material tested including reference to product specification.

(3) Specimen details: Type and dimensions of test specimen and number of replicates.

(4) Identification of solution tested, concentration used and diluent used.

(5) Test conditions: temperature, exposure time and humidity.

(6) Identification of testing laboratory and responsible technical point of contact.

(7) Individual and average test results.

(8) Results of visual inspections, observations and discussion of specimen condition.

(9) Photographic documentation, if needed, of specimen conditions.

Appendix F Corpus Christi Army Depot Demonstration

CCAD TBAC Performance Test – UH-60 Flight Controls Mixer Shaft

1. Objective

The objective of this hand-wipe cleaning solvent performance test is to determine if TBAC is an effective and alternative pollution prevention substitution for acetone. The process demonstration at CCAD is required to obtain results for measuring specific primary performance criteria as described in the Performance Objectives of the demonstration design. The primary performance criteria is measured against tests and/or standards that include laboratory tests such as ADS-61A-PRF, published EPA lists for HAPs or exempt VOCs, and performance results from a CCAD process demonstration test. The results of each of these measurements including the CCAD process demonstration test are represented and published in this report.

The CCAD production process demonstration selected for testing is the hand-wipe solvent cleaning of the shaft which is part of the UH-60 Flight Controls Mixer Assembly depicted in photo 1 and shown separately in photo 2. The following table describes the details of the process and demonstration part. Currently, a hand wipe cleaning procedure moistened with the solvent acetone is used to remove light grease, dust and dirt from the shaft before it is used for assembly of the UH-60 Flight Controls Mixer.

Facility	Industrial Operation	Part	Part Number / Component	Contamination	Current Hand Wipe Solvent
AVIM	Assembly of UH-60 Flight Controls Mixer	Shaft, chromeplated	70400-02155-103	Light grease, dust, dirt	Acetone

Photo 1. UH-60 Flight Controls Mixer Assembly

Photo 2. S haft Part no. 70400-02155-103

2. Approach

As previously stated this CCAD hand-wipe process demonstration test will determine the results to measure specific primary performance criteria. A single shaft was selected and cleaned for establishing a baseline comparison using the existing solvent acetone. Following the establishment of the baseline for comparison, the demonstration consisted of three separate tests with three separate but identical parts (photo 3).

The procedure for each test required a standard lint-free dry cloth moistened with TBAC to clean the entire surface area of the shaft. After each cleaning procedure the shaft was visually inspected and performance criteria results were discussed with the mechanic performing the demonstration (photo 4). The performance data obtained from each demonstration was manually recorded.

Photo 3. Three parts tested

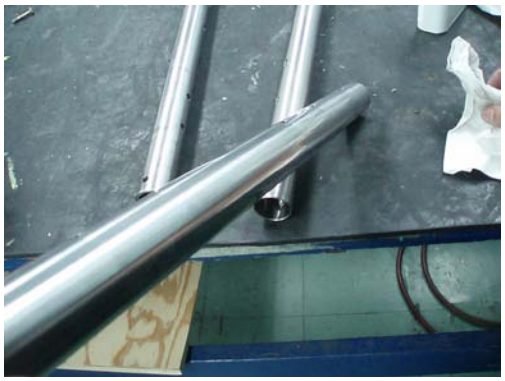


Photo 4. Inspection after cleaning

3. Demonstration Results

The performance data results and score for each test is shown in each of the following tables I, II, III. It should be noted that only those primary performance criteria assessed by the CCAD process demonstration is marked with a footnote number one (1). However, the tables include all primary performance objectives and test results.

In each of three (3) tests, TBAC performed satisfactory against all criteria except in two categories. After hand wiping the shaft with TBAC, visual inspection revealed a slight residue that required additional wiping with a dry cloth. The residue remaining after wiping the shaft with TBAC caused the wipe test to fail in meeting the performance criteria for “drying time” and “performance effectiveness”. The results of these two categories should not be considered a show stopper for considering TBAC as an acceptable substitution in this application. TBAC was successful at removing all contaminants equal to the current solvent acetone. However, there would be an additional step required of wiping the shaft with a dry cloth in the current procedure to achieve an equal surface finish. The impact on production due to the low number of shafts processed per month and the short time required performing an extra wipe would be minimal.

Table I – Performance Test #1

Project:Demonstration/Validation of TBAC for Hand Wipe Solvent Cleaning
Part Number: 70400-02155-103
Description: UH-60 Flight Controls Assembly Shaft
CCAD Industrial Operation: AVIM Work Center 529B0
DMWR Reference: 1-1615-282
Contamination: light grease, dust, dirt
Current Solvent Replaced in Demonstration: Acetone

Performance
Successful (Pass)
Not Successful (Fail)

Date: 12 March 2007
Time: 09:40
Test #1

Primary Performance Critera	Expected Performance (Metric)	Performance Objective Met?	Comments
Quantitative			
Effective cleaning on painted aircraft surfaces	Not cause streaking, discoloration, blistering. Not cause permanent decrease in film hardness. (> 1 pencil hardness)	Pass	criterion met per Lab Test ADS-61A-PRF ASTM F502-93
Total Immersion Corrosion	No Corrosion	Pass	criterion met per Lab Test ASTM F-483
Drying Time (1)	Acceptable drying time without affecting production	Fail	TBAc requires additional dry wiping
Toxicity	Shall have no adverse effect on human health when used as intended	Pass	clearance granted by U.S. Army CHPPM
Flammability	Shall not increase hazard category of the operation	Pass	higher flash point
Volatile Organic Compounds	Shall contain less than 50 g/l VOC, be VOC exempt, or a SCAQMD certified clean air solvent	Pass	exempt by EPA
Hazardous Air Pollutants (HAPs)	Total quantity of HAPs contained in the solvent shall be less than 0.1%.	Pass	TBAc not contained on EPA HAP list
ODC	Total quantity of ODCs in the solvent shall be less than 0.1%.	Pass	Not on EPA ODC list
Global Warming Compounds	Shall not be a GWC	Pass	Not on EPA GWC list
Qualitative			
Effectiveness (1)	Effective removal of contaminants comparable to the current solvent; no adverse impact on process due to residue left on surface	Fail	Effectively removes dust & grease, however TBAc leaves slight residue
Production Time (1)	Acceptable to production	Pass	Additional wiping is undesirable but acceptable
Odor compatibility (1)	Satisfactory odor per worker/observer survey based on operating experience; less obtrusive than current solvent	Pass	Odor noticeable by workers but not more obtrusive than current solvent
Reliability (1)	The demonstration solvent must be chemically compatible with materials and chemicals that are part of the process during which the demonstration solvent is used.	Pass	Part is chrome plated and baked to remove hydrogen introduced by functional chrome plating
Cost/Safety/Environmental Factors	The demonstration solvent must not require significant capital investment. No adverse change in safety requirements or PPE.	Pass	TBAc cost equal; no increase in capital; no adverse change in PPE
Ease of Use (1)	The demonstration solvent must not significantly affect the process parameters.	Pass	No significant affect on process parameters
Versatility	The demonstration solvent is particularly suitable for non-attainment areas (exempt / low VOC's)	Pass	

(1) Primary Performance Criteria assessed by CCAD production process demonstration

Table II – Performance Test #2

Project:Demonstration/Validation of TBAC for Hand Wipe Solvent Cleaning
Part Number: 70400-02155-103
Description: UH-60 Flight Controls Assembly Shaft
CCAD Industrial Operation: AVIM Work Center 529B0
DMWR Reference: 1-1615-282
Contamination: light grease, dust, dirt
Current Solvent Replaced in Demonstration: Acetone

Performance
Successful (Pass)
Not Successful (Fail)

Date: 12 March 2007
Time: 09:50
Test #2

Primary Performance Critera	Expected Performance (Metric)	Performance Objective Met?	Comments
Quantitative			
Effective cleaning on painted aircraft surfaces	Not cause streaking, discoloration, blistering. Not cause permanent decrease in film hardness. (> 1 pencil hardness)	Pass	criterion met per Lab Test ADS-61A-PRF ASTM F502-93
Total Immersion Corrosion	No Corrosion	Pass	criterion met per Lab Test ASTM F-483
Drying Time (1)	Acceptable drying time without affecting production	Fail	TBAc requires additional dry wiping
Toxicity	Shall have no adverse effect on human health when used as intended	Pass	clearance granted by U.S. Army CHPPM
Flammability	Shall not increase hazard category of the operation	Pass	higher flash point
Volatile Organic Compounds	Shall contain less than 50 g/l VOC, be VOC exempt, or a SCAQMD certified clean air solvent	Pass	exempt by EPA
Hazardous Air Pollutants (HAPs)	Total quantity of HAPs contained in the solvent shall be less than 0.1%.	Pass	TBAc not contained on EPA HAP list
ODC	Total quantity of ODCs in the solvent shall be less than 0.1%.	Pass	Not on EPA ODC list
Global Warming Compounds	Shall not be a GWC	Pass	Not on EPA GWC list
Qualitative			
Effectiveness (1)	Effective removal of contaminants comparable to the current solvent; no adverse impact on process due to residue left on surface	Fail	Effectively removes dust & grease, however TBAc leaves slight residue
Production Time (1)	Acceptable to production	Pass	Additional wiping is undesirable but acceptable
Odor compatibility (1)	Satisfactory odor per worker/observer survey based on operating experience; less obtrusive than current solvent	Pass	Odor noticeable by workers but not more obtrusive than current solvent
Reliability (1)	The demonstration solvent must be chemically compatible with materials and chemicals that are part of the process during which the demonstration solvent is used.	Pass	Part is chrome plated and baked to remove hydrogen introduced by functional chrome plating
Cost/Safety/Environmental Factors	The demonstration solvent must not require significant capital investment. No adverse change in safety requirements or PPE.	Pass	TBAc cost equal; no increase in capital; no adverse change in PPE
Ease of Use (1)	The demonstration solvent must not significantly affect the process parameters.	Pass	No significant affect on process parameters
Versatility	The demonstration solvent is particularly suitable for non-attainment areas (exempt / low VOC's)	Pass	

(1) Primary Performance Criteria assessed by CCAD production process demonstration

Table III – Performance Test #3

Project:Demonstration/Validation of TBAC for Hand Wipe Solvent Cleaning
Part Number: 70400-02155-103
Description: UH-60 Flight Controls Assembly Shaft
CCAD Industrial Operation: AVIM Work Center 529B0
DMWR Reference: 1-1615-282
Contamination: light grease, dust, dirt
Current Solvent Replaced in Demonstration: Acetone

Performance
Successful (Pass)
Not Successful (Fail)

Date: 12 March 2007
Time: 10:00
Test #3

Primary Performance Critera	Expected Performance (Metric)	Performance Objective Met?	Comments
Quantitative			
Effective cleaning on painted aircraft surfaces	Not cause streaking, discoloration, blistering. Not cause permanent decrease in film hardness. (> 1 pencil hardness)	Pass	criterion met per Lab Test ADS-61A-PRF ASTM F502-93
Total Immersion Corrosion	No Corrosion	Pass	criterion met per Lab Test ASTM F-483
Drying Time (1)	Acceptable drying time without affecting production	Fail	TBAc requires additional dry wiping
Toxicity	Shall have no adverse effect on human health when used as intended	Pass	clearance granted by U.S. Army CHPPM
Flammability	Shall not increase hazard category of the operation	Pass	higher flash point
Volatile Organic Compounds	Shall contain less than 50 g/l VOC, be VOC exempt, or a SCAQMD certified clean air solvent	Pass	exempt by EPA
Hazardous Air Pollutants (HAPs)	Total quantity of HAPs contained in the solvent shall be less than 0.1%.	Pass	TBAc not contained on EPA HAP list
ODC	Total quantity of ODCs in the solvent shall be less than 0.1%.	Pass	Not on EPA ODC list
Global Warming Compounds	Shall not be a GWC	Pass	Not on EPA GWC list
Qualitative			
Effectiveness (1)	Effective removal of contaminants comparable to the current solvent; no adverse impact on process due to residue left on surface	Fail	Effectively removes dust & grease, however TBAc leaves slight residue
Production Time (1)	Acceptable to production	Pass	Additional wiping is undesirable but acceptable
Odor compatibility (1)	Satisfactory odor per worker/observer survey based on operating experience; less obtrusive than current solvent	Pass	Odor noticeable by workers but not more obtrusive than current solvent
Reliability (1)	The demonstration solvent must be chemically compatible with materials and chemicals that are part of the process during which the demonstration solvent is used.	Pass	Part is chrome plated and baked to remove hydrogen introduced by functional chrome plating
Cost/Safety/Environmental Factors	The demonstration solvent must not require significant capital investment. No adverse change in safety requirements or PPE.	Pass	TBAc cost equal; no increase in capital; no adverse change in PPE
Ease of Use (1)	The demonstration solvent must not significantly affect the process parameters.	Pass	No significant affect on process parameters
Versatility	The demonstration solvent is particularly suitable for non-attainment areas (exempt / low VOC's)	Pass	

(1) Primary Performance Criteria assessed by CCAD production process demonstration

CCAD TBAC Performance Test – UH-60 Aircraft Fuselage

1. Objective

The objective of this hand-wipe cleaning solvent performance test is to determine if TBAC is an effective and alternative pollution prevention substitution for Toluene. The process demonstration at CCAD is required to obtain results for measuring specific primary performance criteria as described in the Performance Objectives of the demonstration design. The primary performance criteria is measured against tests and/or standards that include laboratory tests such as ADS-61A-PRF, published EPA lists for HAPs or exempt VOCs, and performance results from a CCAD process demonstration test. The results of each of these measurements including the CCAD process demonstration test are represented and published in this report.

The CCAD production process demonstration selected for testing is the hand-wipe solvent cleaning of the UH-60 fuselage tub (photo 1) and other fuselage panels (photo 2 & 3) during initial cleaning after pre-shop analysis (PSA) dis-assembly. The tub is primed and is contaminated with grease, oil, dirt and lubricants. In addition the tub stringers contain adhesive residue that is used to bond the floor boards. The other panels tested are also primed and contaminated with grease, oils, dirt and lubricants. The following table describes the details of the current process and selected aircraft for demonstration. Currently, a hand wipe moistened with the solvent Toluene is used to clean and remove the contaminants before it proceeds to the next production operation.

Facility	Industrial Operation	Part / Component	Part Number	Contamination	Current Hand Wipe Solvent
Aircraft Cleaning WC 554 A0	UH-60 Aircraft Cleaning	Fuselage cabin/tub & panels	UH-60 Aircraft Tail# 80-23440	grease, oils, adhesive residue, dirt, lubricants	Toluene

Photo 1. Fuselage tub

Photo 2. Canted bulkhead

Photo 3. Roof panel

2. Approach

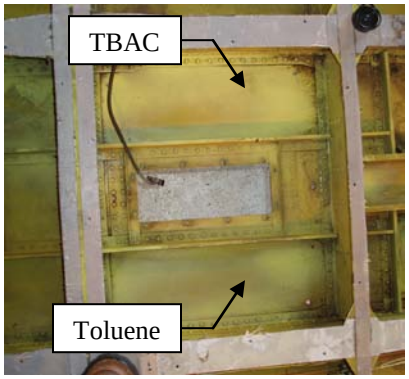
As previously stated this CCAD hand-wipe process demonstration test will determine the results to measure specific primary performance criteria. An area measuring approximately one square foot of the various areas chosen for cleaning were tested by first creating a baseline cleaning with Toluene followed by a cleaning of an equal area with TBAC. All the tests were performed on one UH-60 aircraft identified as tail number (SN) 80-23440.

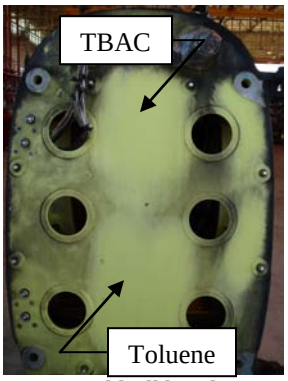
The procedure for each test required a standard lint-free dry cloth moistened with TBAC to clean the surface area selected. After each cleaning procedure the area was visually inspected and performance criteria results were discussed with the operator performing the demonstration. The performance data obtained from each demonstration was manually recorded.

3. Demonstration Results

The performance data results and score for each test is shown in each of the following tables Table I, Table II, Table III, Table IV, & Table V. Tests 1, 2 & 3 were performed in the fuselage tub area (photo 3) and tests 4 & 5 (photo 4 & 5) were performed on other fuselage panel areas. It should be noted that only those primary performance criteria assessed by the CCAD process demonstration is marked with a footnote number one (1). However, the tables include all primary performance objectives and test results.

In all of the tests for the tub and panels for removing grease, oil, dirt and lubricants, TBAC performed satisfactory against all criteria except in one category “odor compatibility”. TBAC was noticed by the operator and observers to have a significantly stronger odor. In the tests to remove adhesive residue, TBAC did not perform satisfactory in the category “effectiveness”. TBAC caused the adhesive residue to swell and become gummy but would not completely dissolve the adhesive residue. Toluene performed more effectively at removing adhesive residue. The effectiveness of TBAC at removing grease, oil, dirt and lubricants in all tests suggests TBAC will be effective as a general degreasing solvent. The removal of adhesive residue will eventually be a non-factor through the use of the newer silicone adhesive tapes being specified for use in installing floor boards that can be removed without any solvents.





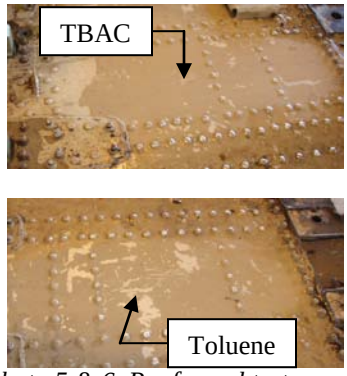


Photo 3. Tub test *Photo 4. Canted bulkhead test* *Photo 5 & 6. Roof panel test*

Table I – Performance Test #1

Project:Demonstration/Validation of TBAC for Hand Wipe Solvent Cleaning			Performance
Part Number / Description: UH-60 Fuselage Tub			Successful (Pass)
CCAD Industrial Operation: Aircraft Cleaning Work Center 554A0			Not Successful (Fail)
Contamination: grease, oil, dirt, lubricants, adhesive residue			
Current Solvent Replaced in Demonstration: Toluene			Date: 09-20-07
			Time: 12:20
			Test #1
Primary Performance Critera	Expected Performance (Metric)	Performance Objective Met?	Comments
Quantitative			
Effective cleaning on painted aircraft surfaces	Not cause streaking, discoloration, blistering. Not cause permanent decrease in film hardness (> 1 pencil hardness)	Pass	criterion met per Lab Test ADS-61A-PRF ASTM F502-93
Total Immersion Corrosion	No Corrosion	Pass	criterion met per Lab Test ASTM F-483
Drying Time (1)	Acceptable drying time without affecting production	Pass	observed it to be equal in the demonstration
Toxicity	Shall have no adverse effect on human health when used as intended	Pass	clearance granted by U.S. Army CHPPM
Flammability	Shall not increase hazard category of the operation	Pass	equal flash points (4°C)
Volatile Organic Compounds	Shall contain less than 50 g/l VOC, be VOC exempt, or a SCAQMD certified clean air solvent	Pass	exempt by EPA
Hazardous Air Pollutants (HAPs)	Total quantity of HAPs contained in the solvent shall be less than 0.1%.	Pass	TBAc not contained on EPA HAP list
ODC	Total quantity of ODCs in the solvent shall be less than 0.1%.	Pass	
Global Warming Compounds	Shall not be a GWC	Pass	
Qualitative			
Effectiveness (1)	Effective removal of contaminants comparable to the current solvent; no adverse impact on process due to residue left on surface	Fail	equally effective on grease, oil and dirt; less effective on adhesive residue
Production Time (1)	Acceptable to production	Pass	
Odor compatibility (1)	Satisfactory odor per worker/observer survey based on operating experience	Fail	Operator/observer noted TBAC had a stronger odor
Reliability (1)	The demonstration solvent must be chemically compatible with materials and chemicals that are part of the process during which the demonstration solvent is used.	Pass	
Cost/Safety/Environmental Factors	The demonstration solvent must not require significant capital investment. No adverse change in safety requirements or PPE.	Pass	TBAc equal in cost; no increase in capital; no adverse change in PPE
Ease of Use (1)	The demonstration solvent must not significantly affect the process parameters.	Pass	
Versatility	The demonstration solvent is particularly suitable for non-attainment areas (VOC exempt or low VOC's).	Pass	
(1) Primary Performance Criteria assessed by CCAD production process demonstration			

Table II – Performance Test #2

Project:Demonstration/Validation of TBAC for Hand Wipe Solvent Cleaning			Performance
Part Number / Description: UH-60 Fuselage Tub			Successful (Pass)
CCAD Industrial Operation: Aircraft Cleaning Work Center 554A0			Not Successful (Fail)
Contamination: grease, oilm dirt, lubricants, adhesive residue			
Current Solvent Replaced in Demonstration: Toluene			Date: 09-20-07
			Time: 12:30
			Test #2
Primary Performance Critera	Expected Performance (Metric)	Performance Objective Met?	Comments
Quantitative			
Effective cleaning on painted aircraft surfaces	Not cause streaking, discoloration, blistering. Not cause permanent decrease in film hardness (> 1 pencil hardness)	Pass	criterion met per Lab Test ADS-61A-PRF ASTM F502-93
Total Immersion Corrosion	No Corrosion	Pass	criterion met per Lab Test ASTM F-483
Drying Time (1)	Acceptable drying time without affecting production	Pass	observed it to be equal in the demonstration
Toxicity	Shall have no adverse effect on human health when used as intended	Pass	clearance granted by U.S. Army CHPPM
Flammability	Shall not increase hazard category of the operation	Pass	equal flash points (4°C)
Volatile Organic Compounds	Shall contain less than 50 g/l VOC, be VOC exempt, or a SCAQMD certified clean air solvent	Pass	exempt by EPA
Hazardous Air Pollutants (HAPs)	Total quantity of HAPs contained in the solvent shall be less than 0.1%.	Pass	TBAc not contained on EPA HAP list
ODC	Total quantity of ODCs in the solvent shall be less than 0.1%.	Pass	
Global Warming Compounds	Shall not be a GWC	Pass	
Qualitative			
Effectiveness (1)	Effective removal of contaminants comparable to the current solvent; no adverse impact on process due to residue left on surface	Fail	equally effective on grease, oil and dirt; less effective on adhesive residue
Production Time (1)	Acceptable to production	Pass	
Odor compatibility (1)	Satisfactory odor per worker/observer survey based on operating experience	Fail	Operator/observer noted TBAC had a stronger odor
Reliability (1)	The demonstration solvent must be chemically compatible with materials and chemicals that are part of the process during which the demonstration solvent is used.	Pass	
Cost/Safety/Environmental Factors	The demonstration solvent must not require significant capital investment. No adverse change in safety requirements or PPE.	Pass	TBAc equal in cost; no increase in capital; no adverse change in PPE
Ease of Use (1)	The demonstration solvent must not significantly affect the process parameters.	Pass	
Versatility	The demonstration solvent is particularly suitable for non-attainment areas (VOC exempt or low VOC's).	Pass	
(1) Primary Performance Criteria assessed by CCAD production process demonstration			

Table III – Performance Test #3

Project:Demonstration/Validation of TBAC for Hand Wipe Solvent Cleaning			Performance
Part Number / Description: UH-60 Fuselage Tub			Successful (Pass)
CCAD Industrial Operation: Aircraft Cleaning Work Center 554A0			Not Successful (Fail)
Contamination: grease, oil, dirt, lubricants, adhesive residue			
Current Solvent Replaced in Demonstration: Toluene			Date: 09-20-07
			Time: 12:40
			Test #3

Primary Performance Critera	Expected Performance (Metric)	Performance Objective Met?	Comments
Quantitative			
Effective cleaning on painted aircraft surfaces	Not cause streaking, discoloration, blistering. Not cause permanent decrease in film hardness (> 1 pencil hardness)	Pass	criterion met per Lab Test ADS-61A-PRF ASTM F502-93
Total Immersion Corrosion	No Corrosion	Pass	criterion met per Lab Test ASTM F-483
Drying Time (1)	Acceptable drying time without affecting production	Pass	observed it to be equal in the demonstration
Toxicity	Shall have no adverse effect on human health when used as intended	Pass	clearance granted by U.S. Army CHPPM
Flammability	Shall not increase hazard category of the operation	Pass	equal flash points (4°C)
Volatile Organic Compounds	Shall contain less than 50 g/l VOC, be VOC exempt, or a SCAQMD certified clean air solvent	Pass	exempt by EPA
Hazardous Air Pollutants (HAPs)	Total quantity of HAPs contained in the solvent shall be less than 0.1%.	Pass	TBAc not contained on EPA HAP list
ODC	Total quantity of ODCs in the solvent shall be less than 0.1%.	Pass	
Global Warming Compounds	Shall not be a GWC	Pass	
Qualitative			
Effectiveness (1)	Effective removal of contaminants comparable to the current solvent; no adverse impact on process due to residue left on surface	Fail	equally effective on grease, oil and dirt; less effective on adhesive residue
Production Time (1)	Acceptable to production	Pass	
Odor compatibility (1)	Satisfactory odor per worker/observer survey based on operating experience	Fail	Operator/observer noted TBAC had a stronger odor
Reliability (1)	The demonstration solvent must be chemically compatible with materials and chemicals that are part of the process during which the demonstration solvent is used.	Pass	
Cost/Safety/Environmental Factors	The demonstration solvent must not require significant capital investment. No adverse change in safety requirements or PPE.	Pass	TBAc equal in cost; no increase in capital; no adverse change in PPE
Ease of Use (1)	The demonstration solvent must not significantly affect the process parameters.	Pass	
Versatility	The demonstration solvent is particularly suitable for non-attainment areas (VOC exempt or low VOC's).	Pass	

(1) Primary Performance Criteria assessed by CCAD production process demonstration

Table IV – Performance Test #4

Project:Demonstration/Validation of TBAC for Hand Wipe Solvent Cleaning			Performance
Part Number / Description: UH-60 Canted Bulkhead			Successful (Pass)
CCAD Industrial Operation: Aircraft Cleaning Work Center 554A0			Not Successful (Fail)
Contamination: grease, dirt, lubricants			
Current Solvent Replaced in Demonstration: Toluene			Date: 09-20-07
			Time: 12:50
			Test #4

Primary Performance Critera	Expected Performance (Metric)	Performance Objective Met?	Comments
Quantitative			
Effective cleaning on painted aircraft surfaces	Not cause streaking, discoloration, blistering. Not cause permanent decrease in film hardness (> 1 pencil hardness)	Pass	criterion met per Lab Test ADS-61A-PRF ASTM F502-93
Total Immersion Corrosion	No Corrosion	Pass	criterion met per Lab Test ASTM F-483
Drying Time (1)	Acceptable drying time without affecting production	Pass	observed it to be equal in the demonstration
Toxicity	Shall have no adverse effect on human health when used as intended	Pass	clearance granted by U.S. Army CHPPM
Flammability	Shall not increase hazard category of the operation	Pass	equal flash points (4°C)
Volatile Organic Compounds	Shall contain less than 50 g/l VOC, be VOC exempt, or a SCAQMD certified clean air solvent	Pass	exempt by EPA
Hazardous Air Pollutants (HAPs)	Total quantity of HAPs contained in the solvent shall be less than 0.1%.	Pass	TBAc not contained on EPA HAP list
ODC	Total quantity of ODCs in the solvent shall be less than 0.1%.	Pass	
Global Warming Compounds	Shall not be a GWC	Pass	
Qualitative			
Effectiveness (1)	Effective removal of contaminants comparable to the current solvent; no adverse impact on process due to residue left on surface	Pass	equally effective on grease, oil and dirt
Production Time (1)	Acceptable to production	Pass	
Odor compatibility (1)	Satisfactory odor per worker/observer survey based on operating experience	Fail	Operator/observer noted TBAC had a stronger odor
Reliability (1)	The demonstration solvent must be chemically compatible with materials and chemicals that are part of the process during which the demonstration solvent is used.	Pass	
Cost/Safety/Environmental Factors	The demonstration solvent must not require significant capital investment. No adverse change in safety requirements or PPE.	Pass	TBAc equal in cost; no increase in capital; no adverse change in PPE
Ease of Use (1)	The demonstration solvent must not significantly affect the process parameters.	Pass	
Versatility	The demonstration solvent is particularly suitable for non-attainment areas (VOC exempt or low VOC's).	Pass	

(1) Primary Performance Criteria assessed by CCAD production process demonstration

Table V – Performance Test #5

Project:Demonstration/Validation of TBAC for Hand Wipe Solvent Cleaning			Performance
Part Number / Description: UH-60 Fuselage Roof Panel			Successful (Pass)
CCAD Industrial Operation: Aircraft Cleaning Work Center 554A0			Not Successful (Fail)
Contamination: grease, dirt, lubricants			
Current Solvent Replaced in Demonstration: Toluene			Date: 09-20-07
			Time: 13:00
			Test #5
Primary Performance Critera	Expected Performance (Metric)	Performance Objective Met?	Comments
Quantitative			
Effective cleaning on painted aircraft surfaces	Not cause streaking, discoloration, blistering. Not cause permanent decrease in film hardness (> 1 pencil hardness)	Pass	criterion met per Lab Test ADS-61A-PRF ASTM F502-93
Total Immersion Corrosion	No Corrosion	Pass	criterion met per Lab Test ASTM F-483
Drying Time (1)	Acceptable drying time without affecting production	Pass	observed it to be equal in the demonstration
Toxicity	Shall have no adverse effect on human health when used as intended	Pass	clearance granted by U.S. Army CHPPM
Flammability	Shall not increase hazard category of the operation	Pass	equal flash points (4°C)
Volatile Organic Compounds	Shall contain less than 50 g/l VOC, be VOC exempt, or a SCAQMD certified clean air solvent	Pass	exempt by EPA
Hazardous Air Pollutants (HAPs)	Total quantity of HAPs contained in the solvent shall be less than 0.1%.	Pass	TBAc not contained on EPA HAP list
ODC	Total quantity of ODCs in the solvent shall be less than 0.1%.	Pass	
Global Warming Compounds	Shall not be a GWC	Pass	
Qualitative			
Effectiveness (1)	Effective removal of contaminants comparable to the current solvent; no adverse impact on process due to residue left on surface	Pass	equally effective on grease, oil and dirt
Production Time (1)	Acceptable to production	Pass	
Odor compatibility (1)	Satisfactory odor per worker/observer survey based on operating experience	Fail	Operator/observer noted TBAC had a stronger odor
Reliability (1)	The demonstration solvent must be chemically compatible with materials and chemicals that are part of the process during which the demonstration solvent is used.	Pass	
Cost/Safety/Environmental Factors	The demonstration solvent must not require significant capital investment. No adverse change in safety requirements or PPE.	Pass	TBAc equal in cost; no increase in capital; no adverse change in PPE
Ease of Use (1)	The demonstration solvent must not significantly affect the process parameters.	Pass	
Versatility	The demonstration solvent is particularly suitable for non-attainment areas (VOC exempt or low VOC's).	Pass	
(1) Primary Performance Criteria assessed by CCAD production process demonstration			

Appendix G Norfolk Naval Shipyard Demonstration

Demonstration/Validation of Tertiary Butyl Acetate (TBAC) for Cleaning of Naval Shipyard Paint Equipment

ESTCP Project WP-0616

Prepared by:

Ben Zlateff, BAE Systems
Doug Fassett, BAE Systems

30 January 2008

Introduction

Background

The Environmental Security Technology Certification Program (ESTCP) and the Naval Sea Systems Command (NAVSEA) both have projects to evaluate the cleaning effectiveness of the solvent tertiary butyl acetate (TBAC). The ESTCP is funding DOD project WP-0616 to demonstrate/validate TBAC as a cleaner. The goal of the ESTCP project is to identify TBAC as an alternative solvent for a variety of applications. The US Army Research Center in Aberdeen, MD is the project lead. The Naval Sea Systems Command (NAVSEA) is completing a separate evaluation of potentially safer alternatives to traditional solvents. NAVSEA is seeking an alternative solvent for cleaning two-part epoxy spray paint equipment. The NAVSEA evaluation of a potential alternative solvent for cleaning epoxy paint from application equipment supports the goals of both organizations at the same time.

The NAVSEA Solvent Substitution Project identified T-10 Thinner as the most widely used solvent with human and environmental risks at NAVSEA facilities. T-10 Thinner was determined to be commonly used at NAVSEA facilities to clean two-part epoxy paints from paint spray pumps. The replacement of T-10 Thinner with a safer alternative offers the opportunity for significant reduction in risk and the environmental footprint of the process.

T-10 Thinner poses risks to workers due to the relatively high toxicity of its ingredients, and due to its high flammability. Also, T-10 Thinner poses risks to the environment due to the presence of EPA regulated hazardous air pollutants (HAPs) and volatile organic compounds (VOCs). Finally, T-10 Thinner contains chemicals that are listed on the NAVSEA Target Chemical List (TCL). The TCL identifies chemicals that NAVSEA has designated as targets for Pollution Prevention (P2) efforts. Therefore, it is desirable to replace T-10 Thinner with a safer solvent.

Purpose

A safe and effective solvent for cleaning two-part epoxy paints from spray paint equipment would significantly improve cleaning operations at NAVSEA facilities. The identification of a safe and effective alternative solvent would allow replacing a traditional, undesirable solvent. The uses of the traditional T-10 Thinner must be considered when selecting an appropriate substitute. A substitute solvent must meet several basic criteria related to the paint cleaning operations. The solvent must:

8. Be effective for applications where T-10 Thinner is used.
9. Reduce risks to workers.
10. Reduce environmental risks.
11. Be cost effective.
12. Be easily useable by workers with basic training.
13. Not damage spray paint equipment.
14. Not interfere with the performance or the level of protection provided by paints.

Both ESTCP and NAVSEA identified the solvent tertiary butyl acetate (TBAC) as a potential alternative to T-10 Thinner or other unacceptable solvents. The evaluation of TBAC requires the

identification of baseline performance. T-10 Thinner is used as a basis for the identification of baseline performance because its widespread use allows for a comparison with well-known performance characteristics.

The characteristics of both TBAC and T-10 Thinner are determined by a properties study, lab tests, and demonstration tests to obtain results that are reliable, repeatable, and quantitative. The characteristics of T-10 Thinner are applied as representative baseline performance. The characteristics of TBAC are compared to the baseline performance to determine whether TBAC is a potential alternative solvent. The determination of whether TBAC is a potential alternative solvent applies to replacing T-10 Thinner as well as to replacing other solvents that are unacceptable or undesirable human health and environmental risks.

The NAVSEA investigations and tests on the characteristics of TBAC and on the performance of TBAC for cleaning two-part epoxy paints from spray paint equipment addresses many but not all of the performance criteria that are specified by ESTCP for a general purpose cleaner. The ESTCP criteria are described in Reference 1, Environmental Security Test and Certification Program (ESTCP) *Draft Demonstration Plan for Demonstration/Validation of Tertiary Butyl Acetate (TBAC) for Hand Wipe Cleaning Applications*. Tables 4.1 and 4.2 in Reference 1 provide the criteria that are important to ESTCP in selecting an acceptable replacement solvent. These criteria are listed in the Table 3.1 in Attachment 3 of this report. The ESTCP criteria that were addressed by the NAVESA investigations and tests are identified in Table 3.1. In addition, NAVSEA determinations on whether TBAC met the ESTCP criteria are included in the table. Those ESTCP requirements not tested as part of the NAVSEA project are noted by the comment "Not evaluated as part of the NAVSEA project".

Scope

Material characterization studies, lab tests, and demonstration tests were necessary to thoroughly characterize the safety and effectiveness of TBAC for cleaning epoxy paint spray paint equipment. These studies and tests also identified baselines that would be used for comparison.

Market Research Studies

Solvent characterization studies in Reference 2, *Alternative Solvents Market Research Report,* gathered information on the potential effectiveness of TBAC and on the baseline solvent. The research studies also gathered information on the characteristics of the solvents that could be environmental or human health concerns. The studies were completed as part of a broader NAVSEA solvent properties investigation. The solvent properties investigation obtained information on the application of a variety of potential solvents to clean two-part epoxy paints from spray paint equipment. Information on potential effectiveness, on primary health and safety or environmental risks, and on secondary safety or environmental risks was gathered for the potential solvents. The results of the solvent evaluation study are described in this report and are thoroughly documented in Reference 2.

Lab Tests

NAVSEA developed lab tests to provide information on selected characteristics of TBAC and to identify baseline performance. Laboratory acceptance and test criteria were developed by NAVSEA with input from the U.S. Army Aberdeen Test Center (ATC) at Aberdeen Proving Ground, Maryland. The lab tests were based on American Society for Testing and Materials (ASTM) standards and on standard laboratory analytical methods. The lab tests are included in NAVSEA T-10 Thinner Replacement Solvent Acceptance and Test Criteria, Attachment 1 to this report. These criteria were also included in Table 3.1 of Attachment 3.

The lab tests were performed in September 2006 by ATC. They were performed according to the Attachment 1, and Laboratory Test Plan, Paint Solvent Cleaning Effectiveness Attachment 2, The lab tests produced information on the characteristics of the solvents that was needed to complete an evaluation of TBAC. Lab tests produced information on the chemical characteristics of the solvents, provided bench scale information on solvent cleaning effectiveness, and provided information on the compatibility of the solvents with spray paint equipment materials. The lab tests produced information that could be used to directly compare TBAC to appropriate baseline performance.

Demonstration Tests

Demonstration tests were planed and completed to characterize the performance of TBAC for cleaning paints in field conditions. The demonstration tests were necessary to obtain quantitative information on the performance of TBAC so that a comparison could be made with baselines. There were three main goals of the demonstration tests. First, the demonstration tests were intended to document the effectiveness of the solvents for cleaning two-part epoxy paint from spray paint equipment during field conditions. Second, the tests were intended to document the affect of the solvents on spray paint equipment during field operations; including the solvent affects on pumps, guns, and transfer lines. Third, the tests were intended to document the affect of the solvents on paint performance during field operations. Table 1 provides the intended demonstration test objectives and gives the methods for achieving the test objectives.

Table 1 – Demonstration Test Objectives

Objectives	Tests	Expected Results
Cleaning effectiveness of TBAC	• Quantity of paint removed during one cleaning cycle • Quantity of solvent required • Paint equipment inspection • Time to Clean Point	• Relative effectiveness of alternative solvents • Effectiveness compared to current operations • Residual paint • Cleaning Time
TBAC affect on paint performance	• Paint adhesion (ADS-61A-PRF & FED-STD-141)	• Change in paint performance
TBAC affect on equipment operation	• Observed equipment performance over test cycles • Observed condition of equipment at end of test cycles	• Change in observed equipment performance • Change in observed equipment condition (damage, deformation)

A demonstration test plan was prepared to identify baseline performance and to obtain performance data for TBAC during field conditions. The demonstration tests were planned to obtain baseline performance criteria for the traditional solvent – T-10 Thinner – used to clean paint spray pumps. Also, the tests were planned to obtain performance data on TBAC for the same field conditions. The field tests were planned to provide results that represented typical field operations that were repeatable so that the performance to the test products could be fairly compared. The equipment used for the demonstration tests, the personnel that performed the tests and the facility where the tests were performed were the same as those used for actual painting operations. However, actual painting and equipment cleaning practices had to be modified to ensure reliable and comparable data was obtained from the demonstration tests. The Norfolk Naval Shipyard Alternative Solvents Demonstration/Validation Plan (Reference 3) was prepared for the demonstration tests. Figure 1 provides an overview of the demonstration plan.

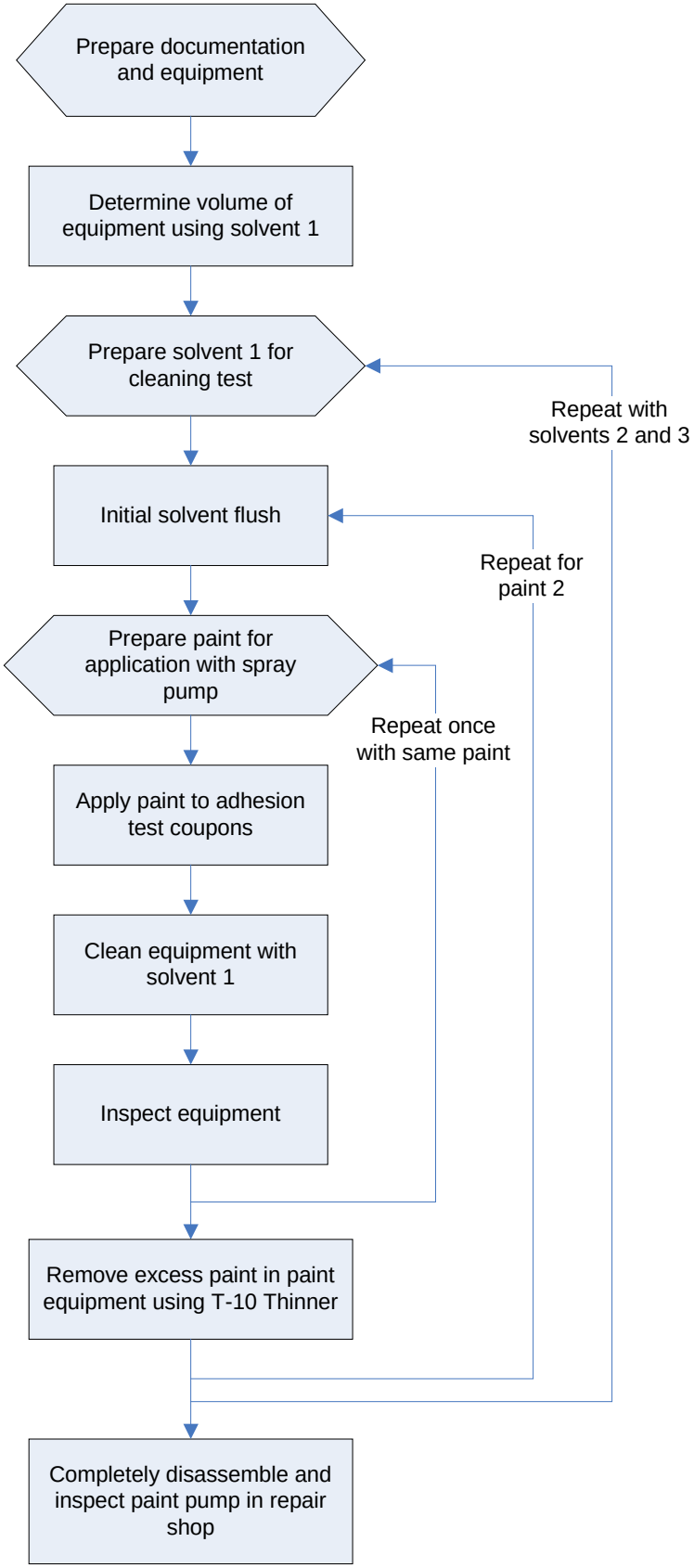


Figure 1 – Demonstration Test Plan Flowchart

Norfolk Naval Shipyard (NNSY) was selected as the preferred location to perform the demonstration tests. The history of painting operations, the types of paints and solvents used, the available facilities, the available equipment, and the skilled and knowledgeable personnel were reasons NNSY was selected. NNSY commonly applied two-part epoxy paints as normal operations. Also, facility personnel were experienced in applying the paints and in cleaning spray paint equipment with solvents such as T-10 Thinner. Finally, the NNSY facilities supported the performance of the demonstration tests under controlled conditions. The Demonstration Tests were conducted at NNSY from 11-14 September 2007 in accordance with Reference 3,

Health and Environmental Risks

Market Research Studies

In Reference 2, a market research investigation of the relevant characteristics of a variety of solvents – including T-10 Thinner and TBAC – was completed to gather available information that could be used to evaluate the potential safety and effectiveness of TBAC. This evaluation specifically addressed the application of solvents to cleaning epoxy paints contained in paint spray pumps. Information was gathered on the following general characteristics.

1. Human safety
2. Environmental safety
3. Potential cleaning effectiveness
4. Cost effectiveness

Information was gathered on a number of specific characteristics to support evaluation of the general characteristics. Specific characteristics were grouped into two groups: primary risks and secondary risks. Descriptions of these two categories are provided in the following sections.

Primary Risks

Primary risks are those specific characteristics that are a high enough concern to disqualify a solvent from consideration as a cleaner for paint spray pumps. The following characteristics are classified as primary risks.

1. IARC confirmed carcinogen
2. IARC probable carcinogen
3. NAVSEA prohibited chemical
4. Hazardous air pollutant
5. Class 1 ozone depleting substance

Secondary Risks

Secondary risks are specific characteristics that are not a great enough concern to disqualify solvents from consideration as cleaners for spray paint equipment. Several secondary risks may

combine and result in an aggregate risk that is high enough to disqualify a solvent from consideration. The following characteristics are classified as secondary risks:

1. IARC possibly carcinogenic
2. OSHA permissible exposure limit
3. Flash point
4. Volatile organic compound content
5. Class II ozone depleting substance content
6. Global warming compound content
7. NAVSEA controlled chemical

Summary of Market Research Study Results

The investigation into the characteristics of potential solvents and the associated results are documented in Reference 2. A summary of the information that was gathered for TBAC and the associated performance characteristics are provided in Table 2.

Table 2 – Environmental and Safety Characteristics

Characteristic	Baseline Performance (Ameron T-10 Thinner)	TBAC
PCCLs – prohibited ingredients[1,2]	xylene and ethylbenzene	No prohibited ingredients
PCCLs – controlled ingredients[1]	None	None
Percentage HAPs[2]	41% (xylene and ethylbenzene)	No HAPs
Percentage VOCs	100%	None for total emissions limitation
Class I ODCs[2]	No ODCs	No ODCs
Class II ODCs	No ODCs	No ODCs
GWCs	No GWCs	No GWCs
Confirmed Carcinogens[2]	None	None
Probably Carcinogenic[2]	None	None
Possibly Carcinogenic	One "IARC Possible"	None
Lowest PEL for any ingredient	50 ppm (xylene and ethylbenzene)	100 ppm (tert-butyl alcohol 0.5%)
Flash point	80F	40F

1 – NAVSEA Prohibited and Controlled Chemicals List
2 – Primary risks

It may be seen from the data in Table 2 that traditional solvent environmental and safety characteristics are a concern for several reasons. The data in Table 2 shows that TBAC meets all of the safety performance criteria except the criteria for flash point. TBAC has a lower flash point than the baseline, therefore it fails this criterion.

Lab Test Results

Laboratory tests obtained data on the flash point, the temperature stability, and the viscosity of TBAC. In addition, laboratory tests produced data on the T-10 Thinner baseline performance for these characteristics. The data are reported in Reference 4, U.S. Army Aberdeen Test Center Report ATC-9557. The physical and chemical characteristics of TBAC and the characteristics of the baseline cleaner are presented in Table 3. The pH test was not conducted since neither T-10 Thinner nor TBAC is an aqueous solution.

Table 3 – Physical and Chemical Test Results

Test	Baseline Performance	TBAC
Flash Point	84F	39 ^{o}F
Temperature Stability	Passed	Passed
Viscosity	0.9 centistokes (cSt)	0.7 cSt
pH	NA	NA

The flash point of TBAC is reported to be 39 oF and the flash point of the baseline is 84 oF. The laboratory test report states that the TBAC performance is equal to the baseline in temperature stability and viscosity tests.

Health and Environmental Risks Conclusions

TBAC is an acceptable alternative solvent because it meets all of the performance criteria for health and environmental risks except for flash point. Failing the flash point criterion does not automatically eliminate TBAC as a viable alternative solvent because flash point is a secondary risk. It is a secondary risk because it does not present an immediate and continuous health hazard and can be mitigated through common workplace and engineering controls.

Solvent Cleaning Effectiveness

Bench scale tests and field demonstration tests were performed to evaluate cleaning effectiveness of TBAC on commonly used paints.

Lab Tests on Solvent Cleaning Effectiveness

Test coupons were coated with Amercoat and Intergard paints that were cured for periods of one hour and three hours. There were 12 sample coupons prepared for each paint and cure time.

This allowed three coupons to be used for each time interval. All 12 coupons were inserted in the test solvent at the same time and three coupons were removed at a time as the test progressed. The quantities of paint that remained on the three test coupons for a single cleaning time were averaged to obtain the cleaning effectiveness result for that cleaning time. Table 4 provides the approach that was used to prepare and test coupons coated with the selected paints.

Table 4 – Sample Matrix for Paint 1

Cleaning Time		Paint Conditioning Time	
		1 hr.	3 hrs
Solvent 1	30 sec.	Samples 1, 2, 3	Samples 13, 14, 15
	1 min.	Samples 4, 5, 6	Samples 16, 17, 18
	2 min.	Samples 7, 8, 9	Samples 19, 20, 21
	5 min.	Samples 10, 11, 12	Samples 22, 23, 24
	5 min.	Blank Coupon	
	TTR*	Samples 25, 26, 27	Samples 28, 29, 30
Solvent 2	30 sec.	Sample 31, 32, 33	Samples 34, 35, 36
	1 min.	Samples 37, 38, 39	Samples 40, 41, 42
	2 min.	Samples 43, 44, 45	Samples 46, 47, 48
	5 min.	Samples 49, 50, 51	Samples 52, 53, 54
	5 min.	Blank Coupon	
	TTR*	Samples 55, 56, 57	Samples 58, 59, 60

*TTR – Time to Total Removal of Paint

The percentages of paints removed for each time interval were determined by comparing the weight of the paint covered coupons at the start and at the finish of the test. The results of the laboratory bench scale paint cleaning tests are reported in Reference 4. The results for each time interval and for each paint were plotted on graphs to allow easy comparison of the results. The lab test results for the paint cleaning tests are plotted in figures 2A – 2D.

Figure 2A – Intergard 264 Paint Cleaning

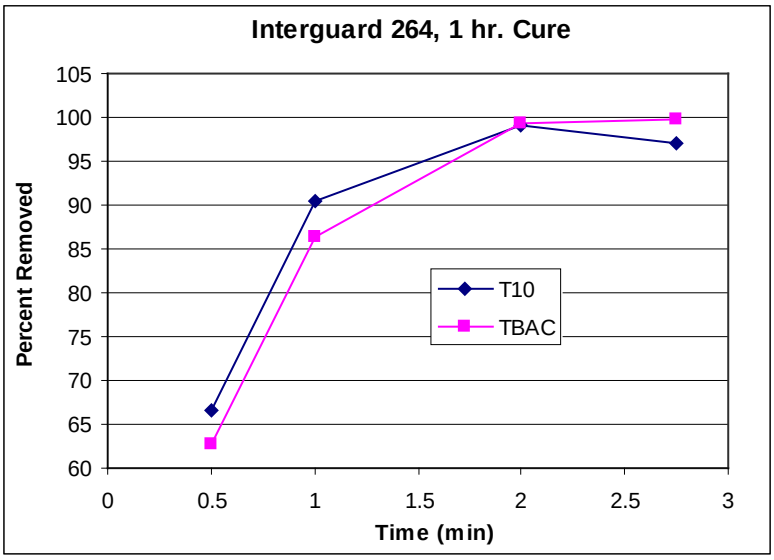


Figure 2B – Intergard 264 Paint Cleaning

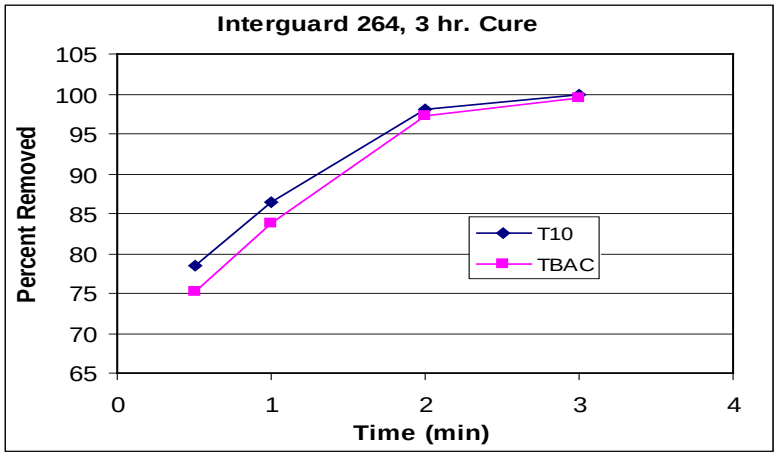


Figure 2C – Amercoat 235 Paint Cleaning

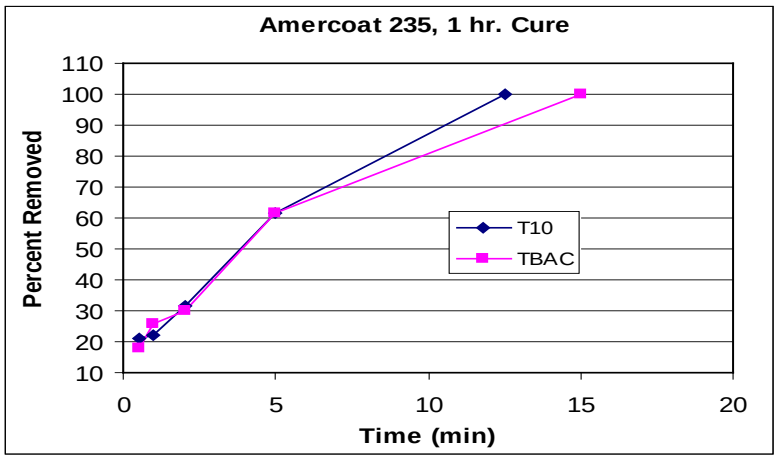
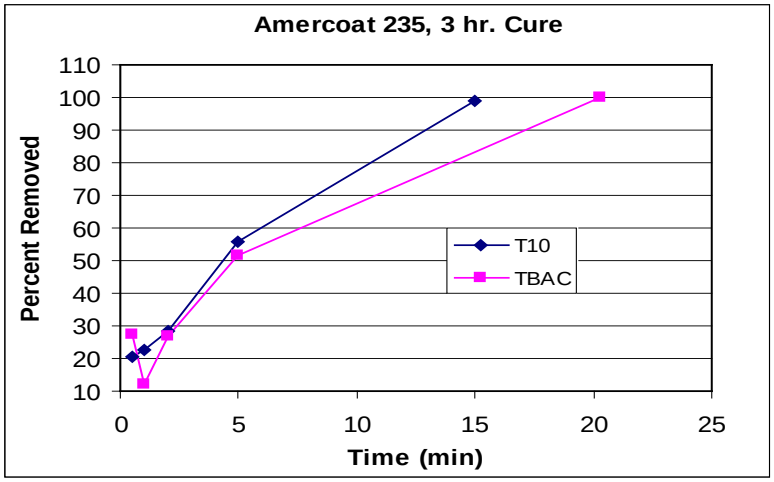


Figure 2D – Amercoat 235 Paint Cleaning



Inconsistent results from the first two time intervals – 30 seconds and one minute – in figures 2A and 2B are attributed to variations in the quantities of paint applied to test coupons. In addition, large quantities of paints that are present at the beginning of the cleaning tests may be susceptible to removal in globs by mechanical forces. Therefore, the data from the first two time intervals is not expected to be indicative of the effectiveness of the solvents.

The last data points in figures 2C and 2D – the points at 15 and 20 minutes – are uncertain because the precise times required to completely clean the test coupons are uncertain. The final cleaning times for the Amercoat coated coupons are uncertain because the cleaning times were determined by periodically removing the coupons from the solvents, inspecting the coupons, and then returning the coupons to the solvents if they were not cleaned. The process of removing the coupons from the cleaning solvent to inspect the cleaning progress could have affected the times required to clean the coupons. Also, the times required to completely clean the coupons are based on subjective observations by the test personnel.

The test coupons were removed from the solvent when they were observed to be clean. Then they were weighed to obtain data to determine the percentage of paint that was removed. The test results indicate that the Amercoat 235 coated coupons were not completely cleaned by the TBAC at the times when the comparable Amercoat 235 coated coupons were cleaned by the baseline T-10 Thinner. The coupons cleaned with TBAC took longer to clean, but the precise times required to completely clean the coupons in TBAC are uncertain. The lab test results report concluded that TBAC was essentially as effective as the baseline T-10 Thinner for cleaning the selected paints.

Demonstration Tests on Solvent Cleaning Effectiveness

Cleaning effectiveness of the solvents was determined by preparing commonly used two-part epoxy paints, applying the paints with normally used spray paint equipment, cleaning the spray paint equipment with the solvents to be tested, collecting the paints that were removed by the solvents, and determining the quantities of paints removed. The quantities of paints removed from the spray paint equipment and the total quantities of solvents required to clean the equipment over time were used to evaluate the effectiveness of the solvents. The results of the demonstration tests on the solvents were evaluated to determine the effectiveness and the relative

effectiveness of the solvents. Table 4 provides the basic test plan for testing the cleaning effectiveness of the solvents on the selected paints.

Each paint-cleaning test identified in Table 5 was performed using a two-stage process. The first stage was to use approximately two gallons of a solvent to clean paint from spray paint equipment. The second stage was to use an additional quantity of the solvent to finish cleaning the paint from the spray paint equipment. The total quantity of solvent used for each cleaning test was limited to about five gallons. The cleaning effectiveness for each of the stages were determined from the test results.

Table 5 – Arrangement of Cleaning Effectiveness Tests

Test Number	Solvent	Paint
Test 1 (C1)	T-10 Thinner	International Paint- Intergard 264 Red
Test 2 (C2)	T-10 Thinner	International Paint- Intergard 264 Red
Test 3 (C1)	T-10 Thinner	Ameron Paint –Amercoat 235 – Haze Gray
Test 4 (C2)	T-10 Thinner	Ameron Paint –Amercoat 235 – Haze Gray
Test 5 (C1)	TBAC	International Paint- Intergard 264 Red
Test 6 (C2)	TBAC	International Paint- Intergard 264 Red
Test 7 (C1)	TBAC	Ameron Paint –Amercoat 235 – Haze Gray
Test 8 (C2)	TBAC	Ameron Paint –Amercoat 235 – Haze Gray

Paint Removal Efficiency

Demonstration test results for the solvent cleaning of paints are reported in Reference 5, *T-10 Thinner Replacement Project Norfolk Naval Shipyard Demonstration & Validation Test Result Technical Report*. The demonstration test results include the paint removal efficiencies for each of the solvent and paint combinations. The weights of paints removed per gram of solvent are the paint removal efficiencies. The paint removal efficiencies are shown on the graphs in figures 3A through 3D to allow easy comparison of the test results.

The paint removal efficiencies for each of the cleaning tests are determined based on the quantities of Intergard 264 and Amercoat 235 removed per gram of solvent. Two tests were performed for each paint and solvent combination. The first test for each paint and solvent combination is identified as C1 and the second test for a paint and solvent combination is C2 (see Table 5). The results for the first tests (C1) on cleaning Intergard 264 with both solvents are compared in Figure 3A. The results for the second tests (C2) on cleaning Intergard 264 are compared in Figure 3B. The results for the first tests (C1) on cleaning Amercoat 235 with both solvents are compared in Figure 3C. Finally, the results for the second tests (C2) on cleaning Amercoat 235 with both solvents are compared in Figure 3D.

Figure 3A – Intergard 264 Paint Removal Efficiency in C1 Tests

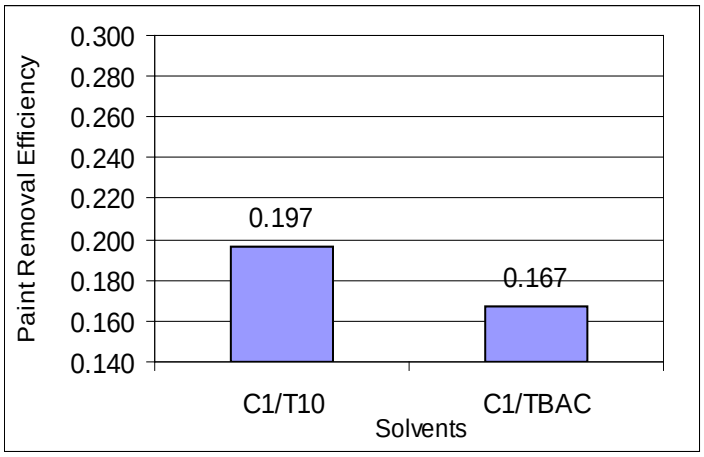


Figure 3B – Intergard 264 Removal Efficiency in C2 Tests

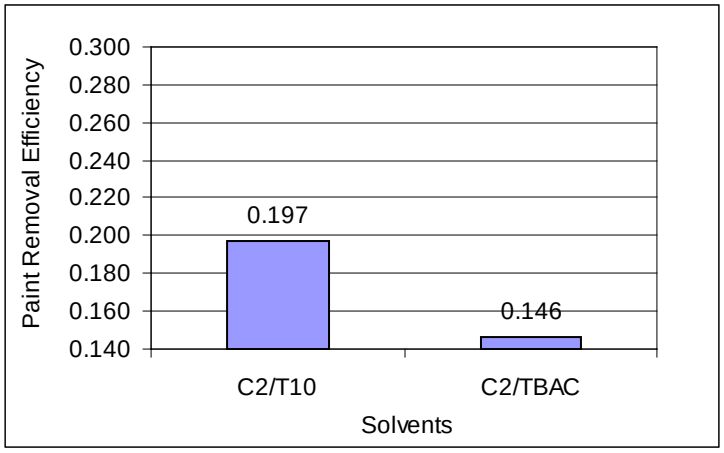


Figure 3C – Amercoat 235 Removal Efficiency in C1 Tests

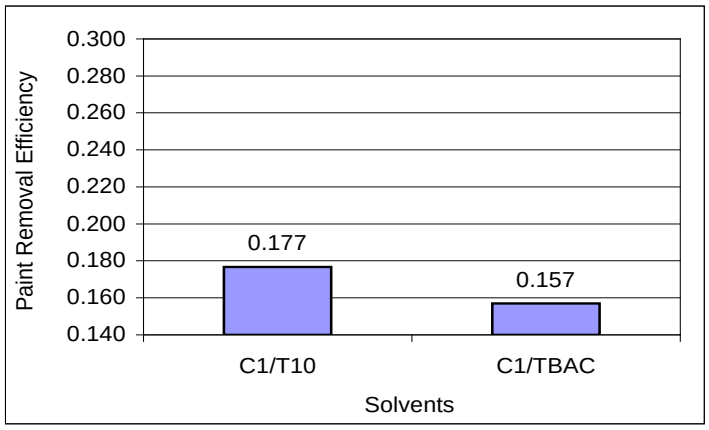


Figure 3D – Amercoat 235 Removal Efficiency in C2 Tests

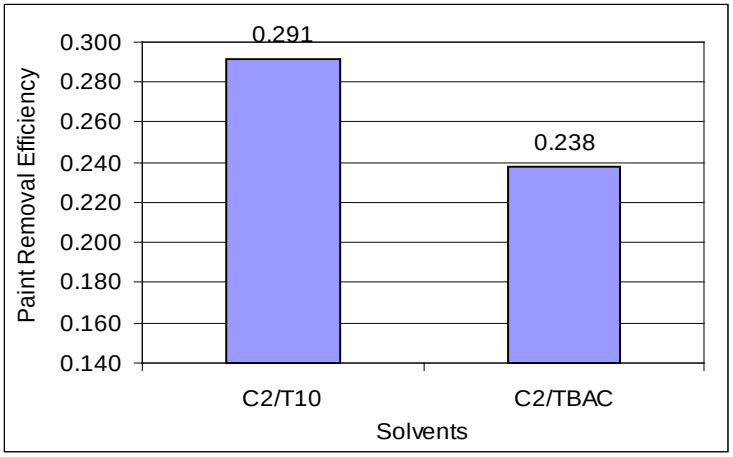


Table 6 shows the relative paint removal efficiencies for TBAC compared to the baseline cleaner, T-10 Thinner. The TBAC paint removal efficiency is compared to the T-10 Thinner baseline for cleaning test C1 and Intergard 264, and then for cleaning test C1 and Amercoat 235 (yellow highlight). They are also compared the same way for cleaning test C2 (green highlight). The average paint removal efficiency is the average between cleaning test C1 and C2 for Intergard 264 and also for Amercoat 235 respectively.

Table 6 - Paint Removal Efficiency and Comparison Data

Test	Wp/Ws	Comp.	Ave.
C1/T10/264	0.197	100.0%	100.0%
C2/T10/264	0.197	100.0%	
C1/TBAC/264	0.167	84.7%	79.4%
C2/TBAC/264[3]	0.146	74.1%	
Test	**Wp/Ws**	**Comp.**	**Ave.**
C1/T10/235	0.177	100.0%	100.0%
C2/T10/235[2]	0.291	100.0%	
C1/TBAC/235	0.157	88.8%	85.2%
C2/TBAC/235	0.238	81.5%	

The notes below pertain to the superscripts in Table 6:

Note 2 - For C2/T10/235 Supply Bucket weights were not recorded. The numbers are an average of all 2 and 3-gal supply bucket weights

Note 3 – C2/TBAC/264 was run by itself similar to a C1 test with equipment completely cleaned out using T-10 before starting the test.

The demonstration test results for paint removal efficiencies indicate that TBAC may be a little less effective than the baseline T-10 Thinner. The second tests with each paint/solvent combination generally resulted in more efficient paint removal with both solvents. The reason for this is not clear, and this result should be taken into account when evaluating the test results.

Cleaning Point (CP) Times

The cleaning times were based on the observed condition of the solvents as they were discharged from the paint pump. The test personnel recorded the times when either the discharged solvents appeared to be "clean" with no indication of paint pigment in the solvent being discharged or if the equipment was not cleaned, it then it was the time to use the allotted 5 gallons of solvent. Reference 5 provides results on the cleaning point times for each of the cleaning tests. The times required to clean the selected paints from the paint spray pump were recorded for each of the cleaning tests. Figures 4A through 4D provide the results for cleaning times for cleaning tests and for paints.

Figure 4A – Intergard 264 Clean Point Times for C1 Tests

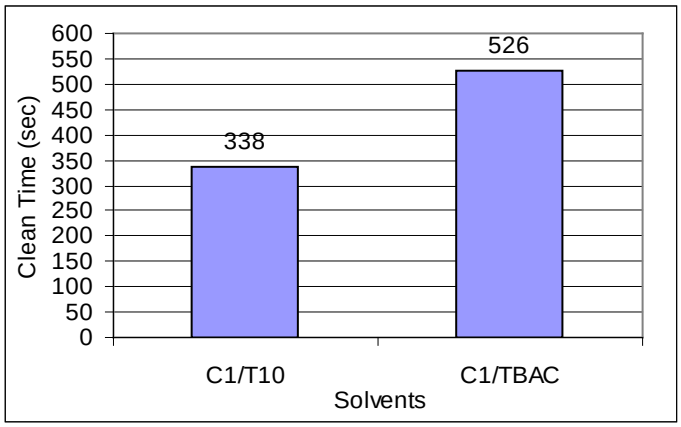


Figure 4B – Intergard 264 Clean Point Times for C2 Tests

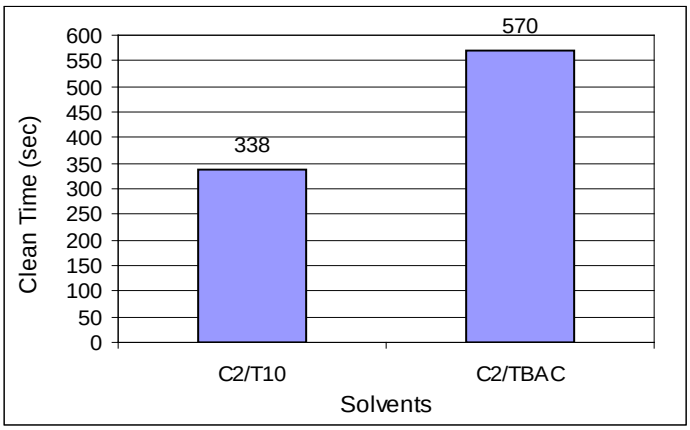


Figure 4C – Amercoat 235 Clean Point Times for C1 Tests

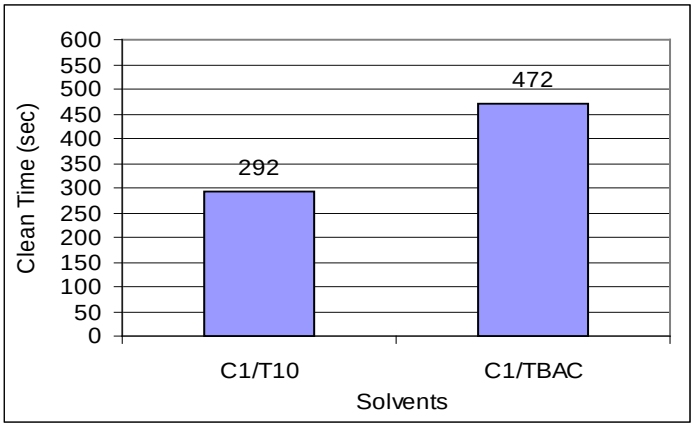
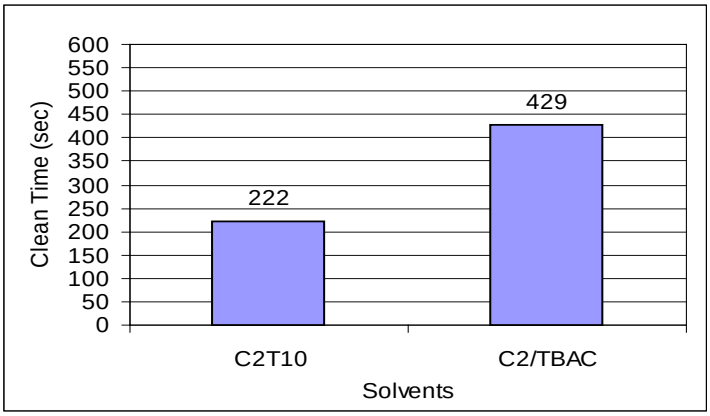


Figure 4D – Amercoat 235 Clean Point Times for C2 Tests



The clean point times for the various demonstration tests are provided in Table 7. The relative effectiveness of TBAC compared to the baseline T-10 Thinner are also provided in Table 7. As with the paint removal efficiencies, the TBAC CP Time is compared to the T-10 Thinner baseline for cleaning test C1 and Intergard 264, and then for cleaning test C1 and Amercoat 235 (yellow highlight). They are also compared the same way for cleaning test C2 (green highlight). The average CP Time is the average between cleaning test C1 and C2 for Intergard 264 and also for Amercoat 235 respectively.

Table 7 – Clean Point Time and Comparison Data

Paint	Test	CP	Comp. To Std.	Ave.	Painter Clean
Intergard 264	C1/T10[4]	338	100.0%	100.0%	NO
Intergard 264	C2/T10	338	100.0%		NO
Intergard 264	C1/TBAC	526	155.6%	162.1%	NO
Intergard 264	C2/TBAC	570	168.6%		NO
Paint	Test	CP	Comp. To Std.	Ave.	Painter Clean
Amercoat 235	C1/T10	292	100.0%	100.0%	YES
Amercoat 235	C2/T10	222	100.0%		YES
Amercoat 235	C1/TBAC	472	161.6%	177.4%	YES
Amercoat 235	C2/TBAC	429	193.2%		YES

The note below pertains to the superscript in Table 7:

Note 4: CP not recorded for C1/T10/264. Since all 5 gal of solvent were used similar to C2/T10/264, the same CP was used.

The CP results may not be absolute quantitative measures of performance due to variations in the demonstration test operations. For example, the pressure setting of the paint spray pump may not have been the same for every test and this could have affected the results. The results may, however, be relative measures of performance because the painter generally followed the same procedure during each test for each solvent and paint combination.

The baseline T-10 Thinner and TBAC did not effectively clean Intergard 264 from the paint spray pumps when using the D/V test procedure outlined in Reference 3. The D/V cleaning procedure is different then the standard operating procedure for cleaning paint equipment. Consequently, the CP times for the D/V test are the times required to use the allotted five gallon quantities of solvents. The solvents did effectively clean Amercoat 235; therefore the CP times are the times when the painter determined that the equipment was clean. The CP time results for Amercoat 235 indicate that TBAC was significantly less effective for cleaning the selected paints than the baseline solvent. .

Visual Observation

The paint spray pump was partially disassembled at the conclusion of each demonstration cleaning test. The internal parts of the spray pump were inspected and photographs taken to obtain additional information on the effectiveness of the solvents to clean the selected paints. The quantities of paints remaining on the internal parts of the spray pump were evaluated. The condition of the internal surfaces of the paint spray pump was evaluated after each of the paints was cleaned with TBAC and with the baseline T-10 Thinner.

The equipment inspection results indicate that TBAC does not clean each of the selected paints equally well. The inspections determined that TBAC does not clean Intergard 264 as well as the baseline, T-10 thinner. However, the inspections determined that TBAC cleans Amercoat 235 almost as well as the baseline solvent. Complete photographs of the visual test are included in Cleaning Test Data Visual Observations Section of Appendix B of Reference 5.

Conclusions on Solvent Cleaning Effectiveness

There was a difference between the lab bench test and the demonstration test cleaning test results.
The lab bench-scale tests indicate that TBAC may be almost as effective as the baseline T-10 Thinner for cleaning Intergard 264 and Amercoat 235 from test coupons. The lab cleaning tests also indicate that TBAC may take a little longer than the baseline cleaner to clean the paints from those coupons. TBAC cleans Intergard 264 more effectively then it cleans Amercoat 235. Standardized, controlled, and repeatable lab tests provide good evidence that TBAC may be used to effectively and efficiently clean Amercoat 235 and Intergard 264 from coupons.

Demonstration tests generally indicate that TBAC is not as effective as the baseline cleaner for cleaning Amercoat 235 and Intergard 264 from paint spray pumps. The painter observed that neither TBAC nor the baseline cleaned Intergard 264 when five gallon quantities of the solvents were used. In addition, TBAC cleans Amercoat 235 more effectively than it cleans Intergard 264. Finally, the painter observed that TBAC took longer then the baseline cleaner to clean Amercoat 235 from spray paint equipment. However, it was concluded in Reference 5 that if TBAC was used in the Standard Shop Practice for Cleaning Paint Equipment (5 gallons recirculated) it would adequately clean Amercoat 235 from the spray paint equipment.

The differences in test results between the laboratory bench test and the D/V test indicates that laboratory testing may or may not be a good representation of the cleaning environment of a closed paint gun system in the field. This reinforces the importance of field demonstrations and

indicates that future evaluations need to be careful about using lab testing only to qualify a cleaner for this application.

Generally, the cleaning effectiveness conclusions are:

- TBAC may be used to clean Amercoat 235 from spray paint equipment. However, TBAC may take a little longer than the baseline cleaner to clean that paint from the spray paint equipment. It is not possible to accurately determine the additional time that would be required to clean equipment with TBAC in actual operations due to differences between the lab tests, D/V tests, and actual cleaning operations.
- Based on the differing results between lab bench tests and demonstration tests, it is uncertain whether TBAC would adequately and effectively clean Intergard 264 from spray paint equipment. However, the baseline cleaner did not adequately clean Intergard 264 in demonstration tests either.

Solvent Affect on Paint Performance

It is important to determine whether the alternative solvent TBAC has any impact on the performance of paints. The use of TBAC may affect the performance of paints if significant quantities are mixed with paints before the paints are applied. Affects on the performance of paints may occur after spray paint equipment has been cleaned and when the first portion of a batch of paint is applied. It is unlikely that the performance of paints will be affected as a batch of paint is applied and the concentrations of residual solvents in the spray paint equipment decrease.

Paint adhesion tests were conducted on 26 September 2007 as part of the demonstration tests to evaluate the affect of TBAC and the baseline T-10 Thinner and on the performance of the two-part epoxy paints. The spray paint equipment was cleaned with the test solvents. The solvents then were discharged from the equipment as the test paints were drawn into the equipment. The test paints then were applied to primed test coupons. One test coupon was used for each paint/solvent cleaning test cycle. The FED-STD-141 Test Method No. 6301 “Adhesion (Wet) Tape Test” was used to evaluate the performance of the tested paints.

The results of the demonstration tests are provided in Reference 5, and are reproduced in Table 8. The thickness of the applied paints, the quality of the applied paints, and the results of the paint adhesion performance tests are provided.

Table 8 - Paint Adhesion Test Results

Test	P_{Thick}	Paint Quality	Adhesion Fail %	Remarks
Intergard 264				
C1/T10/264	6.0	SAT	0	None
C2/T10/264	6.0	SAT	0	None
C1/TBAC/264	?	USAT	0	Note 1
C2/TBAC/264	6.0	SAT	100	Note 2
Amercoat 235				
C1/T10/235	7.0	SAT	0	None
C2/T10/235	5.0	SAT	0	None
C1/TBAC/235	7.0	SAT	0	None
C2/TBAC/235	7.0	SAT	0	None

The notes below pertain to the notes in the remarks column of Table 8:

Note 1: C1/TBAC/264 - Topcoat over wrong primer (Primed with Amercoat 235 Buff). Topcoat uneven.

Note 2: C2/TBAC/264 - Adhesion failure occurred at substrate. No evidence of interbond adhesion failure. No indication of cause of primer failure.

The paint adhesion test results indicate that there is no detrimental affect on paint performance due to the use of either TBAC or the baseline solvent. The failure of the primer in the C2/TBAC/Intergard 264 test is attributed to the failure of the primer that was used for the test coupon.

Solvent Compatibility with Equipment

Solvent compatibility with paint spray pumps was evaluated in lab tests and in field demonstration tests.

Lab Tests on Solvent Compatibility

Lab tests on solvent compatibility evaluated the affects of TBAC and the baseline T-10 Thinner on metallic and on non-metallic constituents in paint spray pumps.

Effects on Elastomerics, Plastics, and Fluorocarbon Compounds

The lab results on the affects of TBAC on non-metallic constituents in paint spray pumps are presented in the following tables. Also, the performance of TBAC is compared with the baseline T-10 Thinner.

Table 9 - Viton® DuPont Compatibility Results

Property	Baseline Performance	TBAC
Change in mass	19.2% > controls	109.% > controls
Change in volume	48.2% > controls	250.% > controls
Change in dimensions	L - 13.3%, w – 19.6%, t – 15.0%	l – 52.1%, w – 44.0%, t – 58.1%
Hardness (Shore A points)	22 points less	42 points less
Change in tensile strength at max. load	-31.4%	-73.0%
Change in tensile strength at break	-100.8%	-99.8%
Change in elongation at max. load	51.5% decrease	96.1% decrease
Change in elongation at break	-27.4%	-77.3%

Great care should be used to minimize or prevent contact of TBAC or the baseline T-10 Thinner with Viton®**.** Reference 4 states that Viton® should not come into contact with TBAC. The effects of the baseline T-10 Thinner on Viton® are reported to be less than the effects of TBAC.

Table 10 – PTFE (Teflon®) Compatibility Results

Property	Baseline Performance	TBAC
Change in mass	.02%	0.0%
Change in volume	.02%	.45%
Change in dimensions	l – -0.03%, w – 0.07%, t – -0.73%	l – 0.05%, w – -0.13%, t – 0.37%
Hardness (Shore D hardness points)	2 decrease	0.0
Tensile strength at max. load	9% decrease	5.1% increase
Change in tensile strength at break	0.7% decrease	57.5% increase
Elongation at max. load	13.7% decrease	5.2% increase
Elongation at break	13.7% decrease	5.1% increase

TBAC may be used with PTFE and T-10 Thinner should perform adequately. Reference 4 states that TBAC had no adverse reactions on Teflon®.

Table 11 – Polyurethane Compatibility Results

Property	Baseline Performance	TBAC
Change in mass	79.8% increase	33.5% increase
Change in volume	81.3% increase	34.9% increase
Change in dimensions	l – 26.6%, w – 27.2%, t – 26.3%	l –12.2%, w – 13.4%, t – 11.7%
Hardness (Shore A hardness points)	16 decrease	5 decrease
Tensile strength at max. load	84% decrease	61% decrease
Tensile strength at break	94.9% decrease	66.5% decrease
Elongation at max. load	89.9% decrease	70% decrease
Elongation at break	89.9% decrease	70.2% decrease

TBAC performed better than the baseline T-10 Thinner on all tests.

Table 12 – Polypropylene Compatibility Results

Property	Baseline Performance	TBAC
Change in mass	2.6% increase	0.63% increase
Change in volume	3.98% increase	2.2% increase
Change in dimensions	l – 0.13%, w – -0.07%, t – 0.72%	l –-0.05%, w – -0.47%, t – -0.71%
Hardness (Shore D points)	5 decrease	1 decrease
Tensile strength at max. load	6.1% decrease	5.4% decrease
Tensile strength at break	4.6% decrease	42.2% decrease
Elongation at max. load	210% increase	130% increase
Elongation at break	14.5% increase	6.58% increase

Control values for elongation are suspect.

TBAC performed better on polypropylene than the baseline T-10 Thinner on all but the Tensile Strength at Break Point test.

Table 13 – Nylon Compatibility Results

Property	Baseline Performance	TBAC
Change in mass	0.19% decrease	0.31% decrease
Change in volume	Results unclear	Results unclear
Change in dimensions	l – -0.27%, w – -0.66%, t – -0.72%	l –-0.20%, w – -0.40%, t – -0.72%
Hardness (Shore D points)	Negligible change	Negligible change
Tensile strength at max. load	0.1% decrease	0.1% decrease
Tensile strength at break	37.4% decrease	15.2% decrease
Elongation at max. load	54.8% increase	50.5% increase
Elongation at break	8.97% increase	38.97% increase

Volume results appear suspect.

TBAC is better than the baseline T-10 Thinner on its effects on Nylon. Laboratory compatibility tests indicated TBAC should not cause equipment problems with its use. T-10 Thinner did not cause adverse effects on the materials tested and should not affect equipment with continued use.

Table 14 – Leather Compatibility Results

Property	Baseline Performance	TBAC
Change in mass	62% increase	39.2% increase
Change in volume	640% increase	22.6% decrease
Change in dimensions	l – -0.06%, w – 1.71%, t – 6.18%	l –-2.87%, w – -1.13%, t – 4.98%
Hardness (Shore A points)	5 decrease	2 decrease
Tensile strength at max. load	28.9% increase	14.3% increase
Tensile strength at break	42.9% decrease	20.2% increase
Elongation at max. load	13.4% decrease	16.2% decrease
Elongation at break	10.8% decrease	18.5% decrease

Tensile strength results are questionable.

Leather that is used as a packing material should perform at least as well with TBAC as it does with the baseline T-10 Thinner.

Table 15 – High Density Polyethylene (HDPE) Compatibility Results

Property	Baseline Performance	TBAC
Change in mass	2.4% increase	0.4% increase
Change in volume	2.45% increase	0.01% increase
Change in dimensions	l – 0.58%, w – 0.40%, t – 0.34%	l –0.02%, w – 0.07%, t – -1.04%
Hardness (Shore D points)	5 decrease	2 decrease
Tensile strength at max. load	5.6% decrease	1.5% increase
Tensile strength at break	2.9% increase	14.9% increase
Elongation at max. load	36.8% increase	No change
Elongation at break	272% increase	198% increase

TBAC is better than the baseline T-10 Thinner with polyethylene.

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Table 16 – Delrin Compatibility Results

Property	Baseline Performance	TBAC
Change in mass	0.12% decrease	0.13% decrease
Change in volume	0.62% increase	0.52% increase
Change in dimensions	l – -0.13%, w – -0.53%, t – -0.71%	l –0.03%, w – -0.47%, t – -0.36%
Hardness (Shore D points)	1 decrease	1 decrease
Tensile strength at max. load	1.1% decrease	1.7% decrease
Tensile strength at break	No change	1.5% decrease
Elongation at max. load	22.5% increase	5.1% increase
Elongation at break	16.5% increase	29.8% increase

TBAC is better than the baseline T-10 Thinner with Delrin (acetal).

Metal Corrosion

Table 17 provides the laboratory test results for corrosion of metals in spray paint equipment.

Table 17 – Corrosion Results

Material	Property	Baseline Performance		TBAC	
		24 hrs	+144 hrs	24 hrs	+144 hrs
304 Stainless steel	Change in mass (mg)	-0.1	-0.5	0.0	0.0
	Change in surface	None	None	None	None
Chrome plated 1010 steel	Change in mass (mg)	-0.1	-0.1	+0.5	+0.6
	Change in surface	None	None	None	None
Nickel plated 1010 steel	Change in mass (mg)	-0.1	-0.4	+0.2	+0.1
	Change in surface	None	None	None	None
Zinc plated 1010 steel	Change in mass (mg)	-0.2	-0.1	0.0	+0.1
	Change in surface	None	None	None	None
A36 steel	Change in mass (mg)	+0.3	-0.1	-0.1	-0.1
	Change in surface	None	None	None	None
4140 steel	Change in mass (mg)	0.0	-0.3	0.0	-0.1
	Change in surface	None	None	None	None
6061 Aluminum	Change in mass (mg)	+0.2	+0.3	+0.3	+0.5
	Change in surface	None	None	None	None

There was no definite corrosion for any of the tested metals with TBAC or the baseline T-10 Thinner. The TBAC may be used in the paint application pumps without corrosion consequences.

Demonstration Tests on Solvent Compatibility with Equipment

There were no reported detrimental affects on the materials used in the paint application spray pump according to the Reference 5.

Conclusions on Solvent Compatibility with Equipment

The laboratory test results and to a lesser extent demonstration test results indicates that TBAC meets or exceeds the baseline performance of T-10 Thinner for compatibility with paint spray pumps.

Cost Benefit Analysis

Basic cost information was gathered to support the evaluation of potential alternative solvents. The operating costs for TBAC and the baseline T-10 Thinner are expected to be similar because they will be used in a similar way. There may be some differences in operations due to variations in effectiveness of the solvents, but these differences are not expected to have a significant impact on the operating costs. Also, it is assumed that the waste disposal costs are similar for all of the potential alternative solvents.

Operating Costs

The cost of cleaning paint application pumps with T-10 Thinner at NNSY was evaluated to obtain a baseline annual cost for equipment cleaning operations.

T-10 Thinner Annual Operating Cost

Material Cost

The average annual T-10 Thinner cost is based on 3518 gallons of solvent used per year.

- Cost of T-10 Thinner based on 5 gal quantity: $10.52/gal
- Annual cost of solvent: 3518 gal*($10.52/gal) = $37,000

The cost for a gallon of T-10 Thinner was found to be $10.52/gallon in 2007 when it was purchased for demonstration tests at NNSY. The quantity of T-10 Thinner used per year was determined by a site visit and investigation at NNSY in May 2005.

Labor Costs

The total elapsed time to complete the Standard Shop Practice for Cleaning spray paint equipment one time is 20 minutes. The labor cost per hour was reported to be $76.98 in Reference 6, *T-10 Thinner Replacement Project, Mid-Project Status Report* dated 12/30/05. Assuming a 5.0% annual rate for inflation, the labor cost per hour is $80.80 at the end of 2006.

Therefore, the annual labor cost may be calculated as follows.

- Number of annual cleaning events: (3518 gal/year)/(5 gal/event) = 703.6 events/year
- Annual labor hours: 704 events/year*(1/3 man-hours/event) = 235 hours/year
- Annual labor costs: 235 hrs/yr*$80.80/hr = $19,000/year

Cost of Waste Disposal

The annual cost of waste solvent disposal is based on the assumption that all used T-10 Thinner is sent to a disposal facility. The average annual quantity of T-10 Thinner that is sent to disposal is 3518 gal. The disposal costs for a gallon of waste were reported to be $3.05 in Reference 6. Assuming a 5.0% annual rate for inflation, the disposal cost is $3.20 at the end of 2006.

- Cost of waste disposal: 3518 gal*$3.20= $11,300

Recycling Cost

See Paragraph 6.2 on Cost Benefits of Recycling below.

Environmental/OSH Costs

There are costs associated with environmental compliance and health and safety compliance. Environmental costs include the cost for preparing and maintaining required permits. Health and safety costs include the costs for the HAZCOM Program, the safety program, and the workman's comp program. These costs could not be determined in the facility investigations that took place in 2005. A more detailed investigation is necessary to determine these costs.

PPE Equipment

There are costs associated with protecting workers from potential detrimental affects of the chemicals and the affects of operations. Costs for basic protective equipment are listed below.

Respirator: $19.95 each x 1/yr = $19.95
Vapor cartridge: $14.95 each x 1/5 events x 704 events/yr = $2100.
Tyvek Suit: $9.95 each x 1/5 events x 704 events/yr = $1400.
Protective Sleeve: $2.95 each x 1/event x 704 events/yr = $2100.
Nitrile Gloves: $3.95/pair x 1 pair/event x 704 events/yr = $2780.
Ear Muffs: $29.95 each x 1/year = $29.95
Ear Plugs: .99/pr x 1 pair/5 events x 704 events/yr = $140.
Goggles: $3.95 each x 1/year = $3.95
Spray Sock: $3.95 each x 1/event x 704 events/yr = $2780.
Wipes: $55.39/box of 15 x 4/event x 704 events/yr = $10,400
Total PPE Cost = $21,800.

Total annual cost for operations that use T-10 Thinner: $37,000 + $19,000 + $11,300 + $21,800 = $89,100

TBAC Cost

Material Cost: The cost for TBAC is $9.59/gal when purchased in 55 gal quantities. It is expected that this solvent is recyclable by distillation and that recycling should significantly mitigate the product cost.

Labor Costs:

- Based on D/V test results, labor costs may be a little higher for cleaning operations that use TBAC for removing Amercoat 235.

- Based on the D/V Test results, labor costs could be significantly higher for cleaning operations that use TBAC to remove Intergard 264.
- Based on laboratory bench test results, there would be no additional labor costs for cleaning operations that use TBAC to clean Intergard 264.
- Based on laboratory bench test results, labor costs would be up to 33% higher for cleaning operations that use TBAC to clean Amercoat 235.
- The time presently needed to clean the spray paint equipment using T-10 Thinner is 20 minutes.
- Assuming 5 gallons of solvent used per cleaning operation and an average annual NNSY usage of 3518 gal (Reference 6) then there are an average 704 cleaning operations per year at NNSY.
- For all the D/V cleaning tests TBAC averaged 11.8% less effective at cleaning Amercoat 235 or an increase of cleaning time of 2.4 minutes. This would be a cost of $3.20 per cleaning operation for an average annual cost increase of $2253 or approximately 28 hours of labor.
- Using a worst case D/V Time Paint Removal Efficiency of 32.6 less effective, this would be an increased cleaning time of 6.6 minutes. This would be a cost of $ 8.83 per cleaning operation for an average annual cost increase of $6216 or approximately 77 hours of labor.
- Using D/V data it is estimated that using TBAC will increase labor costs between $2300 and $6200 per year when cleaning Amercoat 235. Labor costs would be considerably higher for cleaning Intergard 264.
- Using Lab bench test data it is estimated that using TBAC will increase labor costs between $2750 and $4950 using TBAC to clean Intergard 264. However, there would be no increase labor costs when using TBAC to clean Amercoat 235.
- Overall, the cost increase for using TBAC to clean Intergard 264 and Amercoat 235 from the spray paint equipment is estimated to range between $0 and $6200 per year.
- D/V test cleaning times will always be more accurate because many variables are not accounted for in lab tests. Lab testing only accounts for the interaction between the cleaner and the soil not the impact of the cleaning process/environment (in this case a closed system under pressure), therefore, additional operational tests are recommended to obtain a more accurate basis for the increased labor costs for using TBAC.

Disposal Costs: The used TBAC would be classified as a hazardous waste due to the flashpoint of about 40F and due to the hazardous constituents in paints that are cleaned. Therefore the disposal costs remain the same as for the baseline T-10 Thinner.

Recycling Cost: See paragraph 6.2 on Cost Benefits of Recycling below.

ESH Costs: The environmental and safety costs are expected to be similar to the costs for the baseline T-10 Thinner. However, there is a potential cost savings because TBAC is a VOC exempt and HAP free solvent and there would be less reporting requirements.

PPE Costs: Both Amercoat 235 and Intergard 264 require full PPE Protection. Therefore, regardless of the solvent used to clean the equipment, there will be paint contained in that solvent and the paint MSDS is the overarching requirement. Therefore, the PPE is the same for both TBAC and T-10 Thinner.

Cost Benefits of Recycling

Recycling provides an opportunity to significantly reduce the cost of cleaning spray paint equipment. Significant cost reductions are possible due to reduced quantities of purchased solvents, and due to reduced quantities of waste solvents that require disposal. There are two recycling methods that may be used to recycle the solvents. The first method is distillation and the second method is settling/filtration. Distillation is probably most appropriate for certain types of solvents. Solvents that are good at dissolving epoxy resins, and solvents with a single ingredient or with ingredients that have similar boiling points are expected to be good candidates for distillation recycling. Also, solvents that are good at dissolving epoxy resins are good candidates for distillation recycling because the dissolved resins would remain suspended in solution for long periods of time and this would reduce the effectiveness of the settling/filtration recycling method.

TBAC is expected to be a good candidate for recycling by distillation because it is composed of a single ingredient and because dissolved paints are expected to remain in solution. It is advantageous to use a single ingredient solvent when there is the potential to lose some of the solvent due to evaporation or due to chemical reaction with the material being cleaned over time. The loss of one or more ingredients in larger proportions than the other ingredients would change the composition of a solvent over time and could affect the effectiveness of a solvent.

The process for recycling T-10 Thinner is expected to be similar to the distillation process that would be used to recycle TBAC. However, T-10 Thinner is expected to be more difficult to recycle than TBAC. T-10 Thinner is a multi-component solvent and the percentages of the different components are important to the performance of the solvent. Recycling this solvent may change the composition of the solvent due to reactions of the solvent ingredients with the paints, or due to evaporation of the more volatile components in the solvent. A change in the composition of T-10 Thinner is expected to affect the performance of this solvent; therefore, there may be difficulties in recycling this solvent.

Cost Analysis Results

Generally, product costs may be a significant part of the cost associated with cleaning spray paint equipment. The differences in product costs could result in significant differences in the costs of using the solvents over time. However, the resolution of several uncertainties could significantly alter this possibility. The most significant uncertainties are the ability to recycle TBAC and the labor associated with TBAC. These uncertainties could make the differences in product costs less significant.

There is the potential for significant cost savings over time if TBAC is recycled. Additional evaluation is required to determine the costs and benefits of recycling TBAC.

Material Costs: There is negligible difference in material costs between T-10 Thinner and TBAC.

Labor Costs*:* Overall, the cost increase for using TBAC to clean Intergard 264 and Amercoat 235 from the spray paint equipment is estimated to range between $0 and $4950 per year. Operational tests are recommended to obtain a more accurate basis for the increased labor costs for TBAC.

Disposal Costs: There are negligible cost differences between T-10 Thinner waste and TBAC waste.

ESH Costs: There would be less reporting requirements with TBAC then with T-10 Thinner, therefore the ESH costs would be less. However, it is difficult to accurately determine the magnitude those costs accurately.

Recycling Costs: TBAC may be easier to recycle then T-10 Thinner; therefore, the recycling costs may be lower. More than likely the same equipment would be used to recycle either solvent. The cost driver would then be the heat of vaporization, which would determine energy costs. However, there is no data on this. Additional evaluation is required to determine the actual cost benefit of recycling.

PPE Costs: PPE costs would be the same whether using T-10 Thinner or TBAC.

Total Costs: Material, disposal, and PPE costs are considered to be a wash. Therefore the total cost difference between using T-10 Thinner and TBAC would be dependent on the magnitude of ESH cost savings when compared to possible operations labor increases, and the savings of recycling TBAC. These numbers are unavailable at the time of this report.

Conclusions and Recommendations

Conclusions

1. ESH Risks: The TBAC is acceptable as a cleaner for two-part epoxy paint in spray paint equipment due to its low health and environmental risks. The broad range of health and environmental criteria that were used mostly indicate that TBAC is safer than the baseline T-10 Thinner. The one criterion that is an exception is flash point. TBAC has a lower flash point and it is less safe than the baseline standard, but this is a non-critical secondary criterion that may be addressed with safe equipment and work practices.

2. Cleaning Tests: Generally, the cleaning effectiveness conclusions are:
   - TBAC may be used to clean Amercoat 235 from spray paint equipment. However, TBAC may take a little longer than the baseline cleaner to clean that paint from the spray paint equipment. It is not possible to accurately determine the additional time that would

be required to clean equipment with TBAC in actual operations due to differences between the lab tests, D/V tests, and actual cleaning operations.

- Based on differing results between lab bench tests and demonstration tests, it is uncertain whether TBAC would adequately and effectively clean Intergard 264 from spray paint equipment. However, the baseline cleaner did not adequately clean Intergard 264 in demonstration tests either. See Reference 5, Cleaning Test Section of Appendix B for additional information.
- D/V test cleaning times will always be more accurate because many variables are not accounted for in lab tests. The closer the D/V tests are to actual operations, the closer the results should be to reality. Lab testing only accounts for the interaction between the cleaner and the soil not the impact of the cleaning process/environment (in this case a closed system under pressure), therefore, additional operational tests that better represent operational practices are recommended to obtain a more accurate basis for the increased labor costs for using TBAC and for a more realistic cleaning performance.

3. Paint Adhesion: The demonstration paint adhesion tests indicate that TBAC did not negatively affect paint performance. The paint adhesion tests also indicate that TBAC did not result in a decrease in paint performance compared to the baseline T-10 Thinner.

4. Compatibility: Laboratory studies indicate that TBAC has fewer detrimental affects on spray paint equipment wetted materials than the baseline T-10 Thinner. In addition, TBAC did not have observable detrimental effects on the operation of spray paint equipment as a result of short-term use.

5. Total Costs: Material, disposal, and PPE costs are considered to be a wash. Therefore the total cost difference between using T-10 Thinner and TBAC would be dependent on the magnitude of ESH cost savings when compared to possible operations labor increases, and the savings of recycling TBAC. These numbers are unavailable at the time of this report.

6. In summary, the benefits of TBAC are lower environmental and health risks, fewer reporting requirements therefore reduced reporting labor costs, it is easier to recycle, does not affect paint adhesion, and has better compatibility with materials in spray paint equipment. The drawbacks are it has a low flash point therefore does not decrease waste disposal costs, it may take longer to clean resulting in greater labor costs, and its ability to clean Intergard 264 from spray paint equipment is uncertain.

Recommendations

1. Solvent used for spray paint equipment cleaning should be recycled to obtain the most efficient beneficial use of the solvent. The potential for a comprehensive and ongoing recycling program should be investigated. A recycling program should be instituted if it is determined that it is feasible and cost effective.

2. TBAC will be considered as an alternative to be evaluated as part of the NAVSEA T-10 Thinner Replacement Project. If TBAC is chosen as the best replacement alternative in this project, then it is recommended that an operational test be performed with TBAC on

Amercoat 235 and on Intergard 264 paints as part of the implementation process at the NAVSEA shipyards. The standard shop practice for cleaning spray paint equipment should be used to verify that actual operations may be adequately performed with the alternative solvent, to gather better labor cost data, and to resolve the uncertainties regarding Intergard 264. The criteria for evaluating the success of the operational tests should be:

- The judgment of the painters on the effectiveness of TBAC,
- The observed affects on the long-term operation of paint spray pumps,
- The long-term maintenance required on paint spray pumps, and
- The time required to clean the paint application pumps

3. Possible Additional Testing – Naval Shipyards have just recently established a Just-In-Time (JIT) contracting arrangements for their paints and thinners/cleaners with Sherwin-Williams (S-W). As a result of these new arrangements, the demands for T-10 Thinner, Amercoat 235 and Intergard 264 two part epoxy paints has decreased substantially from their historic levels and have been replaced with a S-W thinner and equivalent S-W 2-part epoxies. Historically, use of S-W 2-part epoxies have been a distant third when compared to Amercoat 235 and Intergard 264. To test the effectiveness of TBAC to clean shipyard paint equipment, additional laboratory and D/V tests should be conducted on the replacement S-W 2-part epoxy paint to determine TBAC's cleaning effectiveness compared to the baseline T-10 Thinner. The recommended scope would be to conduct the laboratory cleaning test only at Aberdeen Test Center on the S-W 2-part epoxy paint, and also conduct the D/V in accordance with a modified Reference 3 that more closely approximates shipyard standard paint equipment cleaning operations. The specifics of this test would be developed by the Mr. Jim Weixel, Project Engineer at Norfolk, NSY and Mr. Thomas Cook the NAVSEA Project Manager at NAVSEA Division NUWC, Newport, RI.

References

1. *Environmental Security Test and Certification Program (ESTCP) Draft Demonstration Plan for Demonstration/Validation of Tertiary Butyl Acetate (TBAC) for Hand Wipe Cleaning Applications*, Army Research Laboratory, MD; October 2006.

2. *Alternative Solvents Market Research Report*, T-10 Thinner Replacement Project, 26 April 2007

3. *Norfolk Naval Shipyard Alternative Solvents Demonstration/Validation Test Plan,* T-10 Thinner Replacement Project 24 October 2007.

4. U.S. Army Aberdeen Test Center Report ATC-9557: Laboratory Report T-10 Thinner Alternatives Analyses, 10 December 2007.

5. *T-10 Thinner Replacement Project, Norfolk Naval Shipyard Demonstration & Validation Test Result Technical Report* 20 December 2007.

6. *T-10 Thinner Replacement Project, Mid-Project Status Report* dated 30 December 2005

Supplement 1
T-10 Thinner Replacement Solvent Acceptance and Test Criteria

NAVSEA T-10 Thinner Replacement Solvent Acceptance and Test Criteria, 8 March 2007

Environmental and Safety				
Test	**Method**	**Units**	**Criteria**	**Remarks**
PCCL*	Source data or GC/MS	%	No prohibited chemicals	Note (4)
HAPs*	Source data or GC/MS	%	None (<0.1%)	Note (1). Certifying activity to select test method.
VOCs	Source data or GC/MS	G/L	Less than 100%	Note (1). Certifying activity to select test method.
ODCs*	Source data or GC/MS	%	None (<0.1%)	Note (1). Certifying activity to select test method.
Global Warming Compounds	Source data or GC/MS	%	None (<0.1%)	Certifying activity to select test method.
Carcinogens*	Source data or GC/MS	%	None (<0.1%)	As listed by the IARC. Applies to "Confirmed" and "Suspected"
PEL	As defined by OSHA	Ppm	>100	
Physical and Chemical				
Test	**Method**	**Units**	**Criteria**	**Remarks**
Flash Point	ASTM D-56 or D-92	F	>140	Use either Tag Closed Cup or Cleveland Open Cup depending on type of solvent.
Temperature Stability	ADS-61A-PRF (Modified)	Descriptio n	No separation or precipitates	Cycle between 0 deg (1 hr) and 120 deg F (1 hr) five times. Invert sample 5 times at room temperature. Observe for separation.
Viscosity	ASTM D 445	CST	0.9 cST ±20%	Criteria are based on T-10 Thinner.
pH	Calibrated Meter	PH	3.0 to 11.0	For aqueous solutions only. Use calibrated probe tester or litmus.
Performance				
Test	**Method**	**Units**	**Criteria**	**Remarks**

Cleaning	ASTM G 122	%	Better than or equal to T-10	The passing of the criteria will be determined by comparison of the alternative solvent results with the T-10 Thinner results. Percent removal is determined from the weight of the coated coupon and the weight of the coupon after cleaning in an ultrasonic bath. The ASTM G 122 test procedure will be modified to address actual process conditions. See note (3).
Compatibility				
Test	**Method**	**Units**	**Criteria**	**Remarks**
Effects on Elastomerics, Plastics, and Fluorocarbon compounds	ASTM D 471 except Paragraphs 13, 14, and 16.	Description	Less effects than T-10, or equal effects to T-10	Substitute equipment seals, packing, etc. if possible. Immerse seals and packing for a period of 96 hours.
Polyethylene UHWPE				Material as described by ASTM D 1248
PTFE (Teflon®)				Material as described by ASTM D 3294
Viton® DuPont				Material as described by ASTM D 6909
Nylon				Material as described by ASTM D 4066
Polypropylene				Material as described by ASTM D 4101
Acetal/Delrin® DuPont				Material as described by ASTM D 6778
Polyurethane				Material as described by ASTM D 5476
Leather				
Metal Corrosion	ASTM F 483	Description	Less corrosive then T-10, or equally corrosive	Total immersion test.
304 Stainless Steel				Material as described by ASTM A 666
Chrome Plated Steel				Material as described by ASTM A 263
Nickel Plated Steel				Material as described by ASTM A 265

Zinc Plated Steel				Material as described by ASTM A 36 Material as described by ASTM A 153
A 36 Carbon Steel				Material as described by ASTM A 36
4140 Alloy Steel				Material as described by ASTM A 29
6061 Aluminum Alloy				Material as described by ASTM B 209

General Comments

a) Market search for possible replacement candidates should be based upon the constituency restrictions, the physical properties, and any performance data available from the manufacturer as identified in the acceptance criteria. Physical properties required for initial screening are identified by an asterisk (*).

b) These criteria do not apply to paint equipment used on nuclear propulsion equipment or systems.

Notes:

(1.) It is desirable that replacement candidates will contain these classes of constituents in quantities no more than indicated. Performance requirements may, however, require the presence of these classes. In these cases the selection criteria must consider the impact on and the requirements of the National Emission Standards for Hazardous Air Pollutants (NESHAPS) for Shipbuilding and Ship Repair (Surface Coating) Operations (40 CFR Part 63).

(2.) All criteria that references T-10 Thinner as a baseline will be replaced with values obtained from the results of independent lab testing of T-10 Thinner on those criteria.

(3.) Modify ASTM G 122 as described in *Laboratory Test Plan, Paint Solvent Cleaning Effectiveness*.

(4.) Products containing Prohibited Chemicals on the NAVSEA Prohibited and Controlled Chemicals List (PCCL) will be eliminated during primary screening. Products containing Controlled Chemicals are evaluated through secondary screening.

Supplement 2
Laboratory Test Plan, Paint Solvent Cleaning Effectiveness

Laboratory Test Plan

Paint Solvent Cleaning Effectiveness

Supplement to ASTM G 122

NAVSEA T-10 Thinner Replacement Project

11 August, 2006

BACKGROUND

The NAVSESA Thinner Replacement Project determined that an alternative solvent was necessary to replace T-10 Thinner in paint equipment cleaning operations. The T-10 Thinner was found to be the most used solvent for NAVSEA painting operations. It was determined that a safer solvent was needed.

The uses of large quantities of T-10 Thinner at Norfolk Navy Shipyards (NNSY) and Puget Sound Navy Shipyards (PSNS) are associated with the uses of large quantities of certain paints at these facilities. The paints that require large quantities of T-10 Thinner need to be tested with potential alternative solvents to ensure that one of the safer solvents does an adequate job of removing paints.

The following paints represent the most used brands of paint at NNSY that use T-10 Thinner. These paints need to be tested to evaluate the cleaning capabilities of the potential alternative solvents for different paint formulations.

Ameron, Amercoat 235, Gray
International Paint, Intergard 264, Gray

Laboratory tests are necessary to evaluate the effectiveness of solvents to clean the two part epoxy paints from paint application equipment. The laboratory test results will be used to identify the most promising alternative solvents. The laboratory tests are based on ASTM G 122 "Standard Test Method for Evaluating the Effectiveness of Cleaning Agents". However, ASTM G 122 does not provide the level of detail necessary to perform the required paint cleaning tests. Therefore, this test plan is intended to serve as a supplement to the test procedure.

TEST PLAN

Test Coupon Preparation

Prepare test coupons as specified in MIL-DTL-24441C, Section 4.5.15.1 Preparation of panels. The test coupons shall have identical preparation to ensure that the characteristics are the same. The test coupons shall have the same surface area to ensure consistency for all samples and to allow easy comparison of test results. The dimensions of the coupons may vary from the specifications provided in MIL-DTL-24441C to allow coupon use in available test apparatus. The coupon size (and the scale accuracy) should be adequate to allow detection of variations between new and cleaned coupons. The coupon size shall be recorded and consistent for all tests.

Weigh the test coupons with a scale with an accuracy of at least 0.1 mg.

Paint Sample Preparation

Prepare paint samples by mixing the proportion of hardener and base specified in the manufacturer's directions. Prepare adequate quantities of paints to allow dipping the coupons in the paints.

Thoroughly mix by hand stirring with a spatula or paint paddle. Allow the paint to condition for one hour and for three hours before testing. Condition the paints at 73 F.

Solvent Preparation

Select test containers or beakers that are large enough to hold enough solvents to submerge the paint coupons and allow for possible complete paint removal on all coupons. Virgin solvent will be used at the start of each test sequence. The amount shall be consistent for all tests. Aberdeen Test Center will specify or document the container size and solvent quantities to set the baseline.

Maintain the solvents at 73° F before and during the tests.

Paint Sample Testing

Place the test coupons in the prepared paint samples so that the coupons are completely coated with paint. All test coupons for paint aged for a particular time should be dipped at the same time or in quick succession to prevent using paint that is aged for different lengths of time. Remove the coupons and allow the excess paint to drain off the coupons. The time that excess paint is allowed to drain should be the same for all test coupons. The holding time should be determined by checking to see how long paint continues to drip from a test coupon after it is removed from a batch of paint. Weigh the paint covered test coupons with a scale with an accuracy of at least 0.1 mg.

Prepare three paint covered test coupons for each cleaning time interval for paint aged a particular time. This will allow an evaluation of the variation of test results, and it will allow for preparation of an average test result for a particular cleaning interval. Table 1 provides the list of test coupons that need to be prepared to test one type of paint in two different solvents.

Include an unpainted test coupon in the process to act as a control for the painted coupons.

Insert the wet test coupons and the unpainted blank coupon in the solvent test containers until the coupons are completely submerged. Immediately begin ultrasonic cleaning of the submerged coupons and begin timing the cleaning operation.

Remove test coupons from each of the solvents at time intervals of 30 seconds, one minute, two minutes, and five minutes. Allow solvents to drip off of the test coupons after they are removed from the solvents. Do not rinse the test coupons. Dry the test coupons for a period of ten hours at ambient conditions 70° F. Ensure that all test coupons are allowed to dry for the same period before they are weighed. Weigh the test coupons with a scale with an accuracy of at least 0.1 mg.

Adjust the time periods for cleaning the test samples to be four equal divisions of the total time to removal if it is found that the specified time periods do not provide useful data on the rate of cleaning the test coupons.

Record observations on the conditions of the cleaned test coupons at the end of each cleaning time interval. Describe the percent of coupon covered if there is visible paint remaining on the cleaned test coupons.

Record visual observations on the time to total removal (TTR) required to clean test coupons. State the times visible paint has been cleaned from the test coupons if different then stated time intervals.

Table 1 – Sample Matrix for Paint 1

Cleaning Time		Paint Conditioning Time	
		1 hr.	3 hrs
Solvent 1	30 sec.	Samples 1, 2, 3	Samples 13, 14, 15
	1 min.	Samples 4, 5, 6	Samples 16, 17, 18
	2 min.	Samples 7, 8, 9	Samples 19, 20, 21
	5 min.	Samples 10, 11, 12	Samples 22, 23, 24
	5 min.	Blank Coupon	
	TTR*	Samples 25, 26, 27	Samples 28, 29, 30
Solvent 2	30 sec.	Sample 31, 32, 33	Samples 34, 35, 36
	1 min.	Samples 37, 38, 39	Samples 40, 41, 42
	2 min.	Samples 43, 44, 45	Samples 46, 47, 48
	5 min.	Samples 49, 50, 51	Samples 52, 53, 54
	5 min.	Blank Coupon	
	TTR*	Samples 55, 56, 57	Samples 58, 59, 60

*TTR – Time to Total Removal of Paint

Supplement 3
ESTCP Demonstration/Validation Test Criteria and Results

Table 3.1 – ESTCP Performance Criteria and Results of Applicable NAVSEA Tests

Performance Criteria	**Description**	*NAVSEA Results*
Environmental, Occupational Safety and Health	**Toxicity** – Shall have no adverse effect on human health when used as intended.	TBAC has a higher minimum PEL than the baseline T-10 Thinner. Therefore, it is safer.
	Flammability – Shall not increase hazard category of the operation.	TBAC is more flamable – has a lower flash point - than the baseline.
	Volatile Organic Compounds – Shall contain less than 50 g/l VOC, be VOC exempt, or a SCAQMD certified clean air solvent.	TBAC does not contain VOCs and it contains less VOCs than the baseline.
	Hazardous Air Pollutants (HAPs) – Shall be HAP-free.	TBAC does not contain HAPs and it contains less HAPs than the baseline.
	ODC – Shall not be an ODC.	TBAC and the baseline do not contain ODCs.
	Global Warming Compounds – Shall not be a GWC.	TBAC and the baseline do not contain GWCs.
Chemical Properties	**Nonvolatile Residue** – Shall not have a nonvolatile residue greater than 2.5 mg/100mL.	TBAC was not tested.
	Appearance – Shall be clear and free from suspended matter and undissolved water when observed at ambient conditions.	Not evaluated as part of the NAVSEA project.
	Viscosity – Criteria shall be established based on baseline testing.	TBAC has a viscosity of 0.7 cSt. This is slightly lower than the baseline.
	Flash Point – Shall meet safety standards for given application.	TBAC is more flammable – has a lower flash point - than the baseline.

Performance Criteria	**Description**	*NAVSEA Results*
Performance - Surface Cleaning	**Soil Cleaning per MIL-PRF-680A –** Shall not have a relative solvency of less than 85 percent (MIL-PRF-680A).	Not evaluated as part of the NAVSEA project.
	Sealant Adhesion – Shall not cause the sealing compound to have minimum peel strength of less than 20 pounds force per inch (lb_f/in.) after a seven (7) day exposure in jet reference fluid. There shall also be 100 percent cohesive failure of the sealant during testing.	Not evaluated as part of the NAVSEA project.
	Paint Adhesion – Shall not cause the primer coating to peel away from the substrate from any test panels after immersion in de-ionized water for 24 hours.	A modified version of ADS-61A-PRF & FED-STD-141 Test Method No. 6301 was applied to test the possible affects of residual solvent in paint application pumps. The results indicate that TBAC probably does not affect paint performance.
	Fluorescent Penetrant Inspection – Shall not impede the identification of known cracks and the intensity of the cracks should be brighter or equal to the control using Fluorescent Penetration Inspection.	Not evaluated as part of the NAVSEA project.
	Water Break – Water break free for any surface cleaned with the manufacturer's suggested working concentration of the cleaning compound shall be greater than one (1) minute.	Not evaluated as part of the NAVSEA project.
	Kauri Butanol Number – for reference	Not evaluated as part of the NAVSEA project.

Performance Criteria	**Description**	*NAVSEA Results*
	only - ≥ 27 (Secondary Criteria) **Cleaning Efficiency** – Shall meet or exceed the cleaning efficiency of the current cleaner. **Adhesive Bonding -** Shall not cause lower percentage of bondline cohesive failure compared to the baseline surface cleaner or solvent.	TBAC was not tested for surface cleaning. TBAC is a little less effective than the baseline for cleaning paint spray pumps. Not evaluated as part of the NAVSEA project.
Performance – Surface Effects	**Effects on Painted Surfaces** - Shall not cause streaking, discoloration, blistering or a permanent decrease in film hardness of more than one (1) pencil hardness level on any painted surfaces. **Effects on Carbon/Epoxy Composites** – Shall not cause the composite test coupon to have an average interlaminar shear strength less than the baseline sample.	Not evaluated as part of the NAVSEA project. Not evaluated as part of the NAVSEA project.
Performance - Storage	**Low Temperature Stability** – shall be such that the cleaning compound returns to its original homogeneous condition after exposure to extreme environments	TBAC passed the temperature stability tests based on a modified version of standard ADS-61A-PRF.
Materials Compatibility - Metals	**Total Immersion Corrosion** – Shall not cause any indication of staining, etching, pitting, or localized attack; nor shall weight change exceed allowable limits.	TBAC passed the corrosion tests for a variety of metals used in paint spray pumps.
Materials Compatibility – Plastics, Elastomers, Sealants	**Effects on Polysulfide Sealants** – Shall not change the durometer hardness (Shore A) of polysulfide sealants more than 5 units **Effects on Rubber** - shall not change the tensile strength +/- 15%, elongation +/- 20% or Shore A hardness +/- 7 of the	Not evaluated as part of the NAVSEA project. Not evaluated as part of the NAVSEA project.

Performance Criteria	**Description**	*NAVSEA Results*
	rubber material **Effects on Elastomers, Plastics, and Flourocarbons** – Shall meet or exceed the performance of the current cleaner/solvent	TBAC passed the plastic tests for a variety of materials used in paint spray pumps. However, it caused significant detrimental affects to Viton®.
Hazardous Materials Reduction	The reduction in traditional solvent use will also reduce the amount of VOCs, and HAPs entering the environment.	TBAC reduces the quantities of HAPs and VOCs entering the environment.
Process Waste	As with the current solvents used, the spent demonstration solvent may be contaminated with bearing cleaning agents, dissolved greases, oils, preservatives and contaminants. This process waste will be disposed of as hazardous waste through existing hazardous waste contracts.	TBAC must be handled as hazardous waste if it is used to clean hazardous materials. TBAC is basically equal to the baseline. However, TBAC may be easier to recycle, thus reducing the quantity of hazardous waste.
Reliability	The demonstration solvent must be chemically compatible with materials and chemicals that are part of the process during which the demonstration solvent is used. The demonstration solvent must be chemically compatible and perform effectively with all materials that are normally found in these processes.	TBAC is as compatible as the baseline for most materials that are used in paint spray pumps. The exception is that TBAC has significant detrimental affects on Viton® and it should be used with caution when this material is present.

Performance Criteria	**Description**	*NAVSEA Results*
Ease of Use	The demonstration solvent must not require significant capital investment and not significantly affect the process parameters. The demonstration solvent shall be chemically compatible with current equipment including current parts washers, recirculation pumps and seals, and filtration systems. Use of the demonstration solvent will not require additional manpower or additional skills.	TBAC may not meet this criterion. Differing lab and D/V cleaning test results indicate uncertain cleaning performance on Intergard 264. Because of this performance uncertainty, there are possible increases in operational labor costs. Additional operational testing is required. TBAC is chemically compatible with current spray paint equipment materials except for Viton®
Versatility	The demonstration solvent is particularly suitable for non-attainment areas (VOC exempt or low VOC's).	TBAC does not contain VOCs. Therefore, it meets this criterion.

Appendix H USMC Maintenance Center Albany Demonstration

Marine Corps Logistics Base Maintenance Center, Albany

ESTCP Demonstration

Tertiary-Butyl Acetate Evaluation Project

Phase II

September 12, 2007

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LIST OF ACRONYMS	
AAV	Amphibious Assault Vehicle
CAS	Clean Air Solvent
CARC	Chemical Agent Resistant Coating
DLSME	Defense Land Systems and Miscellaneous Equipment
DoD	Department of Defense
EST	Eastern Standard Time
ESTCP	Environmental Security Technology Certification Program
HAP	Hazardous Air Pollutant
HAZMAT	Hazardous Material
MCA	Maintenance Center Albany
MCLB	Marine Corp Logistics Base
MEK	methyl ethyl ketone
MILSPEC	Military Specifications
MSDS	Material Safety Data Sheet
NESHAP	National Emission Standard for Hazardous Air Pollutants
SARA	Superfund Amendments and Reauthorization Act
TBAC	*tertiary*-Butyl acetate (CH3COOC(CH3)3)
VOC	Volatile Organic Compound

POCs			
NAME	**FUNCTION**	**PHONE#**	**E-MAIL**
Frank Perigo	Paint Shop Supv	(229) 639-6828	frank.perigo@usmc.mil
Greg Russell	Maint. Directorate	(229) 639-8072	gregory.russell.ctr@usmc.mil
Ricky Hortman	HAZMAT	(229) 639-7742	david.hortman@usmc.mil
Alex J. Sanders	Maint. Directorate	(229) 639-8077	alex.sanders@usmc.mil

REFERENCES (Available upon request)
(1) Environmental Security Technology Certification Program Draft Demonstration Plan for Demonstration/Validation of Tertiary Butyl Acetate
(2) MSDS and Technical Data Sheet (Lyondell)
(3) MIL-DTL-53072C, Chemical Agent Resistant Coating (CARC) System Application Procedures and Quality Control Inspection
(4) Product Data Sheet, Sherwin-Williams, MIL-P-53022B, Type II, 3.5 VOC Lead & Chromate Free Epoxy Primer
(5) Product Data Sheet, Sherwin-Williams, DoD-P-15228D, Ordnance Metal Wash Primer
(6) NESHAP, “Defense Land Systems and Miscellaneous Equipment (DLSME)

*

1.0 BACKGROUND

This demonstration was conducted under a Phase II extension of the Tertiary Butyl Acetate Evaluation Project. The objective of the proposed effort is to demonstrate the efficacy and validate the economic and process impact of TBAC solvent in DoD solvent applications as a replacement for HAP and VOC solvents. Traditionally, vehicle, equipment, aircraft, and ship maintenance operations utilize organic solvents containing HAP(s), such as MIL-PRF-680, xylene, and methyl ethyl ketone (MEK), to remove dirt, grease, soot, and burned-on carbon from various parts. The DoD Services Clean Air Steering Committee and its workgroups have established a bottom line goal for DoD to stop using HAP solvents. The implementation of HAP free, environmentally friendly solvents for cleaning will reduce HAP and VOC emissions, improve worker health and safety and significantly reduce the record keeping burden associated with demonstrating compliance with the NESHAP regulations.

MCA has overhauled primarily ground combat vehicles since 1955. This includes the repair and painting of these and their components in accordance with various military specifications as required by the customer. MCA is currently qualified to apply various military approved coatings including CARC (Chemical Agent Resistant Coating, MIL-DTL-64159, Type !! (MIL-DTL-53072C) and Powder. In addition, we apply other types of MILSPEC coatings depending on the requirements of our customers, which range from other DoD members and foreign military customers.

Maintenance Center, MCLB, Albany intends to evaluate the use of TBAC as a medium in the Fluidics Plural Paint mixers for paint flushing and application, as an alternative to the medium currently employed on paint application components and as a paint thinner to replace MIL-T-81772 (75% Methyl Ethyl Ketone). Replacement of MIL-T-81772 will constitute an annual cost savings of $108,000 from our total HAZMAT waste stream. They do not anticipate a dramatic savings in operational and labor (<5%); however, they do anticipate a significant reduction in our overall HAZMAT footprint and VOC emissions.

2.0 TECHNICAL OBJECTIVES

The objective of this test is to replace environmentally hazardous products currently in use with more benign alternatives without impacting production. This will be accomplished by conducting comparison testing of approved Tertiary-Butyl Acetate (TBAC – CAS No. 540-88-5, see Figure 1.) products as an alternative to current products (T-10 Thinner, MIL-C-81702) used in processes for paint thinning and paint detritus clean up. This testing will focus on dry times, cleanup efficiency, compatibility with current coatings, and worker acceptance.

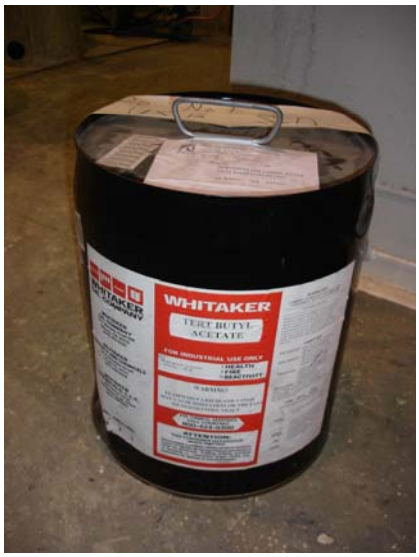

Figure 1. TBAc

3.0 TECHNICAL APPROACH

Conduct a demonstration/validation comparison of tertiary butyl acetate as an alternative to T-10 thinner utilizing the Fluidics Plural Paint system for paint application.

The full-scale demonstration will evaluate TBAc solvent as a drop-in replacement T-10 for paint thinning in paint applications. The success of the demonstration will be evaluated based on a comparison of the application and cleaning performance, economic factors, worker acceptance and process compatibility.

3.1 Performance

Performance evaluation will be based on dry times, viscosity measurements, application (wet/dry film thickness) and cleaning efficiency.

3.2 Economic Factors

Economic factors to be evaluated include initial product cost; volume used, and waste stream disposal costs compared to similar factors of T-10. Test will include an evaluation of the impact on cure time/throughput.

3.3 Worker Acceptance

Worker acceptance is a valuable subjective measure that will be evaluated through observation and questioning of the process workers who will be part of the project stake holder's team.

3.4 Process Compatibility

The process compatibility will be evaluated using the standard quality conformance measures that are applied to the existing application and cleaning process steps.

4.0 TERTIARY BUTYL ACETATE

TBAC has a flash point of 40°F. It is a flammable liquid as defined under SARA Title III, section 311/312 hazard category but is not subject to the reporting requirements of SARA Title III, section 313. The flashpoint of TBAC was a consideration in the selection of the demonstration applications. Applications were selected where flammability was not a primary consideration or where the flashpoint of TBAC did not change the flammability classification of the process.

TBAC (tertiary-butyl acetate, CAS 540-88-5) is a natural gas-derived ester solvent originally developed in the 1950's by Texaco as a fuel additive to improve cetane and reduce harmful exhaust emissions. However, it was never commercialized for that purpose. Until recently, it had found limited commercial use as a pharmaceutical intermediate. In 1997, Lyondell Chemical (then ARCO Chemical) identified TBAC as a chemical with negligible photochemical reactivity and petitioned the US EPA to add it to their list of VOC exempt compounds.

5.0 ANTICIPATED BENEFITS

Maintenance Center Albany intends to evaluate the use of tertiary butyl acetate as an alternative to the flushing medium currently employed on painting application components and as a paint thinner to replace MIL-C-81702 (75% Methyl Ethyl Ketone). Replacement of MIL-C-81702 will constitute an annual cost savings of $108,000 from our total HAZMAT waste stream. While we don't anticipate a dramatic savings in operations and labor (<5%), the USMC anticipates a significant reduction in overall HAZMAT footprint and VOC emissions and an improvement in worker health and safety.

6.0 DEMONSTRATION/VALIDATION TEST

6.1 Site

Testing was conducted at the Marine Corps Logistics Base Albany, GA, Paint Booth No. SC-9 (see Figure 2)

Figure 2. Paint Booth SC-9

Figure 3. AAV

6.2 Test Platform

One Amphibious Assault Vehicle (AAV) hull constructed of 5083 and 5086 aluminum (see Figure 3). The AAV hull has been depainted and blasted with Almondite garnett. Oxidation is removed with Chemetal Oakite Gard acid (see Figure 4.)

Figure 4. Prepared AAV

6.3 Environmental Conditions

Testing was conducted on 12 September 2007 commencing at 8:30 AM (EST). Recorded temperature 75°F - Relative Humidity 90% (see Figure 5 and Table 1).

TIME	TEMP.	REL.HUM.
8:30 AM	75°F	90%
9:30 AM	77°F	88%
11:00 AM	83°F	74%
12:00 AM	85°F	70%

Table 1. Environmental Conditions.

Figure 5. Humidity

6.4 Washcoating

Hull was prepared prior to the application of the primer coat by the application of an ordnance wash primer process (DoD-P-15328D, Type I – (see Table 2 for lot numbers).

6.4.1 Washprimer Mixing

Wash primer is mixed in accordance with the technical data sheet to the following ratio: 4 parts Component A, 1 part Component B (see Figure 6) and 1 part Isopropyl Alcohol (see Figure 7)

Part #	Lot #	Expiration Date
A	OX3346H	November 2007
B	BC3246A	November 2007

Table 2. Lot Numbers.

Figure 6. Catalyst

Figure 7. Isopropyl Alcohol

6.4.2 Wash Primer Application

Wash primer is applied using conventional application equipment (see Figures 8 and 9)

Figure 8. Washcoat Application

Figure 9. Washcoat Completed

6.5 Primer

AAV hull was coated using MIL-P-53022, Type II as the primer (see Figure 10).

Figure 10. Primer Component B

6.5.1 Primer Mixing Preparation

Filled pressure pots with component A, B, and C (TBAc). Mix concentration was in accordance with tech data sheet. Set unit to provide mix ratio:1/2 cup of TBAc Thinner per quart of primer. No induction time was required due to static mix tube capability of fluidics machines.

The viscosity was sampled three times using a No. 4 Ford Cup and the measurements were averaged (see Table 3).

TBAc Viscosity
26.1

Table 3. Viscosity Averages

6.5.2 Primer Application.

Primer was applied at a rate of 4-5 mils wet (see Figure 11) with conventional guns from plural mixing equipment (see Figure 12) using .055 needles (JGA 510 DeVilbus).

Figure 11. Wet Film Thickness

Figure 12. Application Equipment

6.5.3 Drying Time

At the completion of primer application the vehicle was delivered to the oven (see Figures 13 and 14) for the drying cycle at 130° F (refer to Table 4 for results).

TBAc	
10:30 AM	Start
11:00 AM	Soft, not tacky
11:30 AM	Soft, paint will peel if scratched – to metal
12:00 AM	Dry to touch but scratchablel
12:30 AM	Still scratchable
1:00 AM	Dry to touch, can indent with finger nail but not to the metal
1:30 AM	Can indent with pressure
2:00 PM	Can indent with pressure
2:30 PM	Light scratch when using fingernail
3:30 PM	Dry, not cured, no paint removed when scratched.

Table 4. Drying Conditions

Figure 13. Drying Oven

Figure 14. Checking Hardness

6.5.4 Clean-up/Flush Lines

Conducted automatic flushing operations for the fluidics unit with TBAc.
Two Cleaning evolutions to be evaluated:
Internal – Normally using xylene and T-10 (depending on components)
External – T-10 thinner

Upon completion of painting operations the application equipment is normally flushed through the lines to the guns with T-10. The catalyst side pump is flushed exclusively with xylene. For this test TBAc was used for both due to the tendency for catalyst to crystallize if it comes into contact with water (T-10 has hydroscopic properties). TBAc was chosen due for its non-hydroscopic nature. The TBAc performance described by the painters was not as effective as the xylene that is normally used on the catalyst side. The TBAc left a noted residue. During external cleaning of the guns, observed a difference in solvency (90% of T-10 usage is for cleanup). The TBAc tended to gel and coagulate more than the

T-10. This could ultimately result in clogged equipment, advanced failure rates, and increased maintenance requirements.

6.5.5 Compatibility with Coatings

TBAC had a slightly higher viscosity compared with an equal amount of thinner. Painters preferred application with TBAC and commented that it had improved flow characteristics. The paint (primer) was inspected numerous times and there is no visible indication there is an issue with compatibility. for either thinner

6.5.6 Worker acceptance

As in Phase I, the painters acknowledged that the TBAc (when used as an alternative thinner to T-10) seemed to have improved flow characteristics. Painters commented that the TBAc was smoother and “layed” down better with a better stand-off distance but also commented that the TBAc had a stronger odor.

6.6 Topcoat

T-10 thinner is not used in topcoat application with the exception of clean-up. No comparison testing was conducted in this phase of paint application between T-10 and TBAc.

7.0 SUMMARY

As in Phase I, the general consensus from the painters is that the TBAc actually performed as good or better as a paint thinner. Application seemed to be slightly improved and the vehicle seemed to dry quicker.

Cleaning and flushing operations constitute approximately 90% of our T-10 and xylene usage totals. As with the results identified in Phase I, the TBAc did not seem to have the same solvency effect as the T-10(or the xylene). It tended to gel and coagulate and gummed up the plural paint equipment resulting in extended efforts to flush and clean the equipment. This equipment is very sensitive to gelling and hardening and can result in significant down time. This would result in the depot incurring additional maintenance and replacement costs.

The primary goal of this project is to evaluate TBAc performance in comparison to T-10 and xylene. One benefit of TBAc to the depot is reducing VOC levels and since TBAc is an exempt non-reportable it is an alternative candidate as a T-10 replacement.

As a result of the Phase I and Phase II testing the maintenance center is unlikely to utilize TBAc as an alternative to either T-10 thinner or xylene.

Appendix I Laboratory Testing Final Report

Final Report Demonstration/Validation of Tertiary Butyl Acetate (TBAC) for Hand-Wipe Cleaning Applications
January 2008
REPORT NO. ATC-9595

U.S. ARMY ABERDEEN TEST CENTER

DTC PROJECT NO. 2005-DT-ATC-ARSPT-C7867
ESTCP PROJECT NO. 06 E-PP3-010/WP-0616
REPORT NO. ATC-9595

Final Report

Demonstration/Validation of Tertiary Butyl Acetate (TBAC) for Hand-Wipe Cleaning Applications

January 2008

William Taylor

Warfighter Directorate, Applied Sciences Test Division
Materials and Standards Testing Team

Prepared for:
U.S. Army Research Laboratory (ARL)
Aberdeen Proving Ground, MD 21005-5069

U.S. Army Developmental Test Command
Aberdeen Proving Ground, MD 21005-5055

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TEDT-AT-WFA

29 JAN 2008

MEMORANDUM FOR Army Research Laboratory, (AMSRD-ARL-WM-MC/Mr. Wayne Ziegler), Bldg 4600, Aberdeen Proving Ground, MD 21005-5055

SUBJECT: Final Report for the Demonstration/Validation of Tertiary Butyl Acetate (TBAC) for Hand-Wipe Cleaning Applications, DTC Project No. 2005-DT-ATC-ARSPT-C7867/ESTCP, Project No. 06-E-PP3-010/WP-0616, Report No. ATC-9595

1. Subject report is forwarded for your information and retention.

2. The point of contact at this activity is Mr. William H. Taylor, Warfighter Directorate, Applied Science Test Division, DSN 298-4461 or email william.taylor@atc.army.mil.

Encl

JOHN B. RUHL
Director, Warfighter Directorate

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1.0 SUMMARY

Federal, state, and local regulations have necessitated the search for replacements of the traditional hydrocarbon-based PD-680 solvents. PD-680 solvents are widely used in the Joint Services and private industry and work very well for degreasing during rebuilds, maintenance, and painting operations. The solvents usually do not cause issues within the U.S. Army and other Services with material degradation of rubber seals, paints, or metals that make up the equipment needed for Soldiers. The influx of new alternative cleaners has given rise to the need to test these new cleaners for material compatibility and effectiveness to assess the impact they have on system readiness. Alternative cleaners seemed to solve the environmental problems of volatile organic compounds (VOCs), hazardous air pollutants (HAPs), toxins, and flammability issues, but these cleaners have never been tested to determine the impact they have on material degradation. The Sustainable Painting Operations for the Total Army (SPOTA) program, a Joint Services Solvent Substitution (JS3) effort, has evolved from the Environmental Protection Agency (EPA) National Emissions Standard for Hazardous Air Pollutants (NESHAP) requirements. This SPOTA effort was designed to seek out HAP-free, low-VOC alternatives for the Army to use during the entire de-painting, painting, and repair paint operation. The U.S. Army Solvent Substitution Working Group (ASSWG) was formed in 2003 in support of the SPOTA effort. The objective of the ASSWG project was to evaluate 17 HAP-free, low-VOC cleaners for hand-wipe and immersion applications related to Department of Defense (DoD) painting operations.

This report is an extension of the SPOTA, JS3, and ASSWG efforts during which a product, tertiary butyl acetate (TBAC), was recently removed from the EPA's list of products that were considered to be VOCs. As a result of this decision, funds were provided by the Environmental Security Technology Certification Program (ESTCP) to test TBAC using the same testing methodology as the original 17 hand-wipe cleaners. Because of separate funding, a report containing only the results of TBAC testing was required.

Testing generally consisted of material compatibility and performance-related tests. The protocol was developed to test the alternatives using established and recognized test methods endorsed by the American Society for Testing and Materials (ASTM) and the Society of Automotive Engineers (SAE). For unique situations, military test specifications were used to meet mission-critical criteria.

Testing was divided into two sections. Section 1 was composed of the Cleaner Evaluation criteria for Safety, Environmental, and Characteristics; Surface Cleaning; and Storage. Section 2 was composed of Material Compatibility tests for Corrosion; Effects on Surfaces; and Effects on Plastics, Rubber, and Sealants.

2.0 TEST OBJECTIVE

The test objective was to provide technical data to the ESTCP, JS3, and ASSWG to determine if TBAC was safe, materially compatible, and a viable alternative replacement for hydrocarbon solvents for hand-wipe applications.

3.0 TESTING AUTHORITY

On 27 October 2005, the U.S. Army Research Laboratory (ARL) received a letter from the ESTCP office authorizing the initiation of TBAC testing. The U.S. Army Aberdeen Test Center (ATC) at Aberdeen Proving Ground (APG), Maryland, was then asked to perform the required testing to maintain continuity of having tested the original 17 products for hand-wipe applications (app AA, ref 1).

4.0 SYSTEM DESCRIPTION

TBAC is a non-HAP, VOC-exempt organic solvent. The brand of TBAC tested was manufactured by Lyondell Chemical Company, 1221 McKinney Street, Houston, TX 77010, under the trade name TBAc™. The product was used as received without dilution.

5.0 TESTING ENVIRONMENT

Virgin product was used for each test. After the solution was used for each test, it was disposed of properly. Each test had unique environmental requirements that were followed in accordance with that test.

6.0 CONCLUSIONS

a. Safety, Environmental, and Characteristics.

(1) TBAC was granted a toxicity clearance by the U.S. Army Center for Health Promotion and Preventive Medicine (CHPPM) (app A).

(2) The flash point of TBAC was 3.9 ^{o}C (39 ^{o}F), which was well below the 60 ^{o}C (140 ^{o}F) ignitability (EPA Hazard Code D001) standard for distinguishing the product as a flammable liquid.

(3) The nonvolatile residue of TBAC was determined to be nondetectable by the equipment used.

b. Chemical Properties.

The vapor pressure value was 1.67 dry vapor pressure equivalent (DVPE).

c. Material Compatibility.

(1) TBAC performed well during the total immersion, elevated temperature, low-embrittling cadmium plate, and copper corrosion testing.

(2) The stress corrosion testing was not performed because of the high evaporation rate of TBAC and the current method of testing in the laboratory.

(3) The hydrogen embrittlement testing was met for TBAC.

(4) The titanium stress corrosion testing was met for TBAC for both materials 4911 and 4916.

(5) Sandwich corrosion was met by all materials except stainless steel 13-8, steel 4340, and magnesium, which all failed by very small margins.

(6) TBAC met the criterion for effects on painted and unpainted surfaces.

(7) TBAC had little effect on polysulfide sealants, sheet molding compound, or polyimide wire.

(8) The reaction of TBAC toward acrylic plastics MIL-P-8184 and MIL-P-5425 and polycarbonate MIL-P-83310 was swift, with most samples breaking. Acrylic plastic MIL-P-25690 met the criterion.

(9) Only one rubber tested, 3217/2B, met all testing criteria. The decrease in hardness of the materials was the main reason for not meeting the criteria.

d. Performance.

(1) TBAC met the criterion for soil cleaning with a value of 96 percent.

(2) TBAC developed a discontinuous film of water after 10 sec during the water break test and did not meet the criterion.

(3) TBAC met the criterion for temperature stability.

(4) TBAC met the criterion for sealant adhesion for MIL-P-23377 but not MIL-P-85582.

(5) All aluminum 2024-T3, clad, conversion-coated panels, painted with MIL-P-23377 or MIL-P-85582 primer and MIL-C-85285 topcoat, remained undisturbed after testing TBAC and met the criterion for paint adhesion.

(6) All aluminum 2024-T3 bare, anodized panels, painted with MIL-P-23377 primer and MIL-C-85285 topcoat met the criterion for paint adhesion.

(7) The aluminum 2024-T3 bare, anodized panels, painted with MIL-P-85582 primer and MIL-C-85285 topcoat did not meet the criterion for paint adhesion.

(8) Although TBAC did not completely meet the criterion for fluorescent penetrant inspection, it is considered to have met the criterion in practical terms and should not cause a problem during the inspection process.

7.0 RECOMMENDATIONS

a. TBAC can be used on most metals without the concern of corrosion because it dries very fast.

b. The flash point of TBAC is a health and safety concern. Stringent safety procedures must be in place because of its low flash point.

c. TBAC causes severe degradation to polycarbonate plastic and some acrylic plastics. When using TBAC around clear plastics, the user must know what the material is.

d. In addition, the user must know the preparation technique and paint application to ensure that the equipment is not aluminum 2024-T3 bare, anodized, and painted with MIL-P-85582 primer and MIL-C-85285 topcoat.

SECTION 1. CLEANER EVALUATION

1.1 SAFETY, ENVIRONMENTAL, AND CHARACTERISTICS

1.1.1 TOXICITY

1.1.1.1 Objective

The objective of this test was to determine whether a toxicity clearance could be granted for the manufacturer's suggested working concentration of the cleaning compound.

1.1.1.2 Criterion

The toxicity of the manufacturer's suggested working concentration of the cleaning compound shall conform to Army Regulation (AR) 40-5 (ref 1.1.1-1) and shall have no adverse effects on the health of personnel or the environment when used properly and with the appropriate personal protection equipment (PPE).

1.1.1.3 Test Procedures

a. A toxicity clearance for any potentially hazardous product to be used by U.S. Army military personnel is granted or denied by CHPPM using the process in AR 40-5. A toxicity evaluation is performed, and clearances are conditionally approved based on the solvent application or use condition. A toxicity clearance involves a toxicological evaluation of materials prior to introduction into the Army supply system. The program manager is responsible for identifying technically feasible materials and requesting a toxicity clearance for use of those materials.

b. CHPPM toxicity evaluations require the following:

(1) Final chemical formulation (handled as proprietary, if required).

(2) Identity and application of new solvent; identity of the solvent being replaced, if applicable.

(3) Reports from manufacturers pertaining to the use of the solvent in the commercial market and material safety data sheets (MSDSs).

(4) Available human and animal toxicity studies and epidemiology information.

1.1.1.4 Test Findings

a. The protocol was not deviated from during testing.

b. A toxicological evaluation was conducted, and a toxicity clearance was granted by CHPPM, APG, Maryland, for TBAC (app A). An approval was granted as long as the guidelines for use, PPE, and other restrictions mentioned in the clearance are followed.

1.1.1.5 Technical Analysis

The product TBAC was granted a toxicity clearance with restrictions as set forth in the clearance.

(Page 1.1.1-2 Blank)

1.1.2 FLASH POINT

1.1.2.1 Objective

The objective of this test was to determine the flash point characteristics of the manufacturer's suggested working concentration of the cleaning compound.

1.1.2.2 Criterion

The flash point of the manufacturer's suggested working concentration of the cleaning compound shall fall within the requirements for each particular organization.

1.1.2.3 Test Procedures

a. The flash point of the manufacturer's suggested working concentration of the cleaning compound was determined using the method outlined in ASTM D93 (ref 1.1.2-1).

b. The test apparatus was prepared, the samples were taken, and all cautionary statements in ASTM D93 were applied.

c. Testing was performed using a GT Instruments D93 tester.

d. The following information was reported for each test performed:

(1) Summary of the test methods and any deviations from the protocol.

(2) Identification of the solution tested and the concentration and diluent used.

(3) Test conditions: temperature, exposure time, and humidity.

(4) Identification of the testing laboratory and the responsible technical point of contact.

(5) Individual and averaged test results.

1.1.2.4 Test Findings

a. Results pertaining to flash point are provided in the Chemistry Laboratory Report (app B).

b. The protocol was not deviated from during testing.

c. The flash point of TBAC was tested to be 39 ^{o}F (3.9 ^{o}C).

1.1.2.5 Technical Analysis

TBAC did not meet the minimum criterion for any standard listed in the test protocol. Caution must be taken in the use of TBAC because of the very low flash point.

(Page 1.1.2-2 Blank)

1.1.3 NONVOLATILE RESIDUE

1.1.3.1 Objective

The objective of this test was to determine the nonvolatile residue (NVR) characteristics of the manufacturer's suggested working concentration of the cleaning compound using the standard and modified methods.

1.1.3.2 Criterion

The NVR of the manufacturer's suggested working concentration of the cleaning compound shall not be greater than 8 mg of residue per 100 mL of solution.

1.1.3.3 Test Procedures

a. The NVR characteristics of the manufacturer's suggested working concentration of the cleaning compound were determined according to ASTM D1353 (ref 1.1.3-1). An additional test was performed using a modified method of ASTM D1353.

b. The products were tested as written in ASTM D1353.

c. One hundred milliliters of the product was measured and placed in an evaporating dish, placed on a steam bath, and evaporated to dryness.

d. The residue remaining in the dish was weighed.

e. NVR determinations were made on three samples, and the average was reported. If the two weights differed by more than 0.5 percent (absolute), the drying procedure was repeated.

f. The following information was reported for each test performed:

(1) Summary of the test methods and any deviations from the protocol.

(2) Identification of the solution tested and the concentration and diluent used.

(3) Test conditions: temperature, exposure time, and humidity.

(4) Identification of the testing laboratory and the responsible technical point of contact.

(5) Individual and averaged test results.

(6) Results of visual inspections, observations, and discussion of specimen condition.

1.1.3.4 Test Findings

a. Results pertaining to NVRs are provided in the Chemistry Laboratory Report (app B).

b. The methodology in ASTM D1353 was not deviated from during initial testing.

c. The NVR of TBAC was reported to be nondetectable with the equipment used.

1.1.3.5 Technical Analysis

TBAC met the criterion for NVR.

1.1.4 VAPOR PRESSURE

1.1.4.1 Objective

The objective of this test was to determine the vapor pressure of the manufacturer's suggested working concentration of the cleaning compound.

1.1.4.2 Criterion

The vapor pressure of the manufacturer's suggested working concentration of the cleaning compound shall be less than that stated in the Test Matrix.

1.1.4.3 Test Procedures

a. The vapor pressure of the manufacturer's suggested working concentration of the cleaning compound was determined using the method outlined in ASTM D2879 (ref 1.1.4-1).

b. The test apparatus was prepared, the samples were taken, and all cautionary statements in ASTM D2879 were applied.

c. Testing was performed by the Chemical Sampling and Analysis Team, ATC, APG, Maryland.

d. The following information was reported for each test performed:

(1) Summary of the test methods and any deviations from the protocol.

(2) Identification of the solution tested and the concentration and diluent used.

(3) Test conditions: temperature, exposure time, and humidity.

(4) Identification of the testing laboratory and the responsible technical point of contact.

(5) Individual and averaged test results.

1.1.4.4 Test Findings

a. Results pertaining to vapor pressure are provided in the Chemistry Laboratory Report (app B).

b. The protocol was not deviated from during testing.

c. The vapor pressure of TBAC was determined to be 1.67 DVPE.

1.1.4.5 Technical Analysis

Users must determine if the values meet their requirements for vapor pressure.

(Page 1.1.4-2 Blank)

1.2 SURFACE CLEANING

1.2.1 SOIL CLEANING

1.2.1.1 Objective

The objective of this test was to determine the relative solvency or soil cleaning characteristics of the manufacturer's suggested working concentration of the cleaner.

1.2.1.2 Criterion

The manufacturer's suggested working concentration of the cleaning compound shall not have a relative solvency of less than 85 percent (MIL-PRF-680A).

1.2.1.3 Test Procedures

a. The soil cleaning of the manufacturer's suggested working concentration of the cleaning compound was determined using a test method developed by the U.S. Army Tank-automotive and Armaments Command (TACOM) (see Appendix of MIL-PRF-680A) (ref 1.2.1-1).

b. Three test specimens, 2.54 by 2.54 by 0.1 cm (1 by 1 by 0.04 in.), were made from steel, carbon, mild (ASTM A366, class 1, commercial bright finish (ref 1.2.1-2)).

c. The metal specimens were washed in toluene (CP, 99 percent) until free of any soil and grease.

d. The test specimens were dried with clean dry air.

e. The test specimens were weighed to the nearest 0.1 gram.

f. Approximately 0.4 gram of MIL-G-10924F grease, automotive and artillery (ref 1.2.1-3), was applied to the test specimen, covering both sides uniformly.

g. The test specimen was placed into a beaker using a holder to prevent contact with the sides or bottom of the beaker.

h. The manufacturer's suggested working concentration of the cleaning compound was added to the beaker until the test coupon was completely immersed.

i. The beaker with the test specimens was partially immersed in an ultrasonic cleaner so that there was no mixing of the test cleaner and the liquid in the ultrasonic cleaner. The liquid in the ultrasonic cleaner was maintained at a water temperature of 50 ^{o}C (122 ^{o}F).

j. The test specimen was observed until all of the grease was removed, and the time was recorded.

k. If grease remained on the test specimen after 100 min, testing was terminated and the cleaning time was recorded as 100 min.

l. The test specimen was dried using clean dry air.

m. The test specimen was weighed to the nearest 0.1 gram.

n. The steps in paragraphs a through m were repeated with the other two specimens.

o. The cleaning power was calculated as follows:

Solvent cleaning power, % = ((100-A)/100) X 100, where A is the average time of three runs obtained from tests.

p. The following information was reported for each test performed:

(1) Summary of the test methods and any deviations from the protocol.

(2) Identification of sample material alloy(s), product temper, and selection of thickness of material tested including reference to product specification.

(3) Specimen details: the type and dimensions of the test specimen and the number of replicates.

(4) Identification of the solution tested and the concentration and diluent used.

(5) Test conditions: temperature, exposure time, and humidity.

(6) Identification of the testing laboratory and the responsible technical point of contact.

(7) Individual and averaged test results.

(8) Results of visual inspections, observations, and discussion of specimen condition.

(9) Photographic documentation, if needed, of specimen conditions (specifically any staining, evidence of general corrosion, etching, pitting, or localized attack).

1.2.1.4 Test Findings

a. Data sheets pertaining to soil cleaning are provided in Appendix C.

b. Performing additional tests for toluene deviated from the protocol.

c. The soil cleaning or relative solvency of TBAC was 96 percent.

d. Toluene was used as a control. The cleaning times for the three specimens were 6, 7, and 6 min with a relative solvency of 94 percent.

1.2.1.5 Technical Analysis

TBAC met the criterion by performing better than 85 percent.

1.2.2 SEALANT ADHESION

1.2.2.1 Objective

The objective of this test was to determine the effect that the manufacturer's suggested working concentration of the cleaning compound had on the sealant peel strength.

1.2.2.2 Criterion

The manufacturer's suggested working concentration of the cleaning compound shall not cause the sealing compound to have a minimum peel strength of <20 lbf/in. after a 7-day exposure in jet reference fluid. There shall also be 100 percent cohesive failure of the sealant during testing (Test Matrix).

1.2.2.3 Test Procedures

a. The effect that the manufacturer's suggested working concentration of the cleaning compound had on sealant peel strength was determined by using a method outlined in section 4.5.17 of Aeronautical Design Standard (ADS)-61A-PRF (ref 1.2.2-1).

b. Two sets of eight test panels, aluminum 2024-T3, 15.24 by 7 by 0.1 cm (6 by 2.75 by 0.04 in.), were prepared.

c. The primer MIL-P-23377 (ref 1.2.2-2) was applied to one set of panels, and the primer MIL-P-85582 (ref 1.2.2-3) was applied to the other set.

d. The panels primed with MIL-P-85582 were scuff-sanded with abrasive mats conforming to AA-58054 (ref 1.2.2-4), type I, class 1, Grade A, or equivalent.

e. A standardized contaminant mixture of two parts (by weight) of hydraulic fluid (MIL-PRF-83282 (ref 1.2.2-5)), one part (by weight) of lubricating grease (MIL-PRF-81322 (ref 1.2.2-6)), and one-tenth part (by weight) of carbon black was prepared.

f. The contaminant mixture was applied to all the test panels and baked for 2 hr at 54 ^{o}C (130 ^{o}F).

g. The test panels were cooled to ambient (room) temperature.

h. The gross contaminant was removed from the test panels with a clean dry cloth.

i. Four test panels of each set were wiped four times with a clean cloth soaked with the manufacturer's suggested working concentration of the cleaning compound. The cleaning was accomplished by first removing excess contaminant with a clean cloth. Cleaning of the coupon was continued using a cloth soaked in the working concentration of the cleaner. The cloth was wiped across the coupon in one direction, folded to expose a clean area of cloth, and the action repeated. The coupon was wiped four times. The remaining panels of each set were cleaned with methyl ethyl ketone (MEK) (ASTM D740 (ref 1.2.2-7)), the control cleaner.

j. If the test cleaner was water based, the panels were wiped clean with a clean cloth soaked in deionized (DI) water (ASTM D1193, type IV (ref 1.2.2-8)) and allowed to dry thoroughly.

k. At least 125 mm (5 in.) of the panels was coated on one side with a 3 $\pm$ 0.5-mm (1/8 $\pm$ 1/64-in.) thickness of sealing compound per MIL-S-8802 (ref 1.2.2-9), type II, class B.

l. A 70- by 300-mm (2.75- by 12-in.) strip of wire screen (20- to 40-mesh aluminum or monel wire fabric) or cotton duck per CCC-C-419 type III (ref 1.2.2-10) or equivalent was impregnated with sealant so that approximately 125 mm (5 in.) of one end was completely covered with sealant on both sides. The sealant was worked well into the fabric.

m. The sealant-impregnated end of the fabric was placed on the sealant-coated panel. The fabric was smoothed down on the panel and care was taken not to trap air beneath the fabric.

n. An additional 1-mm- (1/32-in.-) thick coating of sealing compound was applied over the fabric. The sealant was allowed to cure fully, in accordance with the manufacturer's recommendations.

o. The panels were completely immersed in jet reference fluid per Aerospace Material Specification (AMS) 2629, type I (ref 1.2.2-11), at 60 $\pm$ 1 ^{o}C (140 $\pm$ 2 ^{o}F) for 7 days, using glass-covered vessels.

p. The panels were placed in jet reference fluid for 24 hr at ambient temperature.

q. The sealant peel strength was measured within 10 min after removal from the jet reference fluid.

(1) Two 25-mm- (1-in.-) wide sections were cut lengthwise through the fabric and sealing compound on each panel.

(2) In a suitable tensile testing machine, the fabric was stripped back to the metal panel at an angle of 180° at a rate of 50 mm/min (2 in./min).

(3) During peel strength testing, three cuts were made through the sealing compound to the panel at approximately 25-mm (1-in.) intervals in an attempt to promote adhesive failure. The wire or cloth was not cut.

(4) The numerical average of the peak loads was measured. Failures of the sealing compound to the fabric were not included in the peel strength values.

(5) The approximate percentage of cohesive/adhesive failures was determined.

(6) If the control specimens that were prepared with MEK did not meet the performance requirements of 20 lbf and 100 percent cohesive failure, the procedure was repeated with a different batch of sealant.

r. The following information was reported for each test performed:

(1) Summary of the test methods and any deviations from the protocol.

(2) Specimen details: the type and dimensions of the test specimen and the number of replicates.

(3) Identification of the solution tested and the concentration and diluent used.

(4) Test conditions: temperature, exposure time, and humidity.

(5) Identification of the testing laboratory and the responsible technical point of contact.

(6) Individual and averaged test results.

(7) Results of visual inspections, observations, and discussion of specimen condition.

(8) Photographic documentation of specimen conditions (specifically any staining, evidence of general corrosion, etching, pitting, or localized attack).

1.2.2.4 Test Findings

a. Data sheets pertaining to sealant adhesion are provided in Appendix D.

b. The criterion and measurement standards for sealant adhesion were deviated from to better reflect the purpose of the test. The preparation, exposure, and test execution remained as stated in the protocol. SAE standards AS5127 and AS5127/1 (refs 1.2.2-12 and 1.2.2-13) describe methods to determine performance properties of sealants. The purpose of the protocol is to use the performance of the sealant to test the ability of the cleaner to provide a reliable surface for sealant adhesion, not to test the sealant. The SAE method was altered to reflect that the peak performance of the sealant would determine the adhesive property of the cleaned surface. During the sealant peel testing, four maximum values greater than 20 lb, whether cohesive or adhesive, from side A and side B from each panel, were used to determine the effectiveness of the cleaner to provide a reliable surface. By testing four panels of each primer, there were 32 values obtained for each product-primer set. If values of the sealant peel testing were not greater than 20 lb for the control panels, the sealant would have been considered inferior and the procedure repeated with a different batch of sealant for all test and control panels.

c. The control panels painted with MIL-P-23377 and cleaned with MEK produced average maximum sealant peel strengths of 30.08 lb. All pulls were 100 percent cohesive failures (app E).

d. The control panels painted with MIL-P-85582 and cleaned with MEK produced average maximum sealant peel strengths of 31.53 lb. Two of the four panels, No. 3 and No. 4, were considered 100 percent cohesive. Panel No. 1 was considered 95 percent cohesive. The 5 percent failure was due to an adhesion failure of the primer to the metal panel; it was not a fault of the sealant. Panel No. 4 was excluded from the calculations and determination of failure because the method of cleaning was not consistent with the procedure (app E).

e. The results of testing are presented in Table 1.2.2-1. The percentage of cohesive failure was a subjective average of the four panels.

TABLE 1.2.2-1. RESULTS OF SEALANT ADHESION TESTING

CLEANER	PRIMER 23377		PRIMER 85582	
	MAXIMUM FORCE (AVERAGE), lb	COHESIVE FAILURE, %	MAXIMUM FORCE (AVERAGE), lb	COHESIVE FAILURE, %
TBAC	28.66	>99	21.64	>21

Note: Photographs of cohesive failure for the two primers can be found in Appendix E.

1.2.2.5 Technical Analysis

a. An attempt was made to develop a consistent method of cleaning the panels. During the cleaning process, it was decided that five wipes of a cotton cloth provided a uniform level of cleaning for each panel as required in the test procedure. Realistically, a person will not clean panels as thoroughly as was done during testing, by using a cloth soaked with cleaner, folding it, holding it in the palm of the hand, applying equal pressure on the cloth while moving it across each panel in one motion, and repeating this procedure four times. This degree of cleaning, although equal for all panels during testing, does not typify what would occur in the real world. It would be difficult to perform real-world cleaning on the 136 panels tested and be unvarying in the method. With this in mind, averaged cohesive failures of 95 percent, or sets of panels where one of four panels had a small amount of cohesive failure and the other three were 100 percent, could be considered as having met the criterion. It is recommended that the photographs provided in Appendix E be examined carefully to note areas of subjectivity.

b. The control panels for both primers cleaned with MEK were considered to have met the criterion for sealant peel strength. The very small amount of adhesive failure was due to the primer not adhering to the substrate and not adhesive failure of the sealant to the primer. All panels produced pulling forces greater than the requirement.

c. The product TBAC is considered to meet the criterion for the primer MIL-P-23377.

d. TBAC does not meet the criterion for primer 85582. Examination of the photographs and consideration of the cleaning procedure may provide information to assess this product as having met or not met the criterion.

e. Historically, the test panels painted with MIL-P-85582 have had more difficulty meeting the criterion for sealant peel strength than test panels painted with MIL-P-23377.

1.2.3 PAINT ADHESION

1.2.3.1 Objective

The objective of this test was to determine how the manufacturer's suggested working concentration of the cleaning compound affected paint adhesion.

1.2.3.2 Criterion

The manufacturer's suggested working concentration of the cleaning compound shall not cause the primer coating to peel away from the substrate from any test panels after immersion in distilled water for 24 hr (Test Matrix).

1.2.3.3 Test Procedures

a. The effects that the manufacturer's suggested working concentration of the cleaning compound had on paint adhesion were determined using FED-STD-141, Test Method No. 6301 (ref 1.2.3-1).

b. A set of six test panels, 10 by 10 by 0.635 cm (4 by 4 by 0.25 in.), were prepared from aluminum (2024-T3 bare) and anodized per MIL-A-8625, type I (ref 1.2.3-2).

c. A second set of six test panels, 10 by 10 by 0.635 cm, were prepared from aluminum (2024-T3 clad) with a conversion coat per MIL-C-5541, class 3 (ref 1.2.3-3).

d. Both sets of test panels were dried for 24 hr at ambient (room) conditions.

e. A standardized contaminant mixture was applied, consisting of two parts by weight of hydraulic fluid (MIL-PRF-83282 or equivalent), one part by weight lubricating grease (MIL-PRF-81322 or equivalent), and one-tenth part by weight of carbon black, to test panels, baked for 2 hr at 55 ^{o}C (130 ^{o}F), and cooled to room temperature.

f. Both sets of panels were cleaned with the manufacturer's suggested working concentration of the cleaning compound. The cleaning was accomplished by first removing excess contaminant with a clean cloth. Cleaning of the coupon was continued using a cloth soaked in the working concentration of the cleaner. The cloth was wiped across the coupon in one direction, folded to expose a clean area of cloth, and the action repeated. The coupon was wiped four times. Test panels were allowed to dry at ambient (room) conditions for 24 hr.

g. Three panels from each set were painted with MIL-P-23377 primer and MIL-C-85285 topcoat (gloss white) (ref 1.2.3-4).

h. The other three panels from each set were painted with MIL-P-85582 primer and MIL-C-85285 topcoat, gloss white.

i. The painted panels were allowed to dry for 7 days at ambient (room) conditions.

j. All test panels were immersed in DI water (ASTM D1193, type IV) for 24 hr.

k. The test specimens were removed from the water and wiped dry with a soft, clean cloth.

l. Within 1 min of removal from the water, two parallel scratches, 2.54 cm (1 in.) apart, were made through the coatings to the metal with a stylus or small, sharp knife.

m. A 2.54-cm-wide strip of flatback paper masking tape (Scotch, code No. 250 or equivalent) was applied across the scratches. The tape used had an average adhesion of 60 oz/in.

n. The tape was pressed into the surface by rolling the tape with a rubber-covered roller eight times. The roller weighed 4.5 lb and had a surface durometer hardness value within the range of 70 to 80. The roller was approximately 3.5 in. in diameter and 1.75 in. in width.

o. The tape was removed with one quick motion.

p. If the tape removed any amount of paint, it was photographically documented immediately upon termination of the test.

q. The following information was reported for each test performed:

(1) Summary of the test methods and any deviations from the protocol.

(2) Identification of the solution tested and the concentration and diluent used.

(3) Test conditions: temperature, exposure time, and humidity.

(4) Identification of the testing laboratory and the responsible technical point of contact.

(5) Individual and averaged test results.

(6) Results of visual inspections, observations, and discussion of specimen condition.

(7) Photographic documentation, if needed, for specimen conditions.

1.2.3.4 Test Findings

a. Data sheets pertaining to paint adhesion are provided in Appendix F.

b. There was no deviation from the protocol during testing.

c. All aluminum 2024-T3, clad, conversion-coated panels, painted with MIL-P-23377 primer and MIL-C-85285 topcoat, remained undisturbed after testing with TBAC.

d. All aluminum 2024-T3, bare, anodized panels, painted with MIL-P-23377 primer and MIL-C-85285 topcoat, remained undisturbed after testing with TBAC.

e. All aluminum 2024-T3, clad, conversion-coated panels, painted with MIL-P-85582 primer and MIL-C-85285 topcoat, remained undisturbed after testing with TBAC.

f. TBAC tested on the aluminum 2024-T3 bare, anodized panels, painted with MIL-P-85582 primer and MIL-C-85285 topcoat, produced adhesive failure (primer to substrate) for all panels (app G).

1.2.3.5 Technical Analysis

a. TBAC met the criterion for paint adhesion for all specimens painted with MIL-P-23377 primer and MIL-C-85285 topcoat.

b. TBAC met the criterion for paint adhesion for all specimens painted with MIL-P-85582 primer and MIL-C-85285 topcoat on the aluminum 2024-T3 clad panels with the conversion coat.

c. TBAC did not meet the criterion for MIL-P-85582 primer and MIL-C-85285 topcoat on aluminum 2024-T3 bare, anodized panels.

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1.2.4 FLUORESCENT PENETRANT INSPECTION

1.2.4.1 Objective

The objective of this test was to determine the effect that the manufacturer's suggested working concentration of the cleaning compound had on fluorescent penetrant inspection.

1.2.4.2 Criterion

The manufacturer's suggested working concentration of the cleaning compound shall not impede the identification of known cracks, and the intensity of the cracks should be brighter or equal to the control using fluorescent penetration inspection (ADS-61A-PRF).

1.2.4.3 Test Procedures

a. The fluorescent penetration inspection characteristics of the manufacturer's suggested working concentration of the cleaning compound were determined by using the inspection method given in ADS-61A-PRF, paragraph, 4.5.2.1.

b. The four bars were cleaned for a minimum of 30 min in an ultrasonic cleaner using MEK as the cleaning agent and inspected under a black light for remaining residue.

c. The bars were dried in an oven at 55 ^{o}C (131 ^{o}F) for 5 min and allowed to cool to room temperature.

d. A standard contaminant mixture was made by combining two parts (by weight) of hydraulic fluid (MIL-PRF-83282) and one part (by weight) of lubricating grease (MIL-PRF-81322).

e. Two drops of the standard contaminant mixture were applied to the test bars in the area of the crack using a clean glass rod and spread evenly. The bars were placed in a dry air-circulating oven for 2 hr at 55 ^{o}C.

f. After baking, the excess contaminant was wiped from the bars with clean cloths. The bars were cleaned with the candidate cleaner, using a cleaning/rinsing process that was recommended for the particular cleaner. When the bars were cleaned with an aqueous-based product, they were rinsed with a moderate stream of tap water without scrubbing.

g. The bars were placed in an oven at 55 ^{o}C for 5 min for drying then removed and allowed to cool to room temperature.

h. Penetrant inspection was performed in accordance with ASTM E1417 (ref 1.2.4-1), ASTM E165 (ref 1.2.4-2), or ASTM E1210 (ref 1.2.4-3), using penetrant materials that were qualified per AMS 2644 (ref 1.2.4-4).

i. The dwell time, the time allowed for the penetrant to stay on the bars, was 1 hr. The penetrant was washed off after the dwell time with a stream of tap water until the bar appeared to be clean. The bar was dipped into the remover and allowed to set flat for exactly 1 min. The remover was washed off with a coarse stream of tap water, and the bar was checked under the black light for excessive background. If the background was excessive, the bar was washed

again with tap water until the background was acceptable. The bar was dried with dry, compressed air. The bar was held horizontally with the crack facing toward the operator while the developer was sprayed in a quick downward motion from a distance of 30.5 to 35.6 cm (12 to 14 in.) toward the crack area. The minimum amount of developer was applied to the bar. The developer was allowed to dry, and the light intensity readings (LIRs) were recorded according to the operation manual.

j. Measurements were recorded using a calibrated Photo Research, Inc., model PR-1500 Spectra Spotmeter. The bars were placed under ultraviolet (black) light per ASTM E1417, ASTM E165, ASTM E1219 (ref 1.2.4-5), or ASTM E1210. Each crack indication was measured for light intensity along with the background intensity value on the bar surface near the crack. The background value was subtracted from the crack value to obtain the relative intensity of the crack indication. All measurements and observations were recorded. All measurements were recorded in similar sequence to minimize the amount of time between readings to ensure similar procedural times.

k. Steps b though i were repeated two times, and the average of the three LIRs for each bar was recorded.

l. The candidate cleaner was replaced with MEK as the cleaner, and three trials for each bar were performed and recorded.

m. The brightness intensity readings obtained with the candidate cleaner and the control cleaner were compared.

n. Although not a criterion of the test protocol, but for further comparison, TAM and JAP panels were used similarly to the inconel and titanium bars to determine the brightness of crack patterns. The TAM panel consisted of a chrome-plated panel with five star-shaped cracks of varying sizes. The largest crack was identified as No. 1 and the smallest as No. 5. The JAP panel consisted of a chrome-plated brass panel that had been stressed to produce lateral cracks across the entire surface of the panel. The cracks on the JAP panel were similar in width and evenly spaced across the panel.

o. The procedures in paragraphs a through j were followed, and the LIRs were recorded for all five cracks of the TAM panel and for the first five cracks of the JAP panel.

p. The readings were recorded three times for each cleaner and for the control cleaner MEK per ADS-61A-PRF, the same method as was used for the bars.

q. The brightness readings for each of the five individual crack patterns of the TAM panel were averaged and compared to the controls. The size of the five cracks varied too much, making averaging impractical.

r. For the JAP panels, the three trials for the first through fifth crack were averaged, and those five values were then averaged to produce one value for all 15 readings recorded.

s. Observations were made of the effects the cleaner produced on the inspection process.

t. The following information was reported for each test performed:

(1) Summary of the test methods and any deviations from the protocol.

(2) Identification of the solution tested and the concentration and diluent used.

(3) Test conditions: temperature, exposure time, and humidity.

(4) Identification of the testing laboratory and the responsible technical point of contact.

(5) Individual and averaged test results.

(6) Results of visual inspections, observations, and discussion of specimen condition.

1.2.4.4 Test Findings

a. Data sheets pertaining to fluorescent penetrant inspection are provided in Appendix H.

b. The procedure was enhanced slightly by the use of a Spectroline DM-365X Long Wave Ultraviolet Meter to maintain the same intensity of the black light at the point of measurement to 1400 $\pm$ 50 $\mu W/cm^2$.

c. The penetrant used was Britemor 760, level 3, and the remover used was H-92, both made by Ely Chemical Co. The developer used was Magnaflux brand SKD-S2.

d. To minimize the variation between how the photometer was read, one laboratory technician was designated to read the brightness values. The bars were oriented the same each time, and the position at which the readings were measured was consistent to the extent possible.

e. Because of the time required to perform this testing, only six products were selected as test cleaners.

f. Averaged LIRs for the MEK cleaner are presented in Table 1.2.4-1.

TABLE 1.2.4-1. AVERAGED LIRs FOR MEK

TEST CONDITION	LIR
Inconel 718 with 0.020-in. crack (R-91)	1.74
Inconel 718 with 0.060-in. crack (R-70)	8.57
Titanium 4911 with 0.375-in. crack (T-1)	14.05
Titanium 4911 with 0.060-in. crack (T-62)	2.32
TAM panel	
Crack No. 1 (largest)	6.71
Crack No. 2	2.34
Crack No. 3	0.84
Crack No. 4	0.50
Crack No. 5 (smallest)	0.52
JAP panel (averaged)	0.53

Note: The crack indications on all bars were well defined.

g. Averaged LIRs for the product TBAC are presented in Table 1.2.4-2.

TABLE 1.2.4-2. AVERAGED LIRs FOR TBAC

TEST CONDITION	LIR
Inconel 718 with 0.020-in. crack (R-91)	2.20
Inconel 718 with 0.060-in. crack (R-70)	7.41
Titanium 4911 with 0.375-in. crack (T-1)	9.91
Titanium 4911 with 0.060-in. crack (T-62)	2.20
TAM panel	
Crack No. 1 (largest)	3.34
Crack No. 2	0.97
Crack No. 3	0.71
Crack No. 4	0.27
Crack No. 5 (smallest)	0.44
JAP panel (averaged)	2.04

Note: The crack indications on all bars were well defined.

1.2.4.5 Technical Analysis

a. TBAC met the portion of the criterion for fluorescent penetrant inspection for cleaning a contaminant from a metal surface with a known crack indication and not masking that indication during inspection. TBAC allowed crack detection during inspection. Under a black light inspection, oils and greases appear blue. There was no trace of blue color on any bar tested, indicating that TBAC removed the contaminant.

b. TBAC failed the portion of the criterion for the candidate cleaner to allow an equal or brighter light intensity as the control cleaner except on the R-91 bar. The R-70, T-1, and T-62 bars tested with TBAC still produced light sufficient for detection. The smaller crack pattern bar, R-91, had a higher reading for TBAC than the controls. The TAM panel readings for the TBAC-cleaned bar were all lower than the controls, but the JAP panel readings were higher than the controls

c. Although procedures were in place to minimize the subjectivity of the test, intensity values on the titanium bar with the 0.375-in. crack changed dramatically depending on the area of the crack that was being measured. Measurements were always recorded at the same approximate position of the crack for every reading.

d. The Photo Research Spotmeter was extremely sensitive. Fluorescent light around a crack that appeared to have the same intensity to the eye could actually be variable by 6 or 7 points along the crack. Considering these variations, the R-70, T-1, and T-62 bars would have all met the criterion.

e. The amount of developer applied to the bar could be another variable between readings. This information is not known, but does more developer cause lower or higher readings? One technician applied the developer during all testing for all products to minimize the unpredictability of application.

f. It is this author's opinion that the intensity of the cracks should be used as a guideline and not as a criterion for cleaner performance during inspection. To expect a cleaner, solvent or water based, to produce LIRs as good as MEK is optimistic.

1.2.5 WATER BREAK FREE

1.2.5.1 Objective

The objective of this test was to determine the water break free of the manufacturer's suggested working concentration of the cleaning compound.

1.2.5.2 Criterion

The water break free for any surface cleaned with the manufacturer's suggested working concentration of the cleaning compound shall be greater than 1 min (Test Matrix).

1.2.5.3 Test Procedures

a. The water break of the manufacturer's suggested working concentration of the cleaning compound was determined using a modified version of ASTM F22 (ref 1.2.5-1).

b. A 10- by 10- by 1.0-cm (4- by 4- by 0.25-in.) test coupon of aluminum 7075-T6 was abraded and cleaned with a Scotch-Brite pad.

c. The test coupon was placed into a container of DI water.

d. The test coupon was removed vertically from the water.

e. The time it took for the draining water layer to become a discontinuous film was determined.

f. The steps in paragraphs a through e were repeated until the time exceeded 1 min.

g. The test coupon was dried.

h. A standard contaminant mixture was made by combining two parts (by weight) of hydraulic fluid (MIL-PRF-83282) and one part (by weight) of lubricating grease (MIL-PRF-81322).

i. The standardized mixture was applied to the test coupon and baked for 2 hr in an air-circulating oven at 54 ^{o}C (129 ^{o}F). The test coupon was allowed to cool to ambient temperature.

j. The test coupon was cleaned with the manufacturer's suggested working concentration of the cleaning compound and allowed to air-dry. The cleaning was accomplished by first removing excess contaminant with a clean cloth. Cleaning of the coupon was continued using a cloth soaked in the working concentration of the cleaner. The cloth was wiped across the coupon in one direction, folded to expose a clean area of cloth, and repeated. The coupon was wiped four times.

k. The test coupon was tested again for water break using the steps in paragraphs b through f.

1.2.5.4 Test Findings

a. Data sheets pertaining to water break free are provided in Appendix I.

b. The ASTM methodology was deviated from by the use of aluminum 7075 plate in place of mica and the use of a Scotch-Brite pad to clean the aluminum surface to provide the required discontinuous film.

c. The timed result for the coupons cleaned with TBAC was 10 sec to water break.

1.2.5.5 Technical Analysis

TBAC did not meet the criterion for a water break free surface.

1.3 STORAGE

1.3.1 TEMPERATURE STABILITY

1.3.1.1 Objective

The objective of this test was to determine the temperature stability of the manufacturer's concentrated or as-received sample of the cleaning compound.

1.3.1.2 Criterion

The temperature stability of the manufacturer's suggested working concentration of the cleaning compound shall be such that the cleaning compound returns to its original homogeneous condition after exposure to extreme environments (Test Matrix).

1.3.1.3 Test Procedures

a. The temperature stability of the manufacturer's as-received concentration of the cleaning compound was determined using a modified version described in ADS-61A-PRF.

b. A 50-mL sample of the manufacturer's as-received concentration of the cleaning compound was placed in a suitable clean test tube.

c. The test tube was cooled to -17.8 ^{o}C (0 ^{o}F) for 1 hr.

d. The test tube was placed in an air-circulating oven for 1 hr at 48.9 ^{o}C (120 ^{o}F).

e. The steps in paragraph c and d were repeated four times (a total of five cycles).

f. At the end of the fifth cycle, the test tube was inverted five times and left to stand at room temperature.

g. The solution was observed for homogeneity or any changes from the original solutions. The appearance of the solution was documented with photographs, if needed.

h. The following information was reported for each method:

(1) Summary of the test methods and any deviations from the protocol.

(2) Identification of the solution tested and the concentration and diluent used.

(3) Test conditions: temperature, exposure time, and humidity.

(4) Identification of the testing laboratory and the responsible technical point of contact.

(5) Results of visual inspections, observations, and discussion of the specimen condition.

1.3.1.5 Test Findings

a. Data sheets pertaining to temperature stability are provided in Appendix J.

b. The product TBAC was exposed to the temperature cycles as stated. The solution was observed for homogeneity or any changes from the original condition. There was no change in physical appearance between the exposed and unexposed solutions.

1.3.1.6 Technical Analysis

TBAC met the criterion for temperature stability.

SECTION 2. MATERIAL COMPATIBILITY TESTS

2.1 CORROSION

2.1.1 TOTAL IMMERSION

2.1.1.1 Objective

The objective of this test was to determine the total immersion characteristics of the manufacturer's suggested working concentration of the cleaning compound.

2.1.1.2 Criterion

The manufacturer's suggested working concentration of the cleaning compound shall not show any indication of staining, etching, pitting, or localized attack on the test panels or cause weight change to an average of three test panels greater than that presented in Table 2.1.1-1 (Test Matrix). Two sets of criteria from two different performance specifications are shown in the table along with the Test Matrix criteria.

TABLE 2.1.1-1. ALLOY AND MAXIMUM AVERAGE WEIGHT LOSS

MATERIAL	MIL-PRF-680A	ADS-61A-PRF	TEST MATRIX
	$mg/cm^2/168$ hr		
Magnesium (AZ31B-H24)[a]	0.50	0.70	-
Aluminum 5083	-	-	0.20
Aluminum 7075-T6	-	0.49	-
Titanium 4911	0.10	0.35	-
Steel 1020	0.25	-	-
Steel 4340	-	0.49	-
AM-355 CRT	-	0.49	-
PH 13-8 Mo	-	0.49	-
Maraging C250	-	0.49	-
Zinc ASTM B852	-	-	1.50
Brass ASTM C35600	-	-	1.0
Steel A36	-	-	0.2
Cadmium	-	-	1.5

[a]AMS 4377 (ref 2.1.1-1) surface treated in accordance with AMS-M-3171, type III (ref 2.1.1-2).

2.1.1.3 Test Procedures

a. The total immersion corrosion caused by the manufacturer's suggested working concentration of the cleaning compound was determined using ASTM F483 (ref 2.1.1-3).

b. Four test specimens, 50.8 by 25.4 by 1.6 mm (2 by 1 by 0.06 in.) with a 3.2-mm- (0.125-in.-) diameter mounting hole suitably located at one end of the specimen, were prepared from the same sheet stock of each material in Table 2.1.1-1.

c. The test specimens were immersed in a beaker of mineral spirits, type II, conforming to ASTM D235 (ref 2.1.1-4) at room temperature. With clean forceps to hold the test specimen, the surface of each specimen was swabbed with a cotton swab.

d. The excess solvent was shaken off. The test specimens were immersed separately several times in a beaker of MEK. The excess MEK was shaken off, and the test specimens were dried in a low-temperature oven at 120 $\pm$ 5 ^{o}C (248 $\pm$ 10 ^{o}F) for 15 min. The specimens were removed to a desiccator and cooled to room temperature.

e. Each panel was identified with No. 1, 2, 3, or 4. Each test specimen was weighed to the nearest 0.1 mg.

f. A container of the manufacturer's suggested maximum use concentration of the cleaning compound was prepared for immersing the test specimens. The volume of the cleaner solution was related to the surface area of the test specimen immersed by 8 mL of cleaner per square centimeter of test specimen. The total surface area of the specimens was determined to be 28.2 cm^2 (4.4 in.^{2}).

g. Separate containers were used for each of the materials.

h. Testing was conducted at 38 $\pm$ 3 ^{o}C (100 $\pm$ 5 ^{o}F).

i. Three test specimens of each material type were immersed into the cleaning product and allowed to soak for 24 hr. The required temperature was maintained for the prescribed exposure period. The fourth test specimen was stored in a desiccator and used as the control specimen for the test.

j. After 24 hr, the test specimens were removed from the cleaning solution and rinsed under hot tap water (49 to 60 ^{o}C (120 to 140 ^{o}F)).

k. The test specimens were rinsed in DI water conforming to ASTM D1193, type IV, at ambient (room) temperature.

l. The test specimens were rinsed with a stream of acetone, conforming to D329 (ref 2.1.1-5), from a wash bottle and oven-dried at 120 ^{o}C.

m. After drying, the test specimens were placed in a desiccator until cooled to ambient (room) temperature.

n. The test specimens were individually weighed to the nearest 0.1 mg.

o. The following visual observations were recorded for each test specimen in comparison to the unexposed control specimen:

(1) Discoloration, staining, and dulling.

(2) Etching.

(3) Presence of accretions and relative amounts.

(4) Pitting.

(5) Presence of selective or localized attack.

p. The three test specimens were returned to the same container they were immersed in for the first 24-hr period for an additional 144 hr.

q. After a total of 168 hr, the steps in paragraphs j through o were repeated.

r. All test specimens were photographically documented immediately upon completion of the test.

s. The following information was reported for each test performed:

(1) Summary of the test methods and any deviations from the protocol.

(2) Identification of the sample material alloy(s), the product temper, and the selection of the thickness of material tested, including reference to the product specification.

(3) Specimen details: the type and dimensions of the test specimen and the number of replicates.

(4) Identification of the solution tested and the concentration and diluent used.

(5) Test conditions: temperature, exposure time, and humidity.

(6) Identification of the testing laboratory and the responsible technical point of contact.

(7) Individual and averaged test results.

(8) Results of visual inspections, observations, and discussion of the specimen condition.

(9) Photographic documentation of specimen conditions (specifically any staining, evidence of general corrosion, etching, pitting, or localized attack).

2.1.1.4 Test Findings

a. Data sheets pertaining to total immersion corrosion are provided in Appendix K.

b. There was no deviation from the ASTM methodology.

c. The results of testing are presented in Table 2.1.1-1.

d. Photographs of total immersion corrosion are provided in Appendix L.

TABLE 2.1.1-1. TBAC CORROSION RESULTS

MATERIAL	PASS/FAIL	OBSERVATIONS AT 168 HR
Titanium 4911	Pass	No effects
Steel A36	Pass	No effects
Steel 1020	Pass	No effects
Steel 4340	Pass	No effects
Magnesium	Pass	No effects
Brass 36000	Pass	No effects
Maraging C250	Pass	No effects
PH 13-8 Mo	Pass	No effects
Zinc	Pass	No effects
Aluminum 7075-T6	Pass	No effects
AM-355 CRT	Pass	No effects
Cadmium	Pass	No effects
Aluminum 5083	Pass	No effects

e. Lyondell Chemical Co., the manufacturer of TBAC, requested that several material compatibility tests be performed by Scientific Material International (SMI), Inc. ASTM F483 testing was performed by SMI, Inc., and the conclusion was made by SMI that TBAC met the criterion for several of the materials in this test (app M).

2.1.1.5 Technical Analysis

TBAC met the criterion for total immersion corrosion for the tested metals by not having an averaged weight loss greater than allowed and by not producing stains or corrosion.

2.1.2 ELEVATED TEMPERATURE CORROSION/STOCK LOSS

2.1.2.1 Objective

The objective of this test was to determine the general corrosion and stock loss characteristics of cleaner systems that use a heated process.

2.1.2.2 Criterion

The manufacturer's maximum recommended concentration plus 10 percent of the cleaning compound tested at the maximum recommended operating temperature plus -3.9 ^{o}C (25 ^{o}F) shall not show any indication of corrosion on the test panels or cause any stock loss greater than that provided in paragraph a of the test procedure (Test Matrix).

2.1.2.3 Test Procedures

a. The stock loss caused by the cleaning compound was determined according to the procedure in SAE Aerospace Recommended Practice (ARP) 1755 (ref 2.1.2-1) with the following exceptions:

(1) The test duration was 8 hr.

(2) The test temperatures were the maximum recommended temperature plus -3.9 ^{o}C, not to exceed the boiling point minus -15 ^{o}C (5 ^{o}F).

(3) The concentration was the maximum recommended plus 10 percent.

b. Four test panels, 51 by 127 by 1.6 mm (2 by 5 by 0.06 in.), were prepared from the same sheet stock of each of the materials presented in Table 2.1.2-1.

TABLE 2.1.2-1. STOCK LOSS

MATERIAL	ALLOWABLE STOCK LOSS, μm/8 hr
AM-355 CRT	1.16
PH 13-8 Mo	1.16
Maraging C250	1.16
Magnesium (AZ31B-H24)	1.16
Aluminum 7075-T6 (nonclad)	1.16
Titanium 6Al-4V	0.464
Steel 4340	1.16
Steel 1020	1.16

c. The panels were prepared as follows:

(1) The panels were prepared from sheet, strip, or transverse cross-section disks with parallel ground faces cut from conveniently sized bars, and a 3.2-cm- (1/8-in.-) diameter hole near one end was drilled or punched if needed for suspension.

(2) The edges were deburred after cutting and drilling or punching.

(3) The test specimens were blasted all over with wet abrasive, using approved alumina or silica abrasive or nonsilicone-treated glass beads with a nominal diameter of 0.02 to 0.08 cm (0.001 to 0.003 in.). The air pressure of the machine was 414 to 689 kPa (60 to 100 psi). Specimens could also have been prepared using dry blasting methods with 500-mesh alumina. Air pressure requirements would be 172 to 207 kPa (25 to 30 psi) on a direct-pressure machine or 345 to 414 kPa (50 to 60 psi) using a suction-type dry blasting machine.

(4) Each panel was numbered for identification.

d. A degreasing method approved by the engine manufacturer or overhaul facility was used.

e. Each panel was rinsed in alcohol or acetone.

f. Each panel was air-dried for 15 to 20 min or oven-dried at a temperature below 93 ^{o}C (200 ^{o}F), air-cooled, and weighed immediately to the nearest milligram. The weight (W_I) was recorded.

g. Each test panel was suspended not less than 51 cm (2 in.) below the surface of the cleaning solution being tested for 8 hr at 57 ^{o}C (135 ^{o}F).

h. To avoid possible error by galvanic action between the specimen and the tank or other grounding source, the specimen was suspended without contact in the cleaning solution using a corrosion-resistant steel wire insulated from the tank or grounding source.

i. The specimens were rinsed in clean, cold tap water.

j. The specimens were brushed with a soft brush, pressure spray applied, or ultrasonically rinsed.

k. The specimens were rinsed again in clean, cold tap water.

l. The specimens were then rinsed in clean, hot tap water.

m. The wire hangers were discarded, and the specimens were rinsed or ultrasonically rinsed in alcohol or acetone.

n. The specimens were air-dried for 15 to 20 min or oven-dried at a temperature below 93 °C and air-cooled. Each panel or disk was immediately weighed to the nearest milligram, and the weight (W_F) was recorded.

o. The weight lost in the cleaning solution was determined by subtracting the weight (W_F) recorded in paragraph n from the weight recorded in paragraph f.

p. From the weight loss recorded in paragraph o, the total surface area of the test specimen, and the density of the metal alloy presented in Table 2.1.2-2, the stock loss in the cleaning solution was determined using Equation 1.

$$\text{Stock Loss} = (W_I - W_F) \div (D \times A)$$

Where:

W_I = Initial weight of specimen.
W_F = Final weight of specimen.
D = Density of specimen.
A = Area of specimen.

TABLE 2.1.2-2. DENSITY OF TEST MATERIALS

MATERIAL	DENSITY, g/cm^2
AM-355 CRT	7.75
PH 13-8 Mo	7.72
Maraging C250	8.00
Magnesium (AZ31B-H24)	1.77
Aluminum 7075-T6 (nonclad)	2.81
Titanium 6Al-4V	4.43
Steel 4340	7.85
Steel 1020	7.85

q. Visual general corrosion, preferential grain boundary attack, pitting, corrosion, or stock loss (in units of micrometers as in paragraph b) and the cleaner concentration, temperature, and processing time used were reported. Preferential grain boundary attack, pitting, corrosion, or stock loss above the allowable limit was cause for rejection.

r. The following information was reported for each test performed:

(1) Summary of the test methods and any deviations from the protocol.

(2) Identification of the sample material alloy(s), the product temper, and the selection of the thickness of the material tested, including reference to the product specification.

(3) Specimen details: type and dimensions of the test specimen and the number of replicates.

(4) Identification of the solution tested and the concentration and diluent used.

(5) Test conditions: temperature, exposure time, and humidity.

(6) Identification of the testing laboratory and the responsible technical point of contact.

(7) Individual and averaged test results.

(8) Results of visual inspections, observations, and discussion of the specimen condition.

(9) Photographic documentation, if needed, of specimen conditions (specifically any staining, evidence of general corrosion, etching, pitting, or localized attack).

2.1.2.4 Test Findings

a. Data sheets pertaining to elevated temperature corrosion are provided in Appendix N.

b. The protocol was deviated from during the cleaning and abrasion process. All samples were degreased before and after dry blasting with acetone only.

c. An increased concentration of TBAC was not possible, but the product was tested at the increased temperature of 57 ^{o}C (135 ^{o}F).

d. The elevated temperature corrosion results for TBAC are presented in Table 2.1.2-3.

TABLE 2.1.2-3. TBAC STOCK LOSS AND CORROSION RESULTS

MATERIAL	STOCK LOSS, μm/8 hr	OBSERVATIONS AT 8 HR
Titanium 4911	0.0	No effects
Steel 1020	0.0	No effects
Steel 4340	0.01	No effects
Magnesium	-0.08	No effects
Maraging C250	-0.1	No effects
PH 13-8 Mo	0.0	No effects
Aluminum 7075-T6	-0.36	No effects
AM-355 CRT	0.0	No effects

2.1.2.5 Technical Analysis

TBAC met the criterion for elevated temperature corrosion and stock loss. The stock loss was within the allowable limits, and there was no staining or corrosion on the test coupons.

2.1.3 HYDROGEN EMBRITTLEMENT

2.1.3.1 Objective

The objective of this test was to determine the hydrogen embrittlement characteristics of the manufacturer's suggested working concentration of the cleaning compound.

2.1.3.2 Criterion

The manufacturer's suggested working concentration of the cleaning compound shall not cause hydrogen embrittlement of cadmium-plated AISI 4340 steel (Test Matrix).

2.1.3.3 Test Procedures

a. The hydrogen embrittlement effect that the manufacturer's suggested working concentration of the cleaning compound had on materials was determined using ASTM F519 (ref 2.1.3-1).

b. The test specimens were prepared, type 1d, according to the requirements of ASTM F519, paragraph 7.2, and Annex A.2.3.

c. All specimens were taken from a single lot.

(1) A lot consisted of only those specimens cut from the same heat of steel in the same orientation, heat-treated together in the same furnace, quenched and tempered together, and subjected to the same manufacturing processes.

(2) All notched specimens were suitable for test purposes if the sampling and inspection results conformed to the requirements of the lot acceptance criterion for type 1d notched specimens, as stated in ASTM F519, Table 1.

d. The sensitivity to hydrogen embrittlement was demonstrated for each heat of American Iron and Steel Institute (AISI) 4340 steel (ref 2.1.3-2) by exposing six trial specimens to two different embrittling environments after manufacture and inspection in accordance with these procedures.

(1) Three specimens were electroplated under the highly embrittling conditions produced in a cadmium cyanide bath by Treatment A (Table 2) in ASTM F519.

(2) Each heat of steel was of suitable sensitivity only if all three specimens plated by Treatment A fractured within 24 hr and none of the three specimens plated by Treatment B fractured within 200 hr after applying the sustained load of 75 percent of the bend notch fracture strength.

(3) To verify further the quality of the manufactured lot of specimens, at least five specimens plated by Treatment B were tensile-tested in accordance with Test Method E8, Table 1, ASTM F519, and all of the tensile test results were within $\pm$10 ksi of the mean of the 10 unplated specimens. The diameter or dimensions of the bare metal specimen were used in the stress calculations.

e. Certification of the lot conformance to the requirements was included in the data package for the results of the Hydrogen Embrittlement test.

f. Five test specimens manufactured and plated in accordance with Treatment B, ASTM F519, were tested to determine the hydrogen embrittling effect of the test cleaner.

g. The test was conducted in air or other controlled environment using an appropriate inert container and fixture that were suitably electrically isolated from the specimen or compensated to prevent a galvanic coupling. The cleaner was tested at the maximum specified dilution to determine the full embrittling effect of exposure in service. All tests were conducted at the operating service temperature of the test cleaner.

h. The test specimens were loaded using the self-loading bolt device. The nut and bolt were cadmium plated to avoid a galvanic reaction with the test specimen. Sixty-five percent of the bend notch fracture strength was applied. Stress levels can be related to the percentage of change in diameter that was required to fracture the specimens. (This was previously determined during lot acceptance testing.)

i. Each type 1d specimen was immersed in a separate container with sufficient quantity of the test cleaner solution to completely cover the specimen.

j. The test cleaner was considered nonembrittling if none of the immersed specimens failed within 200 hr after immersion into the chemical. The time to failure was recorded if it was less than 200 hr. The test was discontinued after 200 hr.

k. If only one of the five specimens fractured within the exposure time, step loading was continued for the remaining specimens, every hour in 5-percent increments to 90 percent of the fracture tensile/bend load after completion of a 200-hr sustained load. After 1 hr at 90 percent, the cleaner was considered nonembrittling if no fractures occurred.

l. The following information was reported for each test performed:

(1) Summary of the test methods and any deviations from the protocol.

(2) Identification of the sample material alloy(s), the product temper, and the selection of the thickness of material tested, including reference to product specification.

(3) Specimen details: type and dimensions of test specimen and number of replicates.

(4) Identification of the solution tested and the concentration and diluent used.

(5) Test conditions: temperature, exposure time, and humidity.

(6) Identification of the testing laboratory and the responsible technical point of contact.

(7) Individual and averaged test results.

(8) Results of visual inspections, observations, and discussion of specimen condition.

(9) Photographic documentation of specimen conditions (specifically any staining, evidence of general corrosion, etching, pitting, or localized attack).

2.1.3.4 Test Findings

a. Data sheets pertaining to hydrogen embrittlement are provided in Appendix O.

b. Ten baseline specimens that were not plated were placed in an Instron materials testing machine to develop load and deflection values for the testing of the regular test samples. The average diameter change or lot acceptance value of the 10 specimens was 0.0676 in.

c. As described in the ASTM method, three Treatment A specimens that were plated but not baked to relieve the hydrogen embrittling condition were loaded to 75 percent of the lot acceptance value of 0.0676 in. The three Treatment A specimens cracked within the required time limit to qualify this lot of specimens.

d. Three specimens that were plated and baked (Treatment B) were loaded to 75 percent of the lot acceptance value. These specimens did not break within 200 hr to qualify this lot of specimens.

e. Four treatment B specimens were loaded to 65 percent of the lot acceptance value and placed in separate beakers filled with TBAC at ambient temperature.

f. The coupons immersed in TBAC did not crack within 200 hr.

g. Lyondell Chemical Co., the manufacturer of TBAC, requested that several material compatibility tests be performed by SMI, Inc. ASTM F519 testing was performed by SMI, Inc., and the conclusion was made that TBAC met the criterion for hydrogen embrittlement (app M).

2.1.3.5 Technical Analysis

TBAC met the criterion for hydrogen embrittlement.

(Page 2.1.3-4 Blank)

2.1.4 SANDWICH CORROSION

2.1.4.1 Objective

The objective of this test was to determine the sandwich corrosion characteristics of the manufacturer's suggested working concentration of the cleaning compound.

2.1.4.2 Criterion

The manufacturer's suggested working concentration of the cleaning compound shall not cause an averaged corrosion rating greater than the averaged corrosion rating of DI water (Test Matrix). The averaged corrosion rating for a product was the average rating of the four sets of test panels. Pitting corrosion of any panel shall be assessed a severity rating of 4.

2.1.4.3 Test Procedures

a. The sandwich corrosion caused by the manufacturer's suggested working concentration of the cleaning compound was determined using ASTM F1110 (ref 2.1.4-1).

b. Sixteen test panels, 50 by 100 by 1.5 mm (2 by 4 by 0.06 in.), were prepared from the same sheet stock of each of the materials listed below:

(1) PH 13-8 Mo (high-strength steel).

(2) Maraging C250 (high-strength steel).

(3) Aluminum 5083 (nonclad).

(4) AM-355 CRT.

(5) Steel A366.

(6) Aluminum 7075-T6 (nonclad).

(7) Titanium 6Al-4V.

(8) Steel 4340.

(9) Magnesium (AZ31B-H24) (AMS 4377). The magnesium surface was treated in accordance with AMS-M-3171, type III.

c. Two sets of test panels were prepared. A test set consisted of eight individual test coupons sandwiched together in pairs of coupons of the same alloy and the same surface treatment to provide four test coupon sandwiches for each test condition.

d. The coupons were individually identified by impression stamping or other suitable permanent method.

e. The test panels were cleaned by solvent, either wiping or vapor degreasing. Caustic or acid cleaners were not used. Ink-stamped markings were removed from the panels. Abrasive materials were not used to clean the panels.

f. A piece of glass filter paper was cut (Whatman GFA or equal filter paper made from glass fibers, 11 or 13 cm (4 or 5 in.), was used) to approximate 25 by 75 mm (1 by 3 in.).

g. The piece of glass filter paper was fitted over one of the coupons. The test solution was added to the paper at the manufacturer's maximum recommended use concentration until saturated. The wet paper was covered with the second coupon of the sandwich pair. The operation was repeated for each of the coupon sets in the group.

h. A second group of panels was prepared as outlined in paragraph g, except that reagent water was applied (ASTM D1193, type IV) to the filter paper between the panels.

i. During each day of the test, the test coupon pairs were exposed to air oven heat and humidity as specified in Table 2.1.4-1.

TABLE 2.1.4-1. SANDWICH CORROSION
EXPOSURE CYCLES AT 37.8 $\pm$ 2.8 ^{o}C (100 $\pm$ 5 ^{o}F)

STEP NO.	EXPOSURE TIME ($\pm$0.5), hr	RELATIVE HUMIDITY, %
1	8	Ambient
2	16	95 to 100
3	8	Ambient
4	16	95 to 100
5	8	Ambient
6	16	95 to 100
7	8	Ambient
8	16	95 to 100
9	8	Ambient
10	64	95 to 100

j. The test coupon pairs were individually laid flat without stacking during the duration of the test.

k. After completing the exposure cycles, the test coupon pairs were rinsed in warm tap water and scrubbed lightly with a soft, nonmetallic bristle brush.

l. The test coupon pairs were then dried.

m. Each test coupon was examined under a 10x magnification.

n. The observations were rated using the following convention:

(1) 0 - no visible corrosion (no corrosion).

(2) 1 - very slight corrosion or discoloration (up to 5 percent of the surface area corroded).

(3) 2 - slight corrosion (5 to 10 percent of the surface area corroded).

(4) 3 - moderate corrosion (10 to 25 percent of the surface area corroded).

(5) 4 - extensive corrosion or pitting (25 percent or more of the surface area corroded).

o. The corrosion rating on the set of panels from the test solution group was compared with those from the reagent water control group. Any corrosion in excess of that shown by the control group was cause for rejection. Pitting corrosion of any panel was assessed a severity rating of 4. Only those surfaces that were under the filter paper were compared. The definition of pitting in ASTM G46 (ref 2.1.4-2) was used.

p. The following information was reported for each test performed:

(1) Summary of test methods and any deviations from the protocol.

(2) Identification of the sample material alloys including reference to product specification.

(3) Specimen details: type and dimensions of the test specimen and the number of replicates.

(4) Identification of the solution tested and the concentration and diluent used.

(5) Test conditions: temperature, exposure time, and humidity.

(6) Identification of the testing laboratory and the responsible technical point of contact.

(7) Individual and averaged test results.

(8) Results of visual inspections, observations, and discussion of specimen condition.

(9) Photographic documentation, if needed, of specimen conditions (specifically any staining, evidence of general corrosion, etching, pitting, or localized attack).

2.1.4.4 Test Findings

a. Data sheets pertaining to sandwich corrosion are provided in Appendix P.

b. There was no deviation from ASTM F1110 during testing.

c. Results of visual inspection, using the relative corrosion severity rating system, under 10x magnification, are presented in Table 2.1.4-2.

d. Lyondell Chemical Co., the manufacturer of TBAC, requested that several material compatibility tests be performed by SMI, Inc. ASTM F1110 testing was performed by SMI, Inc., and the conclusion was made that TBAC met the criterion for sandwich corrosion for aluminum QQ-A-250/4; AMS 4037 (app M).

TABLE 2.1.4-2. VISUAL INSPECTION RESULTS

PRODUCT	AVERAGED CORROSION RATINGS OF FOUR PANEL SETS								
	PH 13-8 Mo	C250	Al 7075-T6	Ti	Steel 4340	Mg	Al 5083	AM-355 CRT	Steel A36
Reagent water	0	4	4	0	3	3.25	4	0	4
TBAC	1	1.5	0	0	4	3.5	0	0	4

2.1.4.5 Technical Analysis

a. TBAC met the criterion for maraging C250, aluminum 7075-T6, titanium, aluminum 5083, AM-355 CRT, and A36 steel.

b. TBAC did not meet the criterion for 13-8 stainless steel and 4340 steel.

c. TBAC marginally did not meet the criterion for magnesium.

2.1.5 TITANIUM STRESS CORROSION

2.1.5.1 Objective

The objective of this test was to determine the titanium stress corrosion characteristics caused by the manufacturer's suggested working concentration of the cleaning compound.

2.1.5.2 Criterion

The manufacturer's suggested working concentration of the cleaning compound shall not cause titanium stress corrosion (Test Matrix).

2.1.5.3 Test Procedures

a. The titanium stress corrosion caused by TBAC was determined using ASTM F945 (ref 2.1.5-1).

b. Lyondell Chemical Co., the manufacturer of TBAC, requested that several material compatibility tests be performed by SMI, Inc. ASTM F945 testing was performed by SMI, Inc., and the conclusion was made that TBAC met the criterion for titanium stress corrosion (app M).

2.1.5.4 Test Findings

TBAC did not produce cracking on AMS 4911 (ref 2.1.5-2) and AMS 4916 (ref 2.1.5-3) titanium.

2.1.5.5 Technical Analysis

TBAC met the criterion for titanium stress corrosion.

(Page 2.1.5-2 Blank)

2.1.6 STRESS CORROSION

2.1.6.1 Objective

The objective of this test was to determine the stress corrosion characteristics of the manufacturer's suggested working concentration of the cleaning compound.

2.1.6.2 Criterion

The manufacturer's suggested working concentration of the cleaning compound shall not cause stress corrosion (ADS-61A-PRF).

2.1.6.3 Test Procedures

a. The stress corrosion caused by the manufacturer's suggested working concentration of the cleaning compound was determined using ASTM G30 (ref 2.1.6-1), type A test specimen, and ASTM G44 (ref 2.1.6-2), modified in the following manner. The manufacturer's suggested working concentration of the cleaning compound was substituted for the 3.5-percent sodium chloride solution, and a 10-min soak and 50-min drying cycle were substituted for a 20-min soak and 100-min drying cycle.

b. Six specimens (three test and three control) were fabricated in accordance with ASTM G30, type A U-bend, from each of the following materials:

(1) PH 13-8 Mo (high-strength steel).

(2) Maraging C250 (high-strength steel).

(3) Aluminum 5083.

(4) AM-355 CRT.

(5) Aluminum MIL-DTL-46063, 7039 (ref 2.1.6-3).

(6) Aluminum 7075-T6 (nonclad).

(7) Titanium 6Al-4V.

(8) Steel 4340.

(9) Magnesium (AZ31B-H24).

c. The three controls were stressed but unexposed to establish validity of the sheet material.

d. All testing was conducted at ambient temperature in accordance with procedures for hand-wipe applications.

e. Sufficient test solution was used to cover the stress portion of the test specimens throughout the 20-min immersion period.

f. The level of test solution was maintained in the immersion baths. On a 7-day interval, the immersion bath test solution was replaced with fresh test solution.

g. This cycle was continued for 24 hr/day for 90 days.

h. After exposure, the specimens were rinsed with water and cleaned as soon as possible.

i. Test specimens that did not show obvious cracks were examined at 20x magnification. If the untreated (control) specimens were cracked, the results of the stress corrosion test were invalid. Metallographic examination was used if needed to verify freedom from cracking.

j. Representative failed specimens were examined metallographically to verify if failure was caused by stress corrosion cracking.

k. Metallographic inspection was conducted. A cross section of each specimen was made at the bend, normal to the bend axis (parallel to the test panel long axis). The specimens were cut using a saw that produced a smooth cut with minimal disturbance of the specimen edges. The cut was made approximately at the center axis in line with the holes. The metallographic section encompassed material from the bend to a point approximately 13 mm (0.5 in.) from the bend. The cut surface was examined over the 13-mm section on both sides of the bend zone at 500x magnification.

l. The following information was reported for each test performed:

(1) Summary of the test methods and any deviations from the protocol.

(2) Identification of the sample material alloy(s), the product temper, and the selection of the thickness of the material tested, including reference to product specification.

(3) Specimen details: the type and dimensions of the test specimen and the number of replicates.

(4) Identification of the solution tested and the concentration and diluent used.

(5) Test conditions: temperature, exposure time, and humidity.

(6) Identification of the testing laboratory and the responsible technical point of contact.

(7) Individual and averaged test results.

(8) Results of visual inspections, observations, and discussion of the specimen condition.

(9) Photographic documentation of specimen conditions, if needed (specifically any staining, evidence of general corrosion, etching, pitting, or localized attack).

2.1.6.4 Test Findings

Because of the high evaporation rate of TBAC, stress corrosion testing could not be performed with the equipment currently available.

2.1.6.5 Technical Analysis

a. The determination of meeting or not meeting the criterion could not be made because this test was not conducted using TBAC.

b. It is this author's opinion that with the high evaporation rate, it would be unlikely that TBAC would cause stress corrosion cracking during hand-wipe applications because the product would not be in contact with the materials for any longer than several seconds.

(Page 2.1-6-4 Blank)

2.1.7 LOW-EMBRITTLING CADMIUM PLATE CORROSION

2.1.7.1 Objective

The objective of this test was to determine the corrosive effects of the manufacturer's maximum suggested use concentration of the cleaning compound on low-embrittling cadmium plating used on aircraft high-strength steel, under conditions of total immersion by quantitative measurements of weight change.

2.1.7.2 Criterion

The manufacturer's maximum suggested use concentration shall not cause a weight change of the average of the three test panels greater than 0.14 $mg/cm^2/24$ hr.

2.1.7.3 Test Procedures

a. The corrosive effect of the manufacturer's maximum recommended use concentration of the cleaning compound was determined according to the procedure given in ASTM F1111 (ref 2.1.7-1).

b. Three test specimens were prepared of 4130 steel in accordance with MIL-S-18729 (ref 2.1.7-2), condition N. The dimensions of the specimens were 25.4 by 50.8 by 1.22 mm (1 by 2 by 0.048 in.), and the specimens were cadmium plated in accordance with ASTM F1111, Appendix XI. The electrodeposited plating had a minimum thickness of 0.13 mm (0.0005 in.).

c. With a stiff brush, loose cadmium plate was brushed off, being careful to brush only as hard as necessary to remove loose cadmium plate. Each test specimen was immersed in a beaker of 1.1.1-trichloroethane maintained at a temperature of 66 $\pm$ 3 ^{o}C (150 $\pm$ 5 ^{o}F), and the surface of each specimen was swabbed thoroughly using clean forceps to hold the specimen.

d. Excess solvent was shaken off the test specimens, and each specimen was immersed separately several times in a beaker of MEK.

e. Excess MEK was shaken off the test specimens, and they were dried in an oven at 110 $\pm$ 2 ^{o}C (230 $\pm$ 4 ^{o}F) for 1 hr.

f. A container was prepared of the manufacturer's maximum recommended use concentration of the cleaning compound. The volume of the test solution was such that a ratio of the area of the immersed metal to the volume of the solution was 25 mL of solution per 625 mm^2 (1 $in.^2$) of specimen surface.

g. The cleaner solution was preheated to the test temperature of 35 $\pm$ 1 ^{o}C (95 $\pm$ 2 ^{o}F).

h. The specimens were removed from the drying oven, allowed to cool to room temperature in a dessicator, and weighed to the nearest 0.1 mg.

i. The specimens were removed to the vessel containing the preheated cleaner solution, and the vessel was sealed to prevent loss of vapor. The cleaner solution was maintained at the required test temperature, and the specimens were immersed for 24 hr.

j. At the end of the 24-hr exposure, the test specimens were removed with forceps and rinsed thoroughly with tap water.

k. The specimens were rinsed thoroughly with DI water (ASTM D1193, type IV) at room temperature.

l. The specimens were rinsed with a stream of acetone from a wash bottle.

m. The specimens were placed in an oven at 110 $\pm$ 2 ^{o}C (230 $\pm$ 4 ^{o}F) for 1 hr and allowed to cool to room temperature in a dessicator.

n. The specimens were reweighed to the nearest 0.1 mg, and the weight was recorded.

o. The following information was reported for each test performed.

(1) Summary of the test methods and any deviations from the protocol.

(2) Identification of the sample material alloy(s), the product temper, and the selection of the thickness of the material tested, including reference to product specification.

(3) Specimen details: the type and dimensions of the test specimen and the number of replicates.

(4) Identification of the solution tested and the concentration and diluent used.

(5) Test conditions: temperature, exposure time, and humidity.

(6) Identification of the testing laboratory and the responsible technical point of contact.

(7) Individual and averaged test results.

(8) Results of visual inspections, observations, and discussion of the specimen condition.

(9) Photographic documentation, if needed, of specimen conditions (specifically any staining, evidence of general corrosion, etching, pitting, or localized attack).

2.1.7.4 <u>Test Findings</u>

a. Data sheets pertaining to low-embrittling cadmium plate corrosion are provided in Appendix Q.

b. There was a deviation from the test procedure stated in paragraph c. The cleaning solvent was not heated because of the increased hazard of dangerous vapors.

c. The surface area of the specimens was 28 cm^2, and the specimens were immersed in 112 mL of test solution.

d. There were no visible signs of staining on any specimens.

e. The average weight change per surface area for three specimens immersed in TBAC was 0.01 mg/cm² for the 24 –hr period.

2.1.7.5 Technical Analysis

TBAC met the criterion for low-embrittling cadmium plate corrosion.

(Page 2.1.7-4 Blank)

2.1.8 COPPER CORROSION

2.1.8.1 Objective

The objective of this test was to assess the relative degree of corrosiveness of the manufacturer's suggested working concentration of the cleaning compound on copper.

2.1.8.2 Criterion

The criterion found in MIL-PRF-680A is based on the testing of Stoddard Solvents at 100 ^{o}C (212 ^{o}F). The testing reported in this document is for hand-wipe operations assumed to be performed below 49 ^{o}C (120 ^{o}F). The products were tested and reported at both temperatures, but the criterion is based on the use of the products during the highest reasonable temperature for hand-wipe operations. The manufacturer's suggested working concentration of the cleaning compound shall not cause a copper corrosion rating of higher than 1b (MIL-PRF-680A) when tested at 49 ^{o}C.

2.1.8.3 Test Procedures

a. The copper corrosion characteristics of the manufacturer's suggested working concentration of the cleaning compound were determined using ASTM D130 (ref 2.1.8-1).

b. Two specimens were examined for each of the test conditions. The specimens were strips that were 12.5 mm (1/2 in.) wide, 1.5 to 3.0 mm (1/16 to 1/8 in.) thick, and 75 mm (3 in.) long, cut from smooth-surfaced, hard-tempered, cold-finished copper of 99.9+ percent purity. The strips were used repeatedly but discarded when the surfaces became deformed from handling.

c. All six surfaces of each specimen were prepared using silicon carbide paper to remove surface blemishes. The test strips were protected at all times from contact with fingers during handling by use of ashless filter paper. To remove all marks from previous grades of paper, the surfaces of each specimen were finished with 65-micron (240-grit) silicon paper. Upon completion of the final paper finish, each specimen was immersed and maintained in solvent until immediately before testing.

d. Immediately before testing, each test strip was removed from the wash solvent and the ends and sides were polished with 105-micron (150-grit) silicon carbide grains picked up from a clean glass plate with a pad of cotton moistened with a drop of wash solvent. Each test strip was wiped vigorously with fresh cotton pads, and the strips were handled only with stainless steel forceps. The main surfaces of each strip were polished, holding the strip in a vice as necessary. The strips were polished in the direction of the long axis of the strip and cleaned of all metal dust by rubbing vigorously with clean cotton pads until a fresh pad remained clean.

e. When the strip was uniformly polished and cleaned, it was immersed in the test solution.

f. Thirty milliliters of the manufacturer's suggested working concentration of the cleaning compound was placed in each of two 25- by 150-mm test tubes.

g. Within 1 min of completing the final preparation (polishing), the test specimens were placed into the test tubes with the manufacturer's suggested working concentration of the cleaning compound. A vented cork was used to stopper the test tubes.

h. The test tubes were placed into a water bath maintained at 49 ^{o}C (120 ^{o}F) for 3 hr. The content of the test tubes was protected from strong light during the test.

i. After 3 hr $\pm$ 5 min in the bath, the test tubes were removed from the bath, and the test specimens were removed with stainless steel forceps.

j. The test specimens were immersed immediately in wash solvent, then removed, and blotted dry.

k. The specimens were inspected for evidence of tarnishing, pitting, and corrosion and compared to the ASTM standard for copper strip corrosion. The corrosiveness was reported in accordance with ASTM D130, Table 1.

l. The complete procedure was repeated for the following additional conditions:

(1) Twenty-four hours of exposure at 49 ^{o}C.

(2) Three hours of exposure at 100 ^{o}C (212 ^{o}F).

(3) Twenty-four hours of exposure at 100 ^{o}C.

m. The following information was reported for each test performed:

(1) Summary of the test methods and any deviations from the protocol.

(2) Identification of the sample material alloy(s), the product temper, and the selection of the thickness of the material tested, including reference to product specification.

(3) Specimen details: the type and dimensions of the test specimen and the number of replicates.

(4) Identification of the solution tested and the concentration and diluent used.

(5) Test conditions: temperature, exposure time, and humidity.

(6) Identification of the testing laboratory and the responsible technical point of contact.

(7) Individual and averaged test results.

(8) Results of visual inspections, observations, and discussion of the specimen condition.

(9) Photographic documentation of specimen conditions, if needed (specifically any staining, evidence of general corrosion, etching, pitting, or localized attack).

2.1.8.4 Test Findings

a. Data sheets pertaining to copper corrosion are provided in Appendix R.

b. There was a deviation from the ASTM methodology. A Precision brand copper corrosion bath was used for the 100 ^{o}C (212 ^{o}F) temperature tests. The 49 ^{o}C (120 ^{o}F) testing was performed by placing the test tubes in a water bath placed in an air-circulating oven.

c. No surface degradation was present on any specimen.

d. The results of testing are presented in Table 2.1.8-1.

TABLE 2.1.8-1. COPPER CORROSION RESULTS

PRODUCT	100 ^{o}C (212 ^{o}F)		49 ^{o}C (120 ^{o}F)	
	3 hr	24 hr	3 hr	24 hr
TBAC	1a	1b	1a	1a

2.1.8.5 Technical Analysis

On the basis that testing of the products was for hand-wipe operations, TBAC passed the criterion for copper corrosion.

2.2 SURFACES

2.2.1 EFFECTS ON PAINTED SURFACES

2.2.1.1 Objective

The objective of this test was to determine the effects on painted surfaces of the manufacturer's suggested working concentration of the cleaning compound.

2.2.1.2 Criterion

The manufacturer's suggested working concentration of the cleaning compound shall not cause streaking, discoloration, blistering, or a permanent decrease in film hardness of more than one pencil hardness level on any painted surfaces (ADS-61A-PRF).

2.2.1.3 Test Procedures

a. The effect of the manufacturer's suggested working concentration of the cleaning compound on the painted surfaces was determined using ASTM F502 (ref 2.2.1-1).

b. The 18 test panels of aluminum Alclad 7075-T6, 76 by 152 by 0.5 mm (3 by 6 by 0.02 in.) were prepared according to the procedure given in ASTM F502.

c. All of the test panels were cleaned with acetone, dried, and abraded lightly with a fine aluminum oxide mat. The surface was then rinsed with distilled water.

d. All of the test panels were coated with a conversion coat conforming to MIL-C-81706, class 1A (ref 2.2.1-2), and allowed to dry.

e. On 12 test panels, one coat of MIL-P-23377 (type I, class C) epoxy primer, 0.6 to 0.8 mil (0.010 to 0.015 mm), was applied.

f. The test panels were allowed to dry at ambient (room) conditions.

g. Each of the following coatings was applied to three test panels. (Aircraft green was the preferred color.)

(1) MIL-C-22750 (ref 2.2.1-3) epoxy topcoat.

(2) MIL-C-85285, type I, high-solids polyurethane topcoat.

(3) MIL-C-46168, type IV (ref 2.2.1-4), single-component aliphatic polyurethane topcoat.

(4) MIL-P-14105 (ref 2.2.1-5) heat-resistant paint.

h. The coatings in paragraph g were applied as a mist coat and allowed to dry for 30 min in ambient (room) conditions.

i. An additional three coats of the coatings were applied in 0.010- to 0.015-mm applications and allowed a 1-hr drying time at ambient (room) conditions between each coat.

j. In accordance with the manufacturer of the heat-resistant paint, it was cured for 30 min at 204.4 ^{o}C (400 ^{o}F).

k. On the remaining six panels, one coat of MIL-P-53022 (type II) (ref 2.2.1-6) epoxy primer, 0.6 to 0.8 mil (0.010 to 0.015 mm), was applied.

l. The test panels were allowed to dry at ambient (room) conditions.

m. Each of the following coatings was applied to three test panels. (Aircraft green was the preferred color.)

(1) MIL-C-64159 (ref 2.2.1-7) epoxy topcoat.

(2) MIL-C-53039, Amendment 2 (ref 2.2.1-8), single-component aliphatic polyurethane topcoat, chemical agent resistant coating (CARC).

n. The coatings in paragraph g were applied as a mist coat and allowed to dry for 30 min in ambient (room) conditions.

o. An additional three coats of the coatings were applied in 0.6- to 0.8-mil (0.010- to 0.015-mm) applications and allowed a 1-hr drying time at ambient (room) conditions between each coat.

p. The test panels were allowed to dry for 4 days at ambient (room) conditions.

q. The test panels were baked for 24 hr in a mechanical convection oven at 82 ^{o}C (180 ^{o}F) or allowed to air-dry an additional 3 to 10 days at room temperature.

r. A set of drawing pencils was prepared as described in ASTM F502.

(1) The wood was stripped away from one end of each pencil approximately 9.5 mm (3/8 in.) without damaging the lead.

(2) The tip of the lead was squared by holding the pencil in a vertical position and moving the lead back and forth over very fine (180- to 320-grit) sandpaper.

(3) The tip of the lead was squared after each trial.

s. The test panels were placed in a horizontal position in an oven maintained at 38 $\pm$ 3 ^{o}C (100 $\pm$ 5 ^{o}F).

t. The test solution was applied to approximately one half of the area of each panel and allowed to remain on the panels for 30 min.

u. The panels were removed from the oven and rinsed with distilled or DI water and allowed to air-dry for 24 hr.

v. The panels were examined for streaking, discoloration, or blistering of the finish.

w. The hardness of the treated and untreated areas was determined in the following manner:

(1) Pencils of decreasing hardness were held by hand at 45° and pushed across the paint film with a firm, uniform pressure until a pencil was found that would not cut the film but would leave a black mark on the surface, whereas the next hardest pencil would cut through the film without leaving a black mark.

(2) The hardness number of the pencil that cut the film expressed the film hardness.

(3) At least three determinations on both exposed and unexposed portions of the coated panel were made.

x. The procedure was performed for each of three panels for each coating set.

y. The paint hardness was not allowed to differ by more than one pencil hardness unit for each of the same type of paint test panels.

z. The following information was reported for each test performed:

(1) Summary of the test methods and any deviations from the protocol.

(2) Identification of the sample material alloy(s), the product temper, and the selection of the thickness of the material tested, including reference to product specification.

(3) Specimen details: type and dimensions of the test specimen and the number of replicates.

(4) Identification of the solution tested and the concentration and diluent used.

(5) Test conditions: temperature, exposure time, and humidity.

(6) Identification of the testing laboratory and the responsible technical point of contact.

(7) Individual and averaged test results.

(8) Results of visual inspections, observations, and discussion of the specimen condition.

(9) Photographic documentation of specimen conditions (specifically any staining, evidence of general corrosion, etching, pitting, or localized attack).

2.2.1.4 <u>Test Findings</u>

a. Data sheets pertaining to effects on painted surfaces are provided in Appendix S.

b. The protocol was deviated from during testing in that more than the three required determinations were performed to obtain the hardness. In addition, there was a deviation in the application of the test cleaner. The cleaner was poured into a glass beaker to a depth equal to one half of the length of the panel. The panels were placed vertically in the beaker to immerse one half of the painted surface for the required 30 min.

c. A mechanical pencil holder made specifically for pencil hardness testing was used to determine the hardness of the coatings on the tested panels. The holder was designed to eliminate the influence and inconsistency that could occur if the pencil was held by a person. The holder applied a constant 300 $\pm$ 3 grams of pressure and held the pencil at 45° to the panel.

d. The range of pencils used, from the hardest to the softest, was 1-6H, F, HB, and 1-6B.

e. There was no streaking, discoloration, or blistering of any of the tested panels using TBAC.

f. All panels, for all top coatings tested, had a hardness of >6H for both the immersed and untreated sides.

2.2.1.5 Technical Analysis

TBAC met the criterion for effects on painted surfaces for all coatings tested.

2.2.2 EFFECTS ON UNPAINTED SURFACES

2.2.2.1 Objective

The objective of this test was to determine the effects on unpainted surfaces of the manufacturer's suggested working concentration of the cleaning compound. This method was used to ensure that candidate cleaners did not leave a residue that, upon drying, would leave a permanent stain requiring polishing to remove.

2.2.2.2 Criterion

The manufacturer's suggested working concentration of the cleaning compound shall not cause streaking or staining not easily removed by hand pressure and water (ADS-61A-PRF). The criterion pertains only to type I, water-soluble products.

2.2.2.3 Test Procedures

a. The effects of the manufacturer's suggested working concentration of the cleaning compound on the unpainted surfaces was determined using ASTM F485 (ref 2.2.2-1), with a modification.

b. Two test panels, 50 by 152 by 0.51 mm (2 by 6 by 0.020 in.), were prepared from each of the following materials:

(1) AM-355 CRT (high-strength steel).

(2) PH 13-8 Mo (high-strength steel).

(3) Maraging C250 (high-strength steel).

(4) Aluminum 7075-T6 (nonclad).

(5) Titanium 6Al-4V, AMS 4911.

(6) Steel 4340.

(7) Magnesium (AZ31B-H24) (AMS 4377). The magnesium surface was treated in accordance with AMS-M-3171, type III.

(8) Steel (ASTM A242) (ref 2.2.2-2).

(9) Aluminum 5083, AMS QQ-A-250/6 (ref 2.2.2-3).

c. Each test panel was cleaned with MEK.

d. The test panels were allowed to dry at ambient (room) conditions.

e. Two test panels from each material were immersed for 4 min in enough of the manufacturer's suggested working concentration of the cleaning compound to cover one half of the test specimens.

f. The test panels were removed from the test solution.

g. The test specimens were placed immediately in a mechanical convection oven at 45° from the horizontal. The oven temperature was maintained at 65.5 $\pm$ 2 ^{o}C (150 $\pm$ 3 ^{o}F).

h. The test specimens were allowed to remain in the oven for 30 min.

i. The panels were removed from the oven and cooled to room temperature.

j. The panels were rinsed on each side within 15 min under running tap water for 1 min without using mechanical agitation.

k. The panels were rinsed on each side with distilled or DI water from a squeeze bottle for 15 sec.

l. The test panels are then allowed to air-dry for 30 min at ambient (room) conditions.

m. The treated and untreated sections of each test specimen were visually examined for stains or residue. All test specimens were photographically documented immediately upon termination of the test.

n. The following information was reported for each test performed:

(1) Summary of the test methods and any deviations from the protocol.

(2) Identification of the sample material alloy tested including reference to product specification.

(3) Type and dimensions of the test specimen and the number of replicates.

(4) Identification of the solution tested and the concentration and diluent used.

(5) Test conditions: temperature, exposure time, and humidity.

(6) Identification of the testing laboratory and the responsible technical point of contact.

(7) Individual and averaged test results.

(8) Results of visual inspections, observations, and discussion of specimen condition.

(9) Photographic documentation of specimen conditions, if needed (specifically any staining, evidence of general corrosion, etching, pitting, or localized attack).

2.2.2.4 Test Findings

a. Data sheets pertaining to effects on unpainted surfaces are provided in Appendix T.

b. There was no deviation from the protocol during testing except that TBAC was tested even though it may or may not have been water soluble.

c. Discolorations or stains associated with areas on the specimens used for support during drying were ignored.

d. Results of testing with TBAC are presented in Table 2.2.2-1.

TABLE 2.2.2-1. TBAC IMMERSION

MATERIAL	OBSERVATIONS
AM-355 CRT	No effect
Titanium	No effect
Maraging C250	No effect
PH 13-8 Mo	No effect
Aluminum 7075-T6	No effect
Aluminum 5083	No effect
Magnesium	No effect
Steel 4340	No effect
Steel ASTM A242	No effect

2.2.2.5 Technical Analysis

TBAC met the criterion for effects on unpainted surfaces for all materials tested.

2.3 PLASTICS, RUBBER, AND SEALANTS

2.3.1 EFFECTS ON POLYSULFIDE SEALANTS

2.3.1.1 Objective

The objective of this test was to determine the effect on polysulfide sealants of the manufacturer's suggested working concentration of the cleaning compound.

2.3.1.2 Criterion

The manufacturer's suggested working concentration of the cleaning compound shall not change the durometer hardness (Shore A) of polysulfide sealants more than 5 units.

2.3.1.3 Test Procedures

a. The effect that the manufacturer's suggested working concentration of the cleaning compound had on polysulfide sealants was determined using ADS-61A-PRF.

b. Two test specimens were prepared from MIL-PRF-81733D, type II (ref 2.3.1-1), and AMS-S-8802, type II (ref 2.3.1-2), sealant sheet stock.

c. It was assumed that these materials did not have hardnesses that depended on humidity.

d. The sheet stock was made by mixing the sealants as specified by the manufacturer and pressing each into a 0.3175-cm- (0.125-in.-) thick sheet mold.

e. The sealant was cured using the standard cure of 14 days at 25 $\pm$ 3 ^{o}C (77 $\pm$ 5 ^{o}F) at 50 percent relative humidity.

f. Test specimens were cut from the cured sheet stock. Specimens had sufficient surface area for hardness testing before and after exposure to the test cleaning compound. Recommended specimen dimensions were 50 mm by 50 mm (2 by 2 in.).

g. Each specimen was tested for Shore A hardness in accordance with ASTM D2240 (ref 2.3.1-3).

h. All testing was conducted at ambient (room) temperature.

i. The two test specimens from each sealant were immersed into the manufacturer's suggested working concentration of the cleaning compound.

j. The test specimens were allowed to soak for 30 min.

k. The test specimens were removed from the manufacturer's suggested working concentration of the cleaning compound and rinsed with cool tap water.

l. The test specimens were tested for a Shore A hardness in accordance with ASTM D2240 within 5 min of removal from the cleaning compound.

m. The cleaning compound did not change the durometer hardness more than 5 units after exposure.

n. The following information was reported for each test performed:

(1) Summary of the test methods and any deviations from the protocol.

(2) Identification of the sample material and the selection of the thickness of the material tested, including reference to product specification.

(3) Specimen details: type and dimensions of the test specimen and the number of replicates.

(4) Identification of the solution tested and the concentration and diluent used.

(5) Test conditions: temperature, exposure time, and humidity.

(6) Identification of the testing laboratory and the responsible technical point of contact.

(7) Individual and averaged test results.

(8) Results of visual inspections, observations, and discussion of specimen condition.

2.3.1.4 Test Findings

a. Data sheets pertaining to effects on polysulfide sealants are provided in Appendix U.

b. The protocol was not deviated from during testing

c. The average of three hardness readings for each specimen was used to determine if the criterion was met.

d. Results of the two specimens, MIL-PRF-81733D and AMS-S-8802, immersed in TBAC are presented in Table 2.3.1-1.

TABLE 2.3.1-1. IMMERSION RESULTS FOR POLYSULFIDE SEALANTS

CLEANER	MIL-PRF-81733D (SHORE A)				AMS-S-8802 (SHORE A)			
	COUPON NO. 1		COUPON NO. 2		COUPON NO. 1		COUPON NO. 2	
	BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER
TBAC	53	53	56	56	56	56	57	56

2.3.1.5 Technical Analysis

TBAC met the criterion for effects on polysulfide sealants for both MIL-PRF-81733D and AMS-S-8802 sealants.

2.3.2 EFFECTS ON ACRYLIC PLASTICS

2.3.2.1 Objective

The objective of this test was to determine the effects on acrylic plastics of the manufacturer's suggested working concentration of the cleaning compound.

2.3.2.2 Criterion

The manufacturer's suggested working concentration of the cleaning compound shall not cause stress crazing or staining of acrylic plastics.

2.3.2.3 Test Procedures

a. The stress-crazing effect that the manufacturer's suggested working concentration of the cleaning compound had on acrylic plastics was determined using ASTM F484 (ref 2.3.2-1).

b. Four test specimens were prepared for each of the following materials:

(1) Type A - MIL-P-5425, finish A (ref 2.3.2-2).

(2) Type B - MIL-P-8184, finish B (ref 2.3.2-3).

(3) Type C - MIL-P-25690 (ref 2.3.2-4).

c. The specimens were prepared and conditioned as follows:

(1) The test specimens were machined from a 6.4 $\pm$ 0.64-mm- (0.25 $\pm$ 0.025-in.-) thick polished acrylic plastic sheet conforming to the applicable specification.

(2) The test specimens were 25.4 $\pm$ 0.8 mm (1 $\pm$ 0.003 in.) wide by 177.8 $\pm$ 1.27 mm (7 $\pm$ 0.05 in.) long by 6.4 $\pm$ 0.64 mm (0.25 $\pm$ 0.025 in.) thick. The edges were a smooth machined surface without cracks.

(3) Type C acrylic specimens were not annealed.

(4) Type A and type B acrylic test specimens were annealed after machining by heating in an air-circulating oven at 91 $\pm$ 3 ^{o}C (195 $\pm$ 5 ^{o}F) for 5.5 hr. The specimens were cooled to room temperature in the oven using a uniform cooling rate of 28 ^{o}C (50 °F)/hr.

(5) All specimens were conditioned at 23 $\pm$ 5 ^{o}C (74.3 $\pm$ 10 ^{o}F) and 50 $\pm$ 5 percent relative humidity for a minimum of 24 hr just before testing.

d. Testing was conducted at 23 $\pm$ 5 ^{o}C (74.3 $\pm$ 10 ^{o}F).

e. Each test specimen was loaded as a cantilever beam as shown in ASTM F484, Figure 1. The following recommended stress levels were applied:

(1) Type A - 20,685 kPa (3000 psi) outer fiber stress.

(2) Type B - 24,132 kPa (3500 psi) outer fiber stress.

(3) Type C - 31,027 kPa (4500 psi) outer fiber stress.

f. The test specimens were stressed for 10 min.

g. The test specimens were examined for crazing under the lighting and visual inspection conditions as prescribed in ASTM F484.

h. If no crazing occurred, testing proceeded. If crazing occurred, a new test specimen was used and the loading test was repeated.

i. The test specimen was loaded again to the proper load.

j. An absorbent cotton swatch, a 12.7-mm (0.5-in.) square, was placed directly over the fulcrum on the tension surface in the middle of the width of the test specimen so that there was a clear space along the edge to avoid initiating crazing of the edge.

k. The cotton swatch was completely soaked with the manufacturer's suggested working concentration of the cleaning compound. The swatch was kept moist with the test compound for the duration of the test.

l. At no time was the manufacturer's suggested working concentration of the cleaning compound allowed to migrate to within 3.2 mm (0.125 in.) of the edge of the test specimen.

m. The test duration was 8 hr. After test compound exposures of 30 min, 1 hr, 2 hr, 4 hr, and 8 hr, the specimens were inspected for crazing or degradation. This was accomplished by sliding the moist swatch approximately 2 in. toward the loaded end. The test area was then carefully wiped clean. A clean cloth, wet with distilled or DI water conforming to ASTM D1193, type IV, was used to remove dry residue if necessary during the cleaning operation.

n. The top (tension) surface of the specimen was carefully examined for any evidence of crazing, cracks, or etching effects on the polished surface of the acrylic test specimen.

o. A single-point source of concentrated collimated light was used for inspection, such as a large-sized microscope illuminator.

p. Crazing that initiated at the edge of the specimen was disregarded unless it grew and extended across the specimen. In this case, the time that the crazing from the edges met was considered the end point of the test. The test was terminated as soon as crazing or degradation was observed, even if the full 8-hr duration had not been reached.

q. After each examination at the specified intervals during the 8-hr period, the moist swatch was moved back to the original position over the stress area and remoistened with test compound as required.

r. Testing was terminated at any point when crazing or degradation was observed.

s. The steps in paragraph e through r were repeated for each type of acrylic.

t. The steps in paragraphs e through s were repeated with the substitution of distilled water conforming to ASTM D1193, type IV, for the manufacturer's suggested working concentration of the cleaning compound in paragraph k.

u. The following information was reported for each test performed:

(1) Summary of the test methods and any deviations from the protocol.

(2) Identification of the sample material alloy(s), the product temper, and the selection of the thickness of the material tested, including reference to product specification.

(3) Specimen details: the type and dimensions of the test specimen and the number of replicates.

(4) Identification of the solution tested and the concentration and diluent used.

(5) Test conditions: temperature, exposure time, and humidity.

(6) Identification of the testing laboratory and the responsible technical point of contact.

(7) Individual and averaged test results.

(8) Results of visual inspections, observations, and discussion of the specimen condition.

2.3.2.4 <u>Test Findings</u>

a. Data sheets pertaining to effects on acrylic plastics are provided in Appendix V.

b. The following force was applied to each plastic based on the required outer fiber stress specified in ASTM F484:

(1) 11.7 lb to MIL-P-25690 specimens.

(2) 9.1 lb to MIL-P-8184 specimens.

(3) 7.8 lb to MIL-P-5425 specimens.

c. Calculations were performed according to ASTM F484, Figure 1.

d. The control specimens for all plastic types did not develop crazing or degradation at any time during the 8-hr test.

e. TBAC had no effects on either specimen of MIL-P-25690.

f. TBAC caused both specimens of MIL-P-5425 to develop crazing within 30 min. The samples continued to be stressed, with one breaking after 2 hr and 15 min and the other after 2 hr and 25 min.

g. TBAC caused both specimens of MIL-P-8184 to develop crazing within 30 min. The samples continued to be stressed, with one breaking after 58 min and the other after 1 hr and 47 min.

h. Lyondell Chemical Co., the manufacturer of TBAC, requested that several material compatibility tests be performed by SMI, Inc. ASTM F484 testing was performed by SMI, Inc., and the conclusion was made that TBAC did not meet the criterion for acrylic plastic, MIL-P-5425 (app M).

2.3.2.5 Technical Analysis

a. TBAC met the criterion for MIL-P-25690.

b. TBAC did not meet the criterion for the effects on acrylic plastics for MIL-P-8184 and MIL-P-5425 plastics.

2.3.3 EFFECTS ON POLYCARBONATE PLASTICS

2.3.3.1 Objective

The objective of this test was to determine the effects on polycarbonate plastics of the manufacturer's suggested working concentration of the cleaning compound.

2.3.3.2 Criterion

The manufacturer's suggested working concentration of the cleaning compound shall not cause stress crazing or staining of polycarbonate plastics.

2.3.3.3 Test Procedures

a. The stress-crazing effect that the manufacturer's suggested working concentration of the cleaning compound had on polycarbonate plastics was determined using ASTM F484, modified.

b. Four specimens, two control and two test, were prepared and conditioned in accordance with ASTM F484, paragraphs 5 and 6, using polycarbonate plastics conforming to MIL-P-83310 (ref 2.3.3-1).

c. Testing was conducted at 23 $\pm$ 5 ^{o}C (74.3 $\pm$ 10 ^{o}F).

d. Each test specimen was loaded as a cantilever beam.

e. An outer fiber stress of 2000 psi was applied.

f. The test specimen was stressed for 10 min at the above load.

g. The test specimen was examined for crazing under the lighting and visual inspection conditions as prescribed in ASTM F484.

h. If no crazing occurred, the test proceeded. If crazing occurred, then a new test specimen was made and the preceding steps were repeated.

i. The test specimen was again loaded to the stated load.

j. An absorbent cotton swatch, 12.7-mm (0.5-in.) square, was placed directly over the fulcrum on the tension surface in the middle of the width of the test specimen so that there was a clear space along the edge to avoid initiating crazing of the edge.

k. The swatch was completely soaked with the manufacturer's suggested working concentration of the cleaning compound. The swatch was kept moist with the test compound for the duration of the test.

l. The manufacturer's suggested working concentration of the cleaning compound was not allowed to migrate to within 3.2 mm (0.125 in.) of the edge of the test specimen.

m. The test specimen was inspected for crazing as in paragraph g, after loading 30 ± 2 min. Inspection was conducted by sliding the swatch 5.08 cm (2 in.) toward the loaded end of the test specimen.

n. The top (tension) surface of the specimen was carefully examined for any evidence of crazing, cracks, or etching effects on the polished surface of the polycarbonate test specimen.

o. A single-point source of concentrated collimated light was used for inspection, such as a large-sized microscope illuminator.

p. Crazing that initiated at the edge of the specimen was disregarded unless it grew and extended across the specimen.

q. The steps in paragraphs d through p were repeated with a second specimen. Two control specimens were tested using distilled water conforming to ASTM D1193, type IV.

r. The following information was reported for each test performed:

(1) Summary of the test methods and any deviations from the protocol.

(2) Identification of the sample material alloy(s), the product temper, and the selection of the thickness of the material tested, including reference to product specification.

(3) Specimen details: the type and dimensions of the test specimen and the number of replicates.

(4) Identification of the solution tested and the concentration and diluent used.

(5) Test conditions: temperature, exposure time, and humidity.

(6) Identification of the testing laboratory and the responsible technical point of contact.

(7) Individual and averaged test results.

(8) Results of visual inspections, observations, and discussion of specimen condition.

2.3.3.4 Test Findings

a. Data sheets pertaining to effects on polycarbonate plastics are provided in Appendix W.

b. Based on the required outer fiber stress specified in ASTM F484, a force of 5.2 lb was applied to the specimens.

c. TBAC caused the first polycarbonate specimen to break immediately and the second to break after 20 min.

d. Lyondell Chemical Co., the manufacturer of TBAC, requested that several material compatibility tests be performed by SMI, Inc. ASTM F484 testing was performed by SMI, Inc., and the conclusion was made that TBAC did not meet the criterion for polycarbonate plastic MIL-P-83310 (app M).

2.3.3.5 Technical Analysis

TBAC did not meet the criterion for effects on polycarbonate plastic MIL-P-83310.

(Page 2.3.3-4 Blank)

2.3.4 EFFECTS ON SHEET MOLDING COMPOUNDS

2.3.4.1 Objective

The objective of this test was to determine the effects on rigid plastics or sheet molding compound (SMC) of the manufacturer's suggested working concentration of the cleaning compound.

2.3.4.2 Criterion

The manufacturer's suggested working concentration of the cleaning compound shall not cause stress crazing, show signs of attack, or cause a change of greater than 5 points using a Barcol Impressor on the SMC.

2.3.4.3 Test Procedures

a. The effect that the manufacturer's suggested working concentration of the cleaning compound had on SMC was determined using ASTM D2583 (ref 2.3.4-1).

b. One test specimen was prepared for each of the products tested.

c. The specimens were prepared and conditioned.

(1) The test specimens were machined from 0.25 $\pm$ 0.025-in.-thick SMC and cut to approximately 1 by 1 in.

(2) The surface of the edges was smooth and without cracks.

d. Specimens were temperature-conditioned at 23 ^{o}C (74.3 ^{o}F) and 50 percent relative humidity for 40 hr prior to testing.

e. Hardness readings were recorded preliminarily of the SMC to determine the number of readings needed to reduce the variance of results. The SMC was found not to be homogeneous, with readings ranging from 42 to 67. With use of the guidelines in ASTM D2583, Table 1, 10 hardness readings were recorded on each test specimen.

f. Each test specimen was immersed in the test solution for 1 hr at 27 $\pm$ 2 ^{o}C (80.6 $\pm$ 3 ^{o}F).

g. Immediately after the immersion period, the specimen was removed from the test solution, and 10 hardness readings were recorded. The specimens were observed under a 10x magnifier for crazing and other forms of attack.

h. The following information was reported for each test performed:

(1) Summary of the test methods and any deviations from the protocol.

(2) Identification of the sample material and the selection of the thickness of the material tested, including reference to product specification.

(3) Specimen details: the type and dimensions of the test specimen and the number of replicates.

(4) Identification of the solution tested and the concentration and diluent used.

(5) Test conditions: temperature, exposure time, and humidity.

(6) Identification of the testing laboratory and the responsible technical point of contact.

(7) Individual and averaged test results.

(8) Results of visual inspections, observations, and discussion of specimen condition.

2.3.4.4 Test Findings

a. Data sheets pertaining to effects on rigid plastics/SMCs are provided in Appendix X.

b. The rigid plastic appeared to be reinforced (nonhomogeneous) and produced a wide range of readings. Ten readings were recorded for the coupons before and after immersion as recommended by ASTM D2583 because of the nature of this material for this hardness number.

c. Ten readings before immersion averaged 50 points using the Barcol Impressor.

d. Ten readings after immersion averaged 50 points using the Barcol Impressor.

e. After the immersion period, there was no sign of crazing or attack on any specimen with the use of TBAC.

2.3.4.5 Technical Analysis

TBAC met the criterion for the effects on SMC by not causing any type of degradation.

2.3.5 EFFECTS ON RUBBER

2.3.5.1 Objective

The objective of this test was to evaluate the effect of the manufacturer's maximum recommended use concentration of the test cleaner on the mechanical properties of strength, elongation, and hardness of the rubber compounds immersed in the cleaner.

2.3.5.2 Criterion

The manufacturer's maximum recommended use concentration of the cleaning compound shall not change the tensile strength ± 15 percent, elongation ± 20 percent, or Shore A hardness ± 7 units of the rubber material (Test Matrix).

2.3.5.3 Test Procedures

a. Compatibility of the manufacturer's maximum recommended use concentration of the cleaning solution with rubber was determined using ASTM D471 (ref 2.3.5-1), section 15, and ASTM D412 (ref 2.3.5-2).

b. Three test specimens and three control specimens were prepared from each of the following rubbers:

(1) AMS 3217/2B (ref 2.3.5-3).

(2) AMS 3217/3B (ref 2.3.5-4).

(3) Various formulas of MIL-DTL-45301E (ref 2.3.5-5).

c. The compounds of MIL-DTL-45301E were as follows:

(1) 0235 from the M88 vehicle roadwheel (RW).

(2) 0135 from the M113, Bradley Fighting Vehicle, and M109 vehicle trackblock wheel side.

(3) 0149 from the Bradley Fighting Vehicle and M1 vehicle RW.

(4) P12 from the M113 RW.

(5) 14A (T107 ground side (G/S)) from the M88 vehicle trackblock.

(6) 10L (T107 wheel side (W/S)) from the M88 and M60 vehicles trackblock.

(7) RW compression from the Bradley Fighting Vehicle and M113.

d. The specimens were prepared from flat vulcanized sheets 2.0 ± 0.1 mm (0.08 ± 0.004 in.) in thickness using ASTM D412, Die C.

e. All material used for the baseline tensile strength, elongation, and hardness as well as test specimens were from the same lot.

f. The thickness and width of each tensile and elongation test specimen were measured.

g. With the use of a Shore A durometer hardness tester, the hardness of each specimen was measured by recording, at a minimum, five readings and recording the average.

h. The specimens were placed in a glass test tube, having an approximate outside diameter of 38 mm (1.5 in.) and an approximate overall length of 300 mm (12 in.), fitted loosely with a stopper. The stopper did not contaminate the test liquid. Clean glass beads were used in the tube as a bumper and to separate the specimens.

i. Test solution was added to the test tube to cover the specimen.

j. The test liquids were not reused.

k. The test specimen was immersed for 2 hr at a temperature of 23 ^{o}C (73.4 ^{o}F). Immersion tests were conducted in the absence of direct light.

l. At the end of the immersion period, the specimens were removed from the test tubes, and at least five Shore A hardness readings were recorded immediately as well as the average.

m. The specimens were allowed to air-dry at 23 ^{o}C and 50 percent relative humidity for 24 hr.

n. The tensile strength and ultimate elongation were determined in accordance with ASTM D412, using the original unimmersed thickness or cross-sectional area. Shore A hardness readings were again recorded as in paragraph g.

o. The change in properties was calculated as follows:

(1) Tensile strength based on the original unstretched cross-sectional area:

$$TS_o = F \div A$$

(2) To express tensile strength and ultimate elongation after immersion as a percentage change from the original properties, the following formula was used:

$$\Delta P, \% = (P_i - P_o) \div (P_o) \times 100$$

(3) The hardness change after immersion in hardness units was calculated:

$$\Delta H = H_i - H_o$$

Where:

TS_o	=	Tensile stress based on the original unstretched cross-sectional area.
F	=	Observed force.
A	=	Original unstretched cross-sectional area of the test specimen before immersion.
ΔP	=	Change in property (tensile strength and ultimate elongation) after immersion, %.
P_o	=	Original property before immersion.
P_i	=	Property after immersion.
ΔH	=	Hardness change after immersion, units.
H_o	=	Original hardness before immersion, units.
H_i	=	Hardness after immersion, units.

p. The following information was reported for each test performed:

(1) Summary of the test methods and any deviations from the protocol.

(2) Identification of the sample materials and the selection of the thickness of the material tested, including reference to product specification.

(3) Specimen details: the type and dimensions of the test specimen and the number of replicates.

(4) Identification of the solution tested and the concentration and diluent used.

(5) Test conditions: temperature, exposure time, and humidity.

(6) Identification of the testing laboratory and the responsible technical point of contact.

(7) Individual and averaged test results.

(8) Results of visual inspections, observations, and discussion of specimen condition.

(9) Photographic documentation, if needed, of specimen conditions.

2.3.5.4 Test Findings

a. Data sheets pertaining to effects on rubber are provided in Appendix Y.

b. There was no deviation from the test procedure during testing.

c. The results of testing with TBAC are presented in Table 2.3.5-1.

TABLE 2.3.5-1. TBAC RESULTS

RUBBER TYPE	HARDNESS UNITS (SHORE A)		TENSILE STRENGTH, %	ELONGATION, %
	IMMERSION	24 HR		
0235	-10	-1	-14.5	-3.2
0135	-11	0	-16.0	-12.3
P12	-13	-5	-14.8	-5.1
T107 W/S	-12	-1	-12.8	0.9
0149	-11	0	-10.7	-3.9
T107 G/S	-11	0	-25.6	-17.0
3217/3B	-10	-7	-11.1	9.1
RW compression	-9	1	-10.3	-4.0
3217/2B	-1	1	-10.1	-19.5

Note: Yellow shading denotes values outside the stated criterion.

2.3.5.5 Technical Analysis

a. The only rubber that met all three tests of tensile strength, elongation, and hardness was 3217/2B.

b. The hardness reading was recorded at two time periods to show the reaction of the product toward the rubber. There was no distinction as to which time period would be used for meeting the criterion. The ability of the rubbers to regain their hardness after TBAC was allowed to evaporate from the materials can be seen in Table 2.3.5-1. Only 3217/3B did not return to enough of its original form to meet the criterion after the drying time. It is interesting to note how rubbers such as 0135, 0149, and T107 G/S had such a large reduction in hardness immediately after immersion but returned to the original hardness after setting for 24 hr. Only two rubbers, P12 and 3217/3B, did not return to a minimum 1-point change after the 24-hr waiting period.

c. Rubbers 0135 and T107 G/S did not meet the criterion for tensile strength. All other rubbers met the criterion.

d. All rubbers met the criterion for elongation. Rubber 3217/2B met the criterion, but elongation was met by only one half of 1 percent.

2.3.6 EFFECTS ON POLYIMIDE WIRE

2.3.6.1 Objective

The objective of this test was to determine the effects on polyimide wire of the manufacturer's suggested working concentration of the cleaning compound.

2.3.6.2 Criterion

The manufacturer's suggested working concentration of the cleaning compound shall not cause cracking, discoloration, dissolution, or dielectric breakdown of the polyimide insulated wire in excess of that produced by distilled water (Test Matrix).

2.3.6.3 Test Procedures

a. The effect that the manufacturer's suggested working concentration of the cleaning compound had on the polyimide-insulated wire was determined using ADS-61A-PRF.

b. Two lengths of MIL-W-81381/11-20 wire (ref 2.3.6-1) approximately 61 cm (24 in.) long were cut.

c. Each segment was coiled tightly around a 0.3-cm- (0.125-in.-) diameter bar and placed into separate 118-mL (4-oz) widemouthed jars.

d. The manufacturer's maximum suggested working concentration of the cleaning compound was added to one jar to completely cover the wire coil.

e. DI water (ASTM D1193, type IV) was added to the other jar (control sample) to completely cover the wire coil.

f. Both jars were capped and stored at room temperature (20 to 25 ^{o}C (68 to 77 ^{o}F)) for 14 days.

g. After immersion, both coils were removed and rinsed thoroughly with distilled water.

h. Both coils were suspended and allowed to dry completely.

i. When dry, the wires were examined for dissolution.

j. Both coils were double-reverse wrapped on a 0.3-cm (0.125-in.) mandrel and observed for cracking under 10x magnification.

k. If the test wire cracked, the test was ended. If the control wire cracked, the test was invalidated and was rerun.

l. The wires were tested for breakdown and/or leakage by subjecting them to a 1-min dielectric test of 2500 V_{rms}, using a Hypot model No. 4045 or equivalent.

m. The following information was reported for each test performed:

(1) Summary of the test methods and any deviations from the protocol.

(2) Identification of the sample materials tested, including reference to product specification.

(3) Specimen details: the type of the test specimen and the number of replicates.

(4) Identification of the solution tested and the concentration and the diluent used.

(5) Test conditions: temperature, exposure time, and humidity.

(6) Identification of the testing laboratory and the responsible technical point of contact.

(7) Individual and averaged test results of the dielectric test.

(8) Results of visual inspections, observations, and discussion of the specimen condition.

(9) Photographic documentation, if needed, of specimen conditions.

2.3.6.4 <u>Test Findings</u>

a. Data sheets pertaining to effects on polyimide wire are provided in Appendix Z.

b. The control wire did not have discoloration, dissolution of the insulation, or cracking and passed the dielectric test.

c. TBAC did not cause any degradation to the insulation or color coding on the wire, and the wire passed the dielectric test.

2.3.6.5 <u>Technical Analysis</u>

TBAC passed the criterion for effects on polyimide wire

APPENDIX A. TOXICOLOGICAL EVALUATION

(Page A-2 Blank)

DEPARTMENT OF THE ARMY
US ARMY CENTER FOR HEALTH PROMOTION AND PREVENTIVE MEDICINE
5158 BLACKHAWK ROAD
ABERDEEN PROVING GROUND MD 21010-5403

MCHB-TS-TTE 16 August 2006

MEMORANDUM FOR Warfighter Directorate (CSTE-DTC-AT-WF-A/Mr. William Taylor), U.S. Army Aberdeen Test Center, 400 Colleran Road, Aberdeen Proving Ground, MD 21005-5059

SUBJECT: Toxicity Clearance for TBAc

1. References (see enclosure 1).

2. Background.

a. The U.S. Army Aberdeen Test Center, Warfighter Directorate has requested Toxicity Clearances be performed by the U.S. Army Center for Health Promotion and Preventive Medicine (USACHPPM) for cleaning products where the ultimate goal is to replace the standard PD-680 hydrocarbon solvent. Currently, PD-680 is used as a cleaner in painting and paint removal operations which is the intended use of the proposed cleaning products (reference 1). This Toxicity Clearance focuses specifically on TBAc manufactured by Lyondell Chemical Company.

b. TBAc solvent is Tert-Butyl Acetate, a volatile organic compound (VOC), non hazardous air pollutant (HAP), urethane grade solvent (reference 2). TBAc has been on the commercial market since the 1980s. Its main use has been as a pharmaceutical intermediate. In December 2004, the U.S. Environmental Protection Agency (USEPA) exempted it as a VOC and its use as a solvent for industrial coatings, adhesives, inks, and cleaners has been growing steadily since then (reference 3). It has been commercially available in the U.S. since 1997. Applications include use in coatings, inks, adhesives, cleaners, electronics, and an intermediate in the pharmaceutical industry. "As a cleaner it is used for solvent-based cleaning, including metal degreasing and specialized equipment cleansing" (reference 2). "According to Lyondell, TBAc will be used as a coating solvent and as a degreaser/cleaner to replace other flammable solvents such as toluene and metyl ethyl ketone. It has physical properties similar to these solvents and will be used in identical applications" (reference 3).

c. "TBAc solvent's oral LD50 (rat) was 4.5 g/kg and the inhalation LC50 (rat) for a 6 hour exposure is approximately 4200 ppm. It is a moderate skin and eye irritant. A battery of genotoxicity studies was negative. Inhalation (6hrs/day, 5 days/week) of 1600 ppm TBAc solvent by rats for 2 weeks caused liver toxicity and unsteady gait. Kidney toxicity; increased

hyaline droplets were found in the kidneys of male rats exposed at 100, 400, and 1600 ppm" (references 2&4). The skin LD50 (rabbit) was greater than 2000 mg/kg (reference 4). "TBAc is not a skin sensitizer. Skin and eye irritation can occur with prolonged exposure. A portion of TBAc solvent is metabolized to its parent alcohol, tert-butanol. Overexposure to TBAc vapor could lead to alcohol intoxication. The Occupational Safety & Health Administration (OSHA) has established a Permissible Exposure Limit (PEL) of 200 ppm for TBAc" (reference 3). Furthermore, Lyondell Chemical Company is not aware of any adverse health effects from the use or manufacture of TBAc (reference 3).

d. According to the Material Safety Data Sheet (MSDS), TBAc contains Tert-Butyl Acetate (CAS # 540-88-5) at less than or equal to 100%. Tert-Butyl Acetate is a skin irritant, slight eye irritant, respiratory tract irritant and a CNS depressant. "There is no data available on the chronic health effects from prolonged or repeated exposure to Tert-Butyl Acetate" (reference 4). The American Conference of Governmental Industrial Hygienists, Inc. (ACGIH) and OSHA 8 hr/TWAs are 200 ppm. According to the Hazardous Substances Data Bank (HSDB) Tert-Butyl Acetate is used as a gasoline additive solvent. People with kidney, chronic respiratory, liver, or skin disease may be at an increased risk from tert-butyl exposure (reference 5).

e. TBAc also contains tert-butyl alcohol (CAS # 75-65-0) at less than or equal to 0.5%. "Tert-Butyl Alcohol is a moderate to severe eye irritant. It is mildly irritating to the skin but not a skin sensitizer. Breathing mist or vapors may cause mucous membrane or upper respiratory tract irritation. Overexposure may cause coughing, shortness of breath, dizziness, CNS depression, intoxication, and collapse. Ingestion would likely cause gastrointestinal tract irritation. May produce symptoms of nervous system depression including headache, dizziness, nausea, loss of sense of balance, drowsiness, and visual disturbances. Prolonged or repeated breathing of high concentrations may cause symptoms of central nervous system depression. May cause dermatitis by defatting the skin from prolonged or repeated contact. This material has been shown to induce tumors in laboratory animals. May be toxic to the developing embryo and fetus" (reference 4). The ACGIH and OSHA 8 hr/TWAs are 100 ppm. Given the small concentration in the final product, this material poses a minimal health risk.

3. Requirements.

a. Avoid contact with eyes and skin. When handling TBAc, impervious gloves, apron, boots, head/face protection, and goggles must be worn. Avoid ingestion and inhalation. This product must always be used in an adequately ventilated environment. Air concentrations must not exceed the OSHA PEL of 200 ppm. Any additional handling instructions found in the MSDS and technical packages should be followed.

b. TBAc must be disposed of properly to prevent unnecessary ecological exposures (enclosure 2).

c. As with all chemicals, unnecessary exposure should be avoided.

4. Conclusions. Based on a review of the MSDS and data package provided by the manufacturer and extensive searches of toxicological databases, a Toxicity Clearance is granted for the addition of TBAc to the Army supply system in hand wipe applications as a degreaser and cleaner during painting and paint removal processes. A new Toxicity Clearance must be performed if there are any changes in the components or usage of TBAc.

5. Point of contact for this action is Mr. John T. Houpt who can be reached at DSN 584-5087, commercial (410) 436-5087, or via e-mail at John.houpt@us.army.mil.

FOR THE COMMANDER:

Carol A. Bossone

2 Encls

CAROL A. BOSSONE
LTC, VC
Director, Toxicology

REFERENCES

1. Memorandum, U.S. Army Aberdeen Test Center, CSTE-DTC-AT-WF-A, undated, subject: Request for Toxicity Clearance for Various Cleaners.

2. Technical Data, TBAc, Lyondell Chemical Company, Houston, TX 77010, 2005.

3. E-mail, Cupron Inc., Daniel Pourreau, 14 July 2006, subject:TBAc.

4. MSDS, 499245 TBAc TM, Lyondell Chemical Company, 2 February 2005.

5. Webpage, HSDB: Hazardous Substances Data Bank, National Library of Medicine, Bethesda, MD (electronic version), Thomson Micromedex, Greenwood Village, CO, USA, Available at: http://csi.micromedex.com (17 July 2006).

Encl 1

Disposal Guidance on Tert Butyl Acetate

1. References:

a. Electronic message, U.S. Army Center for Health Promotion and Preventive Medicine, (MCHB-TS-TTE), Mr John Houpt, 17 July 2006, subject: Request for Disposal Guidance on Tert Butyl Acetate.

b. Title 40 Code of Federal Regulations Parts 260 through 279.

2. The following is in response to the reference.

a. Unused quantities of Tert Butyl Acetate to be discarded are not listed as hazardous wastes under Subpart D of the 40 CFR 261. However, the flash point of the Tert Butyl Acetate is 40°F so it does exhibit the hazardous characteristic of ignitability as described in 40 CFR 261.21. Therefore, these materials are hazardous waste for disposal under Subtitle C of the Resource Conservation and Recovery Act (RCRA).

b. Spill clean-up materials involving Tert Butyl Acetate will need to be tested for the ignitability characteristic before disposal.

3. Questions pertaining to the information in this memorandum can be directed to Mr. Richard Price. He may be reached at 410-436-5231.

Encl 2.

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APPENDIX B. CHEMISTRY LABORATORY REPORT

(Page B-2 Blank)

U.S. Army Aberdeen Test Center

400 Colleran Road
Aberdeen Proving Ground, MD 21005-5059

WARFIGHTER DIRECTORATE
APPLIED SCIENCE TEST DIVISION
CHEMICAL SAMPLING AND ANALYSIS TEAM
Petroleum Oil Lubricants & Fuels Report
Supplement to Test Report 2007-CC-038A

Taylor, William
TEDT-AT-WFA (AJNC)
MATLS & STDS TESTING TEAM
APG, MD 21005

ATEC Project Number: C7867

Test Report Number: 2007-CC-038A
LIMS Reference Number: 0602004

This report shall not be reproduced **except in its entirety** without the written approval of the Chemical Sampling & Analysis Team. The results relate only to the specific samples/test item/test scenario identified within the report.

Authorized for Release:

Signature: Craig S. Miser
Craig S. Miser
Chief, Applied Science Test Team

Date: 18 Dec 07

U.S. ARMY ABERDEEN TEST CENTER
ABERDEEN PROVING GROUND, MARYLAND 21005-5059
WARFIGHTER DIRECTORATE
APPLIED SCIENCE TEST DIVISION
CHEMICAL SAMPLING AND ANALYSIS TEAM
TEST REPORT NO. 2007-CC-038A

Title of Report:	**TBAC/ Alternative Cleaning Test**
ATEC Project Title:	**TBAC/ Alternative Cleaning Test**
ATEC Project No.:	**C7867**
Conducted For:	**Taylor, William** **TEDT-AT-WFA (AJNC)** **MATLS & STDS TESTING TEAM** **APG MD, 21005**
References:	**None Provided**

1.1 INTRODUCTION

The following report outlines the analyses completed by CSAT of the samples taken on 02-Feb-06 00:00, and received on 02-Feb-06 13:34.

2.1 OBJECTIVE

To analyze organic samples for TBAC testing

2.2 CRITERIA

N/A

2.3 TEST PROCEDURE

Table 2.3.1 Testing Procedures

Analyte	Matrix	Test Method	Internal Operating Procedure (IOP)
Flashpoint Open Cup	Organic	ASTM D93	IOP#222.1
Non-Volatile Residue (Max)	Organic	ASTM D1353	IOP#NA
Vapor Pressure	Organic	ASTM D6378	IOP#NA

Table Definitions:

EPA = Environmental Protection Agency
NIOSH = National Institute of Occupational Safety and Health

2.3.1 INSTRUMENTATION

The following instruments were used to analyze the samples listed:

2.3.2 TEST ITEMS

Table 2.3.2 Sample Information

Customer Sample ID#	CSAT Laboratory ID#	Sample Matrix	Date & Time Sampled	Date & Time Received	Sample Comments
TBAC	0602004-01	Organic	02-Feb-06 00:00	02-Feb-06 13:34	
TBAC	0602004-02	Organic	18-Oct-06 00:00	02-Feb-06 13:34	

2.4 TEST FINDINGS

Table 2.4.1 Analysis of Samples

Analyte	Result	Units	Reporting Limit	Dilution	Batch	Prepared	Analyzed	Qualifier
TBAC (0602004-01)								
Flashpoint-Open	<39/4	°F/°C		1	B604008	04/17/06	04/18/06	
TBAC (0602004-02)								
Nonvolatile Matter	ND	mg/ml	0.00	1	B610032	10/31/06	10/31/06	
Vapor Pressure	1.67	DVPE	0.00	1	B610032	10/31/06	10/31/06	

Table Definitions:
* ND = Non Detect

2.5 DATA ASSESSMENT

Two aliquots (0602004-01 and 0602004-02) of the same sample, TBAC, were received to the POLF group on 02-Feb-06. The samples were submitted to the lab by William Taylor of the Materials and Standards Testing Team. The samples were analyzed in accordance to the methods referenced in Table 2.3.1. The results are documented in Table 2.4.1.

2.6 POINT OF CONTACT

This report was compiled and written by Gwendolyn McKinney, CSAT Quality Manager - Aberdeen Test Center, Chemical Sampling and Analysis Team, 410-278-2868. All questions concerning the data presented in this report should be directed to this POC.

Gwen McKinney

Gwendolyn McKinney, CSAT Quality Manager

Valerie Young

Data Reviewer

APPENDIX C. SOIL CLEANING DATA SHEETS

(Page C-2 Blank)

SOIL CLEANING

(1.3.1)

ATC MATERIALS LABORATORY

	TESTING LABORATORY
Client Name Army Research Laboratory (ARL)	Name ATC Materials Laboratory
POC Mr. Wayne W. Ziegler	POC Mr. William Taylor
Address	Address ATTN: TEDT-AT-WFA
	APG, MD 21005-5059
Telephone 410-306-0746	Telephone (410) 278-4461

Cleaner Tested

Product Name: TBAc

Company Name: Lyondell Chemical Company

Company Address:

POC:

Specimen Information:

Alloy Type STEEL ASTM A366

Surface Treatment

Condition/Humidity

Solution Conditions:

Concentration Standard

Diluent Used

Temperature

Test Condition:

Exposure: Maximum 100 min

Date/Time In:

Date/Time Out:

POC for Testing: Mr. William Taylor

Test Instrumentation: Branson 8510 Ultrasonic Cleaner

SAMPLE TYPE	SAMPLE NUMBER	WEIGHT (g) ORIGINAL	WEIGHT (g) CLEANED	CLEANING TIME (MIN)	SOLVENT CLEANING POWER, %
STEEL,CARBON,	1	3.467	3.468	4	96
MILD (ASTM-A-366)	2	3.376	3.376	2	98
	3	3.381	3.381	6	94
	AVG	3.408	3.408	4	96

TEST FINDINGS:

Bath temperature started at approximately 72 ºF.

SOIL CLEANING

(1.3.1)

ATC MATERIALS LABORATORY

Client Name Army Research Laboratory (ARL)
POC Mr. Wayne W. Ziegler
Address
Telephone 410-306-0746

TESTING LABORATORY
Name ATC Materials Laboratory
POC Mr. William Taylor
Address ATTN: TEDT-AT-WFA
APG, MD 21005-5059
Telephone (410) 278-4461

Cleaner Tested
Product Name: SAFETY SOLVENT
Company Name:
Company Address:
POC:

Specimen Information:
Alloy Type STEEL ASTM A366
Surface Treatment
Condition/Humidity

Solution Conditions:
Concentration Standard
Diluent Used
Temperature

Test Condition:
Exposure: Maximum 100 min
Date/Time In:
Date/Time Out:
POC for Testing: Mr. William Taylor
Test Instrumentation: Branson 8510 Ultrasonic Cleaner

SAMPLE TYPE	SAMPLE NUMBER	WEIGHT (g) ORIGINAL	WEIGHT (g) CLEANED	CLEANING TIME (MIN)	SOLVENT CLEANING POWER, %
STEEL,CARBON,	1	3.410	3.410	19	81
MILD (ASTM-A-366)	2	3.403	3.402	21	79
	3	3.445	3.444	28	72
	AVG	3.419	3.419	23	77

TEST FINDINGS:

Bath temperature started at approximately 72º F.

SOIL CLEANING

(1.3.1)

ATC MATERIALS LABORATORY

	TESTING LABORATORY
Client Name Army Research Laboratory (ARL)	Name ATC Materials Laboratory
POC Mr. Wayne W. Ziegler	POC Mr. William Taylor
Address	Address ATTN: TEDT-AT-WFA
	APG, MD 21005-5059
Telephone 410-306-0746	Telephone (410) 278-4461

Cleaner Tested

Product Name: TOLUENE

Company Name:

Company Address:

POC:

Specimen Information:

Alloy Type STEEL ASTM A366

Surface Treatment

Condition/Humidity

Solution Conditions:

Concentration Standard

Diluent Used

Temperature

Test Condition:

Exposure: Maximum 100 min

Date/Time In:

Date/Time Out:

POC for Testing: Mr. William Taylor

Test Instrumentation: Branson 8510 Ultrasonic Cleaner

SAMPLE TYPE	SAMPLE NUMBER	WEIGHT (g) ORIGINAL	WEIGHT (g) CLEANED	CLEANING TIME (MIN)	SOLVENT CLEANING POWER, %
STEEL,CARBON,	1	3.519	3.519	6	94
MILD (ASTM-A-366)	2	3.546	3.546	7	93
	3	3.372	3.372	6	94
	AVG	3.479	3.479	6	94

TEST FINDINGS:

Bath temperature started at approximately 72º F.

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APPENDIX D. SEALANT ADHESION DATA SHEETS

(Page D-2 Blank)

EFFECTS ON SEALANT PEEL STRENGTH

(1.3.3)

ATC MATERIALS LABORATORY

Client Name Army Research Laboratory (ARL)
POC Mr. Wayne W. Ziegler
Address
Telephone 410-306-0746

TESTING LABORATORY
Name ATC Materials Laboratory
POC Mr. William Taylor
Address ATTN: TEDT-AT-WFA
APG, MD 21005-5059
Telephone (410) 278-4461

Cleaner Tested
Product Name: TBAc
Company Name: Lyondell Chemical Company

Specimen Information:
Alloy Type
Surface Treatment
Condition Coupons Made 8 September 2005

Solution Conditions:
Concentration Standard
Diluent Used DI Water as Required
Temperature Ambient

Test Condition:
Exposure: 7 Days @ 60ºC
Date/Time In:
Date/Time Out:
POC for Testing: Mr. William Taylor
Test Instrumentation: Instron, Model 1125

PRIMER 23377 (A) - CONTROL SAMPLES					
SAMPLE ID#	AVG OF 4 PEAK LOADS		AVERAGE	PERCENT OF FAILURE	
	A SIDE	B SIDE		ADHESIVE	COHESIVE
MEK-1A	17.65	20.75	**19.20**	0	100
MEK-2A	27.53	35.35	**31.44**	0	100
MEK-3A	37.29	32.71	**35.00**	0	100
MEK-4A	32.71	31.51	**32.11**	0	100
AVERAGE	**28.80**	**30.08**	**29.44**		
PRIMER 85582 (B) - CONTROL SAMPLES					
MEK-1B	31.90	34.17	**33.04**	5	95
MEK-2B					
MEK-3B	30.94	29.67	**30.31**	0	100
MEK-4B	30.93	31.55	**31.24**	0	100
AVERAGE	**31.26**	**31.80**	**31.53**		

PRIMER 23377 (A) - TEST SAMPLES					
SAMPLE ID#	AVG OF 4 PEAK LOADS		AVERAGE	PERCENT OF FAILURE	
	A SIDE	B SIDE		ADHESIVE	COHESIVE
18-1A	23.66	25.91	**24.79**	5	95
18-2A	25.64	26.70	**26.17**	0	100
18-3A	27.71	31.71	**29.71**	0	100
18-4A	28.54	30.33	**29.44**	0	100
AVERAGE	**26.39**	**28.66**	**27.53**	**1**	**99**
PRIMER 85582 (B) - TEST SAMPLES					
18-1B	10.27	16.47	**13.37**	75	25
18-2B	20.31	23.39	**21.85**	85	15
18-3B	21.22	13.56	**17.39**	60	40
18-4B	21.65	25.48	**23.57**	95	5
AVERAGE	**18.36**	**19.73**	**19.04**	**79**	**21**

REMARKS:

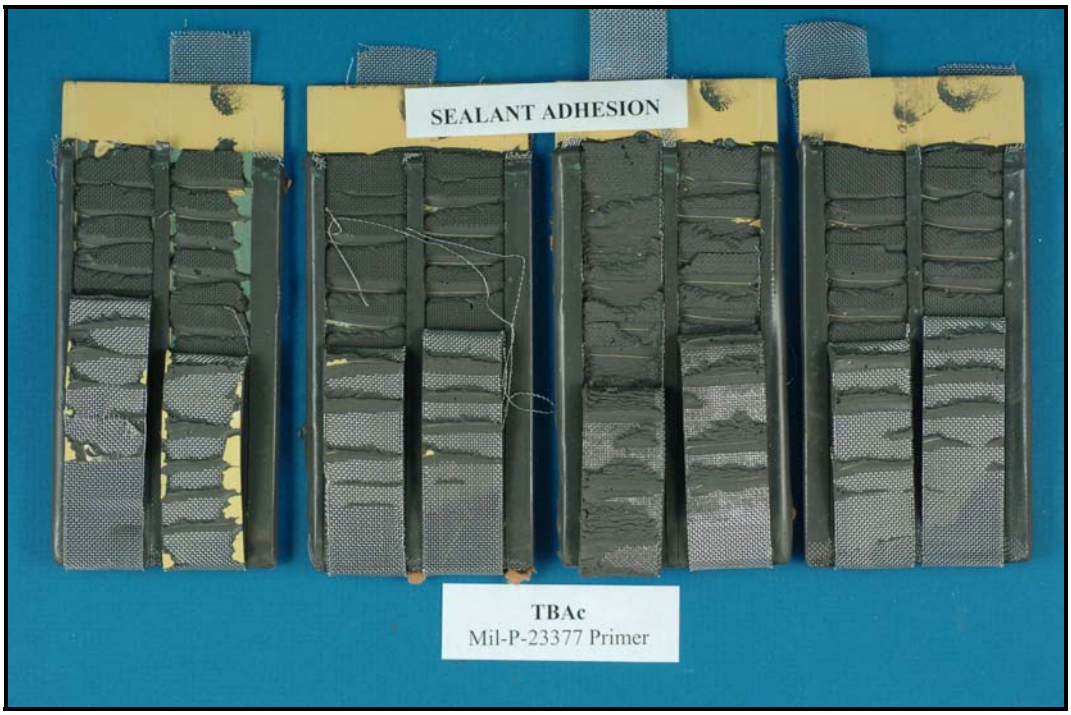
(Page D-4 Blank)

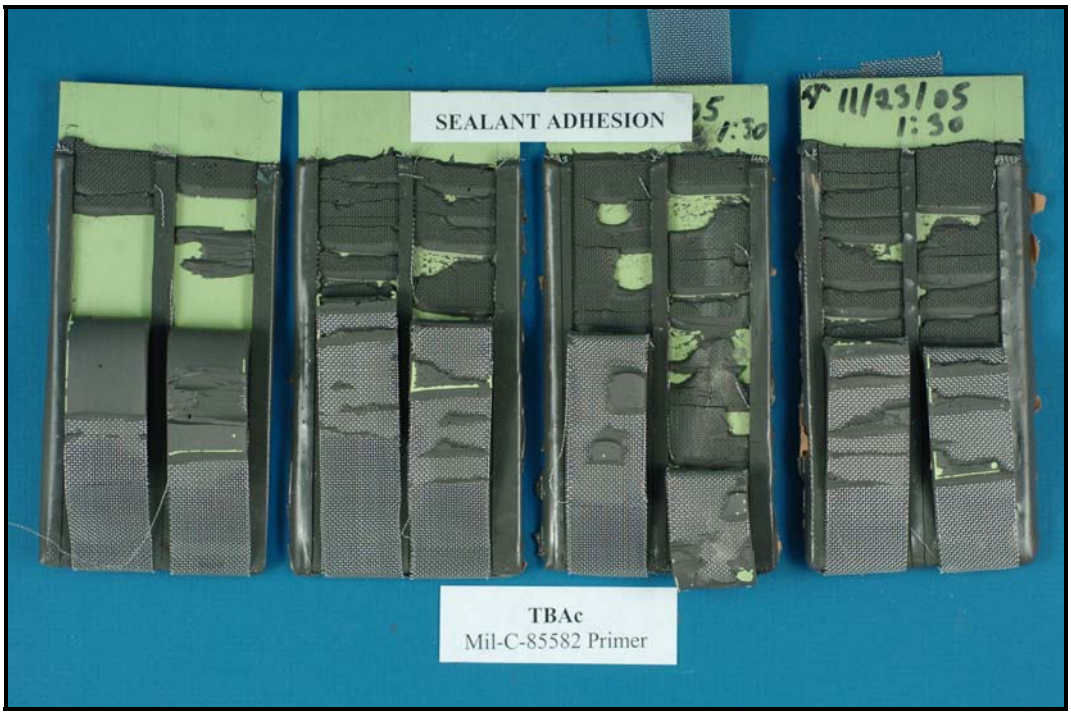
APPENDIX E. SEALANT ADHESION PHOTOGRAPHS

(Page E-2 Blank)

SEALANT ADHESION
A
MEK
Mil-P-23377 Primer

SEALANT ADHESION
MEK
Mil-C-85582 Primer


SEALANT ADHESION
TBAc
Mil-P-23377 Primer


SEALANT ADHESION
11/23/05
1:30
TBAc
Mil-C-85582 Primer

APPENDIX F. PAINT ADHESION DATA SHEETS

(Page F-2 Blank)

PAINT ADHESION

(1.3.4)

ATC MATERIALS LABORATORY

	TESTING LABORATORY
Client Name Army Research Laboratory (ARL)	Name ATC Materials Laboratory
POC Mr. Wayne W. Ziegler	POC Mr. William Taylor
Address	Address ATTN: TEDT-AT-WFA
	APG, MD 21005-5059
Telephone 410-306-0746	Telephone (410) 278-4461

Cleaner Tested

Product Name: TBAc

Company Name: Lyondell Chemical Company

Company Address:

POC:

Specimen Information:

Alloy Type

Surface Treatment

Condition

Solution Conditions:

Concentration Standard

Diluent Used DI Water

Temperature Ambient

Test Condition:

Exposure: 8 hours

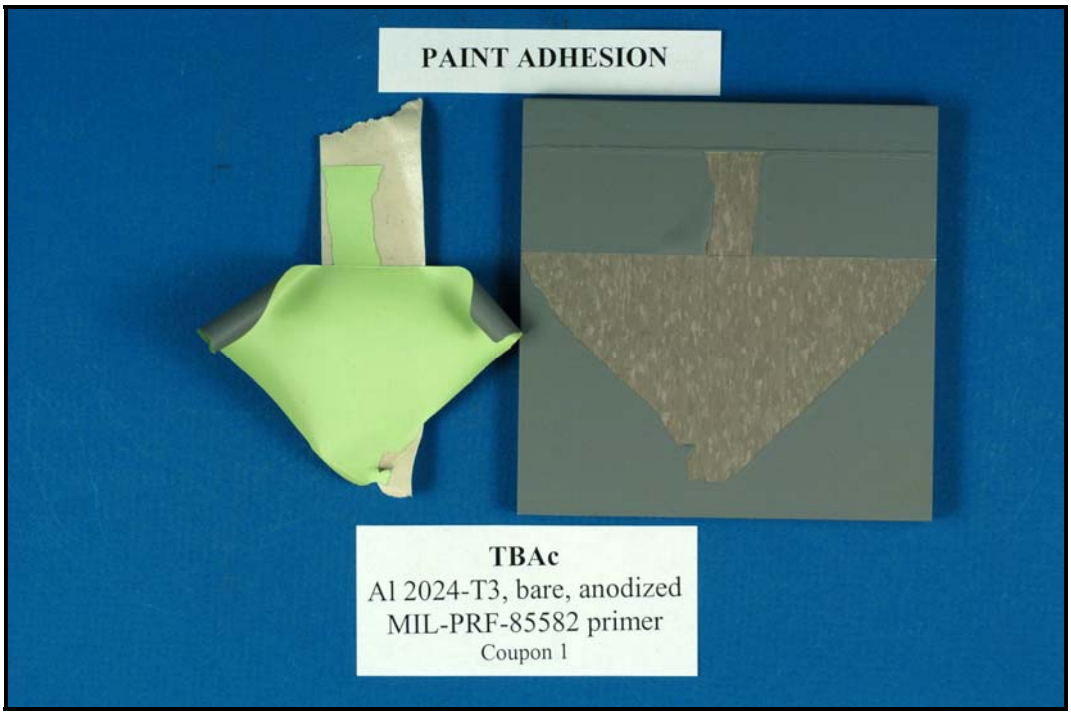
Date/Time In: Date/Time Out:

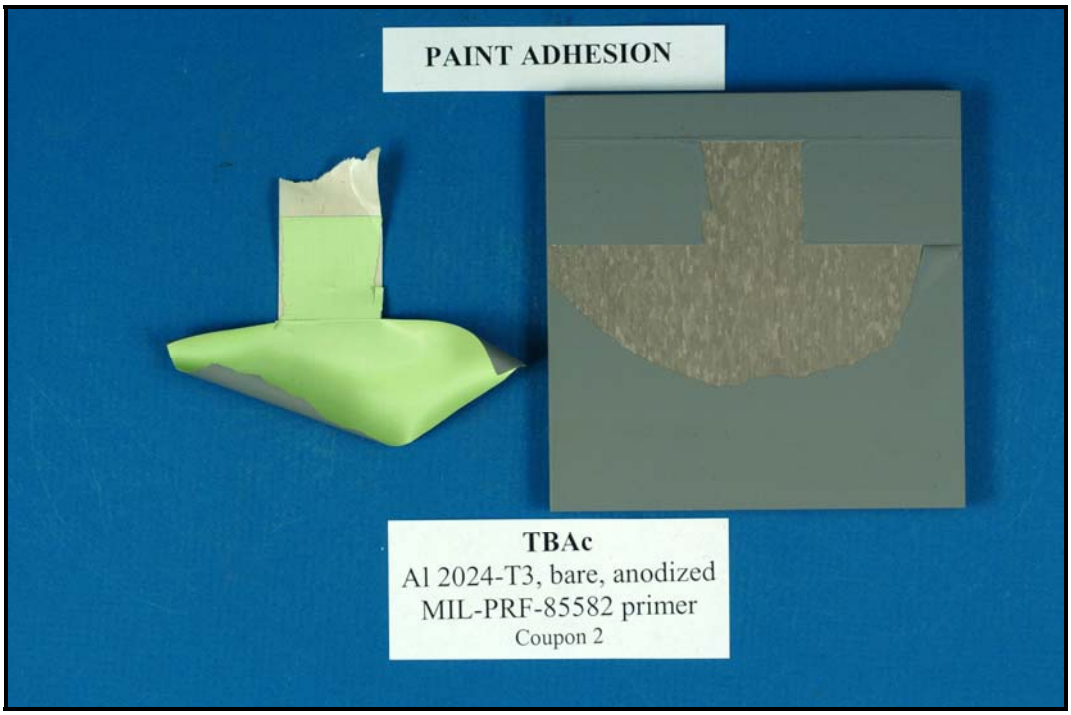
POC for Testing: Mr. William Taylor Test Instrumentation:

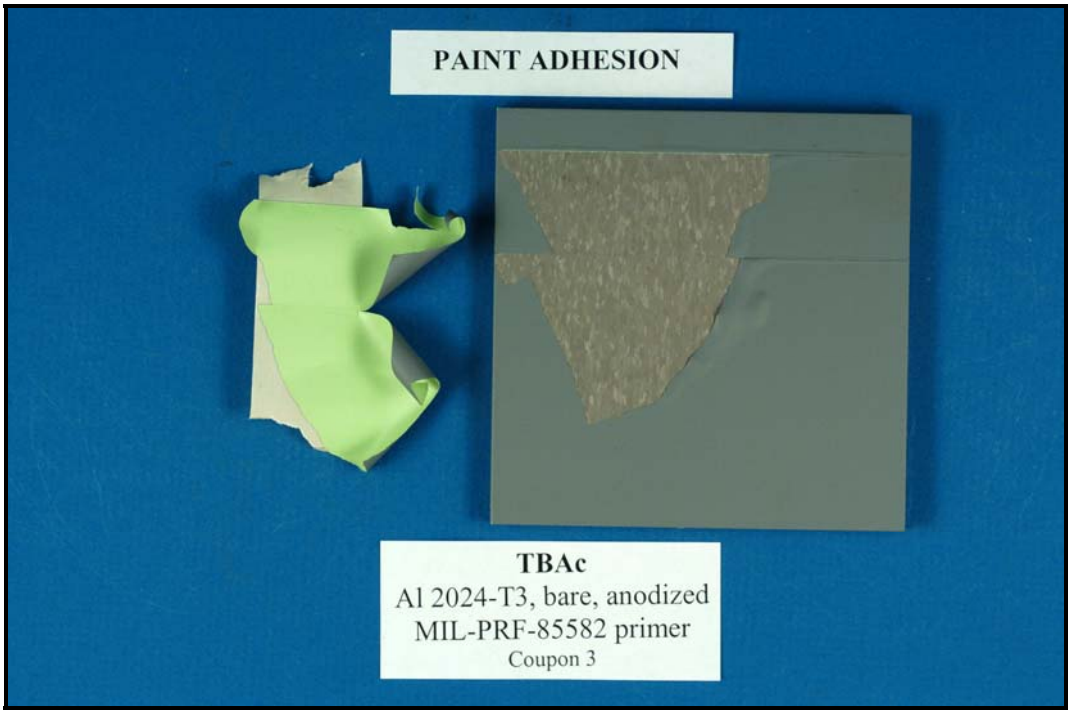
TEST PANEL	PANEL ID	OBSERVATIONS (Damage to Surface and Coatings)
AL 2024-T3 Bare (anodized per MIL-A-8625,Type I; w/ MIL-P-23377 primer & MIL-C85285 top coat)	1	OK
	2	OK
	3	OK
AL 2024-T3 Clad (conversion coated per MIL-C-5541, Class 3; w/ MIL-P-23377 primer & MIL-C-85285 top coat)	1	OK
	2	OK
	3	OK
AL 2024-T3 Bare (anodized per MIL-A-8625,Type I; w/ MIL-P-85582 primer & MIL- C-85285 top coat)	1	Adhesive Failure – Primer to Substrate
	2	Adhesive Failure – Primer to Substrate
	3	Adhesive Failure – Primer to Substrate
AL 2024-T3 Clad (conversion coated per MIL-C-5541, Class 3; w/ MIL-P-85582 primer & MIL- C-85285 top coat)	1	OK
	2	OK
	3	OK

APPENDIX G. PAINT ADHESION PHOTOGRAPHS

(Page G-2 Blank)


PAINT ADHESION
TBAc
Al 2024-T3, bare, anodized
MIL-PRF-85582 primer
Coupon 1


PAINT ADHESION
TBAc
Al 2024-T3, bare, anodized
MIL-PRF-85582 primer
Coupon 2


PAINT ADHESION
TBAc
Al 2024-T3, bare, anodized
MIL-PRF-85582 primer
Coupon 3

APPENDIX H. FLUORESCENT PENETRANT DATA SHEETS

(Page H-2 Blank)

FLUORESCENT PENETRATION INSPECTION

(1.3.5)

ATC MATERIALS LABORATORY

Client Name Army Research Laboratory (ARL)
POC Mr. Wayne W. Ziegler
Address
Telephone 410-306-0746

TESTING LABORATORY
Name ATC Materials Laboratory
POC Mr. William Taylor
Address ATTN: TEDT-AT-WFA
APG, MD 21005-5059
Telephone (410) 278-4461

Cleaner Tested

Product Name: TBAc
Company Name: Lyondell Chemical Company
Company Address:
POC:

Specimen Information:

Alloy Type
Surface Treatment
Condition

Solution Conditions:

Concentration
Diluent Used
Temperature

Test Condition:

Exposure:
Date/Time In:
Date/Time Out:
POC for Testing: Mr. William Taylor
Test Instrumentation:

CONTROL SAMPLES															
	CRACK 1			CRACK 2			CRACK 3			CRACK 4			CRACK 5		
TAM	BKGD	CRACK	DIFF	BKGD	CRACK	DIFF	BKGD	CRACK	DIFF	BKGD	CRACK	DIFF	BKGD	CRACK	DIFF
TRIAL 1	0.05	5.81	5.76	0.05	1.43	1.38	0.05	0.78	0.73	0.05	0.56	0.51	0.05	0.57	0.52
TRIAL 2	0.05	6.30	6.25	0.05	1.82	1.77	0.05	0.47	0.42	0.05	0.38	0.33	0.05	0.47	0.42
TRIAL 3	0.05	8.18	8.13	0.05	3.92	3.87	0.05	1.43	1.38	0.05	0.72	0.67	0.05	0.67	0.62
AVG			6.71			2.34			0.84			0.50			0.52
JAP															
TRIAL 1	0.06	0.35	0.29	0.06	0.28	0.22	0.07	0.80	0.73	0.05	0.26	0.21	0.05	0.35	0.30
TRIAL 2	0.05	0.44	0.39	0.05	0.41	0.36	0.05	0.80	0.75	0.05	0.59	0.54	0.05	0.86	0.81
TRIAL 3	0.05	0.53	0.48	0.05	0.45	0.40	0.06	0.66	0.60	0.05	1.23	1.18	0.05	0.71	0.66
AVG			0.39			0.33			0.69			0.64			0.59
TOTAL AVG		0.53													

TEST SAMPLES															
	CRACK 1			CRACK 2			CRACK 3			CRACK 4			CRACK 5		
TAM	BKGD	CRACK	DIFF	BKGD	CRACK	DIFF	BKGD	CRACK	DIFF	BKGD	CRACK	DIFF	BKGD	CRACK	DIFF
TRIAL 1	0.03	3.63	3.60	0.03	1.27	1.24	0.03	0.88	0.85	0.03	0.56	0.53	0.03	0.87	0.84
TRIAL 2	0.04	3.59	3.55	0.04	0.78	0.74	0.04	0.78	0.74	0.04	0.19	0.15	0.04	0.21	0.17
TRIAL 3	0.03	2.91	2.88	0.03	0.97	0.94	0.03	0.57	0.54	0.03	0.15	0.12	0.03	0.35	0.32
AVG			3.34			0.97			0.71			0.27			0.44
JAP															
TRIAL 1	0.03	1.85	1.82	0.03	3.87	3.84	0.03	2.04	2.01	0.03	2.42	2.39	0.03	3.53	3.50
TRIAL 2	0.03	1.23	1.20	0.03	2.78	2.75	0.03	1.14	1.11	0.03	2.87	2.84	0.03	1.83	1.80
TRIAL 3	0.03	1.17	1.14	0.03	1.07	1.04	0.03	1.26	1.23	0.03	2.39	2.36	0.03	1.65	1.62
AVG			1.39			2.54			1.45			2.53			2.31
TOTAL AVG		2.04													

FLUORESCENT PENETRATION INSPECTION

(1.3.5)

ATC MATERIALS LABORATORY

Client Name Army Research Laboratory (ARL)
POC Mr. Wayne W. Ziegler
Address
Telephone 410-306-0746

TESTING LABORATORY
Name ATC Materials Laboratory
POC Mr. William Taylor
Address ATTN: TEDT-AT-WFA
APG, MD 21005-5059
Telephone (410) 278-4461

Cleaner Tested
Product Name: TBAc
Company Name: Lyondell Chemical Company
Company Address:
POC:

Specimen Information:
Alloy Type
Surface Treatment
Condition

Solution Conditions:
Concentration
Diluent Used
Temperature

Test Condition:
Exposure:
Date/Time In:
Date/Time Out:
POC for Testing: Mr. William Taylor
Test Instrumentation:

SPOT METER LIGHT INTENSITY VALUE - CONTROL SAMPLES										
SAMPLE	TRIAL 1			TRIAL 2			TRIAL 3			Avg
	BKGD	CRACK	DIFF	BKGD	CRACK	DIFF	BKGD	CRACK	DIFF	
Inconel 718 w/ 0.020 crack (R-91)	0.27	1.77	1.50	0.09	1.80	1.71	0.46	2.49	2.03	1.75
Inconel 718 w/ 0.060 crack (R-70)	0.24	9.83	9.59	0.99	9.60	8.61	0.38	7.89	7.51	8.57
Titanium 4911 w/ 0.375 crack (T-1)	0.65	13.63	12.98	0.06	12.42	12.36	0.69	17.50	16.81	14.05
Titanium 4911 w/ 0.060 crack (T-62)	0.04	2.14	2.10	0.11	2.99	2.88	0.04	2.03	1.99	2.32

SPOT METER LIGHT INTENSITY VALUE - TEST SAMPLES										
SAMPLE	TRIAL 1			TRIAL 2			TRIAL 3			Avg
	BKGD	CRACK	DIFF	BKGD	CRACK	DIFF	BKGD	CRACK	DIFF	
Inconel 718 w/ 0.020 crack (R-91)	0.21	2.12	1.91	0.14	2.75	2.61	0.17	2.25	2.08	2.20
Inconel 718 w/ 0.060 crack (R-70)	1.16	8.06	6.90	0.64	7.93	7.29	0.33	8.37	8.04	7.41
Titanium 4911 w/ 0.375 crack (T-1)	0.20	3.69	3.49	0.21	8.39	8.18	0.10	12.17	12.07	7.91
Titanium 4911 w/ 0.060 crack (T-62)	0.16	1.86	1.70	0.38	2.76	2.38	0.05	2.57	2.52	2.20

APPENDIX I. WATER BREAK FREE DATA SHEETS

(Page I-2 Blank)

WATER BREAK FREE

(1.3.6)

ATC MATERIALS LABORATORY

	TESTING LABORATORY
Client Name Army Research Laboratory (ARL)	Name ATC Materials Laboratory
POC Mr. Wayne W. Ziegler	POC Mr. William Taylor
Address	Address ATTN: TEDT-AT-WFA
	APG, MD 21005-5059
Telephone 410-306-0746	Telephone (410) 278-4461

Cleaner Tested

Product Name: TBAc

Company Name: Lyondell Chemical Company

Company Address:

POC:

Specimen Information:	**Solution Conditions:**
Alloy Type	Concentration Standard
Surface Treatment	Diluent Used DI Water if Needed
Condition/Humidity	Temperature Ambient

Test Condition:

Exposure: Standard Contaminant for 2 hr @ 130ºF

Date/Time In:	Date/Time Out:
POC for Testing: Mr. William Taylor	Test Instrumentation:

OBSERVATIONS/DISCUSSION OF TEST RESULTS:

Water break = 10 seconds.

(Page I-4 Blank)

APPENDIX J. TEMPERATURE STABILITY DATA SHEETS

(Page J-2 Blank)

TEMPERATURE STABILITY

(1.4.1)

ATC MATERIALS LABORATORY

	TESTING LABORATORY
Client Name Army Research Laboratory (ARL)	Name ATC Materials Laboratory
POC Mr. Wayne W. Ziegler	POC Mr. William Taylor
Address	Address ATTN: TEDT-AT-WFA
	APG, MD 21005-5059
Telephone 410-306-0746	Telephone (410) 278-4461

Cleaner Tested

Product Name: TBAc

Company Name: Lyondell Chemical Company

Company Address:

POC:

Specimen Information:

Alloy Type

Surface Treatment

Condition/Humidity

Solution Conditions:

Concentration as received

Diluent Used none

Temperature

Test Condition:

Exposure: Cycle between 0°F (-17.8°C) for one hour and 120°F (48.9°C) for one hour a total of five times

Date/Time In: 25 November 2005

Date/Time Out:

POC for Testing: Mr. William Taylor

Test Instrumentation:

CYCLE NO.	OBSERVATIONS
1	No Effects
2	No Effects
3	No Effects
4	No Effects
5	No Effects

(Page J-4 Blank)

APPENDIX K. TOTAL IMMERSION CORROSION DATA SHEETS

(Page K-2 Blank)

TOTAL IMMERSION CORROSION

(2.1.1)

ATC MATERIALS LABORATORY

	TESTING LABORATORY
Client Name Army Research Laboratory (ARL)	Name ATC Materials Laboratory
POC Mr. Wayne W. Ziegler	POC Mr. William Taylor
Address	Address ATTN: TEDT-AT-WFA
	APG, MD 21005-5059
Telephone 410-306-0746	Telephone (410) 278-4461

Cleaner Tested

Product Name: TBAC

Company Name: Lyondell Chemical Company

Company Address:

POC:

Specimen Information:	**Solution Conditions:**
Alloy Type TI AMS 4911	Concentration
Surface Treatment	Diluent Used As Received
Condition/Humidity	Temperature 100°F

Test Condition:

Exposure: 24 hr + 144 hr

Date/Time In: 22 August 2005, 0730 — Date/Time Out 24 hr Insp: 23 August 2005, 0730

POC for Testing: Mr. William Taylor — Date/Time Out 168 hr Insp: 29 August 2005, 0930

ALLOY TYPE: TI AMS 4911

	WEIGHTS					
		AFTER		Weight Loss/Gain (mg)		Total
SPECIMEN #	ORIGINAL	24 Hrs	+144 Hrs	24 Hrs	+144 Hrs	mg / cm^2
Control	9.4929	9.4928	9.4928	-0.1	-0.1	0.00
1	6.8838	6.8838	6.8833	0.0	-0.5	-0.02
2	6.8550	6.8548	6.8546	-0.2	-0.4	-0.01
3	6.7563	6.7562	6.7560	-0.1	-0.3	-0.01
AVG	6.8317	6.8316	6.8313	-0.1	-0.4	-0.01

REMARKS:

24 Hours: No Effects.

144 Hours: No Effects.

TOTAL IMMERSION CORROSION

(2.1.1)

ATC MATERIALS LABORATORY

	TESTING LABORATORY
Client Name Army Research Laboratory (ARL)	Name ATC Materials Laboratory
POC Mr. Wayne W. Ziegler	POC Mr. William Taylor
Address	Address ATTN: TEDT-AT-WFA
	APG, MD 21005-5059
Telephone 410-306-0746	Telephone (410) 278-4461

Cleaner Tested

Product Name: TBAC

Company Name: Lyondell Chemical Company

Company Address:

POC:

Specimen Information:	**Solution Conditions:**
Alloy Type STEEL A36	Concentration
Surface Treatment	Diluent Used As Received
Condition/Humidity	Temperature 100°F

Test Condition:

Exposure: 24 hr + 144 hr

Date/Time In: 28 July 2005, 0730 — Date/Time Out 24 hr Insp: 29 July 2005, 0730

POC for Testing: Mr. William Taylor — Date/Time Out 168 hr Insp: 3 August 2005, 0930

ALLOY TYPE: STEEL A36

	WEIGHTS					
		AFTER		Weight Loss/Gain (mg)		Total
SPECIMEN #	ORIGINAL	24 Hrs	+144 Hrs	24 Hrs	+144 Hrs	mg / cm^2
Control	14.6245	14.6251	14.6251	0.6	0.6	0.02
1	16.5240	16.5238	16.5237	-0.2	-0.3	-0.01
2	16.6454	16.6451	16.6451	-0.3	-0.3	-0.01
3	15.9951	15.9952	15.9953	0.1	0.2	0.01
AVG	16.3882	16.3880	16.3880	-0.1	-0.1	0.00

REMARKS:

24 Hours: No Effects.

144 Hours: No Effects.

TOTAL IMMERSION CORROSION

(2.1.1)

ATC MATERIALS LABORATORY

	TESTING LABORATORY
Client Name Army Research Laboratory (ARL)	Name ATC Materials Laboratory
POC Mr. Wayne W. Ziegler	POC Mr. William Taylor
Address	Address ATTN: TEDT-AT-WFA
	APG, MD 21005-5059
Telephone 410-306-0746	Telephone (410) 278-4461

Cleaner Tested

Product Name: TBAC

Company Name: Lyondell Chemical Company

Company Address:

POC:

Specimen Information:	**Solution Conditions:**
Alloy Type 1020	Concentration
Surface Treatment	Diluent Used As Received
Condition/Humidity	Temperature 100°F

Test Condition:

Exposure: 24 hr + 144 hr

Date/Time In: 3 August 2005, 0730 — Date/Time Out 24 hr Insp: 4 August 2005, 0730

POC for Testing: Mr. William Taylor — Date/Time Out 168 hr Insp: 10 August 2005, 0930

ALLOY TYPE: 1020

	WEIGHTS					
		AFTER		Weight Loss/Gain (mg)		Total
SPECIMEN #	ORIGINAL	24 Hrs	+144 Hrs	24 Hrs	+144 Hrs	mg / cm^2
Control	15.7339	15.7343	15.7343	0.4	0.4	0.01
1	15.6855	15.6856	15.6860	0.1	0.5	0.02
2	15.6858	15.6860	15.6860	0.2	0.2	0.01
3	15.4730	15.4728	15.4733	-0.2	0.3	0.01
AVG	15.6148	15.6148	15.6151	0.0	0.3	0.01

REMARKS:

24 Hours: No Effects.

144 Hours: No Effects.

TOTAL IMMERSION CORROSION

(2.1.1)

ATC MATERIALS LABORATORY

	TESTING LABORATORY
Client Name Army Research Laboratory (ARL)	Name ATC Materials Laboratory
POC Mr. Wayne W. Ziegler	POC Mr. William Taylor
Address	Address ATTN: TEDT-AT-WFA
	APG, MD 21005-5059
Telephone 410-306-0746	Telephone (410) 278-4461

Cleaner Tested

Product Name: TBAC

Company Name: Lyondell Chemical Company

Company Address:

POC:

Specimen Information:	**Solution Conditions:**
Alloy Type 4340	Concentration
Surface Treatment	Diluent Used As Received
Condition/Humidity	Temperature 100°F

Test Condition:

Exposure: 24 hr + 144 hr

Date/Time In: 17 August 2005, 0730 — Date/Time Out 24 hr Insp: 18 August 2005, 0730

POC for Testing: Mr. William Taylor — Date/Time Out 168 hr Insp: 24 August 2005, 0930

ALLOY TYPE: 4340

	WEIGHTS					
		AFTER		Weight Loss/Gain (mg)		Total
SPECIMEN #	ORIGINAL	24 Hrs	+144 Hrs	24 Hrs	+144 Hrs	mg / cm^2
Control	14.9257	14.9257	14.9258	0.0	0.1	0.00
1	15.8981	15.8967	15.8976	-1.4	-0.5	-0.02
2	16.9862	16.9851	16.9862	-1.1	0.0	0.00
3	16.4226	16.4211	16.4227	-1.5	0.1	0.00
AVG	16.4356	16.4343	16.4355	-1.3	-0.1	0.00

REMARKS:

24 Hours: No Effects.

144 Hours: No Effects.

TOTAL IMMERSION CORROSION

(2.1.1)

ATC MATERIALS LABORATORY

	TESTING LABORATORY
Client Name Army Research Laboratory (ARL)	Name ATC Materials Laboratory
POC Mr. Wayne W. Ziegler	POC Mr. William Taylor
Address	Address ATTN: TEDT-AT-WFA
	APG, MD 21005-5059
Telephone 410-306-0746	Telephone (410) 278-4461

Cleaner Tested

Product Name: TBAC

Company Name: Lyondell Chemical Company

Company Address:

POC:

Specimen Information:	**Solution Conditions:**
Alloy Type MG - MAGNESIUM	Concentration
Surface Treatment	Diluent Used As Received
Condition/Humidity	Temperature 100°F

Test Condition:

Exposure: 24 hr + 144 hr

Date/Time In: 17 August 2005, 0730 — Date/Time Out 24 hr Insp: 18 August 2005, 0730

POC for Testing: Mr. William Taylor — Date/Time Out 168 hr Insp: 24 August 2005, 0930

ALLOY TYPE: MG - MAGNESIUM

	WEIGHTS					
		AFTER		Weight Loss/Gain (mg)		Total
SPECIMEN #	ORIGINAL	24 Hrs	+144 Hrs	24 Hrs	+144 Hrs	mg / cm^2
Control	3.6920	3.6918	3.6920	-0.2	0.0	0.00
1	3.7191	3.7186	3.7184	-0.5	-0.7	-0.02
2	3.7181	3.7177	3.7175	-0.4	-0.6	-0.02
3	3.6795	3.6794	3.6793	-0.1	-0.2	-0.01
AVG	3.7056	3.7052	3.7051	-0.3	-0.5	-0.02

REMARKS:

24 Hours: No Effects.

144 Hours: No Effects.

TOTAL IMMERSION CORROSION

(2.1.1)

ATC MATERIALS LABORATORY

	TESTING LABORATORY
Client Name Army Research Laboratory (ARL)	Name ATC Materials Laboratory
POC Mr. Wayne W. Ziegler	POC Mr. William Taylor
Address	Address ATTN: TEDT-AT-WFA
	APG, MD 21005-5059
Telephone 410-306-0746	Telephone (410) 278-4461

Cleaner Tested

Product Name: TBAC

Company Name: Lyondell Chemical Company

Company Address:

POC:

Specimen Information:	**Solution Conditions:**
Alloy Type BRASS 36000	Concentration
Surface Treatment	Diluent Used As Received
Condition/Humidity	Temperature 100°F

Test Condition:

Exposure: 24 hr + 144 hr

Date/Time In: 28 July 2005, 0730 — Date/Time Out 24 hr Insp: 29 July 2005, 0730

POC for Testing: Mr. William Taylor — Date/Time Out 168 hr Insp: 4 August 2005, 0930

ALLOY TYPE: BRASS 36000

	WEIGHTS					
		AFTER		Weight Loss/Gain (mg)		Total
SPECIMEN #	ORIGINAL	24 Hrs	+144 Hrs	24 Hrs	+144 Hrs	mg / cm^2
Control	19.2848	19.2846	19.2847	-0.2	-0.1	0.00
1	18.9775	18.9782	18.9785	0.7	1.0	0.04
2	18.6994	18.6998	18.6995	0.4	0.1	0.00
3	17.8560	17.8561	17.8558	0.1	-0.2	-0.01
AVG	18.5110	18.5114	18.5113	0.4	0.3	0.01

REMARKS:

24 Hours: No Effects..

144 Hours: No Effects.

TOTAL IMMERSION CORROSION

(2.1.1)

ATC MATERIALS LABORATORY

	TESTING LABORATORY
Client Name Army Research Laboratory (ARL)	Name ATC Materials Laboratory
POC Mr. Wayne W. Ziegler	POC Mr. William Taylor
Address	Address ATTN: TEDT-AT-WFA
	APG, MD 21005-5059
Telephone 410-306-0746	Telephone (410) 278-4461

Cleaner Tested

Product Name: TBAC

Company Name: Lyondell Chemical Company

Company Address:

POC:

Specimen Information:	**Solution Conditions:**
Alloy Type MAR	Concentration
Surface Treatment	Diluent Used As Received
Condition/Humidity	Temperature 100°F

Test Condition:

Exposure: 24 hr + 144 hr

Date/Time In: 2 August 2005, 0730 — Date/Time Out 24 hr Insp: 3 August 2005, 0730

POC for Testing: Mr. William Taylor — Date/Time Out 168 hr Insp: 9 August 2005, 0930

ALLOY TYPE: MAR

	WEIGHTS					
		AFTER		Weight Loss/Gain (mg)		Total
SPECIMEN #	ORIGINAL	24 Hrs	+144 Hrs	24 Hrs	+144 Hrs	mg / cm^2
Control	16.9232	16.9231	16.9233	-0.1	0.1	0.00
1	16.4973	16.4978	16.4979	0.5	0.6	0.02
2	16.8876	16.8875	16.8873	-0.1	-0.3	-0.01
3	19.6596	19.6594	19.6596	-0.2	0.0	0.00
AVG	17.6815	17.6816	17.6816	0.1	0.1	0.00

REMARKS:

24 Hours: No Effects.

144 Hours: No Effects.

TOTAL IMMERSION CORROSION

(2.1.1)

ATC MATERIALS LABORATORY

	TESTING LABORATORY
Client Name Army Research Laboratory (ARL)	Name ATC Materials Laboratory
POC Mr. Wayne W. Ziegler	POC Mr. William Taylor
Address	Address ATTN: TEDT-AT-WFA
	APG, MD 21005-5059
Telephone 410-306-0746	Telephone (410) 278-4461

Cleaner Tested

Product Name: TBAC

Company Name: Lyondell Chemical Company

Company Address:

POC:

Specimen Information:	**Solution Conditions:**
Alloy Type 13-8	Concentration
Surface Treatment	Diluent Used As Received
Condition/Humidity	Temperature 100°F

Test Condition:

Exposure: 24 hr + 144 hr

Date/Time In: 3 August 2005, 0730 — Date/Time Out 24 hr Insp: 4 August 2005, 0730

POC for Testing: Mr. William Taylor — Date/Time Out 168 hr Insp: 10 August 2005, 0930

ALLOY TYPE: 13-8

	WEIGHTS					
		AFTER		Weight Loss/Gain (mg)		Total
SPECIMEN #	ORIGINAL	24 Hrs	+144 Hrs	24 Hrs	+144 Hrs	mg / cm^2
Control	15.8999	15.9000	15.8999	0.1	0.0	0.00
1	15.8812	15.8811	15.8812	-0.1	0.0	0.00
2	16.3507	16.3500	16.3501	-0.7	-0.6	-0.02
3	16.8935	16.8936	16.8940	0.1	0.5	0.02
AVG	16.3751	16.3749	16.3751	-0.2	0.0	0.00

REMARKS:

24 Hours: No Effects.

144 Hours: No Effects.

TOTAL IMMERSION CORROSION

(2.1.1)

ATC MATERIALS LABORATORY

	TESTING LABORATORY
Client Name Army Research Laboratory (ARL)	Name ATC Materials Laboratory
POC Mr. Wayne W. Ziegler	POC Mr. William Taylor
Address	Address ATTN: TEDT-AT-WFA
	APG, MD 21005-5059
Telephone 410-306-0746	Telephone (410) 278-4461

Cleaner Tested

Product Name: TBAC

Company Name: Lyondell Chemical Company

Company Address:

POC:

Specimen Information:	**Solution Conditions:**
Alloy Type ZN - ZINC	Concentration
Surface Treatment	Diluent Used As Received
Condition/Humidity	Temperature 100°F

Test Condition:

Exposure: 24 hr + 144 hr

Date/Time In: 15 August 2005, 0730 — Date/Time Out 24 hr Insp: 16 August 2005, 0730

POC for Testing: Mr. William Taylor — Date/Time Out 168 hr Insp: 22 August 2005, 0930

ALLOY TYPE: ZN - ZINC

	WEIGHTS					
		AFTER		Weight Loss/Gain (mg)		Total
SPECIMEN #	ORIGINAL	24 Hrs	+144 Hrs	24 Hrs	+144 Hrs	mg / cm^2
Control	14.3321	14.3319	14.3321	-0.2	0.0	0.00
1	14.1685	14.1680	14.1684	-0.5	-0.1	0.00
2	14.2426	14.2423	14.2429	-0.3	0.3	0.01
3	14.2744	14.2742	14.2746	-0.2	0.2	0.01
AVG	14.2285	14.2282	14.2286	-0.3	0.1	0.00

REMARKS:

24 Hours: No Effects.

144 Hours: No Effects.

TOTAL IMMERSION CORROSION

(2.1.1)

ATC MATERIALS LABORATORY

	TESTING LABORATORY
Client Name Army Research Laboratory (ARL)	Name ATC Materials Laboratory
POC Mr. Wayne W. Ziegler	POC Mr. William Taylor
Address	Address ATTN: TEDT-AT-WFA
	APG, MD 21005-5059
Telephone 410-306-0746	Telephone (410) 278-4461

Cleaner Tested

Product Name: TBAC

Company Name: Lyondell Chemical Company

Company Address:

POC:

Specimen Information:	**Solution Conditions:**
Alloy Type ALUM 7075- T6 BARE	Concentration
Surface Treatment	Diluent Used As Received
Condition/Humidity	Temperature 100°F

Test Condition:

Exposure: 24 hr + 144 hr

Date/Time In: 15 August 2005, 0730 — Date/Time Out 24 hr Insp: 16 August 2005, 0730

POC for Testing: Mr. William Taylor — Date/Time Out 168 hr Insp: 22 August 2005, 0930

ALLOY TYPE: ALUM 7075- T6 BARE

	WEIGHTS					
		AFTER		Weight Loss/Gain (mg)		Total
SPECIMEN #	ORIGINAL	24 Hrs	+144 Hrs	24 Hrs	+144 Hrs	mg / cm^2
Control	5.4860	5.4861	5.4861	0.1	0.1	0.00
1	5.4335	5.4337	5.4338	0.2	0.3	0.01
2	5.4518	5.4520	5.4521	0.2	0.3	0.01
3	5.4483	5.4483	5.4485	0.0	0.2	0.01
AVG	5.4445	5.4447	5.4448	0.1	0.3	0.01

REMARKS:

24 Hours: No Effects.

144 Hours: No Effects.

TOTAL IMMERSION CORROSION

(2.1.1)

ATC MATERIALS LABORATORY

	TESTING LABORATORY
Client Name Army Research Laboratory (ARL)	Name ATC Materials Laboratory
POC Mr. Wayne W. Ziegler	POC Mr. William Taylor
Address	Address ATTN: TEDT-AT-WFA
	APG, MD 21005-5059
Telephone 410-306-0746	Telephone (410) 278-4461

Cleaner Tested

Product Name: TBAC

Company Name: Lyondell Chemical Company

Company Address:

POC:

Specimen Information:	**Solution Conditions:**
Alloy Type AM355	Concentration
Surface Treatment	Diluent Used As Received
Condition/Humidity	Temperature 100°F

Test Condition:

Exposure: 24 hr + 144 hr

Date/Time In: 15 August 2005, 0730 — Date/Time Out 24 hr Insp: 16 August 2005, 0730

POC for Testing: Mr. William Taylor — Date/Time Out 168 hr Insp: 22 August 2005, 0930

ALLOY TYPE: AM355

	WEIGHTS					
		AFTER		Weight Loss/Gain (mg)		Total
SPECIMEN #	ORIGINAL	24 Hrs	+144 Hrs	24 Hrs	+144 Hrs	mg / cm^2
Control	3.7380	3.7380	3.7380	0.0	0.0	0.00
1	3.7132	3.7133	3.7136	0.1	0.4	0.01
2	3.6731	3.6733	3.6735	0.2	0.4	0.01
3	3.7095	3.7097	3.7098	0.2	0.3	0.01
AVG	3.6986	3.6988	3.6990	0.2	0.4	0.01

REMARKS:

24 Hours: No Effects.

144 Hours: No Effects.

TOTAL IMMERSION CORROSION

(2.1.1)

ATC MATERIALS LABORATORY

	TESTING LABORATORY
Client Name Army Research Laboratory (ARL)	Name ATC Materials Laboratory
POC Mr. Wayne W. Ziegler	POC Mr. William Taylor
Address	Address ATTN: TEDT-AT-WFA
	APG, MD 21005-5059
Telephone 410-306-0746	Telephone (410) 278-4461

Cleaner Tested

Product Name: TBAC

Company Name: Lyondell Chemical Company

Company Address:

POC:

Specimen Information:	**Solution Conditions:**
Alloy Type CAD	Concentration
Surface Treatment	Diluent Used As Received
Condition/Humidity	Temperature 100°F

Test Condition:

Exposure: 24 hr + 144 hr

Date/Time In: 15 August 2005, 0730 — Date/Time Out 24 hr Insp: 16 August 2005, 0730

POC for Testing: Mr. William Taylor — Date/Time Out 168 hr Insp: 22 August 2005, 0930

ALLOY TYPE: CAD

	WEIGHTS					
		AFTER		Weight Loss/Gain (mg)		Total
SPECIMEN #	ORIGINAL	24 Hrs	+144 Hrs	24 Hrs	+144 Hrs	mg / cm^2
Control	13.5770	13.5770	13.5770	0.0	0.0	0.00
1	13.6462	13.6451	13.6459	-1.1	-0.3	-0.01
2	14.1362	14.1351	14.1361	-1.1	-0.1	0.00
3	14.3382	14.3369	14.3375	-1.3	-0.7	-0.02
AVG	14.0402	14.0390	14.0398	-1.2	-0.4	-0.01

REMARKS:

24 Hours: No Effects.

144 Hours: No Effects.

TOTAL IMMERSION CORROSION

(2.1.1)

ATC MATERIALS LABORATORY

	TESTING LABORATORY
Client Name Army Research Laboratory (ARL)	Name ATC Materials Laboratory
POC Mr. Wayne W. Ziegler	POC Mr. William Taylor
Address	Address ATTN: TEDT-AT-WFA
	APG, MD 21005-5059
Telephone 410-306-0746	Telephone (410) 278-4461

Cleaner Tested

Product Name: TBAC

Company Name: Lyondell Chemical Company

Company Address:

POC:

Specimen Information:	**Solution Conditions:**
Alloy Type 5083	Concentration
Surface Treatment	Diluent Used As Received
Condition/Humidity	Temperature 100°F

Test Condition:

Exposure: 24 hr + 144 hr

Date/Time In: 15 August 2005, 0730 — Date/Time Out 24 hr Insp: 16 August 2005, 0730

POC for Testing: Mr. William Taylor — Date/Time Out 168 hr Insp: 22 August 2005, 0930

ALLOY TYPE: 5083

	WEIGHTS					
		AFTER		Weight Loss/Gain (mg)		Total
SPECIMEN #	ORIGINAL	24 Hrs	+144 Hrs	24 Hrs	+144 Hrs	mg / cm^2
Control	5.4280	5.4270	5.4280	-1.0	0.0	0.00
1	5.3658	5.3656	5.3658	-0.2	0.0	0.00
2	5.2401	5.2403	5.2401	0.2	0.0	0.00
3	5.3411	5.3414	5.3415	0.3	0.4	0.01
AVG	5.3157	5.3158	5.3158	0.1	0.1	0.00

REMARKS:

24 Hours: No Effects.

144 Hours: No Effects.

TOTAL IMMERSION CORROSION

(2.1.1)

ATC MATERIALS LABORATORY

	TESTING LABORATORY
Client Name Army Research Laboratory (ARL)	Name ATC Materials Laboratory
POC Mr. Wayne W. Ziegler	POC Mr. William Taylor
Address	Address ATTN: TEDT-AT-WFA
	APG, MD 21005-5059
Telephone 410-306-0746	Telephone (410) 278-4461

Cleaner Tested

Product Name: TBAC

Company Name: Lyondell Chemical Company

Company Address:

POC:

Specimen Information:	**Solution Conditions:**
Alloy Type 4140	Concentration
Surface Treatment	Diluent Used As Received
Condition/Humidity	Temperature 100°F

Test Condition:

Exposure: 24 hr + 144 hr

Date/Time In: 31 July 2006, 0730 — Date/Time Out 24 hr Insp: 1 August 2006, 0730

POC for Testing: Mr. William Taylor — Date/Time Out 168 hr Insp: 7 August 2006, 0900

ALLOY TYPE: 4140

	WEIGHTS					
		AFTER		Weight Loss/Gain (mg)		Total
SPECIMEN #	ORIGINAL	24 Hrs	+144 Hrs	24 Hrs	+144 Hrs	mg / cm^2
Control	18.0053	18.0055	18.0053	0.2	0.0	0.00
1	15.4531	15.4533	15.4532	0.2	0.1	0.00
2	15.0574	15.0571	15.0571	-0.3	-0.3	-0.01
3	13.5807	13.5807	13.5805	0.0	-0.2	-0.01
AVG	14.6971	14.6970	14.6969	0.0	-0.1	0.00

REMARKS:

24 Hours: No Effects.

144 Hours: No Effects.

TOTAL IMMERSION CORROSION

(2.1.1)

ATC MATERIALS LABORATORY

	TESTING LABORATORY
Client Name Army Research Laboratory (ARL)	Name ATC Materials Laboratory
POC Mr. Wayne W. Ziegler	POC Mr. William Taylor
Address	Address ATTN: TEDT-AT-WFA
	APG, MD 21005-5059
Telephone 410-306-0746	Telephone (410) 278-4461

Cleaner Tested

Product Name: TBAC

Company Name: Lyondell Chemical Company

Company Address:

POC:

Specimen Information:	**Solution Conditions:**
Alloy Type 2024	Concentration
Surface Treatment	Diluent Used As Received
Condition/Humidity	Temperature 100°F

Test Condition:

Exposure: 24 hr + 144 hr

Date/Time In: 31 July 2006, 0730 — Date/Time Out 24 hr Insp: 1 August 2006, 0730

POC for Testing: Mr. William Taylor — Date/Time Out 168 hr Insp: 7 August 2006, 0900

ALLOY TYPE: 2024

	WEIGHTS					
		AFTER		Weight Loss/Gain (mg)		Total
SPECIMEN #	ORIGINAL	24 Hrs	+144 Hrs	24 Hrs	+144 Hrs	mg / cm^2
Control	5.5944	5.5947	5.5945	0.3	0.1	0.00
1	5.5866	5.5864	5.5866	-0.2	0.0	0.00
2	5.5914	5.5913	5.5914	-0.1	0.0	0.00
3	5.6069	5.6069	5.6070	0.0	0.1	0.00
AVG	5.5950	5.5949	5.5950	-0.1	0.0	0.00

REMARKS:

24 Hours: No Effects.

144 Hours: No Effects.

TOTAL IMMERSION CORROSION

(2.1.1)

ATC MATERIALS LABORATORY

	TESTING LABORATORY
Client Name Army Research Laboratory (ARL)	Name ATC Materials Laboratory
POC Mr. Wayne W. Ziegler	POC Mr. William Taylor
Address	Address ATTN: TEDT-AT-WFA
	APG, MD 21005-5059
Telephone 410-306-0746	Telephone (410) 278-4461

Cleaner Tested

Product Name: TBAC

Company Name: Lyondell Chemical Company

Company Address:

POC:

Specimen Information:	**Solution Conditions:**
Alloy Type 304	Concentration
Surface Treatment	Diluent Used As Received
Condition/Humidity	Temperature 100°F

Test Condition:

Exposure: 24 hr + 144 hr

Date/Time In: 31 July 2006, 0730 — Date/Time Out 24 hr Insp: 1 August 2006, 0730

POC for Testing: Mr. William Taylor — Date/Time Out 168 hr Insp: 7 August 2006, 0900

ALLOY TYPE: 304

	WEIGHTS					
		AFTER		Weight Loss/Gain (mg)		Total
SPECIMEN #	ORIGINAL	24 Hrs	+144 Hrs	24 Hrs	+144 Hrs	mg / cm^2
Control	14.9064	14.9068	14.9065	0.4	0.1	0.00
1	14.8855	14.8856	14.8856	0.1	0.1	0.00
2	15.0083	15.0083	15.0083	0.0	0.0	0.00
3	14.9184	14.9182	14.9182	-0.2	-0.2	-0.01
AVG	14.9374	14.9374	14.9374	0.0	0.0	0.00

REMARKS:

24 Hours: No Effects.

144 Hours: No Effects.

TOTAL IMMERSION CORROSION

(2.1.1)

ATC MATERIALS LABORATORY

	TESTING LABORATORY
Client Name Army Research Laboratory (ARL)	Name ATC Materials Laboratory
POC Mr. Wayne W. Ziegler	POC Mr. William Taylor
Address	Address ATTN: TEDT-AT-WFA
	APG, MD 21005-5059
Telephone 410-306-0746	Telephone (410) 278-4461

Cleaner Tested

Product Name: TBAC

Company Name: Lyondell Chemical Company

Company Address:

POC:

Specimen Information:	**Solution Conditions:**
Alloy Type 6061	Concentration
Surface Treatment	Diluent Used As Received
Condition/Humidity	Temperature 100°F

Test Condition:

Exposure: 24 hr + 144 hr

Date/Time In: 31 July 2006, 0730 — Date/Time Out 24 hr Insp: 1 August 2006, 0730

POC for Testing: Mr. William Taylor — Date/Time Out 168 hr Insp: 7 August 2006, 0900

ALLOY TYPE: 6061

	WEIGHTS					
		AFTER		Weight Loss/Gain (mg)		Total
SPECIMEN #	ORIGINAL	24 Hrs	+144 Hrs	24 Hrs	+144 Hrs	mg / cm^2
Control	5.2771	5.2774	5.2775	0.3	0.4	0.01
1	5.2292	5.2294	5.2296	0.2	0.4	0.01
2	5.2198	5.2202	5.2203	0.4	0.5	0.02
3	5.2502	5.2506	5.2507	0.4	0.5	0.02
AVG	5.2331	5.2334	5.2335	0.3	0.5	0.02

REMARKS:

24 Hours: No Effects.

144 Hours: No Effects.

TOTAL IMMERSION CORROSION

(2.1.1)

ATC MATERIALS LABORATORY

	TESTING LABORATORY
Client Name Army Research Laboratory (ARL)	Name ATC Materials Laboratory
POC Mr. Wayne W. Ziegler	POC Mr. William Taylor
Address	Address ATTN: TEDT-AT-WFA
	APG, MD 21005-5059
Telephone 410-306-0746	Telephone (410) 278-4461

Cleaner Tested

Product Name: TBAC

Company Name: Lyondell Chemical Company

Company Address:

POC:

Specimen Information:	**Solution Conditions:**
Alloy Type Ni Plate	Concentration
Surface Treatment	Diluent Used As Received
Condition/Humidity	Temperature 100°F

Test Condition:

Exposure: 24 hr + 144 hr

Date/Time In: 31 July 2006, 0730 — Date/Time Out 24 hr Insp: 1 August 2006, 0730

POC for Testing: Mr. William Taylor — Date/Time Out 168 hr Insp: 7 August 2006, 0900

ALLOY TYPE: Ni Plate

	WEIGHTS					
		AFTER		Weight Loss/Gain (mg)		Total
SPECIMEN #	ORIGINAL	24 Hrs	+144 Hrs	24 Hrs	+144 Hrs	mg / cm^2
Control	15.9484	15.9487	15.9484	0.3	0.0	0.00
1	15.9136	15.9138	15.9137	0.2	0.1	0.00
2	15.9097	15.9099	15.9097	0.2	0.0	0.00
3	16.0060	16.0062	16.0061	0.2	0.1	0.00
AVG	15.9431	15.9433	15.9432	0.2	0.1	0.00

REMARKS:

24 Hours: No Effects.

144 Hours: No Effects.

TOTAL IMMERSION CORROSION

(2.1.1)

ATC MATERIALS LABORATORY

	TESTING LABORATORY
Client Name Army Research Laboratory (ARL)	Name ATC Materials Laboratory
POC Mr. Wayne W. Ziegler	POC Mr. William Taylor
Address	Address ATTN: TEDT-AT-WFA
	APG, MD 21005-5059
Telephone 410-306-0746	Telephone (410) 278-4461

Cleaner Tested

Product Name: TBAC

Company Name: Lyondell Chemical Company

Company Address:

POC:

Specimen Information:	**Solution Conditions:**
Alloy Type Chrome Plate	Concentration
Surface Treatment	Diluent Used As Received
Condition/Humidity	Temperature 100°F

Test Condition:

Exposure: 24 hr + 144 hr

Date/Time In: 31 July 2006, 0730 — Date/Time Out 24 hr Insp: 1 August 2006, 0730

POC for Testing: Mr. William Taylor — Date/Time Out 168 hr Insp: 7 August 2006, 0900

ALLOY TYPE: Chrome Plate

	WEIGHTS					
		AFTER		Weight Loss/Gain (mg)		Total
SPECIMEN #	ORIGINAL	24 Hrs	+144 Hrs	24 Hrs	+144 Hrs	mg / cm^2
Control	15.5461	15.5466	15.5463	0.5	0.2	0.01
1	15.6518	15.6523	15.6525	0.5	0.7	0.02
2	15.3421	15.3426	15.3427	0.5	0.6	0.02
3	15.8298	15.8302	15.8303	0.4	0.5	0.02
AVG	15.6079	15.6084	15.6085	0.5	0.6	0.02

REMARKS:

24 Hours: No Effects.

144 Hours: No Effects.

TOTAL IMMERSION CORROSION

(2.1.1)

ATC MATERIALS LABORATORY

	TESTING LABORATORY
Client Name Army Research Laboratory (ARL)	Name ATC Materials Laboratory
POC Mr. Wayne W. Ziegler	POC Mr. William Taylor
Address	Address ATTN: TEDT-AT-WFA
	APG, MD 21005-5059
Telephone 410-306-0746	Telephone (410) 278-4461

Cleaner Tested

Product Name: TBAC

Company Name: Lyondell Chemical Company

Company Address:

POC:

Specimen Information:	**Solution Conditions:**
Alloy Type Zn Plate	Concentration
Surface Treatment	Diluent Used As Received
Condition/Humidity	Temperature 100°F

Test Condition:

Exposure: 24 hr + 144 hr

Date/Time In: 31 July 2006, 0730 — Date/Time Out 24 hr Insp: 1 August 2006, 0730

POC for Testing: Mr. William Taylor — Date/Time Out 168 hr Insp: 7 August 2006, 0900

ALLOY TYPE: Zn Plate

	WEIGHTS					
		AFTER		Weight Loss/Gain (mg)		Total
SPECIMEN #	ORIGINAL	24 Hrs	+144 Hrs	24 Hrs	+144 Hrs	mg / cm^2
Control	15.5367	15.5370	15.5370	0.3	0.3	0.01
1	15.6662	15.6664	15.6665	0.2	0.3	0.01
2	15.5970	15.5969	15.5970	-0.1	0.0	0.00
3	15.4293	15.4291	15.4293	-0.2	0.0	0.00
AVG	15.5642	15.5641	15.5643	0.0	0.1	0.00

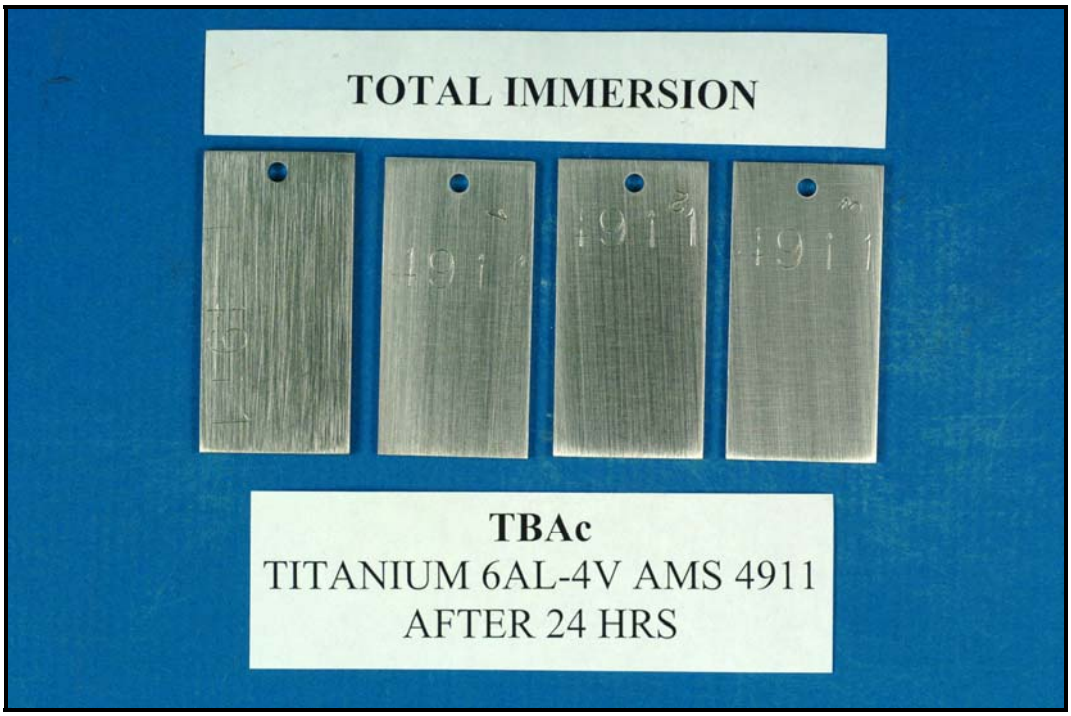
REMARKS:

24 Hours: No Effects.

144 Hours: No Effects.

APPENDIX L. TOTAL IMMERSION CORROSION PHOTOGRAPHS

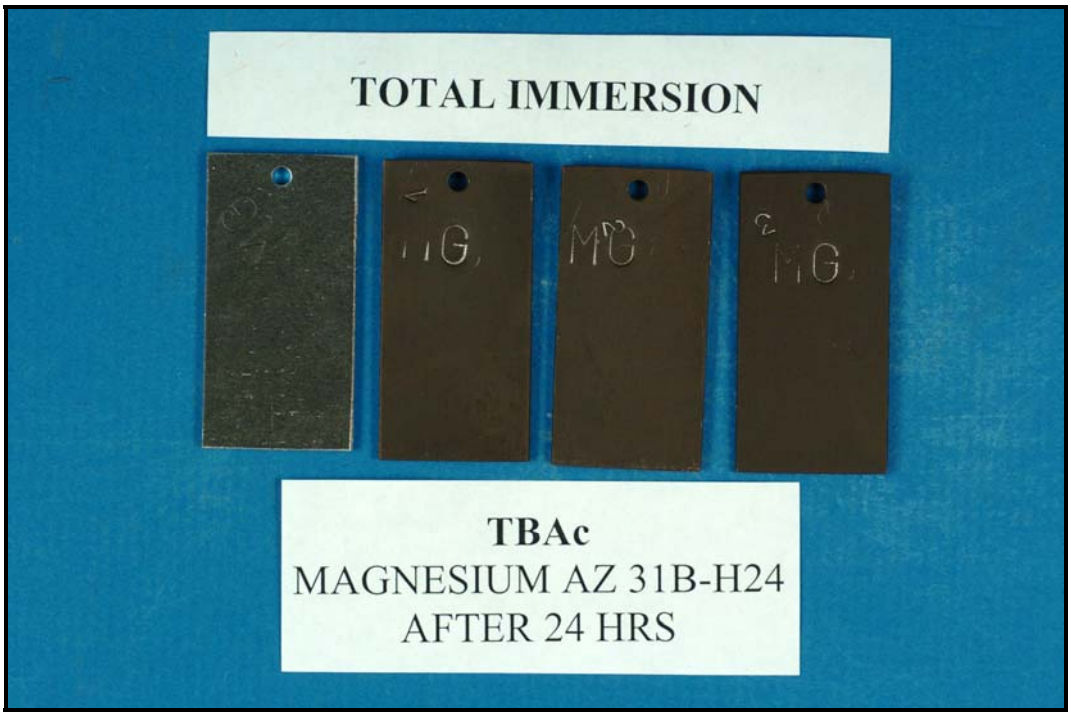
(Page L-2 Blank)


TOTAL IMMERSION
TBAc
TITANIUM 6AL-4V AMS 4911
AFTER 24 HRS

TOTAL IMMERSION
TBAc
STEEL ASTM A36
AFTER 24 HRS

TOTAL IMMERSION
TBAc
STEEL 1020 AMS 5046
AFTER 24 HRS

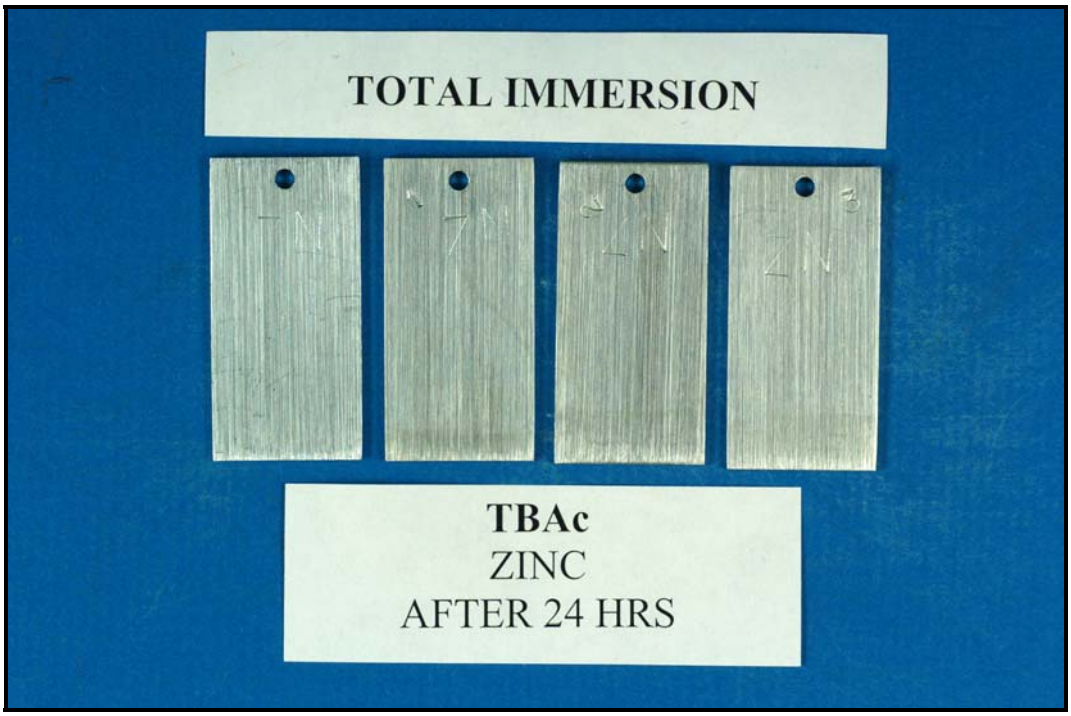
TOTAL IMMERSION
TBAc
STEEL 4340
AFTER 24 HRS


TOTAL IMMERSION
TBAc
MAGNESIUM AZ 31B-H24
AFTER 24 HRS

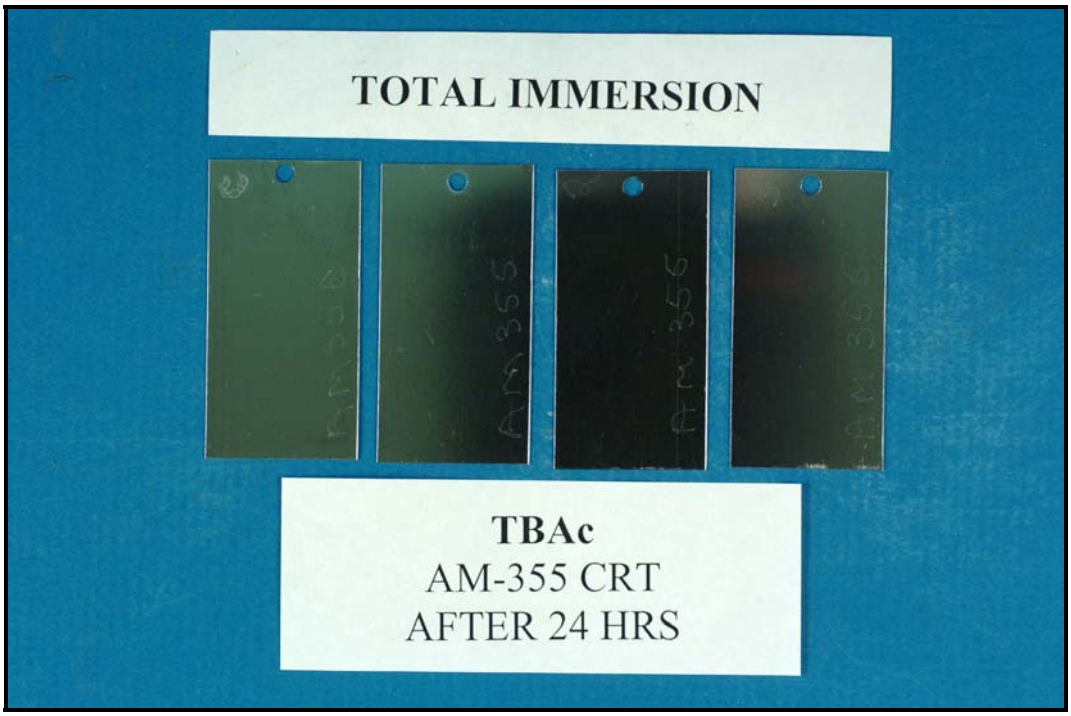
TOTAL IMMERSION
TBAc
BRASS
AFTER 24 HRS

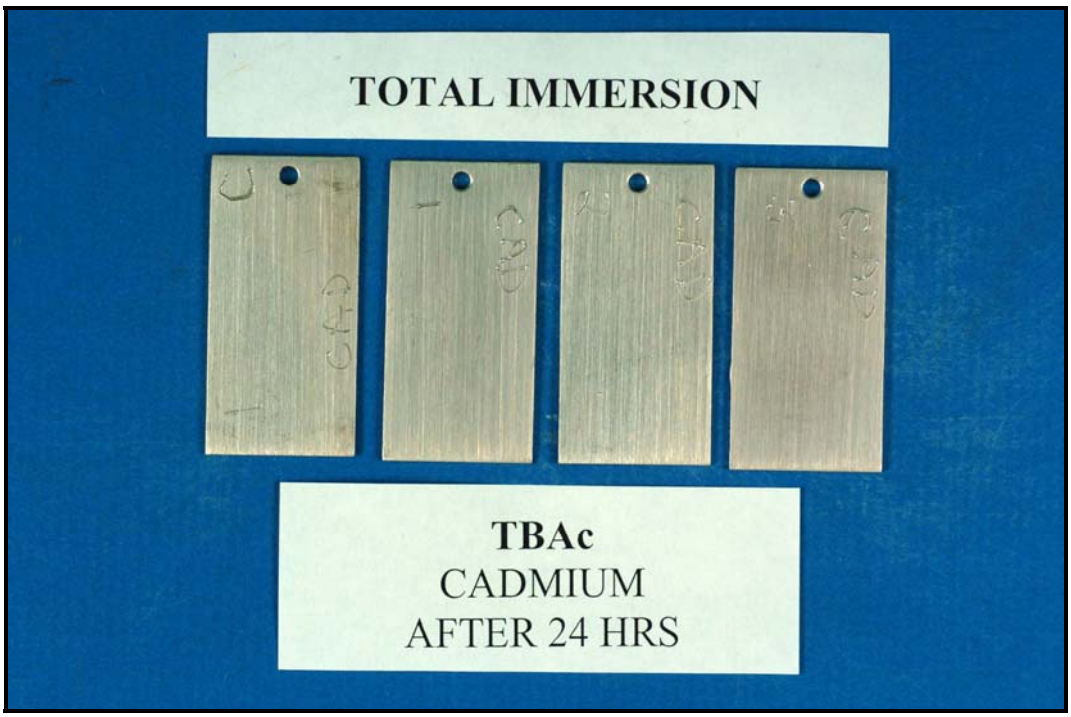
TOTAL IMMERSION
MAR
MAR
MAR
TBAc
MARAGING C250
AFTER 24 HRS

TOTAL IMMERSION
TBAc
STAINLESS STEEL 13-8 MO
AFTER 24 HRS

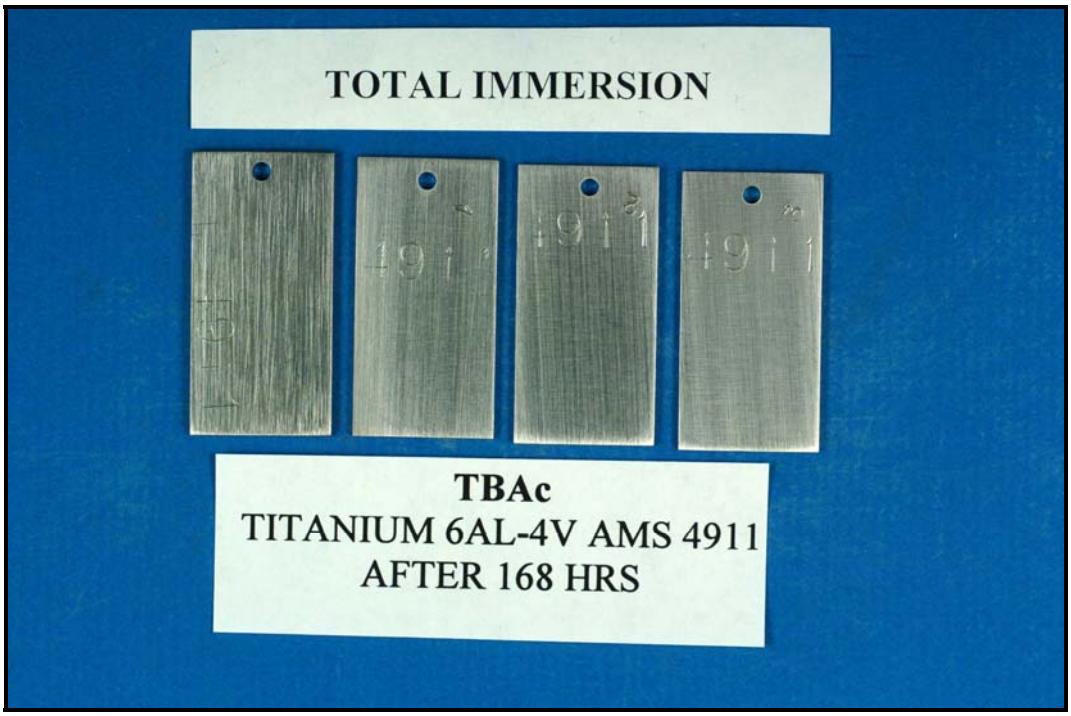

TOTAL IMMERSION
TBAc
ZINC
AFTER 24 HRS

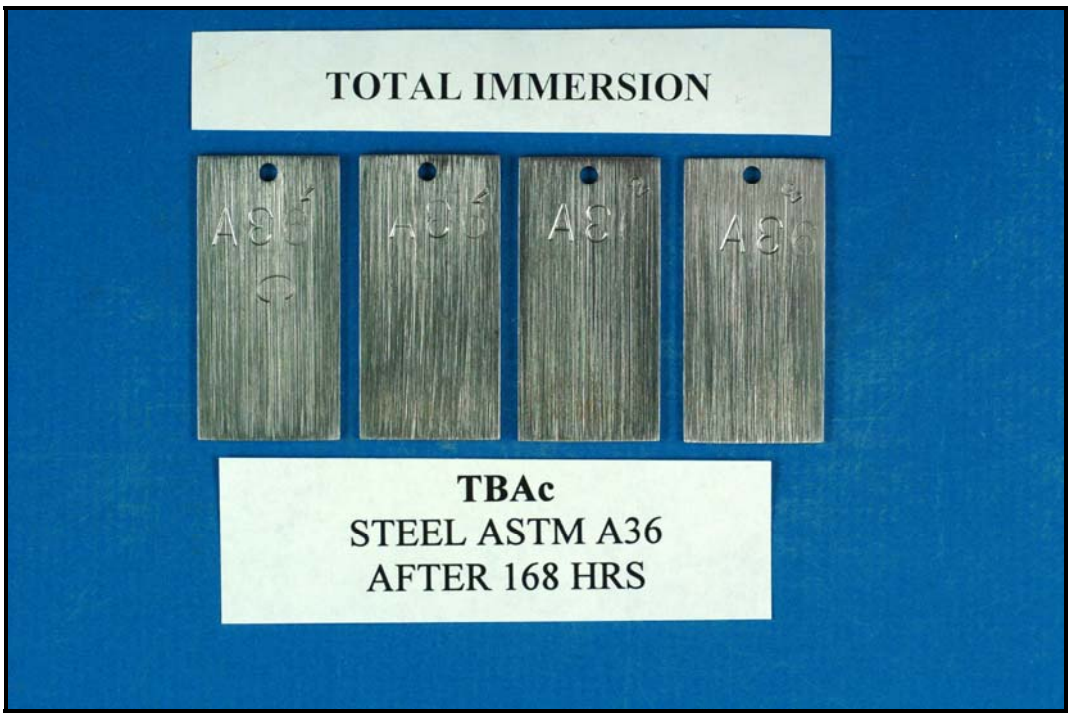
TOTAL IMMERSION
TBAc
ALUMINUM 7075 T6 BARE
AFTER 24 HRS


TOTAL IMMERSION
TBAc
AM-355 CRT
AFTER 24 HRS


TOTAL IMMERSION
TBAc
CADMIUM
AFTER 24 HRS

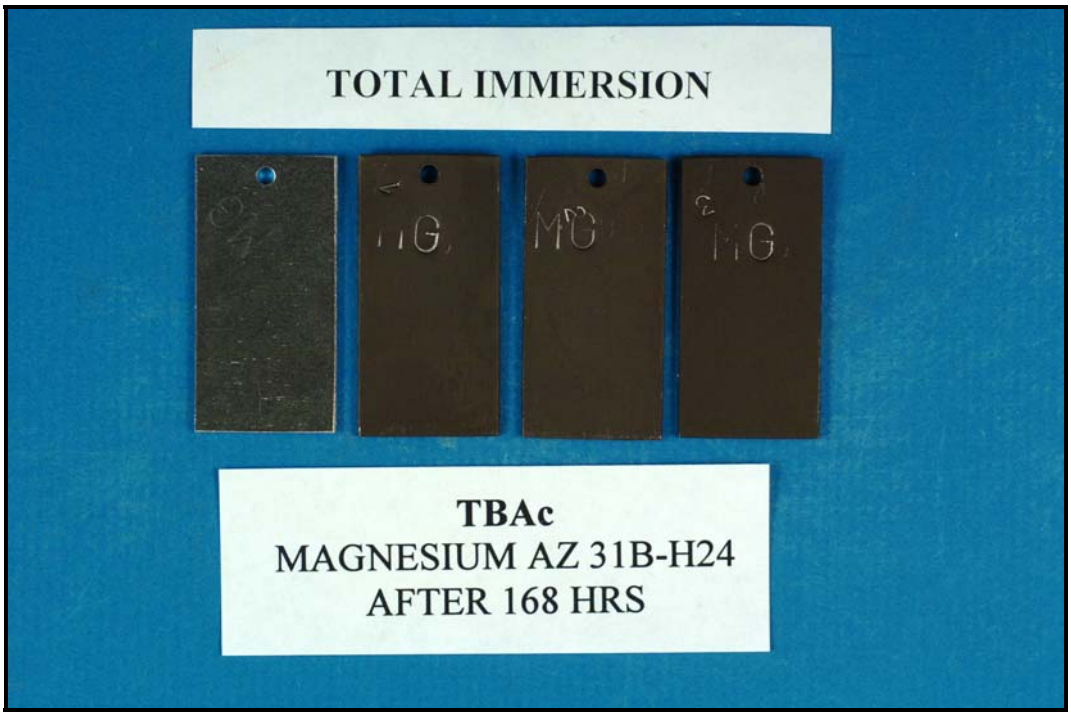
TOTAL IMMERSION
TBAc
ALUMINUM 5083 BARE
AFTER 24 HRS

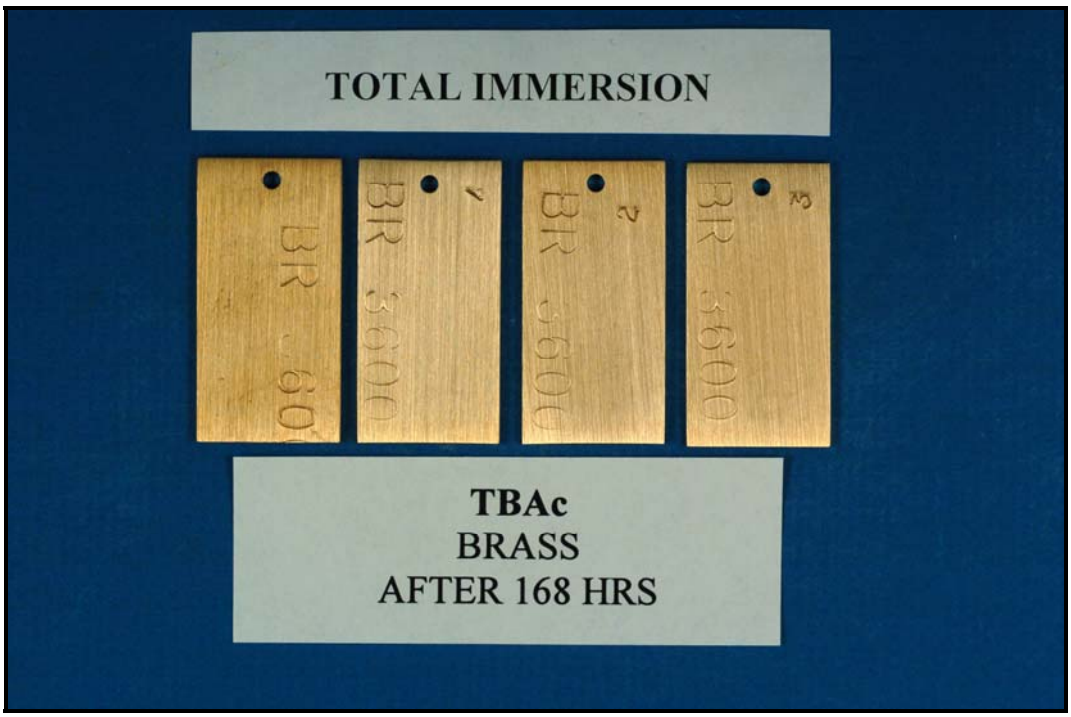

TOTAL IMMERSION
TBAc
TITANIUM 6AL-4V AMS 4911
AFTER 168 HRS


TOTAL IMMERSION
TBAc
STEEL ASTM A36
AFTER 168 HRS

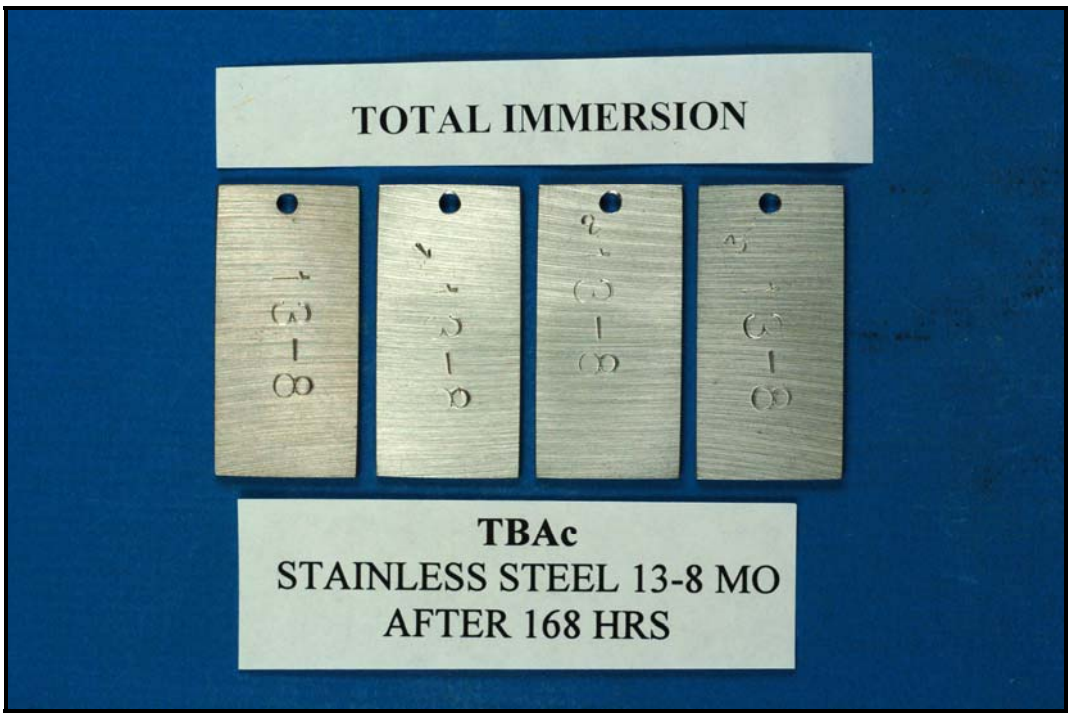
TOTAL IMMERSION
TBAc
STEEL 1020 AMS 5046
AFTER 168 HRS

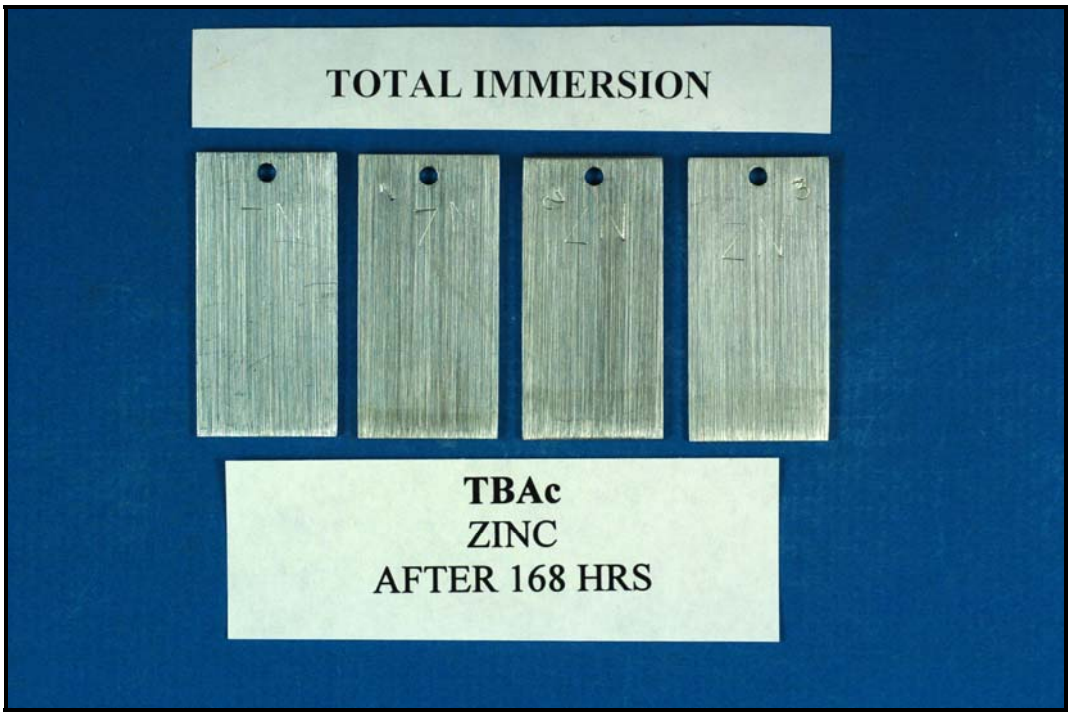
TOTAL IMMERSION
TBAc
STEEL 4340
AFTER 168 HRS

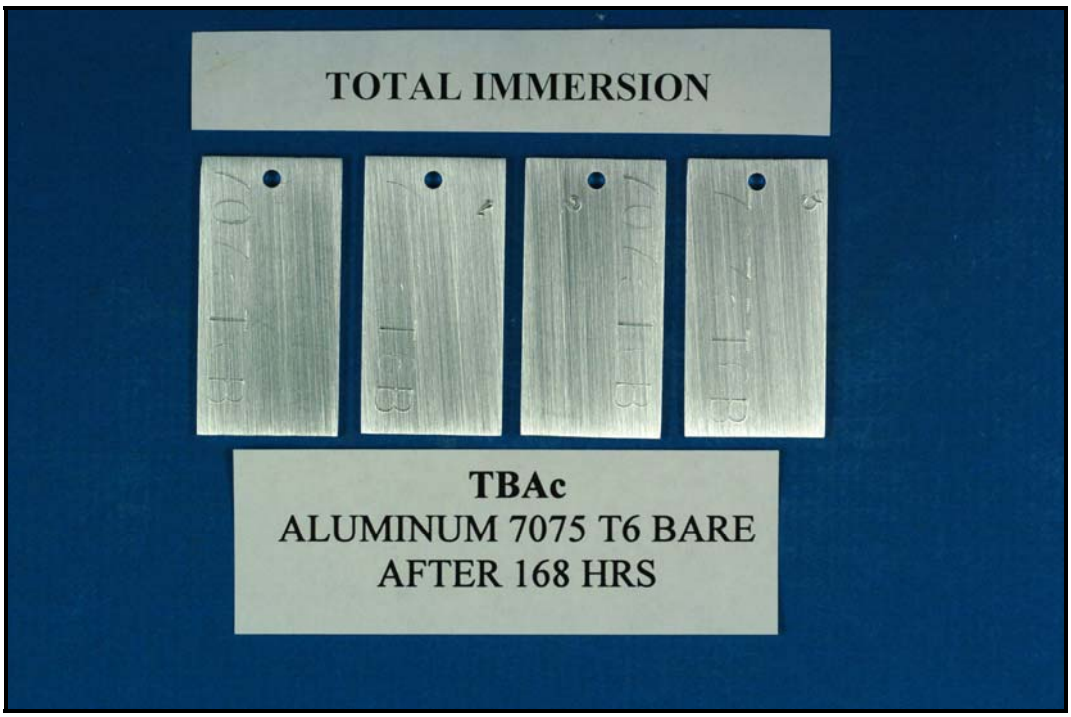

TOTAL IMMERSION
TBAc
MAGNESIUM AZ 31B-H24
AFTER 168 HRS

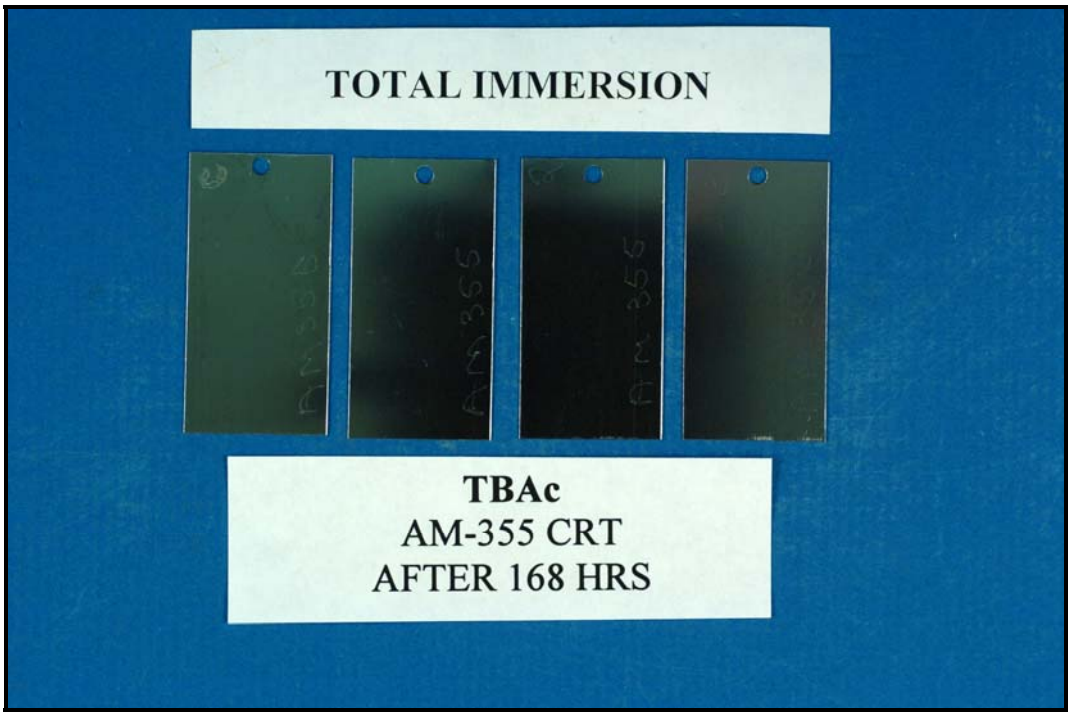

TOTAL IMMERSION
TBAc
BRASS
AFTER 168 HRS

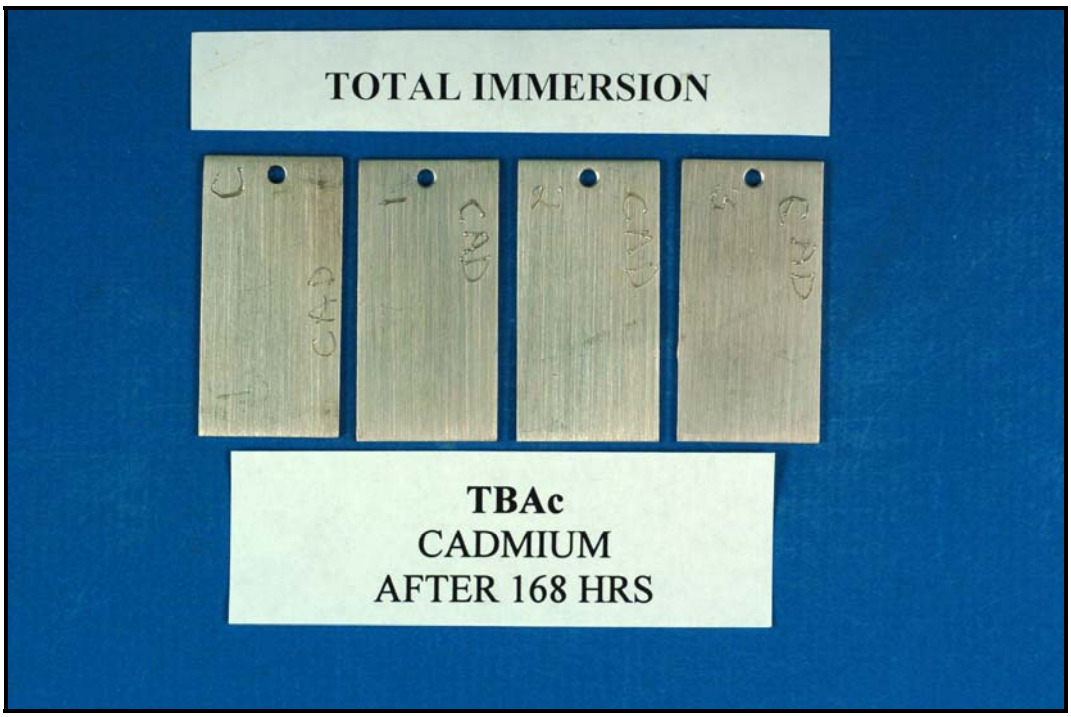
TOTAL IMMERSION
MAR
MAR
MAR
TBAc
MARAGING C250
AFTER 168 HRS

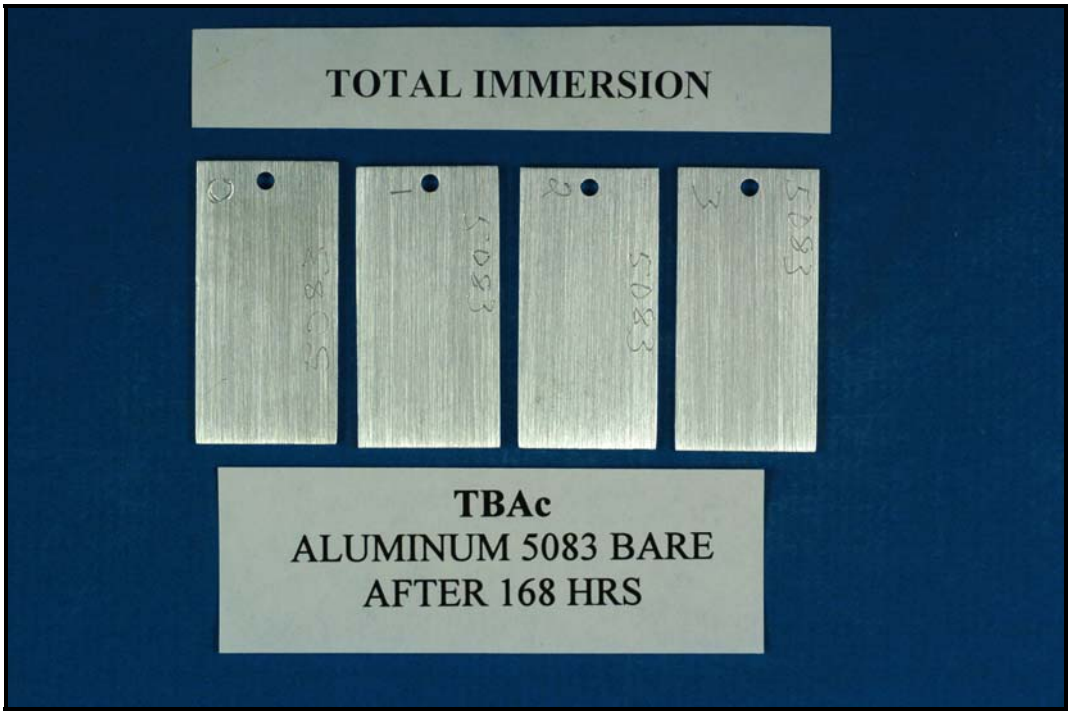

TOTAL IMMERSION
TBAc
STAINLESS STEEL 13-8 MO
AFTER 168 HRS


TOTAL IMMERSION
TBAc
ZINC
AFTER 168 HRS


TOTAL IMMERSION
TBAc
ALUMINUM 7075 T6 BARE
AFTER 168 HRS


TOTAL IMMERSION
TBAc
AM-355 CRT
AFTER 168 HRS


TOTAL IMMERSION
TBAc
CADMIUM
AFTER 168 HRS


TOTAL IMMERSION
TBAc
ALUMINUM 5083 BARE
AFTER 168 HRS

APPENDIX M. SMI REPORT

(Page M-2 Blank)

959500
WORK CONTINUED
FROM PAGE

ARCO Chemical Company

Research and Development

PROJECT NO.

SUBJECT TBAc Corrosion Testing

OBJECTIVE

DATE 11/9/99

One gallon of TBAc was shipped to SMI for a variety of ASTM corrosion test for mat'ls which come in contact with aerospace components

ASTM F1110 Sandwich Corrosion Test
ASTM F483 Total Immersion
ASTM F945 Stress Corrosion of Titanium Alloys by Aircraft Engine Cleaning Materials
ASTM F519 Hydrogen Embrittlement
ASTM F484 Stress Crazing of Acrylic Plastics

Quote rec'd from SMI : #1525

SMI Ref: 9911017-R
LYO PO#: N0028772

Ship to: SMI Inc.
12219 SW 131st Ave.
Miami, FL 33186-6401

Sample labeled: Solvent #959500

WORK DONE BY Jim Greaney (SIGNATURE) DATE 11/9/99 WORK CONTINUED ON PAGE

READ AND UNDERSTOOD BY (1) Shanti Patel (SIGNATURE) DATE 7-3-01

(2) (SIGNATURE) DATE

SMI, Inc.
SCIENTIFIC MATERIAL INTERNATIONAL

12219 SW 131 Avenue Miami, Florida 33186-6401 USA
Phone (305) 971-7047 Facsimile (305) 971-7048

Attn: Jim Greaney
Lyondell
3801 West Chester Pike
Newtown Square, PA 19073

Date: 14-Dec-1999

SMI/REF: 9911017

Product: **SOLVENT # 959500** (received 10-Nov-1999)
Dilution: Ready to Use

Sandwich Corrosion per ASTM F 1110

Aluminum panels having clad or anodized nonclad surfaces are sandwiched together with filter paper saturated with the test material between the panels. The sandwiched panels are cycled between warm ambient air and warm humid air for 7 days. The coupons are then inspected to determine whether corrosion more severe than that caused by a reagent water has occurred on the surfaces exposed to the test material. This test method may be used for solutions of dry granular material or for liquid materials.

Relative corrosion severity rating system:

0 - No visible corrosion
1 - Very slight corrosion or discoloration (up to 5% of surface area corroded)
2 - Slight corrosion (5 to 15%)
3 - Moderate corrosion (10 to 25%)
4 - Extensive corrosion or pitting (25% or more)

TEST RESULTS:
(Tested utilizing QQ-A-250/4; AMS 4037 Aluminum only per Mfr's instruction.)

	QQ-A-250/4 AMS 4037
Ready to Use	1
CONTROL	1

Result Conforms

Respectfully submitted,

Patricia D. Otero, SMI Inc.

SMI, Inc.
SCIENTIFIC MATERIAL INTERNATIONAL

12219 SW 131 Avenue Miami, Florida 33186-6401 USA
Phone (305) 971-7047 Facsimile (305) 971-7048

Attn:	Jim Greaney Lyondell 3801 West Chester Pike Newtown Square, PA 19073	Date: SMI/REF:	14-Dec-1999 9911017

Product: **SOLVENT # 959500** (received 10-Nov-1999) Page 1 of 2
Dilution: Ready to Use

ASTM F 483-98
Standard Test Method for
Total Immersion Corrosion Test for Aircraft Maintenance Chemicals

9. **PROCEDURE**

9.1 Weigh three of four specimens of the same alloy to the nearest 0.1 mg.

9.2 Immerse three weighed specimens of each alloy in the solution at the prescribed temperature. Place only specimens of the same alloy in the containing vessel. Maintain at the required temperature for the prescribed exposure period. Retain the fourth specimen of each alloy for comparison purposes.

9.3 At the end of 24 hours, remove the test specimens and proceed as follows:

9.3.1 Rinse thoroughly under hot tap water, 49 to 60°C. Follow with a rinse in water conforming to ASTM D 1193, Type IV at room temperature.

9.3.2 Rinse with a stream of acetone, conforming to ASTM D 329, from a wash bottle and oven dry at 120°C, desiccate until cooled to ambient, weigh and record.

9.3.3 Then examine for and record the following visible changes in comparison with the fourth virgin specimen of each alloy.

9.3.3.1 Discoloration and dulling,
9.3.3.2 Etching,
9.3.3.3 Presence of accretions and relative amounts,
9.3.3.4 Pitting, and
9.3.3.5 Presence of selective or localized attack.

9.4 Immerse the panels in the same test solution for a further 144 hours, then repeat 9.3.1 through 9.3.3.5.

9.5 Reweigh specimens to nearest 0.1 g, calculate weight loss or gain, and record.

Client: Lyondell
Product: **SOLVENT # 959500**
Dilution: Ready to Use
ASTM F 483 Total Immersion Corrosion

Date: 14-Dec-1999
SMI/REF: 9911017

ALLOY	WGT LOSS (mg)		WGT LOSS $mg/cm^2/24hrs$
	After 24hrs	After 168hrs	
AMS 4041 Clad Aluminum; QQ-A-250/5	< 0.1	< 0.1	< 0.01
AMS 4049 Clad Aluminum; QQ-A-250/13	< 0.1	0.1	< 0.01
AMS 4037 Bare Aluminum; QQ-A-250/4; anodized per MIL-A-8625 Ty I	< 0.1	< 0.1	< 0.01
AMS 5046; grade 1020 steel	0.2	0.3	0.01
AMS 5046; grade 1020 steel; cadmium plated per QQ-P-416 Ty I, Cl 3	0.3	< 0.1	0.01
AMS 4911 Titanium 6Al-4V	0.1	0.1	< 0.01

No visible corrosion on any panel.

Respectfully submitted,

Patricia D. Otero, SMI Inc.

SMI, Inc.
SCIENTIFIC MATERIAL INTERNATIONAL

12219 SW 131 Avenue Miami, Florida 33186-6401 USA
Phone (305) 971-7047 Facsimile (305) 971-7048

Attn:	Jim Greaney Lyondell 3801 West Chester Pike Newtown Square, PA 19073	Date: SMI/REF:	14-Dec-1999 9911017

Product: **SOLVENT # 959500** (received 10-Nov-1999) Page 1 of 3
Dilution: Ready to Use

ASTM F 945-98
Stress Corrosion of Titanium Alloys
by Aircraft Engine Cleaning Materials (Method A)

8. Procedure:

8.1 Test a minimum of nine specimens of each alloy using the following procedure.

8.1.1 To establish acceptability of the titanium alloy sheet materials for use in these tests, test three restrained test specimens of each alloy without contacting any test solution after acid cleaning.

8.1.2 To establish sensitivity of the titanium alloy sheet materials to stress corrosion attack, wet three restrained test specimens of each alloy by immersing in a solution of 3 weight % of sodium chloride in reagent water. Hang to dry with the bend zone down. Remove and test as in 8.2.

8.1.3 To evaluate the effect of the candidate solution, wet three restrained test specimens of each alloy by immersing in the candidate solution at the maximum recommended concentration. Hang to dry with the bend zone down and test as in 8.2.

8.2 Heat the restrained specimens in an air circulation furnace in accordance with method(s) to be specified by the purchaser as follows:

8.2.1 *Method A* - Heat at 900 ± 20°F (480 ± 10°C) for 8 ± 0.2 hours.

8.2.2 *Method B* - Heat at 500 ± 20°F (260 ± 10°C) for 168 ± 4 hours.

8.2.3 After heating, remove the specimens from the furnace, allow to cool, and inspect for cracks.

8.3 *Preliminary Evaluation* - Inspect all of the restrained specimens visually using 20-diameters magnification.

8.3.1 If cracks are found on the untreated (control) specimens, repeat the entire stress corrosion test using acceptable titanium alloy sheet material.

8.3 *Preliminary Evaluation* continued:

8.3.2 If cracks are found on all candidate solution-treated specimens, this shall be cause for rejection of the candidate cleaning material.

8.3.3 All restrained specimens not found to be cracked during visual inspection at 20-diameters magnification prepare for further inspection as follows:

8.3.3.1 Remove the bolt restrains.

8.3.3.2 Rinse in warm tap water; do not permit to dry.

8.3.3.3 While wet, immerse in acid cleaning solution of 5.3 for 15 ± 5 seconds.

8.3.3.4 Rinse in tap water and air dry.

8.3.3.5 Inspect metallographically as in 8.4.1.

8.4 *Metallographic Inspection.*

8.4.1 Make a cross section of each specimen at the bend normal to the bend axis (parallel to the test panel long axis). Cut the specimens using a fine-tooth hacksaw or other apparatus capable of producing a smooth cut with minimal disturbance of specimen edges. Make the cut approximately at the center axis in line with the holes. The metallographic specimen shall encompass material from the bend to a point approximately 0.5 inches (13 mm) from the bend. Examine the cut surface over the 0.5 inch (13 mm) distance on both sides of the bend zone at 500 diameters following metallographic preparation appropriate to the specimen alloy composition.

9. Determination of Test Results

9.1 Detection of cracks on either the tension or compression surfaces of any of the untreated (control) specimens shall be cause to repeat the entire stress corrosion test using acceptable titanium alloy sheet material.

9.2 Failure to detect cracks on either the tension or compression surfaces of all of the sodium chloride solution-treated specimens shall be cause to repeat the entire stress corrosion test using titanium alloy sheet having a demonstrated susceptibility to stress corrosion cracking.

9.3 Examine tension and compression surfaces of candidate solution treated specimens for cracks and make one of the following dispositions:

9.3.1 Failure to detect cracks on any specimen shall constitute an acceptance test for the candidate cleaning material.

9. Determination of Test Results continued

9.3.2 Detection of cracks on all specimens shall be cause for rejection of the candidate cleaning material.

9.3.3 If some of the specimens do not exhibit cracks, the entire stress corrosion test may be repeated at the option of the testing facility.

Method A:

TITANIUM ALLOY	OBSERVATION	RESULT
AMS 4911	No cracking observed.	CONFORMS
AMS 4916	No cracking observed.	CONFORMS

Respectfully submitted,

Patricia D. Otero, SMI Inc.

SMI, Inc.
SCIENTIFIC MATERIAL INTERNATIONAL

12219 SW 131 Avenue Miami, Florida 33186-6401 USA
Phone (305) 971-7047 Facsimile (305) 971-7048

Attn:	Jim Greaney Lyondell 3801 West Chester Pike Newtown Square, PA 19073	Date: SMI/REF:	14-Dec-1999 9911017

Product: **SOLVENT # 959500** (received 10-Nov-1999)
Dilution: Ready to Use

ASTM F 484-83
Stress Crazing of Acrylic Plastics in Contact
with Liquid or Semi-Liquid Compounds*

This test method covers determination of the crazing effect of a liquid or semi-liquid test compound on transparent acrylic plastic material which is under bending stress.

Test Material: MIL-P-83310 Polycarbonate
Exposure: 3000 psi for 30 minutes

Specimens failed upon contact with sample.

Test Material MIL-P-5425 Type A cast acrylic
Exposure: 3000 psi for 8 hours

Specimens failed within 2 hours.

Respectfully submitted,

Patricia D. Otero, SMI Inc.

SMI, Inc.
SCIENTIFIC MATERIAL INTERNATIONAL

12219 SW 131 Avenue Miami, Florida 33186-6401 USA
Phone (305) 971-7047 Facsimile (305) 971-7048

Attn:	Jim Greaney Lyondell 3801 West Chester Pike Newtown Square, PA 19073	Date: SMI/REF:	14-Dec-1999 9911017

Product: **SOLVENT # 959500** (received 10-Nov-1999)
Dilution: Ready to Use

ASTM F 519-97 Type 1A.1
Standard Test Method for Mechanical Hydrogen Embrittlement Evaluation of Plating Processes and Service Environments
(Passive Chemicals)

A1. Special Requirements for the Testing of Notched Round Bar Tension Specimens Under Constant Load

A1.1 Type 1A: The notched round bar tension specimen is given in two sizes. If the specimen geometry is not called out, the Type 1a.1, standard notched round bar specimen under load control shall be used.

A1.2 Type 1a.1: The dimensions for the standard sized specimen for the sustained load test (SLT) is shown in Figure A1.1. The test machine shall have a minimum load capacity of 10 kips to measure the notched fracture strength in accordance with Table I. Correspondingly, a test machine with a minimum load capacity of 7 kip is required to maintain a sustained load of 75% of the notched fracture strength in accordance with Table 3.

A5. Details of Testing in Service Environments

A5.1 Service Environments: Notice: Because of the extensive variety of newly developed cleaners and maintenance chemicals, loading sequences and times of exposure, the requirements are often user specific. As a result, the testing protocol described in this section should only be used as a guideline. A more extensive protocol and details for use in specific applications is currently in process.

A5.1.1 Surface Finish: Specimens shall be coated or plated as specified by the procuring agency. Unplated specimens can be specified by the procuring agency for specific service environment testing. The unplated specimens shall also meet the surface finish requirements of this standard.

A5.1.2 Number: A minimum of four specimens shall be used per test.

A5.2 Classification of Chemicals:

A5.2.1 Process or service chemicals shall be classified as aggressive or passive.

A5.2.1.1 With aggressive chemicals (such as temper etching with nitric acid) the time of exposure is intentionally limited due to their aggressive corrosive reaction with AISI E 4340 steel.

A5.2.1.2 Passive chemicals include cleaners and paint strippers, which typically do not result in any measurable corrosive attack of AISI E 4340 steel.

A5. Service Chemical Testing Procedure:

A5.3.2 Passive Chemicals: Test specimens under 45% notched bend fracture load shall be coated or immersed in passive chemicals for the duration of the test. After the test is completed, the test specimen and fixtures are rinsed and dried with compressed air.

A5.4 Test Conditions: The test shall be conducted in air or any other controlled environment using an appropriate inert container and fixture that is suitably electrically isolated from the specimen or compensated to prevent a galvanic coupling.

A5.4.1 Test liquids in the concentrated condition and at the maximum specified dilution to determine the full embrittling effect on exposure in service.

A5.4.2 Test solids in the saturated condition and at the minimum specified concentration to determine the full embrittling effect of exposure in service.

A5.4.3 Conduct all tests at 68-86°F (20-30°C) or the operating service temperature of the maintenance chemicals. Do not exceed 150°F (66°C).

A5.5 Loading Protocol:

A5.5.1 Install the test specimens into the loading frame. Apply the loads specified in Table 4. For testing maintenance chemicals, any containment chamber shall be isolated around the notched section of the specimens. If the entire loading frame is immersed into the chemicals, the loading frames shall be designed to avoid any galvanic reaction with the test specimens. The sequence of exposure to the environment and load application shall be documented.

A5.6 Interpretation of Results:

A5.6.2 A passive chemical shall be considered non-embrittling if none of the immersed specimens fail within 150 hours after immersion into the chemical at the loads specified in table A5.1. Record the time to failure if less than 150 hours. The test may be discontinued after 150 hours.

A5.6.3 If only one of a minimum of four specimens fractures within the exposure time, continue to step load the remaining three specimens, every hour in five (5) percent increments to 90% of the fracture tensile/bend load after completion of a minimum 200 hour or 150 hour sustained load. After one hour at 90%, the process shall be considered non-embrittling if no fracture occurs.

A5.6.4 If two or more specimens fracture within the exposure time, the service environment shall be considered as having excessive embrittling characteristics.

A5.6.5 The root cause and corrective action must be determined prior to any retest.

A5.6.6 Retest the service environment with four unused specimens. If no fracture occurs within the exposure time, the material or process shall be considered non-embrittling. If any specimen fractures during retest, the service environment shall be considered embrittling.

Plating: Low-embrittling cadmium plate in accordance with Table II; Treatment B of ASTM F 519-97

Modification:
Load (Type 1a.1): 75 % notched tensile fracture load.
Exposure time: 200 hours

No failures occurred within 200 hours.

Result Conforms

Respectfully submitted,

Patricia D. Otero, SMI Inc.

APPENDIX N. ELEVATED TEMPERATURE CORROSION DATA SHEETS

(Page N-2 Blank)

ELEVATED TEMPERATURE CORROSION/STOCK LOSS

(2.1.2)

ATC MATERIALS LABORATORY

	TESTING LABORATORY
Client Name Army Research Laboratory (ARL)	Name ATC Materials Laboratory
POC Mr. Wayne W. Ziegler	POC Mr. William Taylor
Address	Address ATTN: TEDT-AT-WFA
	APG, MD 21005-5059
Telephone 410-306-0746	Telephone (410) 278-4461

Cleaner Tested

Product Name: TBAC

Company Name: Lyondell Chemical Company

Company Address:

POC:

Specimen Information:	**Solution Conditions:**
Alloy Type PH 13-8	Concentration 110%
Surface Treatment	Diluent Used
Condition	Temperature

Test Condition:

Exposure: 8 hr @ 135°F (57.2°C)

Date/Time In: Date/Time Out:

POC for Testing: Mr. William Taylor Test Instrumentation:

ALLOY TYPE: PH 13-8

Specimen #	Original Weight	Final Weight	Density of Specimen (g/cm2)	Area of Specimen (cm2)	Stock Loss (µm)
1 (Control)	255.30	255.30	8.00	134.32	0.00
2.00	256.81	256.81	8.00	134.32	0.00
3.00	256.36	256.36	8.00	134.32	0.00
4.00	254.86	254.86	8.00	134.32	0.00
AVG	256.01	256.01	8.00	134.32	0.00

ELEVATED TEMPERATURE CORROSION/STOCK LOSS

(2.1.2)

ATC MATERIALS LABORATORY

	TESTING LABORATORY
Client Name Army Research Laboratory (ARL)	Name ATC Materials Laboratory
POC Mr. Wayne W. Ziegler	POC Mr. William Taylor
Address	Address ATTN: TEDT-AT-WFA
	APG, MD 21005-5059
Telephone 410-306-0746	Telephone (410) 278-4461

Cleaner Tested

Product Name: TBAC

Company Name: Lyondell Chemical Company

Company Address:

POC:

Specimen Information:	**Solution Conditions:**
Alloy Type Maraging C-250	Concentration 110%
Surface Treatment	Diluent Used
Condition/Humidity	Temperature

Test Condition:

Exposure: 8 hr @ 135°F (57.2°C)

Date/Time In: Date/Time Out:

POC for Testing: Mr. William Taylor Test Instrumentation:

ALLOY TYPE: Maraging C-250

Specimen #	Original Weight	Final Weight	Density of Specimen (g/cm2)	Area of Specimen (cm2)	Stock Loss (µm)
1 (Control)	71.50	71.50	8.00	134.32	-0.01
2.00	80.49	80.49	8.00	134.32	-0.01
3.00	73.50	73.50	8.00	134.32	0.00
4.00	81.11	81.11	8.00	134.32	-0.02
AVG	78.37	78.36	8.00	134.32	-0.01

ELEVATED TEMPERATURE CORROSION/STOCK LOSS

(2.1.2)

ATC MATERIALS LABORATORY

	TESTING LABORATORY
Client Name Army Research Laboratory (ARL)	Name ATC Materials Laboratory
POC Mr. Wayne W. Ziegler	POC Mr. William Taylor
Address	Address ATTN: TEDT-AT-WFA
	APG, MD 21005-5059
Telephone 410-306-0746	Telephone (410) 278-4461

Cleaner Tested

Product Name: TBAC

Company Name: Lyondell Chemical Company

Company Address:

POC:

Specimen Information:	**Solution Conditions:**
Alloy Type Magnesium (AZ31B-H24)	Concentration 110%
Surface Treatment	Diluent Used
Condition/Humidity	Temperature

Test Condition:

Exposure: 8 hr @ 135°F (57.2°C)

Date/Time In: Date/Time Out:

POC for Testing: Mr. William Taylor Test Instrumentation:

ALLOY TYPE: Magnesium (AZ31B-H24)

Specimen #	Original Weight	Final Weight	Density of Specimen (g/cm2)	Area of Specimen (cm2)	Stock Loss (µm)
1 (Control)	18.94	18.94	1.77	135.15	-0.04
2.00	18.99	18.98	1.77	135.15	-0.13
3.00	18.96	18.96	1.77	135.15	-0.08
4.00	18.67	18.67	1.77	135.15	-0.08
AVG	18.87	18.87	1.77	135.15	-0.08

ELEVATED TEMPERATURE CORROSION/STOCK LOSS

(2.1.2)

ATC MATERIALS LABORATORY

	TESTING LABORATORY
Client Name Army Research Laboratory (ARL)	Name ATC Materials Laboratory
POC Mr. Wayne W. Ziegler	POC Mr. William Taylor
Address	Address ATTN: TEDT-AT-WFA
	APG, MD 21005-5059
Telephone 410-306-0746	Telephone (410) 278-4461

Cleaner Tested

Product Name: TBAC

Company Name: Lyondell Chemical Company

Company Address:

POC:

Specimen Information:	**Solution Conditions:**
Alloy Type Al 7075	Concentration 110%
Surface Treatment	Diluent Used
Condition/Humidity	Temperature

Test Condition:

Exposure: 8 hr @ 135°F (57.2°C)

Date/Time In: Date/Time Out:

POC for Testing: Mr. William Taylor Test Instrumentation:

ALLOY TYPE: Al 7075

Specimen #	Original Weight	Final Weight	Density of Specimen (g/cm2)	Area of Specimen (cm2)	Stock Loss (µm)
1 (Control)	28.39	28.39	1.77	135.15	0.00
2.00	28.77	28.74	1.77	135.15	-1.30
3.00	28.44	28.44	1.77	135.15	-0.08
4.00	28.36	28.36	1.77	135.15	-0.04
AVG	28.53	28.52	1.77	135.15	-0.36

ELEVATED TEMPERATURE CORROSION/STOCK LOSS

(2.1.2)

ATC MATERIALS LABORATORY

	TESTING LABORATORY
Client Name Army Research Laboratory (ARL)	Name ATC Materials Laboratory
POC Mr. Wayne W. Ziegler	POC Mr. William Taylor
Address	Address ATTN: TEDT-AT-WFA
	APG, MD 21005-5059
Telephone 410-306-0746	Telephone (410) 278-4461

Cleaner Tested

Product Name: TBAC

Company Name: Lyondell Chemical Company

Company Address:

POC:

Specimen Information:	**Solution Conditions:**
Alloy Type Titanium 6AL-4V	Concentration 110%
Surface Treatment	Diluent Used
Condition/Humidity	Temperature

Test Condition:

Exposure: 8 hr @ 135°F (57.2°C)

Date/Time In: Date/Time Out:

POC for Testing: Mr. William Taylor Test Instrumentation:

ALLOY TYPE: Titanium 6AL-4V

Specimen #	Original Weight	Final Weight	Density of Specimen (g/cm2)	Area of Specimen (cm2)	Stock Loss (µm)
1 (Control)	49.90	49.90	4.43	135.25	0.00
2.00	34.34	34.34	4.43	135.25	0.00
3.00	34.64	34.64	4.43	135.25	0.00
4.00	34.92	34.92	4.43	135.25	0.00
AVG	34.63	34.63	4.43	135.25	0.00

ELEVATED TEMPERATURE CORROSION/STOCK LOSS

(2.1.2)

ATC MATERIALS LABORATORY

	TESTING LABORATORY
Client Name Army Research Laboratory (ARL)	Name ATC Materials Laboratory
POC Mr. Wayne W. Ziegler	POC Mr. William Taylor
Address	Address ATTN: TEDT-AT-WFA
	APG, MD 21005-5059
Telephone 410-306-0746	Telephone (410) 278-4461

Cleaner Tested

Product Name: TBAC

Company Name: Lyondell Chemical Company

Company Address:

POC:

Specimen Information:

Alloy Type Steel 4340

Surface Treatment

Condition/Humidity

Solution Conditions:

Concentration 110%

Diluent Used

Temperature

Test Condition:

Exposure: 8 hr @ 135°F (57.2°C)

Date/Time In:

Date/Time Out:

POC for Testing: Mr. William Taylor

Test Instrumentation:

ALLOY TYPE: Steel 4340

Specimen #	Original Weight	Final Weight	Density of Specimen (g/cm2)	Area of Specimen (cm2)	Stock Loss (µm)
1 (Control)	94.69	94.70	4.43	135.25	0.02
2.00	99.60	99.60	4.43	135.25	0.03
3.00	84.96	84.96	4.43	135.25	0.02
4.00	94.81	94.81	4.43	135.25	-0.02
AVG	93.12	93.12	4.43	135.25	0.01

ELEVATED TEMPERATURE CORROSION/STOCK LOSS

(2.1.2)

ATC MATERIALS LABORATORY

	TESTING LABORATORY
Client Name Army Research Laboratory (ARL)	Name ATC Materials Laboratory
POC Mr. Wayne W. Ziegler	POC Mr. William Taylor
Address	Address ATTN: TEDT-AT-WFA
	APG, MD 21005-5059
Telephone 410-306-0746	Telephone (410) 278-4461

Cleaner Tested

Product Name: TBAC

Company Name: Lyondell Chemical Company

Company Address:

POC:

Specimen Information:	**Solution Conditions:**
Alloy Type 1020	Concentration 110%
Surface Treatment	Diluent Used
Condition/Humidity	Temperature

Test Condition:

Exposure: 8 hr @ 135°F (57.2°C)

Date/Time In: Date/Time Out:

POC for Testing: Mr. William Taylor Test Instrumentation:

ALLOY TYPE: 1020

Specimen #	Original Weight	Final Weight	Density of Specimen (g/cm2)	Area of Specimen (cm2)	Stock Loss (µm)
1 (Control)	78.99	78.99	7.85	134.60	0.00
2.00	78.89	78.89	7.85	134.60	0.01
3.00	78.87	78.87	7.85	134.60	0.01
4.00	78.94	78.94	7.85	134.60	0.00
AVG	78.90	78.90	7.85	134.60	0.00

ELEVATED TEMPERATURE CORROSION/STOCK LOSS

(2.1.2)

ATC MATERIALS LABORATORY

	TESTING LABORATORY
Client Name Army Research Laboratory (ARL)	Name ATC Materials Laboratory
POC Mr. Wayne W. Ziegler	POC Mr. William Taylor
Address	Address ATTN: TEDT-AT-WFA
	APG, MD 21005-5059
Telephone 410-306-0746	Telephone (410) 278-4461

Cleaner Tested

Product Name: TBAC

Company Name: Lyondell Chemical Company

Company Address:

POC:

Specimen Information:	**Solution Conditions:**
Alloy Type AM 355	Concentration 110%
Surface Treatment	Diluent Used
Condition/Humidity	Temperature

Test Condition:

Exposure: 8 hr @ 135°F (57.2°C)

Date/Time In: Date/Time Out:

POC for Testing: Mr. William Taylor Test Instrumentation:

ALLOY TYPE: AM 355

Specimen #	Original Weight	Final Weight	Density of Specimen (g/cm2)	Area of Specimen (cm2)	Stock Loss (µm)
1 (Control)	18.54	18.54	7.75	130.23	0.00
2.00	18.71	18.71	7.75	130.23	0.00
3.00	18.57	18.57	7.75	130.23	0.00
4.00	18.63	18.63	7.75	130.23	0.00
AVG	18.64	18.64	7.75	130.23	0.00

APPENDIX O. HYDROGEN EMBRITTLEMENT DATA SHEETS

HYDROGEN EMBRITTLEMENT

(2.1.3)

ATC MATERIALS LABORATORY

	TESTING LABORATORY
Client Name Army Research Laboratory (ARL)	Name ATC Materials Laboratory
POC Mr. Wayne W. Ziegler	POC Mr. William Taylor
Address	Address ATTN: TEDT-AT-WFA
	APG, MD 21005-5059
Telephone 410-306-0746	Telephone (410) 278-4461

Cleaner Tested

Product Name: TBAc

Company Name: Lyondell Chemical Company

Company Address:

POC:

Specimen Information:	**Solution Conditions:**
Type 1D	Concentration Standard
Surface Treatment	Diluent Used DI Water
Condition	Temperature Ambient

Test Condition:

Exposure: As required by ASTM

Date/Time In:	Date/Time Out:
POC for Testing: Mr. William Taylor	Test Instrumentation: INSTRON 1125

Determination of Average Diameter of Notched C-ring at Fracture of Unplated Specimens

Unplated Specimen No.	1	2	3	4	5	6	7	8	9	10	Avg
Deflection to Failure (in.)	.0568	.0662	.0613	.0533	.0656	.0652	.0551	.0644	.0610	.0592	.0608

Observations at 200 Hours: No cracks observed.

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APPENDIX P. SANDWICH CORROSION DATA SHEETS

(Page P-2 Blank)

SANDWICH CORROSION

(2.1.4)

ATC MATERIALS LABORATORY

Client Name Army Research Laboratory (ARL)
POC Mr. Wayne W. Ziegler
Address
Telephone 410-306-0746

TESTING LABORATORY
Name ATC Materials Laboratory
POC Mr. William Taylor
Address ATTN: TEDT-AT-WFA
APG, MD 21005-5059
Telephone (410) 278-4461

Cleaner Tested
Product Name: TBAc
Company Name: Lyondell Chemical Company
Company Address:
POC:

Specimen Information:
Alloy Type Listed Below
Surface Treatment
Condition

Solution Conditions:
Concentration Standard
Diluent Used As Stated
Temperature

Test Condition:
Exposure: IAW ASTM F1110
Date/Time In: 14 October 2005, 0700
Date/Time Out: 21 October 2005, 0700
POC for Testing: Mr. William Taylor
Test Instrumentation:

	Cleaner				Deionized Water (DW)				**Comments & Observations:**
Material	A1	A2	A3	A4	D1	D2	D3	D4	
PH 13-8 Mo	0	1	2		0	0	0	0	
MARGAGING C-250	0	1	4		4	4	4	4	
AL 7075-T6	0	0	0		4	4	4	4	
AMS 4911	0	0	0	0	0	0	0	0	
AISI 4340	4	4	4	4	1	4	4	3	
MG AMS 4377	4	3	4	3	4	3	3	3	
AL 5083	0	0	0		4	4	4	4	
AM 355 CRT	0	0	0		0	0	0	0	
STEEL A366	4	4	4		4	4	4	4	

Rate the observations following this convention:

0 - No visible corrosion (no corrosion).
1 - Very slight corrosion or discoloration (up to 5 percent of the surface area corroded).
2 - Slight corrosion (5 to 10 percent of the surface area corroded).
3 - Moderate corrosion (10 to 25 percent of the surface area corroded).
4 - Extensive corrosion or pitting (25 percent or more of the surface area corroded).

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APPENDIX Q. LOW-EMBRITTLING CADMIUM PLATE CORROSION DATA SHEETS

(Page Q-2 Blank)

LOW EMBRITTLING CADMIUM PLATE CORROSION

(2.1.7)

ATC MATERIALS LABORATORY

	TESTING LABORATORY
Client Name Army Research Laboratory (ARL)	Name ATC Materials Laboratory
POC Mr. Wayne W. Ziegler	POC Mr. William Taylor
Address	Address ATTN: TEDT-AT-WFA
	APG, MD 21005-5059
Telephone 410-306-0746	Telephone (410) 278-4461

Cleaner Tested

Product Name: TBAc

Company Name: Lyondell Chemical Company

Company Address:

POC:

Specimen Information:

Alloy Type

Surface Treatment

Condition

Solution Conditions:

Concentration N/A

Diluent Used N/A

Temperature

Test Condition:

Exposure: 24 hr @ 35 ± 1ºC

Date/Time In:

Date/Time Out:

POC for Testing: Mr. William Taylor

Test Instrumentation:

SPECIMEN #	WEIGHTS (g) ORIGINAL	AFTER 24 HRS	WEIGHT CHANGE (mg)	TOTAL WEIGHT CHANGE ($mg/cm^2/24$ hrs)
Control	15.7870	15.7860	-1.00	-0.04
1	15.7650	15.7660	1.00	0.04
2	15.7480	15.7480	0.00	0.00
3	15.7990	15.7990	0.00	0.00
Avg	15.7707	15.7710	0.33	0.01

OBSERVATIONS:

(Page Q-4 Blank)

APPENDIX R. COPPER CORROSION DATA SHEETS

(Page R-2 Blank)

COPPER CORROSION

(2.1.8)

ATC MATERIALS LABORATORY

Client Name Army Research Laboratory (ARL)
POC Mr. Wayne W. Ziegler
Address
Telephone 410-306-0746

TESTING LABORATORY
Name ATC Materials Laboratory
POC Mr. William Taylor
Address ATTN: TEDT-AT-WFA
APG, MD 21005-5059
Telephone (410) 278-4461

Cleaner Tested
Product Name: TBAc
Company Name: Lyondell Chemical Company
Company Address:
POC:

Specimen Information:
Alloy Type
Surface Treatment
Condition/Humidity

Solution Conditions:
Concentration Standard
Diluent Used N/A
Temperature

Test Condition:
Exposure: 3 hr & 24 hr @ 49ºC (120ºF) and 3 hr & 24 hr @ 100ºC (212ºF)
Date/Time In:
Date/Time Out:
POC for Testing: Mr. William Taylor
Test Instrumentation: Precision Copper Corrosion Bath

	OBSERVATIONS	
	SPECIMEN 1	SPECIMEN 2
3 hrs @ 49ºC	1A	1A
3 hrs @ 100ºC	1A	1A
24 hrs @ 49ºC	1A	1A
24 hrs @ 100ºC	1B	1B

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APPENDIX S. EFFECTS ON PAINTED SURFACES DATA SHEETS

(Page S-2 Blank)

EFFECTS ON PAINTED SURFACES

(2.2.1)

ATC MATERIALS LABORATORY

	TESTING LABORATORY
Client Name Army Research Laboratory (ARL)	Name ATC Materials Laboratory
POC Mr. Wayne W. Ziegler	POC Mr. William Taylor
Address	Address ATTN: TEDT-AT-WFA
	APG, MD 21005-5059
Telephone 410-306-0746	Telephone (410) 278-4461

Cleaner Tested

Product Name: TBAc

Company Name: Lyondell Chemical Company

Company Address:

POC:

Specimen Information:	**Solution Conditions:**
Alloy Type 7075-T6 Bare Aluminum	Concentration Standard
Surface Treatment N/A	Diluent Used N/A
Condition	Temperature 110°F

Test Condition:

Exposure: 30 Minutes Exposure @ 110°F

Date/Time In: 29 November 2005, 1000 Date/Time Out: 29 November 2005, 1030

POC for Testing: Mr. William Taylor Date/Time Tested: 30 November 2005, 1030

Coating: MIL-C-22750, Epoxy Topcoat

Sample ID	Paint Hardness *	Observations
1 – Untreated	>6H	
- Treated	>6H	
2 – Untreated	>6H	
- Treated	>6H	
3 – Untreated	>6H	
- Treated	>6H	

EFFECTS ON PAINTED SURFACES

(2.2.1)

ATC MATERIALS LABORATORY

	TESTING LABORATORY
Client Name Army Research Laboratory (ARL)	Name ATC Materials Laboratory
POC Mr. Wayne W. Ziegler	POC Mr. William Taylor
Address	Address ATTN: TEDT-AT-WFA
	APG, MD 21005-5059
Telephone 410-306-0746	Telephone (410) 278-4461

Cleaner Tested

Product Name: TBAc

Company Name:

Company Address:

POC:

Specimen Information:

Alloy Type 7075-T6 Bare Aluminum

Surface Treatment N/A

Condition

Solution Conditions:

Concentration Standard

Diluent Used N/A

Temperature 110°F

Test Condition:

Exposure: 30 Minutes Exposure @ 110°F

Date/Time In: 29 November 2005, 1000

Date/Time Out: 29 November 2005, 1030

POC for Testing: Mr. William Taylor

Date/Time Tested: 30 November 2005, 1030

Coating: MIL-C-85285, Polyurethane, High Solids Topcoat

Sample ID	Paint Hardness *	Observations
1 – Untreated	>6H	
- Treated	>6H	
2 – Untreated	>6H	
- Treated	>6H	
3 – Untreated	>6H	
- Treated	>6H	

EFFECTS ON PAINTED SURFACES

(2.2.1)

ATC MATERIALS LABORATORY

	TESTING LABORATORY
Client Name Army Research Laboratory (ARL)	Name ATC Materials Laboratory
POC Mr. Wayne W. Ziegler	POC Mr. William Taylor
Address	Address ATTN: TEDT-AT-WFA
	APG, MD 21005-5059
Telephone 410-306-0746	Telephone (410) 278-4461

Cleaner Tested

Product Name: TBAc

Company Name:

Company Address:

POC:

Specimen Information:	**Solution Conditions:**
Alloy Type 7075-T6 Bare Aluminum	Concentration Standard
Surface Treatment N/A	Diluent Used N/A
Condition	Temperature 110°F

Test Condition:

Exposure: 30 Minutes Exposure @ 110°F

Date/Time In: 29 November 2005, 1000 Date/Time Out: 29 November 2005, 1030

POC for Testing: Mr. William Taylor Date/Time Tested: 30 November 2005, 1030

Coating: MIL-C-46168, Aliphatic Polyurethane, Single-Component Topcoat

Sample ID	Paint Hardness *	Observations
1 – Untreated	>6H	
- Treated	>6H	
2 – Untreated	>6H	
- Treated	>6H	
3 – Untreated	>6H	
- Treated	>6H	

EFFECTS ON PAINTED SURFACES

(2.2.1)

ATC MATERIALS LABORATORY

Client Name Army Research Laboratory (ARL)
POC Mr. Wayne W. Ziegler
Address
Telephone 410-306-0746

TESTING LABORATORY
Name ATC Materials Laboratory
POC Mr. William Taylor
Address ATTN: TEDT-AT-WFA
APG, MD 21005-5059
Telephone (410) 278-4461

Cleaner Tested
Product Name: TBAc
Company Name:
Company Address:
POC:

Specimen Information:
Alloy Type 7075-T6 Bare Aluminum
Surface Treatment N/A
Condition

Solution Conditions:
Concentration Standard
Diluent Used N/A
Temperature 110°F

Test Condition:
Exposure: 30 Minutes Exposure @ 110°F
Date/Time In: 29 November 2005, 1000
Date/Time Out: 29 November 2005, 1030
POC for Testing: Mr. William Taylor
Date/Time Tested: 30 November 2005, 1030

Coating: MIL-C-14105, Heat Resistant Paint

Sample ID	Paint Hardness *	Observations
1 – Untreated	>6H	
- Treated	>6H	
2 – Untreated	>6H	
- Treated	>6H	
3 – Untreated		Only 2 coupons
- Treated		

EFFECTS ON PAINTED SURFACES

(2.2.1)

ATC MATERIALS LABORATORY

	TESTING LABORATORY
Client Name Army Research Laboratory (ARL)	Name ATC Materials Laboratory
POC Mr. Wayne W. Ziegler	POC Mr. William Taylor
Address	Address ATTN: TEDT-AT-WFA
	APG, MD 21005-5059
Telephone 410-306-0746	Telephone (410) 278-4461

Cleaner Tested

Product Name: TBAc

Company Name:

Company Address:

POC:

Specimen Information:	**Solution Conditions:**
Alloy Type 7075-T6 Bare Aluminum	Concentration Standard
Surface Treatment N/A	Diluent Used N/A
Condition	Temperature 110°F

Test Condition:

Exposure: 30 Minutes Exposure @ 110°F

Date/Time In: 29 November 2005, 1000 Date/Time Out: 29 November 2005, 1030

POC for Testing: Mr. William Taylor Date/Time Tested: 30 November 2005, 1030

Coating: MIL-C-64159, Heat Resistant Paint

Sample ID	Paint Hardness *	Observations
1 – Untreated	>6H	
- Treated	>6H	
2 – Untreated	>6H	
- Treated	>6H	
3 – Untreated	>6H	
- Treated	>6H	

EFFECTS ON PAINTED SURFACES

(2.2.1)

ATC MATERIALS LABORATORY

	TESTING LABORATORY
Client Name Army Research Laboratory (ARL)	Name ATC Materials Laboratory
POC Mr. Wayne W. Ziegler	POC Mr. William Taylor
Address	Address ATTN: TEDT-AT-WFA
	APG, MD 21005-5059
Telephone 410-306-0746	Telephone (410) 278-4461

Cleaner Tested

Product Name: TBAc

Company Name:

Company Address:

POC:

Specimen Information:	**Solution Conditions:**
Alloy Type 7075-T6 Bare Aluminum	Concentration Standard
Surface Treatment N/A	Diluent Used N/A
Condition	Temperature 110°F

Test Condition:

Exposure: 30 Minutes Exposure @ 110°F

Date/Time In: 29 November 2005, 1000 Date/Time Out: 29 November 2005, 1030

POC for Testing: Mr. William Taylor Date/Time Tested: 30 November 2005, 1030

Coating: MIL-C-53039, Heat Resistant Paint

Sample ID	Paint Hardness *	Observations
1 – Untreated	>6H	
- Treated	>6H	
2 – Untreated	>6H	
- Treated	>6H	
3 – Untreated	>6H	
- Treated	>6H	

APPENDIX T. EFFECTS ON UNPAINTED SURFACES DATA SHEETS

(Page T-2 Blank)

EFFECTS ON UNPAINTED SURFACES

(2.2.2)

ATC MATERIALS LABORATORY

	TESTING LABORATORY
Client Name Army Research Laboratory (ARL)	Name ATC Materials Laboratory
POC Mr. Wayne W. Ziegler	POC Mr. William Taylor
Address	Address ATTN: TEDT-AT-WFA
	APG, MD 21005-5059
Telephone 410-306-0746	Telephone (410) 278-4461

Cleaner Tested

Product Name: TBAc

Company Name: Lyondell Chemical Company

Company Address:

POC:

Specimen Information:

Alloy Type

Surface Treatment

Condition

Solution Conditions:

Concentration Standard

Diluent Used N/A

Temperature

Test Condition:

Exposure: 3 min Exposure & 30 min Baked

Date/Time In: Date/Time Out:

POC for Testing: Mr. William Taylor Test Instrumentation:

Visual Observations after Rinsing & 30 Minutes of Drying @ Ambient

TIME (IN/OUT)	MATERIAL	EFFECTS	
		COUPON 1	COUPON 2
	Am 355 CRT	No Effects	No Effects
	Titanium	No Effects	No Effects
	Maraging	No Effects	No Effects
	PH 13-8 Mo	No Effects	No Effects
	Aluminum 7075	No Effects	No Effects
	Magnesium (AZ 31B-H24)	No Effects	No Effects
	Steel 4340	No Effects	No Effects
	Aluminum 5083	No Effects	No Effects
	Steel A-242	No Effects	No Effects

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APPENDIX U. EFFECTS ON POLYSULFIDE SEALANTS DATA SHEETS

(Page U-2 Blank)

EFFECTS ON POLYSULFIDE SEALANT

(2.3.1)

ATC MATERIALS LABORATORY

	TESTING LABORATORY
Client Name Army Research Laboratory (ARL)	Name ATC Materials Laboratory
POC Mr. Wayne W. Ziegler	POC Mr. William Taylor
Address	Address ATTN: TEDT-AT-WFA
	APG, MD 21005-5059
Telephone 410-306-0746	Telephone (410) 278-4461

Cleaner Tested

Product Name: TBAc

Company Name: Lyondell Chemical Company

Company Address:

POC:

Specimen Information:	**Solution Conditions:**
Alloy Type	Concentration Standard
Surface Treatment	Diluent Used
Condition Product Cast 17 Jul 05; Tested 7 Sep 05	Temperature

Test Condition:

Exposure: 30 min Immersion

Date/Time In:	Date/Time Out:
POC for Testing: Mr. William Taylor	Test Instrumentation: Härte Prüfer, Calibrated 9-11-05

HARDNESS MEASUREMENTS (SHORE A) (Average of 3 Readings)

	COUPON 1		COUPON 2	
SPECIMEN	**BEFORE**	**AFTER**	**BEFORE**	**AFTER**
MIL-S-81733, TYPE II	53.00	53.00	56.00	56.00
AMS-S-8802, TYPE II	56.00	56.00	57.00	56.00

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APPENDIX V. EFFECTS ON ACRYLIC PLASTICS DATA SHEETS

(Page V-2 Blank)

EFFECTS ON ACRYLIC PLASTICS

(2.3.2)

ATC MATERIALS LABORATORY

Client Name Army Research Laboratory (ARL)
POC Mr. Wayne W. Ziegler
Address
Telephone 410-306-0746

TESTING LABORATORY
Name ATC Materials Laboratory
POC Mr. William Taylor
Address ATTN: TEDT-AT-WFA
APG, MD 21005-5059
Telephone (410) 278-4461

Cleaner Tested
Product Name: TBAc
Company Name: Lyondell Chemical Company
Company Address:
POC:

Specimen Information:
Alloy Type MIL-P-5425 Acrylic Type A
Surface Treatment
Condition

Solution Conditions:
Concentration Standard
Diluent Used DI Water
Temperature

Test Condition:
Exposure: 8 hour
Date/Time In: 22 November 2005; 0650
Date/Time Out: 22 November 2005, 1450
POC for Testing: Mr. William Taylor
Test Instrumentation:

Time	ACRYLIC TYPE A, MIL-P-5425			
	Control 1	Control 2	Test Specimen 1	Test Specimen 2
Initial Stress 10 Min.	No Effects	No Effects	No Effects	No Effects
.5 hr	No Effects	No Effects	Crazing	Crazing
1 hr	No Effects	No Effects	Crazing	Crazing
2 hr	No Effects	No Effects	Crazing	Crazing
4 hr	No Effects	No Effects	Broke @ 1415	Broke @ 1425
8 hr	No Effects	No Effects		

EFFECTS ON ACRYLIC PLASTICS

(2.3.2)

ATC MATERIALS LABORATORY

Client Name Army Research Laboratory (ARL)
POC Mr. Wayne W. Ziegler
Address
Telephone 410-306-0746

TESTING LABORATORY
Name ATC Materials Laboratory
POC Mr. William Taylor
Address ATTN: TEDT-AT-WFA
APG, MD 21005-5059
Telephone (410) 278-4461

Cleaner Tested
Product Name: TBAc
Company Name:
Company Address:
POC:

Specimen Information:
Alloy Type MIL-P-8184 Acrylic Type B
Surface Treatment
Condition

Solution Conditions:
Concentration Standard
Diluent Used DI Water
Temperature

Test Condition:
Exposure: 8 hour
Date/Time In: 22 November 2005; 0745
Date/Time Out: 22 November 2005, 1545
POC for Testing: Mr. William Taylor
Test Instrumentation:

Time	ACRYLIC TYPE B, MIL-P-8184			
	Control 1	Control 2	Test Specimen 1	Test Specimen 2
Initial Stress 10 Min.	No Effects	No Effects	No Effects	No Effects
.5 hr	No Effects	No Effects	Crazing	Crazing
1 hr	No Effects	No Effects	Broke @ 58 min.	Crazing
2 hr	No Effects	No Effects		Broke at 1:47 min.
4 hr	No Effects	No Effects		
8 hr	No Effects	No Effects		

EFFECTS ON ACRYLIC PLASTICS

(2.3.2)

ATC MATERIALS LABORATORY

	TESTING LABORATORY
Client Name Army Research Laboratory (ARL)	Name ATC Materials Laboratory
POC Mr. Wayne W. Ziegler	POC Mr. William Taylor
Address	Address ATTN: TEDT-AT-WFA
	APG, MD 21005-5059
Telephone 410-306-0746	Telephone (410) 278-4461

Cleaner Tested

Product Name: TBAc

Company Name:

Company Address:

POC:

Specimen Information:

Alloy Type MIL-P-25690

Surface Treatment

Condition

Solution Conditions:

Concentration Standard

Diluent Used DI Water

Temperature

Test Condition:

Exposure: 8 hour

Date/Time In: 22 November 2005; 0745

Date/Time Out: 22 November 2005, 1545

POC for Testing: Mr. William Taylor

Test Instrumentation:

Time	ACRYLIC TYPE C, MIL-P-25690			
	Control 1	Control 2	Test Specimen 1	Test Specimen 2
Initial Stress 10 Min.	No Effects	No Effects	No Effects	No Effects
.5 hr	No Effects	No Effects	No Effects	No Effects
1 hr	No Effects	No Effects	No Effects	No Effects
2 hr	No Effects	No Effects	No Effects	No Effects
4 hr	No Effects	No Effects	No Effects	No Effects
8 hr	No Effects	No Effects	No Effects	No Effects

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APPENDIX W. EFFECTS ON POLYCARBONATE PLASTICS DATA SHEETS

(Page W-2 Blank)

EFFECTS ON POLYCARBONATE

(2.3.3)

ATC MATERIALS LABORATORY

	TESTING LABORATORY
Client Name Army Research Laboratory (ARL)	Name ATC Materials Laboratory
POC Mr. Wayne W. Ziegler	POC Mr. William Taylor
Address	Address ATTN: TEDT-AT-WFA
	APG, MD 21005-5059
Telephone 410-306-0746	Telephone (410) 278-4461

Cleaner Tested

Product Name: TBAc

Company Name: Lyondell Chemical Company

Company Address:

POC:

Specimen Information:	**Solution Conditions:**
Alloy Type Polycarbonate	Concentration Standard
Surface Treatment	Diluent Used DI Water
Condition	Temperature Ambient

Test Condition:

Exposure: 8 hour

Date/Time In: 22 November 2005; 0650	Date/Time Out: 22 November 2005, 1450
POC for Testing: Mr. William Taylor	Test Instrumentation:

Time	POLYCARBONATE PLASTIC, MIL-P-83310			
	Control 1	Control 2	Test Specimen 1	Test Specimen 2
Initial Stress 10 Min.	No Effects	No Effects	No Effects	No Effects
.5 hr	No Effects	No Effects	Broke Immediately	Broke @ 0720
1 hr	No Effects	No Effects		
2 hr	No Effects	No Effects		
4 hr	No Effects	No Effects		
8 hr	No Effects	No Effects		

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APPENDIX X. EFFECTS ON SHEET MOLDING COMPOUNDS DATA SHEETS

(Page X-2 Blank)

EFFECTS ON RIGID PLASTICS

(2.3.4)

ATC MATERIALS LABORATORY

Client Name Army Research Laboratory (ARL)
POC Mr. Wayne W. Ziegler
Address
Telephone 410-306-0746

TESTING LABORATORY
Name ATC Materials Laboratory
POC Mr. William Taylor
Address ATTN: TEDT-AT-WFA
APG, MD 21005-5059
Telephone (410) 278-4461

Cleaner Tested
Product Name: TBAc
Company Name: Lyondell Chemical Company
Company Address:
POC:

Specimen Information:
Alloy Type
Surface Treatment
Condition/Humidity

Solution Conditions:
Concentration Standard
Diluent Used
Temperature Ambient

Test Condition:
Exposure: 1 hour @ 80°F
Date/Time In:
POC for Testing: Mr. William Taylor
Date/Time Out:
Test Instrumentation: Barcol Impressor, GYZJ-934-1, SN# 050201-23

HARDNESS MEASUREMENT	HARDNESS READING										AVG	STD DEV
	1	2	3	4	5	6	7	8	9	10		
BEFORE IMMERSION	48	52	50	52	57	50	48	46	52	49	**50**	**3**
AFTER IMMERSION	52	48	51	49	50	49	55	51	46	50	**50**	**2**

OBSERVATIONS:

No crazing or visible signs of attack.

(Page X-4 Blank)

APPENDIX Y. EFFECTS ON RUBBER DATA SHEETS

(Page Y-2 Blank)

RUBBER COMPATIBILITY – MECHANICAL PROPERTIES

(2.3.5)

ATC MATERIALS LABORATORY

	TESTING LABORATORY
Client Name Army Research Laboratory (ARL)	Name ATC Materials Laboratory
POC Mr. Wayne W. Ziegler	POC Mr. William Taylor
Address	Address ATTN: TEDT-AT-WFA
	APG, MD 21005-5059
Telephone 410-306-0746	Telephone (410) 278-4461

Cleaner Tested

Product Name: TBAc

Company Name: Lyondell Chemical Company

Company Address:

POC:

Specimen Information:

Alloy Type N/A

Surface Treatment

Condition/Humidity 70ºF, 50% RH

Solution Conditions:

Concentration Standard

Diluent Used

Temperature Ambient

Test Condition:

Exposure: 2 hr Immersion, test after 24 hr @ 70ºF, 50% RH

Date/Time In: 1 December 2005, 1040

Date/Time Out 1 December 2005, 1240

POC for Testing: Mr. William Taylor

Test Instrumentation: Instron Model 1125

SPECIMEN: 0235

					TENSILE	
SPECIMEN	BEFORE IMMERSION			BREAKING	STRENGTH	ELONGATION
NUMBER	THICKNESS (in.)	WIDTH (in.)	Shore A HARDNESS	FORCE (lbs)	(psi)	(in.)
1 (Control)	0.093	0.244	68	3465.0	9091.0	12.0
2 (Control)	0.096	0.246	68	4017.0	10293.6	12.9
3 (Control)	0.088	0.245	68	3469.0	9658.0	11.0
AVG (Control)	0.092	0.245	68	3650.3	9680.8	12.0
1 (Test Sp.)	0.091	0.242	68	3529.3	9385.6	12.7
2 (Test Sp.)	0.097	0.244	69	2851.3	7172.3	10.5
3 (Test Sp.)						
AVG (Test Sp.)	0.094	0.243	69	3190.3	8279.0	11.6
	% CHANGE IN TEST SPECIMEN					
	TO AVG CONTROL		Shore A HARDNESS		(ΔH) CHANGE IN HARDNESS	
	TENSILE		(AFTER IMMERSION)		COMPARED TO INITIAL	
	STRENGTH	ELONGATION	IMMEDIATE	24 Hrs	IMMEDIATE	24 HRS
1 (Test Sp.)	-3.0	5.7	59	67	-9	-1
2 (Test Sp.)	-25.9	-12.1	58	69	-11	0
3 (Test Sp.)						
AVG (Test Sp.)	-14.5	-3.2	59	68	-10	-1

*****Pulled out of grips.

RUBBER COMPATIBILITY – MECHANICAL PROPERTIES

(2.3.5)

ATC MATERIALS LABORATORY

Client Name Army Research Laboratory (ARL)
POC Mr. Wayne W. Ziegler
Address
Telephone 410-306-0746

TESTING LABORATORY
Name ATC Materials Laboratory
POC Mr. William Taylor
Address ATTN: TEDT-AT-WFA
APG, MD 21005-5059
Telephone (410) 278-4461

Cleaner Tested
Product Name: TBAc
Company Name: Lyondell Chemical Company
Company Address:
POC:

Specimen Information:
Alloy Type N/A
Surface Treatment
Condition/Humidity 70 ºF, 50% RH

Solution Conditions:
Concentration Standard
Diluent Used
Temperature Ambient

Test Condition:
Exposure: 2 hr Immersion, test after 24 hr @ 70ºF, 50% RH
Date/Time In: 1 December 2005, 1000
Date/Time Out 1 December 2005, 1200
POC for Testing: Mr. William Taylor
Test Instrumentation: Instron Model 1125

SPECIMEN: 0135

					TENSILE	
SPECIMEN	BEFORE IMMERSION			BREAKING	STRENGTH	ELONGATION
NUMBER	THICKNESS (in.)	WIDTH (in.)	Shore A HARDNESS	FORCE (lbs)	(psi)	(in.)
1 (Control)	0.093	0.247	78	3042.0	8079.3	10.1
2 (Control)	0.099	0.247	78	3071.0	7662.0	11.3
3 (Control)	0.091	0.247	78	3068.0	8327.4	10.0
AVG (Control)	0.094	0.247	78	3060.3	8022.9	10.5
1 (Test Sp.)	0.098	0.247	73	2802.3	7062.9	9.7
2 (Test Sp.)	0.097	0.249	74	2498.8	6414.4	8.7
3 (Test Sp.)						
AVG (Test Sp.)	0.098	0.248	74	2650.6	6738.7	9.2
	% CHANGE IN TEST SPECIMEN					
	TO AVG CONTROL		Shore A HARDNESS		(ΔH) CHANGE IN HARDNESS	
	TENSILE		(AFTER IMMERSION)		COMPARED TO INITIAL	
	STRENGTH	ELONGATION	IMMEDIATE	24 Hrs	IMMEDIATE	24 HRS
1 (Test Sp.)	-12.0	-7.5	62	73	-11	0
2 (Test Sp.)	-20.0	-17.2	63	74	-11	0
3 (Test Sp.)						
AVG (Test Sp.)	-16.0	-12.3	63	74	-11	0

RUBBER COMPATIBILITY – MECHANICAL PROPERTIES

(2.3.5)

ATC MATERIALS LABORATORY

Client Name Army Research Laboratory (ARL)
POC Mr. Wayne W. Ziegler
Address
Telephone 410-306-0746

TESTING LABORATORY
Name ATC Materials Laboratory
POC Mr. William Taylor
Address ATTN: TEDT-AT-WFA
APG, MD 21005-5059
Telephone (410) 278-4461

Cleaner Tested
Product Name: TBAc
Company Name: Lyondell Chemical Company
Company Address:
POC:

Specimen Information:
Alloy Type N/A
Surface Treatment
Condition/Humidity 70ºF, 50% RH

Solution Conditions:
Concentration Standard
Diluent Used
Temperature Ambient

Test Condition:
Exposure: 2 hr Immersion, test after 24 hr @ 70ºF, 50% RH
Date/Time In: 1 December 2005, 1100
Date/Time Out 1 December 2005, 1300
POC for Testing: Mr. William Taylor
Test Instrumentation: Instron Model 1125

SPECIMEN: P-12 Compound

SPECIMEN NUMBER	BEFORE IMMERSION THICKNESS (in.)	WIDTH (in.)	Shore A HARDNESS	BREAKING FORCE (lbs)	TENSILE STRENGTH (psi)	ELONGATION (in.)
1 (Control)	0.105	0.246	74	3239.0	7588.5	12.3
2 (Control)	0.098	0.252	75	3269.0	8406.0	12.6
3 (Control)	0.101	0.250	75	3123.0	7730.2	12.4
AVG (Control)	0.101	0.249	75	3210.3	7908.2	12.4
1 (Test Sp.)	0.105	0.244	75	2839.0	6597.3	11.3
2 (Test Sp.)	0.104	0.246	75	2994.5	7083.1	12.3
3 (Test Sp.)	0.105	0.245	75	2795.6	6523.1	11.7
AVG (Test Sp.)	0.105	0.245	75	2876.4	6734.5	11.8

	% CHANGE IN TEST SPECIMEN TO AVG CONTROL		Shore A HARDNESS (AFTER IMMERSION)		(ΔH) CHANGE IN HARDNESS COMPARED TO INITIAL	
	TENSILE STRENGTH	ELONGATION	IMMEDIATE	24 Hrs	IMMEDIATE	24 HRS
1 (Test Sp.)	-16.6	-8.8	62	70	-13	-5
2 (Test Sp.)	-10.4	-0.8	62	69	-13	-6
3 (Test Sp.)	-17.5	-5.7	62	71	-13	-4
AVG (Test Sp.)	-14.8	-5.1	62	70	-13	-5

RUBBER COMPATIBILITY – MECHANICAL PROPERTIES

(2.3.5)

ATC MATERIALS LABORATORY

Client Name Army Research Laboratory (ARL)
POC Mr. Wayne W. Ziegler
Address
Telephone 410-306-0746

TESTING LABORATORY
Name ATC Materials Laboratory
POC Mr. William Taylor
Address ATTN: TEDT-AT-WFA
APG, MD 21005-5059
Telephone (410) 278-4461

Cleaner Tested
Product Name: TBAc
Company Name: Lyondell Chemical Company
Company Address:
POC:

Specimen Information:
Alloy Type N/A
Surface Treatment
Condition/Humidity 70ºF, 50% RH

Solution Conditions:
Concentration Standard
Diluent Used
Temperature Ambient

Test Condition:
Exposure: 2 hr Immersion, test after 24 hr @ 70ºF, 50% RH
Date/Time In: 1 December 2005, 1215
Date/Time Out 1 December 2005, 1415
POC for Testing: Mr. William Taylor
Test Instrumentation: Instron Model 1125

SPECIMEN: T107 W/S

SPECIMEN NUMBER	BEFORE IMMERSION THICKNESS (in.)	WIDTH (in.)	Shore A HARDNESS	BREAKING FORCE (lbs)	TENSILE STRENGTH (psi)	ELONGATION (in.)
1 (Control)	0.096	0.247	78	2764.0	7111.5	8.0
2 (Control)	0.100	0.252	79	2757.0	6947.6	8.3
3 (Control)	0.098	0.249	79	2839.0	7213.4	8.1
AVG (Control)	0.098	0.249	79	2786.7	7090.9	8.1
1 (Test Sp.)	0.104	0.252	79	2559.9	6202.8	8.4
2 (Test Sp.)	0.103	0.248	80	2609.5	6283.1	8.4
3 (Test Sp.)	0.101	0.246	80	2488.4	6060.9	7.8
AVG (Test Sp.)	0.103	0.249	80	2552.6	6182.3	8.2

	% CHANGE IN TEST SPECIMEN TO AVG CONTROL		Shore A HARDNESS (AFTER IMMERSION)		(ΔH) CHANGE IN HARDNESS COMPARED TO INITIAL	
	TENSILE STRENGTH	ELONGATION	IMMEDIATE	24 Hrs	IMMEDIATE	24 HRS
1 (Test Sp.)	-12.5	3.0	68	79	-11	0
2 (Test Sp.)	-11.4	3.2	67	79	-13	-1
3 (Test Sp.)	-14.5	-3.6	68	79	-12	-1
AVG (Test Sp.)	-12.8	0.9	68	79	-12	-1

RUBBER COMPATIBILITY – MECHANICAL PROPERTIES

(2.3.5)

ATC MATERIALS LABORATORY

	TESTING LABORATORY
Client Name Army Research Laboratory (ARL)	Name ATC Materials Laboratory
POC Mr. Wayne W. Ziegler	POC Mr. William Taylor
Address	Address ATTN: TEDT-AT-WFA
	APG, MD 21005-5059
Telephone 410-306-0746	Telephone (410) 278-4461

Cleaner Tested

Product Name: TBAc

Company Name: Lyondell Chemical Company

Company Address:

POC:

Specimen Information:

Alloy Type N/A

Surface Treatment

Condition/Humidity 70ºF, 50% RH

Solution Conditions:

Concentration Standard

Diluent Used

Temperature Ambient

Test Condition:

Exposure: 2 hr Immersion, test after 24 hr @ 70ºF, 50% RH

Date/Time In: 1 December 2005, 1145

Date/Time Out 1 December 2005, 1345

POC for Testing: Mr. William Taylor

Test Instrumentation: Instron Model 1125

SPECIMEN: 0149 Compound

					TENSILE	
SPECIMEN	BEFORE IMMERSION			BREAKING	STRENGTH	ELONGATION
NUMBER	THICKNESS (in.)	WIDTH (in.)	Shore A HARDNESS	FORCE (lbs)	(psi)	(in.)
1 (Control)	0.094	0.250	76	2971.0	7901.6	10.2
2 (Control)	0.098	0.250	77	2951.0	7528.1	10.7
3 (Control)	0.093	0.250	77	2954.0	7940.9	10.4
AVG (Control)	0.095	0.250	77	2958.7	7790.2	10.4
1 (Test Sp.)	0.096	0.247	75	2739.6	7048.8	10.2
2 (Test Sp.)	0.098	0.243	74	2559.0	6345.3	9.5
3 (Test Sp.)	0.094	0.246	75	2852.2	7464.3	10.4
AVG (Test Sp.)	0.096	0.245	75	2716.9	6952.8	10.0
	% CHANGE IN TEST SPECIMEN					
	TO AVG CONTROL		Shore A HARDNESS		(ΔH) CHANGE IN HARDNESS	
	TENSILE		(AFTER IMMERSION)		COMPARED TO INITIAL	
	STRENGTH	ELONGATION	IMMEDIATE	24 Hrs	IMMEDIATE	24 HRS
1 (Test Sp.)	-9.5	-2.0	64	74	-11	-1
2 (Test Sp.)	-18.5	-9.4	63	74	-11	0
3 (Test Sp.)	-4.2	-0.2	63	75	-12	0
AVG (Test Sp.)	-10.7	-3.9	63	74	-11	0

RUBBER COMPATIBILITY – MECHANICAL PROPERTIES

(2.3.5)

ATC MATERIALS LABORATORY

	TESTING LABORATORY
Client Name Army Research Laboratory (ARL)	Name ATC Materials Laboratory
POC Mr. Wayne W. Ziegler	POC Mr. William Taylor
Address	Address ATTN: TEDT-AT-WFA
	APG, MD 21005-5059
Telephone 410-306-0746	Telephone (410) 278-4461

Cleaner Tested

Product Name: TBAc

Company Name: Lyondell Chemical Company

Company Address:

POC:

Specimen Information:

Alloy Type N/A

Surface Treatment

Condition/Humidity 70ºF, 50% RH

Solution Conditions:

Concentration Standard

Diluent Used

Temperature Ambient

Test Condition:

Exposure: 2 hr Immersion, test after 24 hr @ 70ºF, 50% RH

Date/Time In: 1 December 2005, 1230

Date/Time Out 1 December 2005, 1430

POC for Testing: Mr. William Taylor

Test Instrumentation: Instron Model 1125

SPECIMEN: 14A T107 G/S

					TENSILE	
SPECIMEN	BEFORE IMMERSION			BREAKING	STRENGTH	ELONGATION
NUMBER	THICKNESS (in.)	WIDTH (in.)	Shore A HARDNESS	FORCE (lbs)	(psi)	(in.)
1 (Control)	0.098	0.242	76	3319.0	8195.9	12.5
2 (Control)	0.095	0.251	75	2970.0	7847.1	9.8
3 (Control)	0.097	0.246	77	3221.0	8168.7	11.2
AVG (Control)	0.097	0.246	76	3170.0	8070.6	11.2
1 (Test Sp.)	0.100	0.241	75	2610.2	6290.6	9.4
2 (Test Sp.)	0.103	0.242	75	2470.6	5804.7	9.2
3 (Test Sp.)	0.102	0.244	75	2475.4	5921.5	9.2
AVG (Test Sp.)	0.102	0.242	75	2518.7	6005.6	9.3
	% CHANGE IN TEST SPECIMEN					
	TO AVG CONTROL		Shore A HARDNESS		(ΔH) CHANGE IN HARDNESS	
	TENSILE		(AFTER IMMERSION)		COMPARED TO INITIAL	
	STRENGTH	ELONGATION	IMMEDIATE	24 Hrs	IMMEDIATE	24 HRS
1 (Test Sp.)	-22.1	-15.7	64	75	-11	0
2 (Test Sp.)	-28.1	-17.9	63	75	-12	0
3 (Test Sp.)	-26.6	-17.3	64	76	-11	1
AVG (Test Sp.)	-25.6	-17.0	64	75	-11	0

RUBBER COMPATIBILITY – MECHANICAL PROPERTIES

(2.3.5)

ATC MATERIALS LABORATORY

Client Name Army Research Laboratory (ARL)
POC Mr. Wayne W. Ziegler
Address
Telephone 410-306-0746

TESTING LABORATORY
Name ATC Materials Laboratory
POC Mr. William Taylor
Address ATTN: TEDT-AT-WFA
APG, MD 21005-5059
Telephone (410) 278-4461

Cleaner Tested
Product Name: TBAc
Company Name: Lyondell Chemical Company
Company Address:
POC:

Specimen Information:
Alloy Type N/A
Surface Treatment
Condition/Humidity 70ºF, 50% RH

Solution Conditions:
Concentration Standard
Diluent Used
Temperature Ambient

Test Condition:
Exposure: 2 hr Immersion, test after 24 hr @ 70ºF, 50% RH
Date/Time In: 1 December 2005, 1115
Date/Time Out 1 December 2005, 1315
POC for Testing: Mr. William Taylor
Test Instrumentation: Instron Model 1510

SPECIMEN: 3217 / 3B

SPECIMEN NUMBER	BEFORE IMMERSION THICKNESS (in.)	WIDTH (in.)	Shore A HARDNESS	BREAKING FORCE (lbs)	TENSILE STRENGTH (psi)	ELONGATION (in.)
1 (Control)	0.088	0.242	78	3391.0	9325.3	6.1
2 (Control)	0.090	0.247	79	3441.0	9443.6	6.5
3 (Control)	0.093	0.242	79	3194.0	8311.3	6.3
AVG (Control)	0.090	0.244	79	3342.0	9026.7	6.3
1 (Test Sp.)	0.074	0.247	75	2447.3	8168.7	6.6
2 (Test Sp.)	0.076	0.246	76	2437.9	7891.1	6.7
3 (Test Sp.)	0.077	0.248	77	2487.1	8010.4	7.3
AVG (Test Sp.)	0.076	0.247	76	2457.4	8023.4	6.9

	% CHANGE IN TEST SPECIMEN TO AVG CONTROL		Shore A HARDNESS (AFTER IMMERSION)		(ΔH) CHANGE IN HARDNESS COMPARED TO INITIAL	
	TENSILE STRENGTH	ELONGATION	IMMEDIATE	24 Hrs	IMMEDIATE	24 HRS
1 (Test Sp.)	-9.5	4.3	68	69	-7	-6
2 (Test Sp.)	-12.6	6.7	66	68	-10	-8
3 (Test Sp.)	-11.3	16.3	65	70	-12	-7
AVG (Test Sp.)	-11.1	9.1	66	69	-10	-7

RUBBER COMPATIBILITY – MECHANICAL PROPERTIES

(2.3.5)

ATC MATERIALS LABORATORY

Client Name Army Research Laboratory (ARL)
POC Mr. Wayne W. Ziegler
Address
Telephone 410-306-0746

TESTING LABORATORY
Name ATC Materials Laboratory
POC Mr. William Taylor
Address ATTN: TEDT-AT-WFA
APG, MD 21005-5059
Telephone (410) 278-4461

Cleaner Tested
Product Name: TBAc
Company Name: Lyondell Chemical Company
Company Address:
POC:

Specimen Information:
Alloy Type N/A
Surface Treatment
Condition/Humidity 70ºF, 50% RH

Solution Conditions:
Concentration Standard
Diluent Used
Temperature Ambient

Test Condition:
Exposure: 2 hr Immersion, test after 24 hr @ 70ºF, 50% RH
Date/Time In: 1 December 2005, 1200
Date/Time Out 1 December 2005, 1400
POC for Testing: Mr. William Taylor
Test Instrumentation: Instron Model 1125

SPECIMEN: RW Compression

SPECIMEN NUMBER	BEFORE IMMERSION THICKNESS (in.)	WIDTH (in.)	Shore A HARDNESS	BREAKING FORCE (lbs)	TENSILE STRENGTH (psi)	ELONGATION (in.)
1 (Control)	0.091	0.247	73	3190.0	8658.6	9.8
2 (Control)	0.090	0.250	73	3219.0	8941.7	10.1
3 (Control)	0.085	0.245	72	3184.0	9177.4	9.0
AVG (Control)	0.089	0.247	73	3197.7	8925.9	9.6
1 (Test Sp.)	0.087	0.242	72	2886.2	8028.3	9.3
2 (Test Sp.)	0.089	0.243	72	2790.3	7618.5	9.1
3 (Test Sp.)	0.085	0.247	72	2884.0	8380.6	9.4
AVG (Test Sp.)	0.087	0.244	72	2853.5	8009.1	9.3

	% CHANGE IN TEST SPECIMEN TO AVG CONTROL		Shore A HARDNESS (AFTER IMMERSION)		(ΔH) CHANGE IN HARDNESS COMPARED TO INITIAL	
	TENSILE STRENGTH	ELONGATION	IMMEDIATE	24 Hrs	IMMEDIATE	24 HRS
1 (Test Sp.)	-10.1	-3.9	63	73	-9	1
2 (Test Sp.)	-14.6	-5.5	64	72	-8	0
3 (Test Sp.)	-6.1	-2.5	63	74	-9	2
AVG (Test Sp.)	-10.3	-4.0	63	73	-9	1

RUBBER COMPATIBILITY – MECHANICAL PROPERTIES

(2.3.5)

ATC MATERIALS LABORATORY

	TESTING LABORATORY
Client Name Army Research Laboratory (ARL)	Name ATC Materials Laboratory
POC Mr. Wayne W. Ziegler	POC Mr. William Taylor
Address	Address ATTN: TEDT-AT-WFA
	APG, MD 21005-5059
Telephone 410-306-0746	Telephone (410) 278-4461

Cleaner Tested

Product Name: TBAc

Company Name: Lyondell Chemical Company

Company Address:

POC:

Specimen Information:

Alloy Type N/A

Surface Treatment

Condition/Humidity 70ºF, 50% RH

Solution Conditions:

Concentration Standard

Diluent Used

Temperature Ambient

Test Condition:

Exposure: 2 hr Immersion, test after 24 hr @ 70ºF, 50% RH

Date/Time In: 1 December 2005, 1130

Date/Time Out 1 December 2005, 1330

POC for Testing: Mr. William Taylor

Test Instrumentation: Instron Model 1125

SPECIMEN: 3217 / 2B

					TENSILE	
SPECIMEN	BEFORE IMMERSION			BREAKING	STRENGTH	ELONGATION
NUMBER	THICKNESS (in.)	WIDTH (in.)	Shore A HARDNESS	FORCE (lbs)	(psi)	(in.)
1 (Control)	0.074	0.247	78	2949.0	9843.3	7.8
2 (Control)	0.075	0.243	77	1969.0	6379.6	5.1
3 (Control)	0.076	0.248	79	2820.0	9202.1	7.6
AVG (Control)	0.075	0.246	78	2579.3	8475.0	6.8
1 (Test Sp.)	0.084	0.247	73	2342.9	6889.2	5.1
2 (Test Sp.)	0.084	0.245	72	2751.5	8025.2	6.0
3 (Test Sp.)	0.089	0.242	72	2919.7	7939.0	5.4
AVG (Test Sp.)	0.086	0.245	72	2671.4	7617.8	5.5

	% CHANGE IN TEST SPECIMEN TO AVG CONTROL		Shore A HARDNESS (AFTER IMMERSION)		(ΔH) CHANGE IN HARDNESS COMPARED TO INITIAL	
	TENSILE STRENGTH	ELONGATION	IMMEDIATE	24 Hrs	IMMEDIATE	24 HRS
1 (Test Sp.)	-18.7	-24.9	70	73	-3	0
2 (Test Sp.)	-5.3	-13.0	71	72	-1	0
3 (Test Sp.)	-6.3	-20.5	72	74	0	2
AVG (Test Sp.)	-10.1	-19.5	71	73	-1	1

APPENDIX Z. EFFECTS ON POLYIMIDE WIRE DATA SHEETS

(Page Z-2 Blank)

EFFECTS ON POLYMIDE WIRE

(2.3.6)

ATC MATERIALS LABORATORY

	TESTING LABORATORY
Client Name Army Research Laboratory (ARL)	Name ATC Materials Laboratory
POC Mr. Wayne W. Ziegler	POC Mr. William Taylor
Address	Address ATTN: TEDT-AT-WFA
	APG, MD 21005-5059
Telephone 410-306-0746	Telephone (410) 278-4461

Cleaner Tested

Product Name: TBAc

Company Name: Lyondell Chemical Company

Company Address:

POC:

Specimen Information:	**Solution Conditions:**
Alloy Type	Concentration Standard
Surface Treatment	Diluent Used DI Water
Condition	Temperature 23º C

Test Condition:

Exposure: 14 Days

Date/Time In: 14 September 2005, 1330	Date/Time Out: 28 September 2005, 1330
POC for Testing: Mr. William Taylor	Test Instrumentation: Slaughter, Model 1101

	OBSERVATIONS		
	Dissolution of Wire	Cracking	Breakdown/Leakage (2500 V)
Control Wire (In Deionized Water)	No Effects	No Effects	Pass
Test Wire (In Cleaner)	No Effects	No Effects	Pass

(Page Z-4 Blank)

APPENDIX AA. REFERENCES

1. Taylor, W., Final Report, Sustainable Painting Operations for the Total Army (SPOTA) Alternative Cleaner Test Support Program, DTC Project No. 2005-DT-ATC-ARSPT-C7867, Report No. ATC-9356, March 2007.

1.1.1-1. AR 40-5, Medical Services, Preventive Medicine.

1.1.2-1. ASTM D93, Standard Test Methods for Flash-Point by Pensky-Martens Closed Cup Tester.

1.1.3-1. ASTM D1353, Standard Test Method for Nonvolatile Matter in Volatile Solvents for Use in Paint, Varnish, Lacquer, and Related Products.

1.1.4-1. ASTM D2879, Standard Test Method for Vapor Pressure-Temperature Relationship and Initial Decomposition Temperature of Liquids by Isoteniscope.

1.2.1-1. MIL-PRF-680A, Degreasing Solvent.

1.2.1-2. ASTM A366, Standard Specification for Commercial Steel (CS) Sheet, Carbon (0.15 Maximum Percent) Cold-Rolled (Withdrawn 2000). Replaced by A1008, Standard Specification for Steel, Sheet, Cold-Rolled, Carbon, Structural, High-Strength Low-Alloy, High-Strength Low-Alloy with Improved Formability, Solution Hardened, and Bake Hardenable.

1.2.1-3. MIL-G-10924F, Grease, Automotive and Artillery.

1.2.2-1. ADS-61A-PRF, Aeronautical Design Standard, Performance Specification for Army Aircraft Cleaners, Aqueous and Solvent.

1.2.2-2. MIL-P-23377, Epoxy-Polyamide, Type I and Type II.

1.2.2-3. MIL-P-85582, Primer Coatings: Epoxy, Waterborne.

1.2.2-4. AA-58054, Abrasive Mats, Non-Woven, Non-Metallic.

1.2.2-5. MIL-PRF-83282 (formerly MIL-H-83282), Hydraulic Fluid, Synthetic, Fire Retardant.

1.2.2-6. MIL-PRF-81322, Grease, Aircraft, General Purpose, Wide Temperature Range.

1.2.2-7. ASTM D740, Standard Specification for Methyl Ethyl Ketone.

1.2.2-8. ASTM D1193, Standard Specification for Reagent Water.

1.2.2-9. MIL-S-8802, Sealing Compound, Type II, Class B.

1.2.2-10. CCC-C-419, Cloth, Cotton, Duck, Unbleached, Plied-Yarns, Army and Numbered.

1.2.2-11. AMS 2629, Jet Reference Fluid.

1.2.2-12. AS5127, Methods for Testing Aerospace Sealants.

1.2.2-13. AS5127/1, Test Methods for Aerospace Sealants Two-Component Synthetic Rubber Compounds.

1.2.3-1. FED-STD-141, Paint, Varnish, Lacquer, and Related Materials: Methods of Inspection, Sampling and Testing.

1.2.3-2. MIL-A-8625, Anodic Coatings for Aluminum and Aluminum Alloys.

1.2.3-3. MIL-C-5541, Chemical Conversion Coatings on Aluminum and Aluminum Alloys.

1.2.3-4. MIL-C-85285, Coating, Polyurethane, High-Solids, Type I and Type II.

1.2.4-1. ASTM E1417, Standard Practice for Liquid Penetrant Testing.

1.2.4-2. ASTM E165, Standard Test Method for Liquid Penetrant Examination.

1.2.4-3. ASTM E1210, Standard Test Method for Fluorescent Liquid Penetrant Examination Using the Hydrophilic Post-Emulsification Process.

1.2.4-4. AMS 2644, Inspection Material, Penetrant.

1.2.4-5. ASTM E1219, Standard Test Method for Fluorescent Liquid Penetrant Examination Using the Solvent-Removable Process.

1.2.5-1. ASTM F22, Standard Test Method for Hydrophobic Surface Films by the Water-Break Test.

2.1.1-1. AMS 4377, Magnesium Alloy, Sheet and Plate, 3.0Al - 1.0Zn - 0.20Mn (AZ31B-H24), Cold Rolled, Partially Annealed.

2.1.1-2. AMS-M-3171, Magnesium Alloy, Processes for Pretreatment and Prevention of Corrosion on.

2.1.1-3. ASTM F483, Standard Test Method for Total Immersion Corrosion Test for Aircraft Maintenance Chemicals.

2.1.1-4. ASTM D235, Standard Specification for Mineral Spirits (Petroleum Spirits) (Hydrocarbon Dry Cleaning Solvent).

2.1.1-5. ASTM D329, Standard Specification for Acetone.

2.1.2-1. SAE ARP1755, Effect of Cleaning Agents on Aircraft Engine Materials, Stock Loss Test Method, 1 March 2000.

2.1.3-1. ASTM F519, Standard Test Method for Mechanical Hydrogen Embrittlement Evaluation of Plating Processes and Service Environments.

2.1.3-2. ANSI 4340 (AISI 4340) Steel, Alloy.

2.1.4-1. ASTM F1110, Standard Test Method for Sandwich Corrosion Test.

2.1.4-2. ASTM G46, Standard Guide for Examination and Evaluation of Pitting Corrosion.

2.1.5-1. ASTM F945, Standard Test Method for Stress-Corrosion of Titanium Alloys by Aircraft Engine Cleaning Materials.

2.1.5-2. AMS 4911, Titanium, Sheet, Strip, and Plate 6Al-4V Annealed.

2.1.5-3. AMS 4916, Titanium, Sheet, Strip, and Plate-8AL 1MO 1V, Duplex Annealed.

2.1.6-1. ASTM G30, Standard Practice for Making and Using U-Bend Stress-Corrosion Test Specimens.

2.1.6-2. ASTM G44, Standard Practice for Exposure of Metals and Alloys by Alternate Immersion in Neutral 3.5% Sodium Chloride Solution.

2.1.6-3. MIL-DTL-46063, Armor Plate, Aluminum Alloy, 7039.

2.1.7-1. ASTM F1111, Standard Test Method for Corrosion of Low-Embrittling Cadmium Plate by Aircraft Maintenance Chemicals.

2.1.7-2. MIL-S-18729, Steel Plate, Sheet, and Strip, Alloy, 4130, Aircraft Quality.

2.1.8-1. ASTM D130, Standard Test Method for Corrosiveness to Copper from Petroleum Products by Copper Strip Test.

2.2.1-1. ASTM F502, Standard Test Method for Effects of Cleaning and Chemical Maintenance Materials on Painted Aircraft Surfaces.

2.2.1-2. MIL-C-81706, Chemical Conversion Materials for Coating Aluminum and Aluminum Alloys.

2.2.1-3. MIL-C-22750, High Solids Epoxy Topcoat.

2.2.1-4. MIL-C-46168, Coating, Aliphatic Polyurethane, Chemical Agent Resistant.

2.2.1-5. MIL-P-14105, Paint, Heat-Resisting (for Steel Surfaces).

2.2.1-6. MIL-P-53022, Primer, Epoxy Coating, Corrosion Inhibiting, Lead and Chromate Free.

2.2.1-7. MIL-C-64159, Water Borne Camouflage, Aliphatic Polyurethane, Chemical Agent Resistant Coating.

2.2.1-8. MIL-C-53039, Coating, Aliphatic Polyurethane, Single Component, Chemical Agent Resistant.

2.2.2-1. ASTM F485, Standard Test Method for Effects of Cleaners on Unpainted Aircraft Surfaces.

2.2.2-2. ASTM A242, Standard Specification for High-Strength Low-Alloy Structural Steel.

2.2.2-3. AMS-QQ-A-250/6, Aluminum Alloy 5083, Plate and Sheet.

2.3.1-1. MIL-PRF-81733D, Sealing and Coating Compound, Corrosion Inhibitive.

2.3.1-2. AMS-S-8802, Sealant Sheet Stock.

2.3.1-3. ASTM D2240, Standard Test Method for Rubber Property - Durometer Hardness.

2.3.2-1. ASTM F484, Standard Test Method for Stress Crazing of Acrylic Plastics in Contact With Liquid or Semi-Liquid Compounds.

2.3.2-2. MIL-P-5425, Plastic, Acrylic Sheet, Heat Resistant.

2.3.2-3. MIL-P-8184, Plastic Sheet, Acrylic, Modified.

2.3.2-4. MIL-P-25690, Plastic, Sheet and Formed Parts, Modified Acrylic Base, Monolithic, Crack Propagation Resistant.

2.3.3-1. MIL-P-83310, Plastic Sheet, Polycarbonate, Transparent.

2.3.4-1. ASTM D2583, Standard Test Method for Indentation Hardness of Rigid Plastics by Means of a Barcol Impressor.

2.3.5-1. ASTM D471, Standard Test Method for Rubber Property - Effect of Liquids.

2.3.5-2. ASTM D412, Standard Test Methods for Vulcanized Rubber and Thermoplastic Elastomers - Tension.

2.3.5-3. AMS3217/2B, Test Slabs, Acrylonitrile Butadiene (Nbr-L), Low Acrylonitrile, 65-75.

2.3.5-4. AMS3217/3B, Test Slabs, Chloroprene (Cr), 65-75.

2.3.5-5. MIL-DTL-45301E, Tread Elastomer: Solid Tire, for Track Laying Vehicles.

2.3.6-1. MIL-W-81381/11-20, Aircraft Wire, Polyimide.

APPENDIX BB. ABBREVIATIONS

ADS	=	Aeronautical Design Standard
AISI	=	American Iron and Steel Institute
AMS	=	Aerospace Material Specification
ANSI	=	American National Standards Institute
APG	=	Aberdeen Proving Ground
AR	=	Army Regulation
ARL	=	U.S. Army Research Laboratory
ARP	=	Aerospace Recommended Practice
ASSWG	=	U.S. Army Solvent Substitution Working Group
ASTM	=	American Society for Testing and Materials
ATC	=	U.S. Army Aberdeen Test Center
CARC	=	chemical agent resistant coating
CHPPM	=	U.S. Army Center for Health Promotion and Preventive Medicine
DI	=	deionized
DoD	=	Department of Defense
DTC	=	U.S. Army Developmental Test Command
DVPE	=	dry vapor pressure equivalent
EPA	=	Environmental Protection Agency
ESTCP	=	Environmental Security Technology Certification Program
G/S	=	ground side
HAP	=	hazardous air pollutant
JS3	=	Joint Services Solvent Substitution
LIR	=	light intensity reading
MEK	=	methyl ethyl ketone
MSDS	=	material safety data sheet
NESHAP	=	National Emissions Standard for Hazardous Air Pollutants
NVR	=	nonvolatile residue
PPE	=	personal protection equipment
RW	=	roadwheel
rms	=	root mean square
SAE	=	Society of Automotive Engineers
SMC	=	sheet molding compound
SMI	=	Scientific Material International, Inc.
SPOTA	=	Sustainable Painting Operations for the Total Army
TACOM	=	U.S. Army Tank-automotive and Armaments Command
TBAC	=	tertiary butyl acetate
VOC	=	volatile organic compound
W/S	=	wheel side

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