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Evaluation of Methylene Chloride Emission Control Technologies at Anniston Army Depot

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Abstract: Anniston Army Depot (ANAD) is responsible for the refurbishment of battlefield U.S. Army tanks and small armaments. One of the processes used during refurbishment is for paint stripping and repainting. The stripping process uses a methylene chloride-based solution that contains methylene chloride, formic acid, surfactants, aromatic hydrocarbons, and wax. The goal of ANAD is to reduce its methylene chloride emissions by 80 percent; therefore, MSE Technology Applications, Inc. examined the Depot's stripping system and identified a number of process modifications that should significantly reduce methylene chloride emissions.

Before implementing any changes to the existing stripping system, it is recommended that offgas emissions be sampled and quantified to establish a baseline. This baseline will allow ANAD to determine the effectiveness of each modification toward meeting the overall emissions reduction goal.

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Preface

This study was conducted at Anniston Army Depot (ANAD), Anniston, AL under the Waste Minimization and Pollution Prevention Program. The technical monitor was Tony Pollard, ANAD.

The work was performed by the Environmental Processes Branch (CN-E) of the Installations Division (CN), Construction Engineering Research Laboratory (CERL). The CERL Project Manager was Michelle Hanson, and the CERL Principal Investigator was Dr. Veera M. Boddu. Marsha Trimble Duncan was project manager for MSE Technology Applications (MSE-TA, Butte, MT), which provided engineering design services. Dr. Stephen Maloney is Acting Chief, CN-E, and Dr. John T. Bandy is Chief, CN. The Technical Director for the Environmental Quality/Installations business area was Martin J. Savoie. The Deputy Director of CERL is Dr. Kirankumar V. Topudurti. The Director of CERL is Dr. Ilker Adiguzel.

CERL is an element of the U.S. Army Engineer Research and Development Center (ERDC), U.S. Army Corps of Engineers. The Commander and Executive Director of ERDC is COL Richard B. Jenkins, and the Director of ERDC is Dr. James R. Houston.

Unit Conversion Factors

Multiply	By	To Obtain
British thermal units (International Table)	1,055.056	joules
cubic feet	0.02831685	cubic meters
cubic inches	1.6387064 E-05	cubic meters
degrees Fahrenheit	$(F-32)/1.8$	degrees Celsius
gallons (U.S. liquid)	3.785412 E-03	cubic meters
inches	0.0254	meters
miles (U.S. statute)	1,609.347	meters
pounds (force) per square inch	6.894757	kilopascals
square feet	0.09290304	square meters
square inches	6.4516 E-04	square meters

1 Introduction

Background

Anniston Army Depot (ANAD) is an active Army facility in northeast Alabama, approximately 8 miles west of the city of Anniston. ANAD's mission includes: repair/rebuild of tanks and other tracked vehicles and heavy equipment; storage, disassembly, and transportation of munitions (chemical and conventional); and repair/rebuild of small arms.

ANAD is currently using a methylene chloride-based solution, NP-66, for its paint stripping operation. In this operation, various parts of battlefield tanks and armaments are sent through a chemical agent resistant compound (CARC) paint and primer stripping process. The major ingredients of the stripper solution are methylene chloride, formic acid, surfactants, aromatic hydrocarbons, and wax. This product is hazardous as defined in the Code of Federal Regulations (CFR) 29 CFR1910.1200. From all of its operations, including stripping, ANAD was emitting approximately 50 tons of methylene chloride per year during the early 2000s. The federal Maximum Achievable Control Technology (MACT) guidelines allow a maximum release of 10 tons of methylene chloride.

The proposed Miscellaneous Metal Parts Coating NESHAP (40 CFR 63.3880, Subpart MMMM, National Emission Standard for Hazardous Air Pollutants: Surface Coating of Miscellaneous Metal Parts and Products) for painting and paint stripping operations requires control of emissions of hazardous air pollutants (such as, methylene chloride) from these operations. The U.S. Environmental Protection Agency (EPA) has proposed the National Emission Standard for Hazardous Air Pollutants (NESHAP) for pollutants (*Federal Register*, Volume 67, No. 65, Proposed Rule dated April 4, 2002). The NESHAP would require the installation of emission controls within 3 years of the date of final publication of the rule in the Federal Register (29 CFR 1910, 1999).

Objective

The primary goal of this project was to search for systems or alternative solvents that will eliminate or control methylene chloride emissions and are applicable to the paint stripping and repainting operation. The goals were realized by investigating: (1) replacement solvents that would effec-

tively replace methylene chloride in ANAD's existing stripping process; (2) installation of emissions control equipment for ANAD's existing system; and (3) alternative paint stripping processes to completely replace ANAD's existing system.

Approach

A review of technologies was conducted to determine if substitution of methylene chloride in ANAD's stripping process is a viable consideration. In addition, alternatives were investigated for the vat stripping process and modifications to the existing process considered to reduce methylene chloride emissions.

ANAD's primary stripping requirements are that the stripper:

- must strip 100 percent of the paint within 30 minutes,
- must meet NESHAP emission requirements,
- must not create a health hazard that is difficult to manage,
- must be available in large enough quantities for ANAD's operation,
- must be reasonably inexpensive, and
- maintenance must be manageable by Depot operations.

The evaluation of replacement solvents included determining the stripping effectiveness of each solvent versus ANAD's stripping requirements and whether the replacement solvent would allow ANAD to meet the proposed new MACT standards.

Mode of technology transfer

Information contained in this report can be used as a basis for modifying stripping systems at Army installations. The results of this research will help reduce methylene chloride emissions during stripping operations. The results of this research will be made available to industrial installations and shared with other DOD installations that use methylene chloride-based stripping process.

This report will be accessible through the World Wide Web (WWW) URL:

<http://www.cecer.army.mil>

2 Methylene Chloride Stripping Solution Description

Methylene chloride (CH_2Cl_2), also known as dichloromethane and methylene dichloride, is a colorless liquid with a chloroform-like odor. Table 1 lists the physical properties of methylene chloride. These strippers usually contain methylene chloride 40 to 50 percent and formic acid up to 15 percent. The chemical is predominantly used as a solvent. Short-term (acute) inhalation of methylene chloride affects mainly the central nervous system (CNS), including decreased visual, auditory, and motor functions; however, these effects are reversible once exposure ceases. Long-term (chronic) exposure to methylene chloride affects the CNS in humans and

Table 1. Physical properties of methylene chloride.

Chemical Formula	CH_2Cl_2	Units
Molecular Weight	84.932	g/mol
Boiling Point @ 760 mm mercury	39.7	°C
	103.5	°F
Freezing Point	-95	°C
	-139	°F
Specific Gravity	1.32	(25/25 °C)
Density @ 25 °C	10.989	lb/gal
	1.32	g/cm ³
Vapor Density (air=1.00)	2.93	
Specific Heat @ 25 °C	0.283	(cal/g °C)
Heat of Vaporization (@ Normal Boiling Point)	78.9	cal/g
	142	Btu/lb
Refractive Index @ 25 °C	1.421	
Viscosity @ 25 °C	0.41	cp
Flash Point	Tag Open Cup ASTM*	Method D-1310
	Tag Closed Cup ASTM	Method D-56
Solubility @ 25 °C	H ₂ O in solvent	0.18 g/100g
	Solvent in H ₂ O	1.3 g/100g
Flammable Limits @ 25 °C	Lower limit	14 volume % of solvent in air
	Upper limit	22 volume % of solvent in air

*ASTM – American Society for Testing and Materials

Source: NIOSH Pocket Guide to Chemical Hazards and Global Chlorinated Organics Business

animals. Human data are inconclusive regarding methylene chloride cancer links; animal studies have shown increases in liver and lung cancer and benign mammary gland tumors following the inhalation of methylene chloride. The EPA has classified methylene chloride as a Group B2, probable human carcinogen (Methylene Chloride [Dichloromethane], EPA <http://www.epa.gov/ttn/atw/hlthef/methylen.html>).

3 Process Evaluation Criteria

Several alternative solvents and processes were evaluated against a set of performance criteria to determine the viability of the new process or material. Input from stripping performance, safety, compliance, production impacts, economics, and infrastructure compatibility were all considered. Any process change or material substitution would require additional formal review by ANAD prior to implementation.

Safety

Concerns related to worker exposure to airborne emissions

Local emissions in the direct vicinity of the vat need to be considered for inhalation health hazards. The National Institute for Occupational Safety and Health (NIOSH) has developed recommended exposure limits (RELs) that are time-weighted average (TWA) concentrations in air established as guidelines for a maximum 10-hour workday during a 40-hour workweek. The Occupational Safety and Health Administration (OSHA) has promulgated permissible exposure limits (PELs) for determining safe interaction with chemicals. The PELs are expressed as a TWA reflecting the concentration of a substance to which most workers can be exposed without adverse effect averaged over a normal 8-hour workday or a 40-hour workweek. OSHA numbers are regulatory, which are values that have been incorporated in Government regulations. NIOSH numbers are nonregulatory values provided by the Government or other groups and are advisory only. Methylene chloride is considered to be a potential occupational carcinogen under NIOSH's REL. A potential occupational carcinogen is defined as any substance, or combination or mixture of substances, which causes an increased incidence of benign and/or malignant neoplasms or a substantial decrease in the latency period between exposure and onset of neoplasms in humans or in one or more experimental mammalian species as the results of any oral, respiratory, or dermal exposure, or any other exposure that results in the induction of tumors at a site other than the site of administration. This definition also includes any substance that is metabolized into one or more potential occupational carcinogens by mammals (NIOSH 1997).

OSHA PELs are found in Tables Z-1, Z-2, and Z-3 of the OSHA General Industry Air Contaminants Standard (29 CFR 1910.1000). The methylene

chloride PEL (OSHA General Industry Air Contaminants Standard, 29CFR1910.1052) is 25 parts per million (ppm). For methylene chloride, 1 ppm = 3.47 milligram per cubic meter (mg/m³); therefore, the PEL is 25x3.47 mg/m³ or 86.75 mg/m³. This PEL is a TWA concentration that must not be exceeded during any 8-hour work shift of a 40-hour work-week. The 15-min short-term exposure limit (STEL) of 125 ppm should not be exceeded at any time during a workday (NIOSH 1997).

NIOSH determined that the level for methylene chloride immediately dangerous to life or health (IDLH) is 2,300 ppm. This limit is defined in the NIOSH Respirator Decision Logic (Department of Health and Human Services [NIOSH] Publication No. 87-108, and National Technical Information Service [NTIS] Publication No. PB-91-151183) where the concentration poses a threat of exposure to airborne contaminants; when that exposure is likely to cause death, or immediate or delayed permanent adverse health effects; or prevent escape from such an environment (NIOSH 1997).

All solvents being considered for substitution of methylene chloride will need to be evaluated in a similar manner for their impacts on workers exposed through airborne emissions.

Other health effects

Other worker health considerations such as skin absorption, skin contact, eye contact, or ingestion need to be evaluated. If substitute solvents or processes are used, controls may need to be installed to reduce human exposure and meet OSHA requirements. The most common method to control worker exposure is by implementing the use of personal protective equipment (PPE). The secondary health effects related to daily use of PPE, including worker comfort, cooling, and morale issues, should be considered. The benefits of implementing PPE (including respirators) must be weighed against the secondary effects to the employee, and an option that does not require the use of PPE is preferred over one requiring PPE.

ANAD's stripping process currently uses methylene chloride at ambient temperature. While temperature increases may accelerate the stripping process for some types of solvents, higher temperatures can result in burns. Precautions need to be taken by employees and any other people in the vicinity to avoid splashes from a dripping cage, or touching a hot vat, or any other accidental contact with the hot solvent. Also, some paint

removal processes, such as sodium bicarbonate blasting, may cause increased noise levels that would require hearing protection.

Environmental compliance

The paint stripping and repainting operation at ANAD will be subject to the MACT guidelines when they come into effect. Since the EPA proposed the NESHAP for hazardous air pollutants such as methylene chloride on 4 April 2002, the requirement for installation of emission controls will be effective within 3 years of the date of final publication of the rule in the *Federal Register* (3 February 2004).

Prior to 2003, the estimated total emissions from ANAD was approximately 50 tons of methylene chloride per year from all its operations and systems; the federal MACT guidelines will require these emissions to be cut by 80 percent to approximately 10 tons per year. Although ANAD was unable to provide a breakdown of methylene chloride emissions by operation unit, the emissions from paint stripping is a significant component of the total. Therefore, reductions in emissions from the paint stripping operation are expected to have a major impact on the goal of meeting the MACT guidelines. Alternative stripping systems that would completely eliminate methylene chloride will also need to be evaluated regarding their effect in meeting the MACT guidelines.

Emission control system requirements at ANAD

According to the head of stripping operations at the Depot, 30 minutes is the maximum allowable turnover time for stripping processes. This timeframe is necessary to meet the production volume of stripped parts without increasing labor requirements for the stripping operation.

Requirements for additional or replacement equipment for the stripping process at ANAD include the footprint of the equipment, space availability, electrical requirements, indoor or outdoor location, and any required separate rooms or enclosures that may need to be built.

Economics

Any proposed new process or equipment, removal or treatment system, or alternative chemical must be analyzed and tested before any implementations are made at ANAD. Factors that affect the cost effectiveness of stripping alternatives include initial capital costs,

investment recovery time, operating costs, raw material availability, and environmental regulatory compliance costs.

4 Potential Methods for Methylene Chloride Emissions Reductions

Replacement solvents

Replacing the methylene chloride-based solvent in the stripping operation with an alternative solvent clearly would significantly affect the total emissions of methylene chloride. The alternative stripping agents suitable as substitutes for methylene-chloride-based solutions would not compromise ANAD's existing stripping requirements.

Chemicals previously investigated for stripping at ANAD

ANAD has made efforts in the past to find a replacement stripping solution. These investigations are summarized below.

Inchemco study

A solicitation (#DAAC01-97-B-0007) placed with the *Commerce Business Daily Issue* (CBD) on 13 November 1996 by ANAD's Directorate of Contracting requested a paint stripping compound solution to meet the specifications outlined. The specifications included a cold working solution compatible with the existing cleaning equipment and wastewater treatment system. Inchemco Chemical, a division of JEM Sales, Inc. and Florida Chemical Supply, Inc. responded to the solicitation; however, their compounds failed to remove 100 percent of the coatings under these specified conditions (ANAD 1996).

Lactate esters

Lactate esters, also known as dimethyl or dibasic esters, have been used to replace methylene chloride in some applications. DuPont Yerkes, a polymer producer in Tonawanda, NY, substituted this ester in its cleaning process. This substitution resulted in an annual reduction of 120,000 pounds of methylene chloride in 2 years (NY Dept. of Environmental Conservation 1999). ANAD has been testing lactate esters for applications other than the stripping operations.

It is suggested that stripping tests be performed using the lactate esters against ANAD's CARC paint. The parts must be rinsed after stripping or

the lactate esters will leave methyl solate on the surface of the part causing adherence problems for future painting.

N-Methyl 2-Pyrrolidone (NMP)

The possibility of using NMP as a substitute for methylene chloride was investigated. Success stories from DuPont Yerkes in Tonawanda, NY, and the Marine Corps Logistics Base (MCLB), Albany, GA, were reviewed.

DuPont Yerkes used methylene chloride to remove hard acrylic residues on floors, machinery, and other surfaces. Methylene chloride was replaced by NMP (1-methyl-2-pyrrolidone) with ethyl-3-ethoxypropionate and operating procedures were revised. An annual reduction of 23,000 pounds of methylene chloride was achieved by 1993. (Groshart 1997).

From 1 November to 21 December 1995, the MCLB conducted a demonstration using NMP for stripping cured coatings from metal parts. MCLB strips CARC paint from small arms to tanks, trucks, and other vehicles for maintenance. The results of this demonstration proved that NMP, when heated to 150 +/- 10 °F (66 +/- 6 °C), was able to remove multiple layers of CARC and strip parts to the base metal within 3 to 4 hours (Elion et al. 1996). Notwithstanding partial success with NMP, the time of 3 to 4 hours needed to strip parts in the demonstration at the MCLB exceeds the acceptable time limit for the ANAD facility.

Acetaldehyde

Acetaldehyde has been shown to strip many paints such as the alkyds and drying oil varieties and is used in dip tanks or as a thickener. Due to its high evaporation rate, it would need an evaporation seal. Even though acetaldehyde is effective for many paints, it is slow for polyurethane and epoxies, often taking up to 24 hours to work (Groshart 1997); consequently, it is not a good candidate for CARC paints.

Other studies of replacement solvents

U.S. Army Construction Engineering Research Laboratory (USACERL) study

USACERL performed tests in May 1988 and subsequently issued a report titled *Alternative Chemical Paint Strippers for Army Installations, Volume I: Identification and Laboratory Analysis* (Reinbold et al. 1993). The report identified a number of alternative chemical paint strippers. Details of the standards and testing may be found in the report. Three

strippers meeting the standards of that time were: Oakite ALM, Patclin 104C, and Patclin 103B.

Subsequent studies identified four additional strippers that merited further investigation. The strippers were: Fine Organics (FO) 606, McGean –Rohco's Cee Bee A-477, Turco 5668, and the CERL Paint Technology Center's PTC#13 (Reinbold et al. 1993).

Idaho National Engineering and Environmental Laboratory (INEEL) study

The Idaho National Engineering and Environmental Laboratory in Idaho Falls, ID, performed some screening tests on 60 paint removal formulations. Out of these 60, 10 paint solvents proved promising enough to move into extended testing (Tsang and Herd 1993). The commercial trade names of these 10 solvents are: Chemical Methods CM-3707; Chemical Solvents SP-800; Fine Organics FO 606; Federick Gumm Clepo Envirostrip 222; GAF M-Pyrol; McGean-ROHCO Cee Bee A245; McGean-ROHCO Cee Bee A477; Patclin 126 Hot Stripper; Rochester Midland PSS 600; and Turco T5668.

INEEL was unable to provide the details of these test results. Further investigation might reveal if any of the 10 solvents could be applied to the stripping application at ANAD.

Test method for evaluation of alternative solvents

A uniform testing procedure was followed to test all the alternative solvents. Effectiveness of each alternative solvent was tested by the vendors on identical metal coupons supplied by the project. Rectangular test coupons (4 in. × 3 in.) were constructed from 16-gauge carbon steel sheet metal and then painted by ANAD. The test coupons were first primed (to a thickness of 1 mil) with the standard primer ANAD uses at the site, Mil-P-53022. After the primer dried, the coupons were painted with two standard paints used during ANAD's normal painting operation. In all, 75 of the coupons were painted green using MIL-C-46168, and the other 75 were painted white using MIL-C-22750. The paint coupons were cured for 7 to 14 days prior to shipping. ANAD shipped the coupons to most of the vendors for analysis on 28 May 2003, and to the remaining vendor and MSE on 3 June 2003. (See Appendix A for photographs of coupons taken at different temperatures.)

Investigation of commercial solvents

MSE Technology Applications, Inc. (MSE; Butte, MT) also contacted several chemical companies with the hope that one or more would possess alternative stripper solutions for use in paint removal tests. Those companies claiming to have a replacement stripping solution meeting ANAD's requirements were provided with paint coupons.

The vendor laboratories receiving the paint coupons for further testing were: Chemetall Oakite®, Berkeley Heights, NJ; Petroferm, Inc., Fernandina Beach, FL; Parts Cleaning Technologies, Indianapolis, IN; McGean-ROHCO, Cleveland, OH; Kolene® Corporation, Detroit, MI / Farr Technical Center, Bowling Green, KY; Polychem, Chestnut Ridge, NY; and Inland Technology Incorporated, Tacoma, WA.

MSE requested that each laboratory submit a report to include the temperature, testing procedure, and results. Appendix B details the project requirements provided to each laboratory. To protect the solvent manufacturers' proprietary interests, solvent components are identified by product names instead of chemical names. From the results of these laboratory tests, only Chemetall Oakite's GARDOSTRIP Q7900 stripper worked within ANAD's 30-min maximum stripping time requirement. Results received for each of the commercial solvents are summarized below and may also be found in Appendix C.

Chemetall Oakite

Results — Chemetall Oakite performed several tests in its laboratories and were successful in finding a stripper that stripped within the 30-min timeframe, removing both types of CARC paint and primer completely. This stripper was used in conjunction with continuous agitation and heat at 180 °F. The GardoStrip Q7900, LO16002, and ChemStrip 5015 were used at 100 percent concentration; the EuroStrip 7028/7031 was prepared at 50 percent concentration of EuroStrip 7028, 38.5 percent of EuroStrip 7031, and 11.5 percent of water; and the EuroStrip 7048/7049 was prepared at a 1:1 ratio. Each bath was heated to 180 °F with agitation, and the coupon was then rinsed with water at ambient temperature. See Table 2 for the stripping time results.

Table 2. Oakite stripping test results for CARC paint.

Chemical	Coupon Color	Temperature (°F)	Time to Strip	Percent Stripped
GardoStrip Q7900	White	180	10 min	100
GardoStrip Q7900	Green	180	30 min	100
EuroStrip 7028/7031	White	180	30 min	100
EuroStrip 7028/7031	Green	180	8 hr	90
EuroStrip 7048/7049	White	180	30 min	100
EuroStrip 7048/7049	Green	180	8 hr	100
LO 16002	White	180	30 min	100
LO 16002	Green	180	3 hr	98
ChemStrip 5015	White	180	10 min	100
ChemStrip 5015	Green	180	1 hr	100

Potential process/production modifications — GardoStrip penetrated the paint and lifted it off from the coupon in sheets. If this chemical was to be used in the vats at ANAD, filtration would be recommended to remove paint debris. A secondary screen may also be needed for retention of floating paint and for easy cleaning. Skimming the bath periodically to remove paint flotation would also be recommended for the normal maintenance routine.

Chemical hazard analysis — The hazardous level of GardoStrip needs further investigation. GardoStrip is an acidic blend of solvents and acid products. Its Material Safety Data Sheet (MSDS) provides limited information about the solvent (see Appendix D). Only one ingredient (sodium lauryl sulfate) is actually listed on the MSDS and is stated to be 1 to 5 percent by weight. The other ingredients are listed as “Trade secret registry (735517).” A statement on the MSDS sheet indicates that the “unidentified ingredients are considered not hazardous under the Federal Hazard Communication Standard (29 CFR 1910.1200).” This CFR Standard states: “Hazardous chemical means any chemical which is a physical hazard or a health hazard” (U.S. EPA 1999). The MSDS for sodium lauryl sulfate indicates that it has a pH of 8 to 10 at 1 percent solution. The MSDS for GardoStrip indicates the pH is two to three. The difference in pH suggests that a strong acid is added and the “Trade secret registry (735517)” ingredients are corrosive. Hazards from skin and eye contact need to be taken into consideration more with GardoStrip than with methylene chloride. From an inhalation standpoint, it is indicated by the MSDS that GardoStrip

Q7900A is less hazardous than methylene chloride. Chemetall Oakite states that GardoStrip Q7900A has low volatility and will not evaporate easily even at 180 °F.

Recommendations — These test results are based on laboratory testing and may vary slightly during actual usage. Further investigation is recommended into this product, and, if further investigation does not rule out usage, a test vat should be set up and used for actual operation for a few weeks to determine if this solvent is a viable alternative.

Kolene® Corporation/Farr Technical Center

Results — Kolene® Corporation of Detroit, MI, in affiliation with Farr Technical Center, a subsidiary of Farr Manufacturing and Engineering Company (a manufacturer of chemical processing systems) tested their products for stripping the paint coupons. The tests were performed under the Research and Technology Development Laboratories, Sample Evaluation CS-2277.03. A report outlining the test method and results is found in Appendix B. Table 3 summarizes the results of the stripping.

Using Kolene® Recover™, the green paint coupons were stripped within 60 minutes at 275 °F. Ultrasound was used to remove inorganics on the surface. No apparent effect was seen on the undercoating. The white coupons were unsuccessful in being stripped within the ANAD time limit.

Recommendations — The Kolene® solution, while effectively stripping the CARC paint, did not strip both colors within the timeframe needed to stay within ANAD's production requirements.

Table 3. Kolene® Corporation stripping test results for CARC paint.

Solvent Name	Coupon Color	Temperature (°F)	Time to Strip	Full or Partial Stripped
Recover™	Green	275	60 min	Full
Recover™	Green	325	15 min	Full
Recover™	White	275	60 min	Full
Recover™	White	325	2.5 hr *	Full
EXP88	Green	275	30 min	Partial
EXP88	Green	325	10 min	Partial
EXP88	White	275	60 min	Partial
EXP88	White	325	2 hr *	Partial

* Questionable data. A temperature increase should result in less stripping time, rather than more.

Polychem

Results — Polychem’s laboratory performed stripping tests using various polychemical products. Appendix B shows the results that Table 4 summarizes.

Table 4. Polychem stripping test results for CARC paint.

Chemical Compound	Concentration	Temperature Applied (°F)	Comments	Test Time	Results
Polychem Acrastrip 600 Military	1:1 mixture with H ₂ O	180-200	Immersion with mixing	2-4 hr	Pinhole blisters
Polychem Acrastrip 600 Military	1:1 mixture with H ₂ O	180-200	Immersion with mixing	8 hr	Pinhole blisters
Polychem Acrastrip 600 Military	Full strength	180-200	Immersion	4 hr	Pinhole blisters
Polychem Acrastrip 600 Automotive	Full strength	180-200	Immersion with mixing	4 hr	Pinhole blisters
Polychem Acrastrip 1000	Full strength	180-200	Immersion with mixing	4 hr	Pinhole blisters
Polychem 36	Full strength	150-180	Immersion	8 hr	Pinhole blisters

Recommendations — These strippers were not successful in stripping off the CARC paint used at ANAD within its operational parameters.

Inland Technology Incorporated

Results — Inland Technology Inc. (IT) has previously provided alternatives to replacing methylene chloride used in painting U.S. Navy aircraft. IT’s research scientist performed testing using its product, Magna Strip, on the CARC paint. The IT report is found in Appendix B.

For this test, Magna Strip was heated to 140 °F; however, the paint coupons did not show signs of any stripping. Raising the temperature above 150 °F created softening effects to the paint. When the surface was scratched with a scotch pad, both the green and white paints started coming off, but not down to bare metal. Raising the temperature above 160 °F and waiting for 1 hour created blistering in the white paint. Table 5 shows the final results.

Table 5. IT Magna Strip at 160–180 °F.

Coupon Color	Stripping Time	Stripping Performance
Green	2-3 hr	Blistering
White	1 hr	Blistering

Recommendations — This stripper will not meet the time requirements of ANAD.

Petroferm

Although Petroferm did not provide a report of the tests performed in its laboratory, two representatives of Petroferm stated that their tests did not find any solvent that would strip the paint coupons completely in 30 min.

Parts Cleaning Technologies

Parts Cleaning Technologies did not provide a report of the tests performed in its laboratories. The Indianapolis, IN, office forwarded these paint coupons to its Charlotte, NC, office for laboratory work. Representatives advised that several chemistries were checked with no success in meeting the specifications outlined.

McGean-ROHCO

McGean-ROHCO's Cee Bee A-477 is one of the solvents with which INEEL performed its screening tests. It is also one of the 10 paint solvents proved productive enough to move into INEEL's extended testing (Tsang and Herd 1993). McGean-ROHCO did not provide a report of the tests performed in its laboratory; however, representatives advised that Cee Bee A-477 was tried but was unsuccessful in meeting the specifications outlined by ANAD.

Summarized Results from Commercial Solvent Testing

Only one stripper met ANAD's 30-min maximum stripping time requirement for both types of CARC paint. This stripper was Chemetall Oakite's GardoStrip Q7900. Table 6 shows the results of this test.

Table 6. Chemetall Oakite GardoStrip Q7900.

	Green: Mil-P 53022 primer Mil-C 46168 paint	White: Mil-P 53022 primer Mil-C 22750 paint
Time 100 percent stripped	30 min	10 min
Stripping results	Paint lifted off in sheets	Paint lifted off in sheets

Evaluation of installing emissions control equipment on the existing paint stripping system

Besides finding an alternative to methylene chloride in paint stripping operations, another approach to controlling emissions is to install additional emissions control equipment on the existing stripping system at ANAD. Examples of additional emissions control equipment are vat lids, higher vat sides, chiller systems, activated carbon systems, and condensers.

Before any modifications are performed on ANAD's stripping system, a baseline characterization of the offgas emissions in the exhaust stack from the methylene chloride vats must be completed. This baseline study will establish existing methylene chloride concentrations and other emissions data that are essential for evaluating the effectiveness of any process modification. The same offgas sampling must be conducted after process modifications are installed; postsampling will quantify reductions in methylene chloride emissions and provide a basis for evaluating additional emission controls.

EPA Method 320 is the recommended method for emissions sampling for formic acid and methylene chloride emissions on the stripping vat operations at ANAD. This method measures the concentrations by Fourier transform infrared spectroscopy (FT-IR). Because it is possible that some of the formic acid will decompose to form formaldehyde, the FT-IR instrument should be calibrated for formaldehyde and possibly other byproduct compounds that could be present. To minimize costs for this task, it is suggested that sampling be done after the vat lids are installed and ANAD has ramped back up into full production mode (1 to 2 weeks after lid installation) with the stack testing subcontractor mobilized at the site. With the vat lids fully open, the subcontractor would take stack readings with the push-pull air system operating (the readings would be taken with and without parts in the vats). The lids would then be closed and additional stack readings taken (these readings would also be taken with and without parts in the vats). This method of measuring "before"

and “after” stack parameters ensures a controlled environment with the same batch of methylene chloride and also allows the subcontractor to perform stack testing with one mobilization to ANAD. This mobilization consists of a setup day and a testing day, consecutively. Stack parameters to be measured include temperature, velocity, flow rate, and oxygen concentration. The subcontractor should also be capable of measuring formaldehyde in the ducts. The sampling plan should provide for design, placement, and installation of sample ports in the 12-in.-diameter exhaust ductwork. The preferred location for the sampling ports is within a 30-in.-long section of Schedule 10 stainless steel exhaust duct before it joins exhaust ducting from other stripping tanks. The port installation should be performed by the sampling contractor during downtime, preferably at the same time as the vat lid installation.

Sanders Engineering & Analytical Services, Inc., an environmental engineering firm specializing in air emissions measurement and permitting, estimated a cost of \$32,000 for 1 day of emissions sampling per the procedure described above. Sampling should be completed in 1 day; however, additional costs may be incurred if unexpected delays are encountered. According to Sanders Engineering & Analytical Services, Inc., additional sampling days would cost approximately \$17,500 per day.

Vat lids

Installing vat lids should provide a quick, relatively easy, and effective reduction of fugitive methylene chloride emissions. The lid reduces the evaporation rate and, therefore, will reduce chemical loss by isolating the bath from the ambient air and the exhaust system except when the vats are open and loading/unloading work is in process. These lids must be designed to allow the parts cage to rest completely inside the vat. The cage would need to be disconnected from the hoist, or completely removed from the vat tank, in order to allow the lids to close. The ventilation push/pull system piping should be located below the cover. The exhaust fan should be turned off when the vat is covered and not in use.

The vat lids for the two stripping tanks in Building 130 would measure 120 by 60 in. and move on and off the vats on a gear-driven rail system. The operational drive gears should be polypropylene. In the removed position, the vat lid would travel to the end of the tank opposite the offgas exhaust pickup. A manual push-button system to open and close the covers should be adequate. Stainless steel framework and rails for the lid covers would need to be installed.

The polyvinylchloride exhaust push header of the vat would need to be raised approximately 1.5 in. to allow clearance for the vat lid. This exhaust push header would remain over the cover storage box area.

MSE solicited a cost estimate for installing lids on the existing stripping vats in Building 130 at ANAD. Farr Technical Services estimated \$20,000 to install two vat lids, including materials and labor. It is recommended that ANAD pursue this modification to the stripping system.

Higher vat sides

In addition to the lids, increasing the height of the sides of the vat should reduce fugitive emissions. Because methylene chloride vapor is denser than air, it will accumulate below an air blanket in an unagitated state. Higher sides on the vats will allow a thicker air blanket that should cause an “air-inversion” effect, thereby reducing the amount of methylene chloride vapors escaping the air blanket.

Chiller Systems

Vapor pressure is a measure of the tendency of the solution to become a vapor; consequently, the methylene chloride emission concentration is proportional to the vapor pressure of the methylene chloride. Calculations indicate that lowering the temperature to 45 °F will reduce the vapor pressure by one-half (see Figure 1 and Appendix D). Since the reduction in methylene chloride emissions should be directly proportional to the reduction in vapor pressure, it is possible that cooling the stripping solution with a chiller would greatly reduce methylene chloride emissions. The project investigated the stripping effectiveness of the ANAD stripping solution at lower temperatures to test this hypothesis.

Vapor pressure tests of chilled solution

Tests at the MSE laboratory in Butte, MT, were performed in an attempt to confirm the theoretical calculations of the vapor pressure. Appendix E shows the test plan for used by MSE.

These vapor pressure tests used the methylene chloride-based solution that ANAD is using in its stripping process. The temperature of the stripping solution was manipulated to various temperatures as low as 40 °F, and the stripper’s vapor emissions were collected using a syringe. The vapor samples were injected into a gas chromatography mass spectrometer

(GCMS), and the measured concentrations were recorded. The results of these tests were inconclusive.

The test plan was modified, and a test was implemented with the solution at room temperature (again at 40 °F and again at 80 °F). The results of the modified tests were also inconclusive (refer to Appendix F).

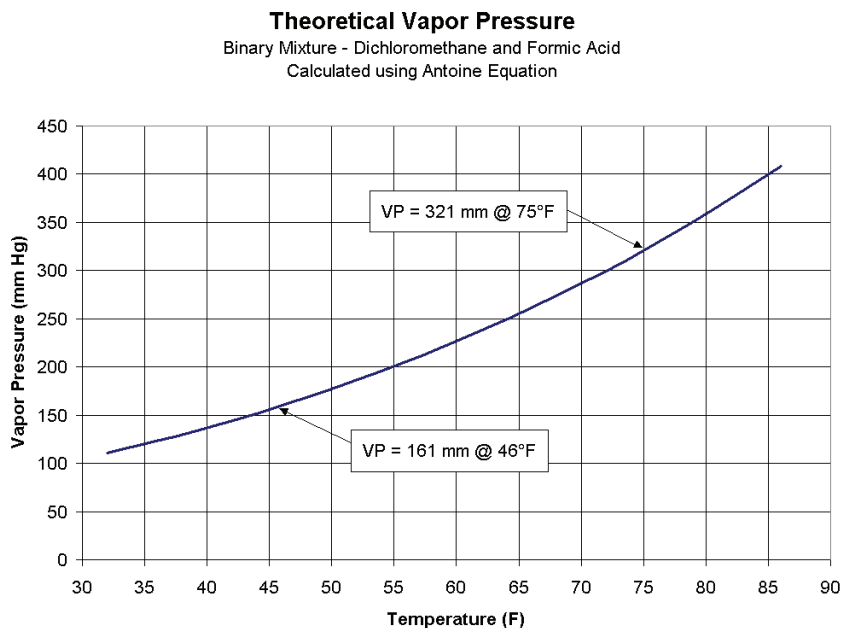


Figure 1. Correlation of temperature to vapor pressure using Antoine Equation (Perry and Chilton 1973).

Stripping tests of chilled solution

The stripping rates of the methylene chloride-based solution were tested at lower temperatures to determine the effect the cooled solution has on its performance. Tests were performed using coupons provided by ANAD and painted with the actual primer and CARC paint the Depot uses in production. The paint coupons were lowered into the same methylene chloride-based solution that ANAD uses at its site; the only variable was the temperature. The results of these tests are shown in Table 7 and Appendix G. The test results indicate that ANAD can still meet the 30-min stripping time, even if the solution is chilled to a temperature of 40 °F.

Table 7. Results of stripping time at various temperatures.

Temperature (°F)	Green: Mil-P 53022 primer Mil-C 46168 paint	White: Mil-P 53022 primer Mil-C 22750 paint
80	7.5 min	7.5 min
75	7.5 min	7.5 min
70	5 min	5 min
60	7.5 min	5 min
50	7.5 min	10 min
40	12.5 min	7.5 min

Although the results indicate that ANAD can still meet its 30-min stripping-time ceiling limit at a temperature of 40 °F, the results clearly show that a stripping solution temperature of 70 °F is optimal for stripping and is less expensive to maintain than a 40 °F temperature.

Sizing the chiller

Under the chiller system presented here, vat cooling is a two-stage process consisting of: (1) initial cooling of the methylene chloride-based solution from room temperature to 45 °F, and (2) maintaining the temperature at 45 °F.

Initial cooling

To size the chiller, some of the factors to be considered would be the heat from the ambient air in the room, vat lid use, the amount of time needed for initial cooldown of the solvent, and the insulation thickness. Estimating the size of the chiller to cool the stripping solution involves knowing the amount of liquid in the vat, its heat capacity, the initial and final temperatures, and the time required. To determine a British thermal unit (Btu) per hour (hr) estimate, a 4-hr cooling period for 2000 gallons (gal) from 75 to 45 °F was assumed. Since this is a rough estimate, it was also assumed that the solution was all methylene chloride with a heat capacity of 0.288 Btu/pound (lb)°F and a density of 11.1 lb/gal (Perry & Chilton 1993). The equation to determine the Btu/hr for the chiller is:

$$H_i = \frac{(total\ mass)(C_p)(\Delta T)}{Time} = Btu/hr$$

Where H_i is the initial chilling of the solvent, total mass is the mass of all the liquid in the vat, C_p is the heat capacity, and ΔT is the temperature dif-

ference. A heat relief of 48,000 Btu/hr cooling requirement was estimated for the initial cooling and also for the steady-state cooling.

Maintenance cooling

In performing cooling load calculations, it is difficult to estimate the rate of heat gain for the vats during the steady-state process. This estimation depends on many factors, including ambient temperature, vat wall thickness, and vat construction materials. Also to be considered are such factors as vat lid use, frequency of parts being inserted into the vat, and the amount of time the vat lids are open during the lowering and lifting of the product to be stripped. Since there were so many unknowns, it was assumed that the rate of heat gain in the vats would be less than or equal to the rate of initial cooling calculated above; therefore, the chiller was sized based on a heat relief requirement of 48,000 Btu/hr. For the purpose of this report, an assumption is made that $H_i \geq H_{ss}$ where H_{ss} is the heat loss during steady-state use.

Heat exchanger sizing

Further engineering would need to be done to size the chiller efficiently. The following assumptions were made in order to look at a cost estimate for this report: chilled water is available (35 to 40 °F); the vats are insulated adequately; and the vats are covered when not in use.

Several configurations would suffice for a chiller. A simple configuration of copper cooling coils in the vat was assumed to be adequate for these purposes. A chilled water flow rate of 20 gallons per minute (gpm) should be adequate assuming a water inlet temperature of 40 °F. The heat exchange area required will be about 32 square feet (ft²) (assuming a heat transfer coefficient of 50 Btu/hr ft² °F [Perry and Chilton 1973]).

Chiller costs

The cost for a heat exchanger of this size is roughly \$27,500 and was determined using Matches' Process Equipment Cost Estimates (<http://www.matche.com/EquipCost/Index.htm>). Conservatively estimating, associated equipment and installation costs would increase the cost by a factor of four (Perry and Chilton 1973, pp 25-26). So the total estimated installed cost for a chiller would be approximately \$110,000.

Activated carbon system

Carbon adsorption, using activated charcoal, has the ability to remove most methylene chloride emissions. A solvent vapor recovery module (SVRM) system that uses activated carbon as the adsorption media can accomplish the removal. A disadvantage of this system is that it would create the need for disposal of some solid hazardous waste. A conservative rough estimate (based on experience with similar systems and on solubility data) of the quantity of hazardous waste emitted from an SVRM would be two or three 55-gallon drums per year. A second disadvantage is that the system may create a small stream of water containing a very minor amount of methylene chloride.

Before determining the type of activated carbon system to install, presampling of the gases emitted from the methylene chloride vats should be performed. This presampling will provide baseline data regarding emissions that will be beneficial for sizing. After the new equipment is installed, performing an offgas postsampling may confirm expected reductions in methylene chloride emissions.

A proposal was obtained for an activated carbon system capable of meeting the applicable requirements of the OSHA and EPA standards for machine operation, equipment design, and environmental considerations as understood by the vendor. This proposal was developed to illustrate typical activated carbon system costs and process operation for the methylene chloride-based stripping at ANAD. Each stripping operation would need an SVRM. The specifications used are limited and are estimates based on the following: new vats located in Building 130 at ANAD; information received from a report by the Tennessee Valley Authority (Mussell Shoals, AL) for some investigation for a bioremediation system that was being installed in Building 409 (provided by ANAD); and measured process data from a site visit to ANAD on 7 January 2003.

According to the vendor, this activated carbon system is sized to move a specified amount of air (i.e., 3250 cubic feet per minute [cfm]) away from a tank having a surface opening of 10 by 5 ft. The SVRM vessels may be insulated with fiberglass covered with a stainless steel wrapper to protect it from the effects of the methylene chloride. The cost for an activated carbon system, excluding sampling, is approximately \$200,000.

Condensers

An in-vat chiller would likely work better than a condenser; however, if the chiller cannot be installed for some reason, the installation of a chilled water condenser in the vapor outlet stream would be another option. Before determining the type of condenser to install, a presampling of the off-gas emitted from the methylene chloride vats should be performed. This presampling would provide baseline data regarding the emissions that would be beneficial for sizing. Postsampling in the vat exhaust stack should be done after installation to monitor reductions in the methylene chloride emissions.

The installation of a chilled water condenser in the vapor outlet stream would presumably be able to capture at least half of the methylene chloride vapors currently being lost to the atmosphere. Some of the assumptions listed for the chiller section (above) are also applicable for this estimate. Other assumptions are: the liquid in the vat is at a temperature of 75 °F; the ambient air temperature is 75 °F; chilled water is available (35 to 40 °F); airflow over each vat is 3300 cfm; and cooling the airflow to 45 °F will condense half of the methylene chloride.

One type of condensing method that may be considered is shown in Figure 2. This method has a condenser box mounted on the side of the vat inline with the exhaust system. By pulling the exhaust vapor flow across the condenser coils and chilling it to the designed chilling point, the methylene chloride will condense and drop out into the condenser box. A hole and connection in the condenser box will allow the methylene chloride in the box to flow back into the vat, mixing the condensed methylene chloride with the main solution in the vat.

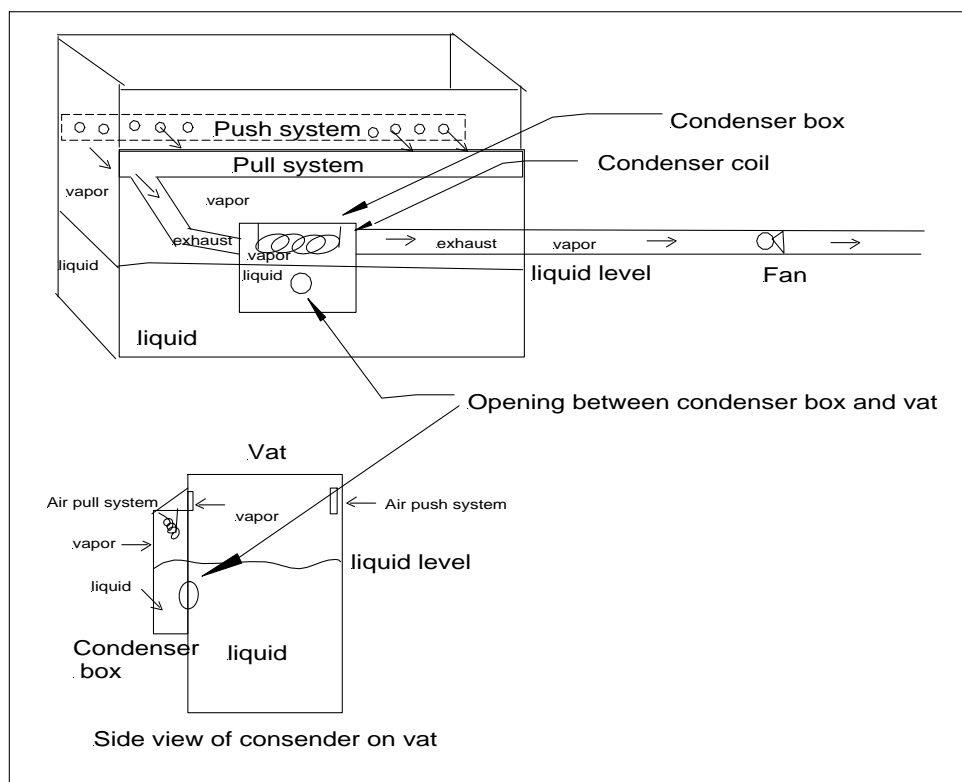


Figure 2. Sketch of condenser system for paint stripping operation at ANAD.

A disadvantage in using a condenser is that it would not capture the emissions created by dragout, etc., while parts were introduced and removed. A better chance to remove the greater percentage of solvent vapor from the air around the tank is by capturing the airstream using a vat lid.

The method for sizing the condenser and determining the costs is similar to the method used to size and cost the chiller. The cooling load required is calculated using a heat capacity of 0.237 Btu/lb °F (Perry & Chilton 1993) and a density of 0.08 lb/ft³. This results in a cooling rate of 113,000 Btu/hr. The heat exchange area required will be about 4,500 ft² (assuming a heat transfer coefficient of 5 Btu/hr ft² °F, (Perry & Chilton 1993, pp 10-39). Using information in Matches' Process Equipment Cost Estimates, the rough cost for a heat exchanger of this size was determined to be approximately \$91,500. Conservatively estimating, associated equipment costs and the installation would increase the cost by a factor of four. Therefore, the total installed cost for a condenser excluding pre- and postsampling costs would be approximately \$365,000 (Perry and Chilton 1973).

Alternative technologies for paint stripping

Alternative paint stripping technologies were investigated to determine the practicality of replacing the solvent-vat stripping method at ANAD. The technologies investigated were blasting, flash lamp stripping, and salt bath stripping. Each of these technologies and results of the investigations are briefly described below.

Blasting

The normal operating procedure for stripping equipment at ANAD is as follows: the equipment is disassembled; parts are sent to different shops, according to work they need; if a part is large, it is sent to the blasting shop; after blasting, the parts are sent on to be stripped; and, if needed, the parts are sent to machining or repairing.

According to ANAD employees, only the largest parts are blasted at this time; a methylene chloride bath is used for the smaller items. ANAD has several blasting booths on site for various operations. Currently, blasting is done with glass beads, walnut hulls, garnets, sodium bicarbonate, and aluminum oxide. The Depot is also investigating setting up plastic media blasting (PMB). The concerns regarding blasting at ANAD include noise pollution and other safety hazards and the need for operators to wear PPE.

The types of alternative blasting media reviewed for this project are sodium bicarbonate, plastic, wheat starch, walnut hulls, carbon dioxide (CO₂) pellets, and sand.

Sodium bicarbonate blasting

The sodium bicarbonate blasting method is a potential alternative to the methylene chloride solution currently being used at ANAD. Sodium bicarbonate blasting has the advantages given below (Wasson et al. 1993).

1. The hazardous waste stream is anticipated to be only 10 percent the amount produced from a PMB method (Aerospace Paint Removal 2002). Only a small volume of water is injected into the blast stream at the nozzle to eliminate nuisance dust.
2. ANAD is already familiar with this operation as it is being performed in a different location at the Depot.
3. ANAD personnel have cited good experience with this method in reaching material in small crevices.

A 1994-95 study of sodium bicarbonate blasting at Robins Air Force Base (AFB) indicated that this method is capable of stripping paint at the same rate as methylene chloride stripping solution. This study examined blast-stripping paint from C-130 and C-141 transport aircraft and component parts at a pressure of 1200 pounds per square inch (psi). Minor environmental and health-related problems were reported. Paint chips were the primary waste (Washington State Univ. 1998).

ANAD personnel voiced a variety of opinions on the feasibility of using the sodium bicarbonate blasting method at the Depot in lieu of the methylene chloride-based stripping method. This blasting method would necessitate changes in the Depot's production methods and employee work requirements, and some resistance to these changes was noted. It is recommended that ANAD further investigate the variables involved in installing one of these systems. The investigation needs to focus on the items below.

1. Perform corrosion tests to determine what effects residual sodium bicarbonate or its byproducts may have on the materials being stripped.
2. Determine collection and disposal methods and requirements for byproduct waste produced during the process.
3. Perform a process optimization study to determine the best combination of stripping rate with the least amount of damage to the substrate. The effectiveness of removing paint in small crevices, traverse speed, standoff distance, angle of impingement, nozzle pressure, media flow rate, and water pressure should be analyzed (Greene 2002).
4. Conduct a material characterization at the optimized parameters to determine exactly what long-term effects the process may have on the life of the stripped parts (Greene 2002). Independent research laboratories may need to be used to perform this work.
5. Analyze costs and benefits and include additional manpower requirements, power consumption, blasting booth expenses, blasting equipment, and wastestream disposal.
6. Perform safety analyses and include the effectiveness of exhaust fans and PPE.

Carbon dioxide blasting

Carbon dioxide blasting uses solid CO₂ to remove surface coatings by impact. Refrigerated liquid CO₂ is compressed and allowed to expand in a pressure-controlled chamber where the temperature drops from about -35 to -109 °F. The temperature drop causes the formation of a mixture of CO₂ vapor and solid CO₂ (Oberg et al. 2003). The solid CO₂ is collected, com-

pressed, and extruded through a die to produce pellets of a specific size and hardness, as required. During this blasting, the pellets transform into a gas and therefore do not add volume to the wastestream. This gas release demands good ventilation. No water is used for CO₂ blasting. The biggest limitations of CO₂ blasting are its slow paint removal rate and, to a lesser extent, its high capital cost (Greene 2002). It is unlikely that CO₂ blasting can meet the production requirements of ANAD's operation.

Plastic media blasting

PMB is a dry media blasting method using low-pressure air or centrifugal wheels to propel sharp plastic media at a surface. The impact against the paint results in chipping and erosion of the paint. This same impact causes fracturing of the plastic leaving new sharp edges for continued use. The plastic dust and the paint debris can be removed with pressurized air or a vacuum. The plastic media should be harder than the paint being removed but softer than the underlying substrate material (U.S. EPA 1999; Oberg et al. 2003).

PMB is used to remove coatings from substrates including aluminum, stainless steel, mild steel, fiberglass, and plastic. The plastic media is non-toxic, no hazardous air pollutant (HAPs) chemicals are used, and no evaporative HAP emissions are created with this dry process. After blasting, the plastic beads may be recycled (U.S. EPA 1999; Oberg et al. 2003).

An open-blast system using a nozzle to blast the equipment may be used for large parts. Cabinet systems for smaller parts are available with automation and remote control. With the numerous and various parts needing stripping at ANAD, however, this type of blasting will require engineering and further research to determine proper system configuration (U.S. EPA 1999; Oberg et al. 2003).

Wheat starch blasting

The wheat starch blasting technique is similar to PMB. However, it is a natural, nontoxic, biodegradable material that is derived from renewable agricultural resources (Oberg et al. 2003).

In wheat starch blasting, particles of wheat starch are thrust against the painted material by pressurized air. The wheat starch particles are clear white granules of 12 to 30 mesh, 1.45 gram (g)/cubic centimeters (cm³) density, and a Shore D hardness of 85. The wheat particles fracture upon

impact. This fracture results in smaller particles and more edges per pound of media. These smaller media are reused until finally the particles are so small that starch dust blocks the coated surface. The used starch is collected and processed to separate the stripped paint and the smallest starch particles (U.S. EPA 1999; Oberg et al. 2003).

Wheat starch blasting is a dry process that does not use HAP chemicals. The only potential HAP emission would be the dust generated from blasting if the coating contained inorganic HAP (U.S. EPA 1999; Oberg et al. 2003). As wheat starch blasting is a gentle stripping process, testing would need to be performed to determine if it would be effective against the CARC paint and primer.

Other blasting media

Additional dry blasting media such as aluminum oxide, garnet, sand, and glass beads were considered for the ANAD application. These dry abrasive blasting techniques physically remove paint by propelling a stream of high-velocity solid particles at the paint surface (HSIA 2003). These blasting processes can be controlled to the extent that a topcoat can be removed while leaving a primer intact (U.S. EPA 1999).

For many applications, dry abrasive processes are good for paint removal. However, extensive process analysis would be required to determine the feasibility of applying any of these blasting processes to paint stripping at ANAD. Substrate damage, residual compressive stresses, and the volume of hazardous waste should all be investigated carefully before implementing any of these processes (Greene 2002).

High-pressure water blasting

Blasting from high-pressure water may be applicable for ANAD paint stripping. Water-jet blasting uses the force of water at very high pressure (greater than 15,000 psi) to remove paint; no solvents or media of any kind are added to the water stream. A filter would remove paint chips from the water, and the paint sludge would be disposed of as a waste. The filtered water may be recycled and reused (Greene 2002).

Water blasting can be performed with minimal labor. A high-pressure blasting system at Tinker Air Force Base (AFB) in Oklahoma City uses a nine-axis robot to propel the water onto the material to be stripped (AIA 1993).

An engineering study would need to be conducted to determine the amount of pressure needed to strip the CARC paint used at ANAD. Higher pressures may be needed for the tougher paint; however, the higher pressures can damage thin metal pieces. Proper selection of the standoff distance should also be carefully considered (Greene 2002).

Flash lamp stripping

Flash lamp stripping uses high-energy lamps that flash at the coating on and off for a fraction of a second, which causes the paint to vaporize. By controlling the number of cycles, the paint can be removed in layers. Robotics may be used for this stripping method. Often, the flash lamp stripping is backed up by a CO₂ snow blast that allows the lamp to char only the paint coating. The actual paint removal is accomplished by the CO₂ blast (Greene 2002; Washington State Univ. 1998).

McDonnell Douglas Aerospace has a patented FLASHJET™ stripping process. FLASHJET™ uses a high-energy xenon discharge lamp along with surface cooling and cleaning using FLASHJET™. The FLASHJET™ process may remove the topcoat only, or all coatings down to the base metal. The waste from this system comes from periodic changeout of the filters (Tramontin and McCarley 1997).

The McDonnell Douglas helicopter systems, Mesa, AZ, has an operational FLASHJET™ system valued at \$2.7 million. McDonnell Douglas is investigating using these systems for military and transport-type aircraft. With this system, an operator can strip an aircraft in a matter of hours. This system works on both metal and composite coated surfaces. It is said to remove a 12-in. path of paint in one, or multiple passes, and deliver maximum energy density equal to 18 joules per square centimeter (Tramontin and McCarley 1997). The capital and operating costs involved in this operation can make it very expensive for small parts.

Further investigation into flash lamp stripping and, in particular into FLASHJET™, may be made along with testing to determine its feasibility at ANAD. The high initial costs for a FLASHJET™ system may preclude its use at ANAD, however.

Salt bath stripping

The molten salt bath stripper method uses heat to thermally decompose the paint coating into an ash that is subsequently removed. Salt baths are

currently being used by Boeing and by a Honeywell facility in New Mexico (Greene 2002).

The molten salt bath stripping process causes chemical oxidation of the paint using a molten salt bath. The process uses mixtures of oxidizing inorganic salts formulated to react with the paint. Parts to be stripped are immersed in a heated mixture of the inorganic salts. Bath operating temperatures range from 550 to 900 °F. A 600 °F molten salt bath could strip ANAD parts in approximately 15 min (Wilson 2002), and it is possible the ANAD parts may tolerate a 600 °F bath. The high temperature of the salt solution oxidizes the coating to CO₂ and water. Most metals are retained in the molten salt bath. In sodium carbonate-based and similar molten salt formulations, halogens combine with the molten salt to form halides and to release CO₂ from the carbonate salts. Metals and any inorganic constituents that were present in the original coating, such as pigments, simply slough off the article being stripped when the organic matrix has been destroyed. This residue is retained in the molten salt and enters the offgas stream only in small amounts (U.S. EPA 1999; Greene 2002).

In molten salt stripping, the items to be stripped are loaded into baskets, or supported on hooks, and lowered into the salt bath. After stripping, the items are removed and rinsed with water for cooling and removal of residual salt, then dried with compressed air. The only HAP emissions are the inorganic HAP in the offgas (U.S. EPA 1999).

Maintenance for the salt bath stripping system would involve cleaning out the sludge regularly by using buckets to pull the sludge off. The sludge would need to be disposed of under ANAD's Hazardous Waste Management Program.

Most states require that certain conditions be met when operating a molten salt bath. Example regulations for the State of California are given below (California Code of Regulations, Title 8, Section 5188 [8CCR5188]).

1. The operator must be protected from splashes of the molten salt while inserting or withdrawing the metal parts.
2. Hoods must be provided for baths containing nitrates or cyanides or other baths if fumes or vapors are produced in harmful amounts. Mechanical exhaust ventilation must be used unless sufficient natural draft is produced.

3. If water can possibly come in contact with the molten salt, a hood or some other preventative device shall be provided to preclude such contact.
4. Workers exposed to spatters or splashes shall be protected as prescribed in Article 10 of the Code of Regulations. Clothing should be of wool or other material that does not burn readily.
5. Baths not protected by hood or shield shall be provided with a removable cover that shall be placed over the bath during temporary shutdowns and at the end of periods of use.
6. Nitrate baths are to be avoided as there is concern that, when nitrate is heated, it gives off nitrogen dioxide. If nitrate baths are used anyway, in addition to the other requirements already listed, there are many more requirements as given below.
 - a. No salt containing any cyanide or any organic compound shall be added to a salt bath that contains nitrate. Proper warning signs to this effect shall be posted near all such baths.
 - b. Nitrate baths shall not be operated at a temperature of greater than 1200 °F.
 - c. Nitrate baths used to treat aluminum or its alloys shall not be operated at a temperature greater than 1000 °F. In such baths, if the temperature reaches 1000 °F or if the objects being treated and the bath appear to be beginning an exothermic reaction, the operator shall withdraw the metal objects from the bath.
 - d. Every nitrate bath over 10 cubic feet in capacity shall be provided with an automatic cutoff safety control that will shut off the source of heat when the temperature reaches the limits set forth in (2) or (3). This control shall be in addition to any regular controls whether they act automatically or manually.
 - e. If external heating by gas or oil is used, the combustion chamber shall be arranged so that the sides of the chamber are bathed in hot gases as uniformly as possible without any flame impinging directly on the containers and so that, in case of failure of the container, molten salt will flow to a safe place and not drip or spatter into the combustion chamber.
 - f. The molten salt container shall be emptied at regular intervals and inspected for deterioration. When inspection shows that deterioration has taken place to such an extent that failure is likely, or that uneven heating of the salt may occur, the container shall be replaced or repaired.
 - g. No article shall be allowed to stay in the bottom of the bath. Accumulations of sediment or products of partial decomposition shall be removed regularly, as often as is necessary to prevent uneven heating of

the bath. The chemical content of the bath should be checked frequently.

- h. Nitrate shall not be stored in the room with the bath. Storage in a separate building is recommended.
- i. Buildings in which nitrate baths are located should be of construction recommended by the National Board of Fire Underwriters Research Report, No. 2, 1954, for such location. Combustible materials in a room with a bath shall be kept to a minimum.

Other issues may preclude the salt bath stripper method from being considered seriously for ANAD application. The scrubbing action of the material in the molten salt effectively strips metals. Some of ANAD's parts have portions made of aluminum and although aluminum will not melt until 1000 °F, an adherent oxide coating on it will be attacked by many salts, especially chloride. This aluminum oxide coating material might not withstand temperatures greater than 200 °F. Also, the hot salt bath will attack the 60-61 heat treatment that is on many of ANAD's other parts. Determination of these effects on ANAD's parts would need to be investigated (Glovan 2003).

Ultrasonic cleaning

Ultrasonic cleaning has been used with various strippers and degreasers in paint removal operations. Microbubbles produced by cavitation burst on the surface to be stripped, and these bursts allow mechanical as well as chemical stripping action to take place (Thomson et al. 1992).

To evaluate the effectiveness of ultrasonic stripping, the frequency of the stripper, the liquid medium, and the coupling between the stripper and the liquid should be considered. A frequency of at least 18 kilohertz (kHz) is required to cavitate the liquid (Thomson et al. 1992). ANAD may consider further research and engineering on ultrasonic cleaning; specifically, on the concept of combining ultrasonic cleaning with alternative stripping solvents.

5 Recommendations

Sequential modifications to the ANAD stripping system are recommended, and it may be desirable to follow more than one of these recommendations. Before implementing any changes to the existing stripping system, it is recommended that offgas emissions be sampled and quantified in order to establish a baseline. This baseline will allow ANAD to determine the effectiveness of each modification toward meeting the overall emissions reduction goal. Offgas emissions should be measured after each step and compared with the baseline to determine progress toward the emissions reduction goal. ANAD may desire to implement only those steps that are necessary to reach the goal.

Construction oversight by a reputable architectural and engineering firm or a prime contractor is recommended to coordinate installations, testing, evaluations, and sampling. On-site engineering supervision during installations, startup, and stack testing should be included in the scope of work by the contractor. All costs shown in these recommendations are estimations and include a 25 percent contingency but do not reflect costs for design, drawings, construction management, subcontractor oversight, or coordination.

Recommendations include:

1. Install vat lids.
2. Increase the height of the vat sides.
3. Install a chiller system to cool the stripping solution.
4. Install an activated carbon system for capture of methylene chloride vapor.
5. Install a condenser to capture methylene chloride vapor.

Recommendations 1 and 2 should be implemented first. For additional recovery of vapors, implement recommendations 3 through 5. Table 8 summarizes the costs for each of the recommended steps.

Table 8. Estimated cost summary for additional equipment.

Recommendation Option	Estimated Cost Per Vat	Comments
Sampling recommended with any further action	\$32,000 for 1 day	Additional sampling days @ \$17,500/day
Install vat lids	\$10,000	
Increase height of vat	\$10,000	
Install chiller system	\$110,000	
Install activated carbon system	\$200,000	
Install condenser	\$365,000	

If these steps are not sufficient to reach the emissions reduction goal, then ANAD should evaluate the following alternatives to methylene chloride-based stripping.

1. Replace the solvent-vat stripping method with a sodium bicarbonate blasting method.
2. Replace the methylene chloride-based stripping solution with Chemetall Oakite GARDOSTRIP Q7900.

The methodologies and techniques developed here could be used by any DoD facilities that use methylene chloride-based surface and parts cleaning.

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Appendix A: Paint Coupon Test Results

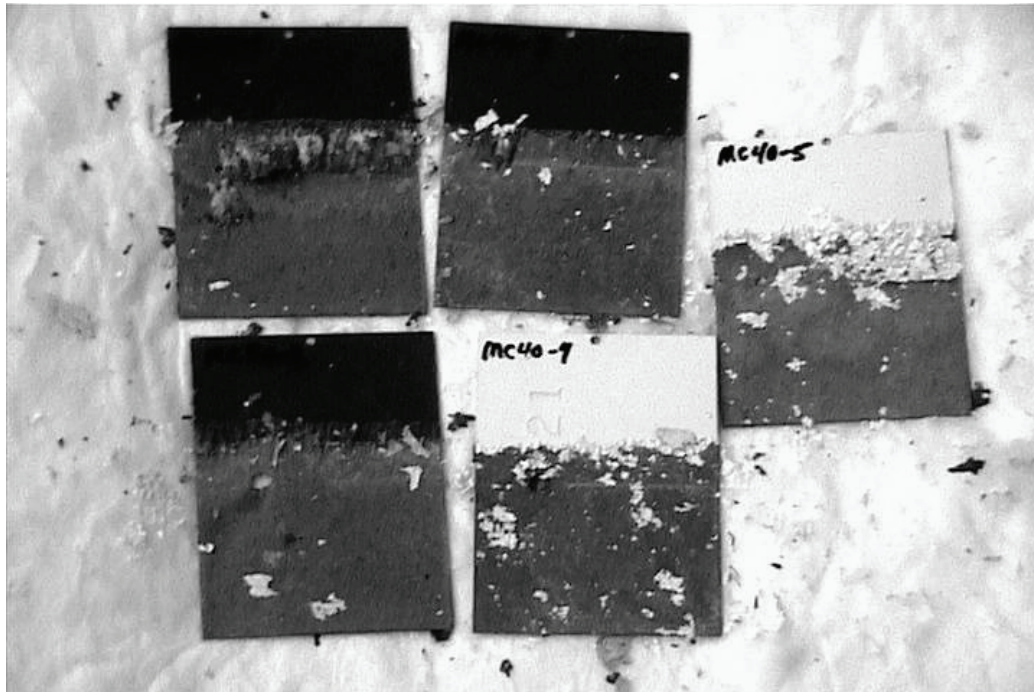


Figure A-1. Paint coupons at 45 °C.

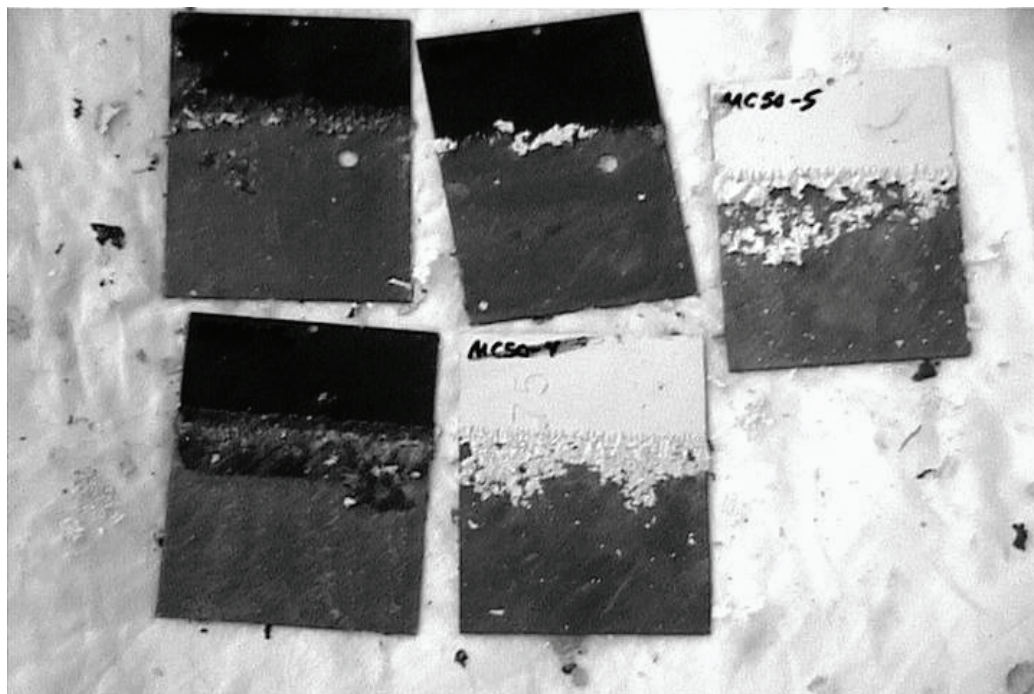


Figure A-2. Paint coupons at 50 °C.

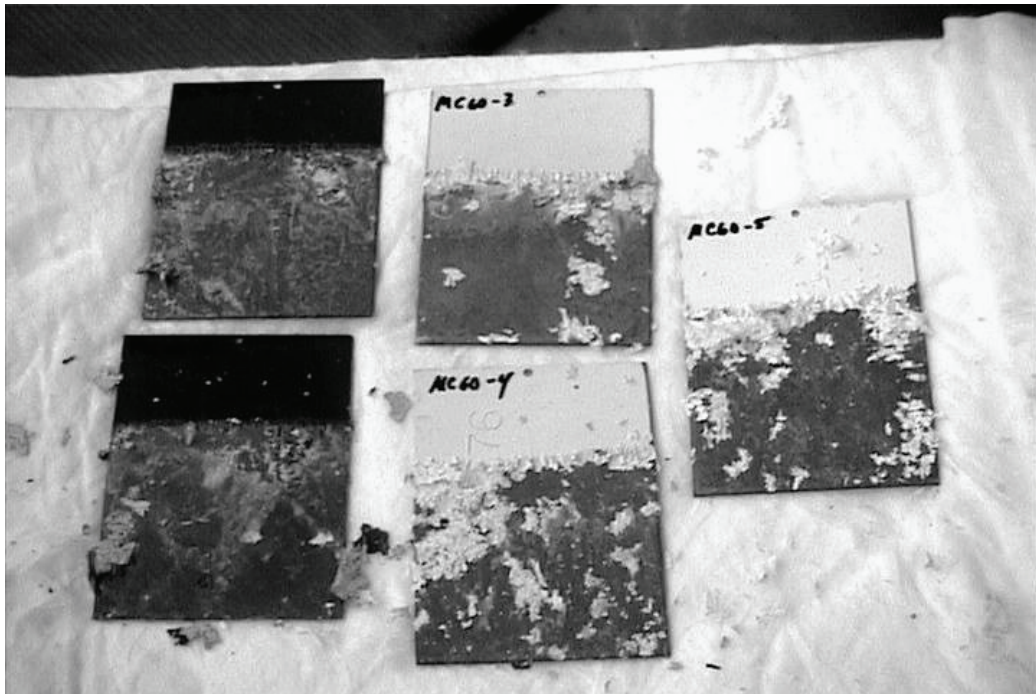


Figure A-3. Paint coupons at 60 °C.

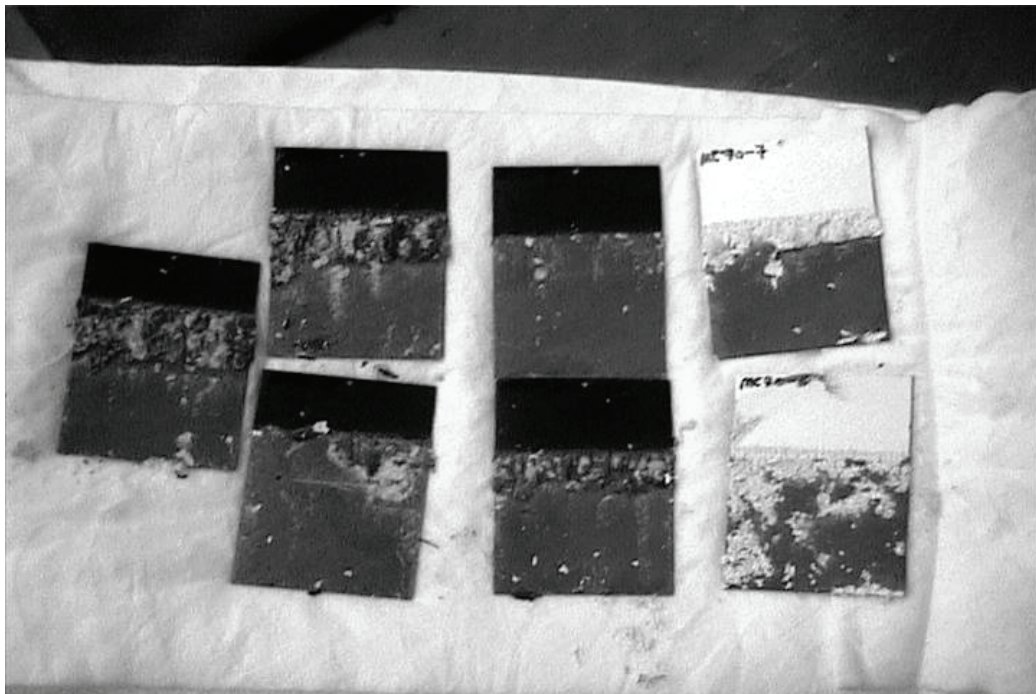


Figure A-4. Paint coupons at 70 °C.

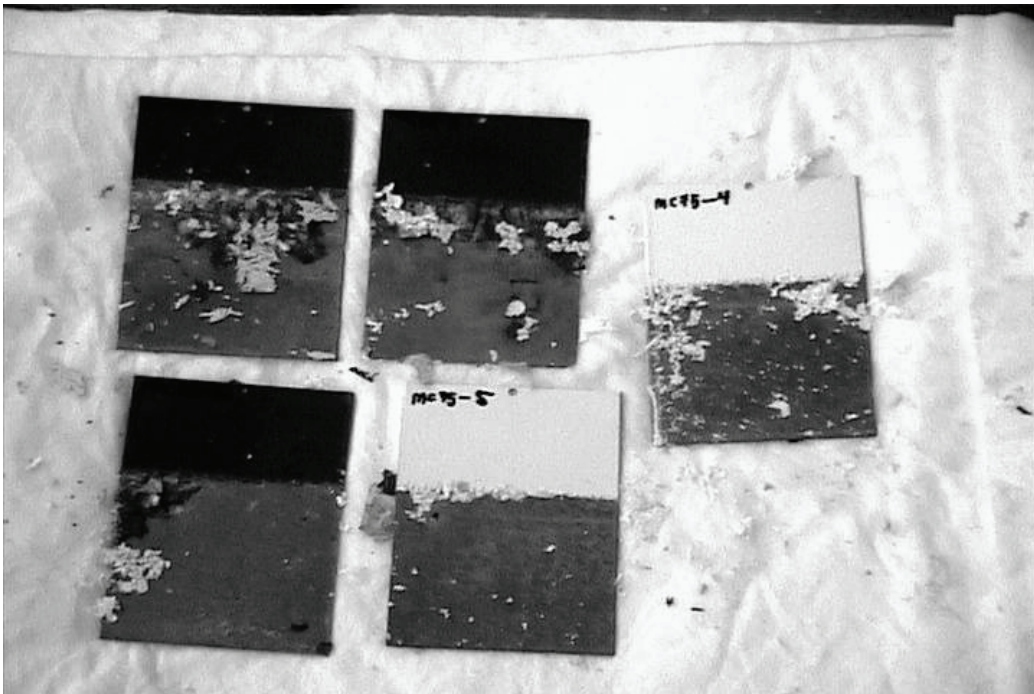


Figure A-5. Paint coupons at 75 °C.

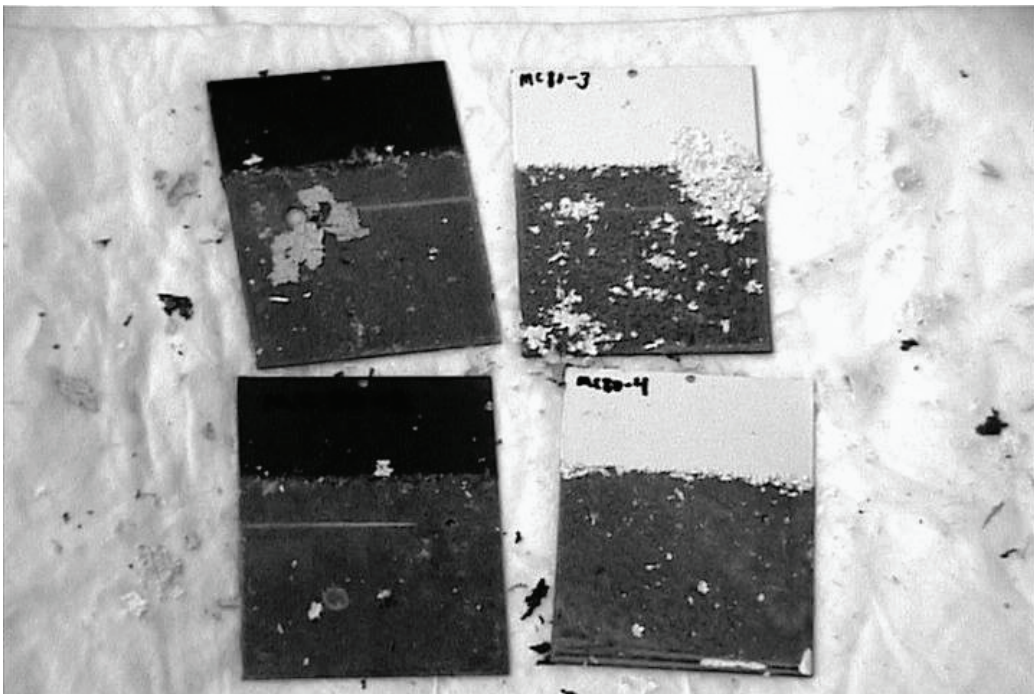


Figure A-6. Paint coupons at 80 °C.

Appendix B: Evaluation of Methylene Chloride Emission Control at ANAD — Project Requirements and Information

RE: Anniston Army Depot, Anniston
C/o MSE Technology Applications, Inc.
P.O. Box 4078
200 Technology Way
Butte, MT 59701

1. Current process is a cold process.
2. Current process uses Formic Acid, Methylene Chloride, Bees Wax & Aromatic hydrocarbons located in vats.
3. Current process uses a push/pull ventilation hood system across the top of the vat.
4. Process preparation: equipment is disassembled. The different pieces are sent to the different shops according to what they need. Sometimes, they are sent to the blasting shop to be stripped by blasting, then on to be stripped. Often they are sent direct to the stripping vats.
5. Must strip 100% to bare metal within 30 minutes to be acceptable, however ANAD would prefer 5 minutes to maintain production rates.
6. Sizes vary from the size of a gun barrel down to small nuts & bolts.
7. The vat sizes vary from 200-gallon vats to 2400-gallon vats. A total of 7000 gallons of stripper is used.
8. The work area consists of three huge buildings. There is lots of traffic in the buildings. One of the vats is currently confined in a controlled area. Others are in open areas.
9. The paints being stripped are as follows:
 - a. Mil-C-46168
 - b. Mil-P-53022
 - c. Mil-C-22750
 - d. Mil-P-63159 (water base)
10. The metals vary from ferrous, nonferrous, magnesium, steel, stainless steel, aluminum 5,000, 6000, 7000 series. No idea of % of each type. Machinery's Handbook by Erik Oberg, Franklin Jones, Holbrook Horton and Henry Ryffel definitions of Aluminum: 5000, 6000 and 7000 series:
 - a. 5000 series aluminum: Magnesium is one of the most effective and widely used alloying elements for aluminum. When it is used as the major alloying element or with manganese, the result is a moderate to high strength non-heat-treatable alloy. Magnesium is considerably more effective than manganese as a hardener, about 0.8 per cent magnesium being

equal to 1.25 per cent manganese, and it can be added in considerably higher quantities. Alloys in this series possess good welding characteristics and good resistance to corrosion in marine atmospheres. However, certain limitations should be placed on the amount of cold work and the safe operating temperatures permissible for the higher magnesium content alloys (over about 3 ½ per cent for operating temperatures over about 150 degrees F.) to avoid susceptibility to stress corrosion.

- b. 6000 series aluminum: Silicon and magnesium in approximate proportions to form magnesium silicide, thus making them capable of being heat-treated. The major alloy in this series is 6061, one of the most versatile of the heat-treatable alloys. Though less strong than most of the 2000 or 7000 alloys, the magnesium-silicon (or magnesium-silicide) alloys possess good formability and corrosion resistance, with medium strength. Alloys in this heat-treatable group may be formed in the –T₄ temper (solution heat-treated but not artificially aged) and then reach full –T₆ properties by artificial aging.
 - c. 7000 series aluminum: Zinc is the major alloying element in this group, and when couple with a smaller percentage of magnesium results in heat-treatable alloys of very high strength. Usually other elements such as copper and chromium are also added in small quantities. A notable member of this group is 7075, which is among the highest strength aluminum alloys available and is used in air-frame structures and for highly stressed parts.
- 11. Steam heat is possible.
 - 12. Agitation is possible.
 - 13. There is a different scope of work for each customer.
 - 14. The chemical must be able to meet maximum achievable control technology MACT standards under NESHAP guidelines (be of low hazard for air emissions).
 - 15. The smallest parts are made of aluminum, steel, magnesium (4" cube)
 - 16. The largest parts are approx. 4'x3'x16' weighing 2000 lbs
 - 17. The aluminum and magnesium is chemical or temperature sensitive.
 - 18. Production rate is up to 2,000 lb per basket; and 1-3 baskets per hour.
 - 19. Don't feel they have space of air-drying.
 - 20. This site is sensitive to supplying information. Information will only be supplied on an as-needed basis.

Appendix C: Paint Stripping Reports from Commercial Vendors/Laboratories

Chemetall Oakite

LABORATORY REPORT

REPORT # 120,621
DATE: June 25, 2003

CUSTOMER: Anniston Army Depot
ID # Prospect

LOCATION: Anniston, Al
TSS: Dale Reese

SAMPLE SOURCE AND DESCRIPTION

Painted steel panels (paint type unknown) received from the customer.

REQUESTED / OBJECTIVE

Find a stripper to replace current Methylene Chloride stripper.

PROCEDURE:

The GardoStrip Q7900, LO16002, and ChemStrip 5015 were used at 100%. The EuroStrip 7028/7031 was prepared at the following concentrations: EuroStrip 7028 at 50%, EuroStrip 7031 at 38.5% and water at 11.5%. The EuroStrip 7048/7049 was prepared at a 1:1 Ratio. Each bath was heated to 180 °F with agitation then rinsed with water used at ambient temperature.

RESULTS / CONCLUSIONS

GardoStrip Q7900	EuroStrip 7028/7031	EuroStrip 7048/7049
White panel	White panel	While panel
100% stripped	100% stripped	100% stripped
10 minutes	30 minutes	30 minutes
Sheets off	Sheets off	Sheets off

LO16002	ChemStrip 5015
White panel	White panel
100% stripped	100% stripped
30 minutes	10 minutes
Sheets off	Sheets off

GardoStrip Q7900	EuroStrip 7028/7031	EuroStrip 7048/7049
Green panel	Green panel	Green panel
100% stripped	90% stripped	100% stripped
30 minutes	8 hours	8 hours
Sheets off	Sheets off	Sheets off

LO16002	ChemStrip 5015
Green panel	Green panel
98% stripped	100% stripped
3 hours	1 hour
Sheets off	Sheets off

COMMENTS / RECOMMENDATIONS:

The GardoStrip Q7900 is the most effective candidate to replace the current methylene Chloride based stripper. The green panels proved the most difficult to strip for all products with the exception of Q7900. Due to the sheeting off of paint from the parts, filtration is recommended to remove paint debris. The results are based on laboratory testing only and may slightly vary during actual usage.

DISPOSITION OF SAMPLES:

All parts submitted were returned to TSS, via regular mail.

Gregg Sanko
Group Leader

Aaron Thompson
Senior Chemist

File/Tservice/D.Peters/D.Reese

Kolene Corporation / Farr Technical Center

JUL-11-2003 16:54

KOLENE

3132735287 P.02/02



Research and Technology Development Laboratories
Sample Evaluation
CS-2277.03

July 10, 2003

FARR MFG. & ENG. COMPANY

Attn: Mr. John Mobley

Sample Description: Six sample coupons; 3 white and 3 olive green. Coatings unknown.

Processing Objectives: NASHAP compliant replacement for current Methylene Chloride cold stripping process.

Sample Processing: All samples were processed in KOLENE® RECOVER™ and EXP88 organic stripping solutions. Upon removal from the strippers, the samples were hot ultrasonic water rinsed to complete the processing.

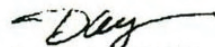
Process Cycling and Data:

Sample #1	(olive green #144)	RECOVER (275F)-60 minutes
Sample #2	(olive green # 91)	RECOVER (325F)-15 minutes
Sample #3	(olive green #149)	EXP88 (275F)-30 minutes/partial
		EXP88 (325F)-10 minutes/partial
Sample #4	(white #39)	RECOVER (275F)-60 minutes
Sample #5	(white #35)	RECOVER (325F)-2.5 hours
Sample #6	(white #28)	EXP88 (275F)-60 minutes/partial
		EXP88 (325F)-2 hours/partial

Observations: No reaction noted during processing.

Conclusions: Olive green coupons-paint was degraded in a matter of a few minutes with either process, ultrasonics used to remove inorganics on surface. No apparent effect on "ceramic type" undercoating. White coupons-no apparent effect on outer coating in a reasonable time period with either process. Request more sample coupons for trials with Kolene molten salt processes. Magnesium components cannot be processed in molten salt.

Samples returned to Farr Mfg. & Eng. Co. to the attention of Mr. John Mobley. Comments and further inquiries can be directed to Mr. Dennis McCardle or Mr. Don Yankasky, Kolene Corporation at 1-800-521-4182.


Donald A. Yankasky
Applications Specialist

cc: Mr. Dennis McCardle - Kolene Sales

Polychem

POLYCHEM

U.S. POLYCHEMICAL
CORPORATIONEXECUTIVE OFFICES · PLANT · LABORATORY
584 Chestnut Ridge Road, Chestnut Ridge, NY 10977
(800) 431-2072 (845) 356-5530
www.uspoly.com Fax (845) 356-6656

LABORATORY REPORT

REPORT #	07142003	DATE:	14 July 2003
CUSTOMER:	MSE Technology Applications, Inc.	ID #	--
LOCATION:	P.O. BOX 4078, 200 TECHNOLOGY WAY, BUTTE, MT 59701	TSS:	JOHN ROBERTS

SAMPLE SOURCE AND DESCRIPTION: Painted steel panels: White and Green Paints.

TEST REQUESTED / OBJECTIVE: Substitute stripping chemical for Methylene Chloride

RESULTS / PROCESS SUMMARY: The painted panles were stripped in various Polychemical Products as described below:

1. Polychem Acrastrip 600 Military: 1:1 mixture with water, 180-200 Deg. F. 4 hours immersion.
2. Same Test continued for 8 hours.
3. Polychem Acrastrip 600 Military: Full strength, 180-200 Deg. F, 4 hours.
4. Polychem Acrastrip 600 Automotive, Full Strength, 180-200 Deg. F, 4 hours.
5. Polychem Acrastrip 1000, full Strength, 180-200 Deg. F. 4 hours.
6. Polychem 36, full strength, 150-180 Deg. F. 8 hours immersion.

COMMENTS: All these products in the above test produced only pin-hole type blistering. The blistered paint surface appeared hard and could not be removed with high pressure water or even with mild scrapping with spatula. All the Acrastrips have about 60% organic solvent content in them while Acrastrip 1000 has 98% solvent. Polychem 36 contains ethylene glycol butyl ether, which on many instances appeared to strip certain coatings.

RECOMMENDATIONS / CONCLUSIONS: CAUSTIC STRIPPERS ARE SUGGESTED FOR EVALUATION IF STEEL PARTS COULD BE ISOLATED.

DISPOSITION OF SAMPLES: Panels are retained in the lab. for future testing, if any.

Jake Jacob
Senior ChemistCST: R. Knipe, Jr.
Customer File

Inland Technology Incorporated

Memorandum

To: Joe Lucas
From: Z Haler
Date: 8/14/2003
Re: paint stripping

Testing and recommendations for further work:

Heating to 140 degrees F did not show signs of any stripping of the painted coupons.

The temperature had to be raised to above 150 degrees to start getting softening effects to the paint. The surface was scratched with a scotch pad. Both the green and white paints were coming off onto the scotch pad, but not down to bare metal.

Raising the temperature above 160 degrees dramatically improved the effect on the paint. After the completion of an hour the white paint had "blistered." The green paint showed only limited blistering after the completion of the hour at 160 degrees. It should be noted that the scratched painted surfaces did not glister as well as the non-scratched surface. The blistering of both paints moved inward from the cut edges of the coupon.

If the painted parts were soaked in Magna Strip heated to 160-180 degrees F for 2 to 3 hours, the parts should be stripped. Only 1 hour for the white paint.

There is still two coupons, Magna Strip, and a beaker and thermometer if you want to do further testing.

Appendix D: Material Safety Data Sheets for Methylene Chloride-Based Solvent Oakite Gardostrip Q7900 Sodium Lauryl Sulfate

Methylene Chloride-Based MSDS

MATERIAL SAFETY DATA SHEET

Page: 1 of 5
Date Prepared: July 22, 2003

SECTION 1 PRODUCT IDENTIFICATION & EMERGENCY INFORMATION

PRODUCT NAME:

GENERAL USE: Heavy duty paint stripper and coating remover

PRODUCT DESCRIPTION: Paint stripper

GENERIC INGREDIENTS: Methylene chloride, formic acid, surfactant, wax

EMERGENCY TELEPHONE NUMBERS:

SECTION 2 HAZARDOUS INGREDIENT SECTION

This product is hazardous as defined in 29 CFR1910.1200.

OSHA HAZARD: CORROSIVE

OSHA HAZARDOUS INGREDIENTS

	CAS#	EXPOSURE LIMITS 8 hrs. TWA (ppm)		
		OSHA PEL	ACGIH TLV	Supplier
Methylene chloride	75-09-2	25 (125 STEL)	50	---
Formic acid	64-18-6	5	5	---

SECTION 3 HEALTH INFORMATION & PROTECTION

EMERGENCY OVERVIEW:

Light pink to purple liquid with sharp irritating odor.

CORROSIVE to eyes, skin, and respiratory tract.

POTENTIAL HEALTH EFFECTS:

EYE CONTACT:

Will cause burns to eyes on contact. High vapor concentrations may be irritating.

SKIN CONTACT:

Will cause burns to skin on contact.

INHALATION:

High vapor concentrations may cause burns respiratory tract, may cause headaches, dizziness, anesthesia, drowsiness, unconsciousness, and other central nervous system effects. Exposure to excessive levels of methylene chloride may impair the blood's ability to transport oxygen (carboxyhemoglobinemia) and may also cause irregular heartbeats (cardiac arrhythmia).

INGESTION:

Small amounts of this liquid may be drawn into the lungs by either swallowing or vomiting. This may cause severe and delayed health effects such as inflammation of the lungs, infection of the bronchi, chemical pneumonia, and pulmonary edema. Ingestion will cause burns to the digestive tract.

Page: 3 of 5

Date Prepared: July 22, 2003

SECTION 5 SPILL CONTROL MEASURES

LAND SPILL:

For small spills, use absorbent material such as towels or absorbent powders. Put all materials into proper waste disposal containers with lids tightly covered. For larger spills, dike spill, recover free liquid, and use absorbent material to dry area. Put all materials into appropriate waste containers.

WATER SPILL:

THIS PRODUCT IS HEAVIER THAN WATER AND WILL SINK. Recovery may be difficult. Methylene chloride and formic acid are listed in the Clean Water Act. Check with local environmental regulatory agencies for reporting requirements.

SECTION 6 HANDLING & STORAGE

STORAGE TEMPERATURE, °F: ambient. DO NOT STORE ABOVE 120 Deg. F.

GENERAL: Keep away from open flames, hot glowing surfaces, electric arcs, and other ignition sources. Do not store near strong oxidants. Strong UV light (e.g., welding arcs) can cause significant phosgene to be generated. Vent off any internal pressure in the drum by opening bung slowly. Keep face away when opening bung.

SECTION 7 TYPICAL PHYSICAL & CHEMICAL PROPERTIES

BOILING POINT, °F:

about 110

EVAPORATION RATE, Acetone = 1:

about 0.3

SOLUBILITY IN WATER:

partial

SPECIFIC GRAVITY at 75°F:

1.26

ODOR AND APPEARANCE:

light pink to purple liquid with sharp irritating odor.

VAPOR PRESSURE, mm Hg at 20°C:

350

VAPOR DENSITY (Air = 1):

about 4

WT% ORGANIC VOLATILES:

about 95

pH:

not applicable

SECTION 8 REACTIVITY DATA

GENERAL:

This product is stable and hazardous polymerization will not occur.

INCOMPATIBLE MATERIALS AND CONDITIONS TO AVOID:

Strong oxidizing agents, caustic potash or caustic soda, and reactive metals (e.g., aluminum, potassium, sodium, zinc, etc.).

SECTION 9 REGULATORY INFORMATION

DEPARTMENT OF TRANSPORTATION (DOT):

PROPER SHIPPING NAME:

CORROSIVE LIQUID, N.O.S.

(contains dichloromethane and formic acid)

HAZARD CLASS: 8

IDENTIFICATION NUMBER: UN 1760

PACKING GROUP: I

LABEL: CORROSIVE

Page: 4 of 5

Date Prepared: July 22, 2003

FLASH POINT: none to boil TCC**pH:** not applicable**TSCA:** The ingredients in this product is listed on the TSCA inventory.**CERCLA:**

This product contains the following reportable materials:

Methylene chloride	CAS# 75-09-2	RQ = 1000 lbs
Formic acid	CAS# 64-18-6	RQ = 5000 lbs

Releases exceeding the RQ must be reported to the national response center, 800-424-8802, and may be subject to state and local reporting.

RCRA HAZARD CLASS:

The following waste classes may apply: U080 Dichloromethane; U123 Formic acid; D002 Corrosive hazardous waste, F001 Spent halogenated solvent used in degreasing; F002 Spent halogenated solvent. The user is responsible for determining the appropriate waste category at the time of disposal.

SARA TITLE III:

311/312 HAZARD CATEGORIES:

Acute and chronic health

313 REPORTABLE INGREDIENTS:

Methylene chloride CAS# 75-09-2 about 70 wt%

CLEAN WATER ACT:

Methylene chloride is listed in the Clean Water Act as a priority pollutant. Formic acid is listed in the Clean Water Act as a hazardous pollutant.

CLEAN AIR ACT (1990):

Methylene chloride is listed in the Clean Air Act as a hazardous air contaminant.

NEW JERSEY RIGHT-TO-KNOW INFORMATION:

This product contains methylene chloride (CAS# 75-09-2), formic acid (CAS# 64-18-6), dodecylbenzene sulfonic acid (CAS# 27176-87-0), and paraffin wax (CAS# 8002-74-2).

CALIFORNIA PROPOSITION 65 INFORMATION:

This product contains a chemical recognized by the state of California to cause cancer and/or birth defects or reproductive harm.

SCAQMD INFORMATION:

Is there a photochemically reactive material present? Yes

What is the % by volume of photochemically reactive material? <5%

What is the VOC content? 1210 g/l

What is the vapor pressure of VOC's? 350 mm Hg @ 20 Deg. C.

Page: 5 of 5
Date Prepared: July 22, 2003

SECTION 10 NOTES

HAZARD RATING SYSTEMS:

	HMIS	NFPA
HEALTH	3	3
FLAMMABILITY	0	0
REACTIVITY	0	0

KEY
4 = Severe
3 = Serious
2 = Moderate
1 = Slight
0 = Minimal

REVISION SUMMARY:

none

SUPERSEDES ISSUE DATE:

FOR ADDITIONAL PRODUCT INFORMATION, CONTACT YOUR SALES ENGINEER
FOR ADDITIONAL HEALTH/SAFETY INFORMATION, CALL 201-567-3000

THE INFORMATION PRESENTED HEREIN HAS BEEN COMPILED FROM SOURCES CONSIDERED TO BE DEPENDABLE AND ACCURATE TO THE BEST OF PENETONE'S KNOWLEDGE. THE INFORMATION RELATES TO THIS SPECIFIC MATERIAL. IT MAY NOT BE VALID FOR THIS MATERIAL IF USED IN COMBINATION WITH ANY OTHER MATERIALS OR IN ANY PROCESS. IT IS THE USER'S RESPONSIBILITY TO SATISFY ONESELF AS TO THE SUITABILITY AND COMPLETENESS OF THIS INFORMATION FOR HIS OWN PARTICULAR USE.

Oakite GardoStrip Q7900 MSDS

Oakite. MATERIAL SAFETY DATA SHEET

10173

PRODUCT CODE: 10173
OAKITE GARDOSTRIP Q7900A
200-221-007

HMIS 2 0 0 H

SECTION I - PRODUCT IDENTIFICATION

TRADE NAME OAKITE GARDOSTRIP Q7900A EMERGENCY TELEPHONE NUMBER:
CHEMICAL NAME NA-Mixture (800) 424-9300 (CHEMTREC)
AND SYNONYMS
MANUFACTURER'S NAME OAKITE PRODUCTS INC. (908) 464-6900 (8am-5pm)
AND TELEPHONE NO. A Member of The CHEMETALL Group
ADDRESS 50 Valley Road Berkeley Heights NJ 07922
DATE OF PREPARATION 07-27-99

SECTION II - HAZARDOUS INGREDIENTS

	CAS NO.	% BY WT	ACGIH OSHA		UNITS
			TLV (TWA)	PEL (TWA)	
Trade secret registry (735517)	-5162P	1-5	NE	NE	
Sodium lauryl sulfate	0000151213	1-5	NE	NE	
Trade secret registry (735517)	-5115P	40-50	NE	NE	
Trade secret registry (735517)	-5124P	5-10	NE	NE	
Trade secret registry (735517)	-5123P	5-10	NE	NE	
Non-hazardous ingredients		Bal.			

Unidentified ingredients are considered not hazardous under Federal Hazard Communication Standard (29CFR 1910.1200).

All components of this material are on the US TSCA Inventory.

CARCINOGENICITY: No substance in this product is listed by IARC, NTP, or regulated by OSHA as a carcinogen.

SECTION III - PHYSICAL DATA

BOILING POINT (F)	NE	SPECIFIC GRAVITY (H2O=1)	1.09
VAPOR PRESSURE (mm Hg)	NE	Bulk Density	9.09 lbs/gal

NA - Not Applicable

NE - Not Established

Oakite® MATERIAL SAFETY DATA SHEET

10173

VAPOR DENSITY (Air=1)	NE	PERCENT VOLATILE	
SOLUBILITY IN WATER	Miscible	BY WEIGHT(%) Excludes H2O	40-50
EVAPORATION RATE (Water=1)	1	PH	
APPEARANCE AND ODOR	Light yellow liquid; nutty odor.	PH (concentrate)	2-3

SECTION IV - FIRE AND EXPLOSION HAZARD DATA

FLASH POINT (Method Used): >212F (TCC)
 FLAMMABLE LIMITS: LEL: NE UEL: NE

EXTINGUISHING MEDIA: Carbon dioxide, dry chemical, or foam.

SPECIAL FIRE FIGHTING PROCEDURES: Wear Self-Contained Breathing Apparatus (SCBA). Use water spray to cool fire-exposed containers.

UNUSUAL FIRE AND EXPLOSION HAZARDS: None known.

SECTION V - HEALTH HAZARD INFORMATION

ROUTE(S) OF ENTRY:	INHALATION:	SKIN:	INGESTION:
	X	X	X

MEDICAL CONDITIONS AGGRAVATED BY EXPOSURE: None known.

SYMPTOMS/EFFECTS OF OVEREXPOSURE:

Inhalation of mist may cause respiratory irritation. Prolonged inhalation of high vapor concentrations may cause headache, dizziness or drowsiness. Skin irritation; prolonged or repeated contact may cause burns. Direct contact with eyes causes severe irritation and possible burns.

FIRST AID

EYES: Immediately flush eyes with plenty of water for at least 15 minutes. Get prompt medical attention.

SKIN: Immediately flush skin with plenty of water for at least 15 minutes. Remove contaminated clothing. Wash clothing before reuse. If irritation develops, get medical attention.

INGESTION: Contact local poison control center or physician IMMEDIATELY!

INHALATION: Move victim to fresh air and restore breathing if necessary. Stay with victim until emergency medical help arrives.

NA - Not Applicable

NE - Not Established

Oakite® MATERIAL SAFETY DATA SHEET

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SECTION VI - REACTIVITY DATA

STABILITY: NORMALLY STABLE
INCOMPATIBLE MATERIALS: Strong oxidizers, Strong alkalies.
HAZARDOUS DECOMPOSITION PRODUCTS: Carbon monoxide, Carbon dioxide, Sulfur oxides, Nitrogen oxides.

SECTION VII - SPILL OR LEAK PROCEDURES

PROCEDURES: Wear personal protective equipment (See Section VIII).
Clean up with noncombustible absorbant material. Flush area with plenty of water.
WASTE DISPOSAL METHOD: Dispose of in accordance with Local State and Federal regulations.

SECTION VIII - SPECIAL PROTECTION INFORMATION

RESPIRATORY: For symptoms of overexposure, wear a NIOSH-approved respirator for organic vapors.
EYEWEAR: Wear chemical safety goggles. If splash potential exists wear chemical splash goggles or faceshield.
CLOTHING/GLOVES: Wear neoprene or other chemical-resistant gloves and clothing as needed to prevent skin contact.
VENTILATION: Local exhaust may be necessary for some handling/use conditions. Specific needs should be addressed by supervisory or health/safety personnel.

SECTION IX - SPECIAL PRECAUTIONS

Store in closed container in cool well-ventilated area.

APPROVAL: Michael Chang Mgr. Health & Environmental Dept. 07/28/1999

NAME

TITLE

DATE OF PRINTING

NA - Not Applicable

NE - Not Established

Sodium Lauryl Sulfate MSDS



Genium Publishing Corporation
1145 Catalyn Street
Schenectady, NY 12303-1836 USA
(518) 377-8854

Material Safety Data Sheets Collection:

Sheet No. 731
Sodium Lauryl Sulfate

Issued: 11/90

Section 1. Material Identification				33
<p>Sodium Lauryl Sulfate ($\text{NaC}_{12}\text{H}_{25}\text{SO}_4$) Description: Prepared by sulfation of lauryl alcohol, followed by neutralization with sodium hydroxide. Used as a wetting agent in the textile industry, a food additive (emulsifier and thickener), a toiletry or detergent, and an ingredient in toothpaste; and in electrophoretic separation of proteins and lipids.</p> <p>Other Designations: CAS No. 0151-21-3, SDS, sodium dodecyl sulfate, sulfuric acid monododecyl ester sodium salt.</p> <p>Manufacturer: Contact your supplier or distributor. Consult the latest <i>Chemicalweek Buyers' Guide</i>⁽⁷⁾ for a suppliers list.</p>				<p>R 0 I - S 1 K 1</p> <p>Genium 1 0 1 -</p> <p>HMIS H 1 F 1 R 0 PPG* * Sec. 8</p>
<p>Cautions: Sodium lauryl sulfate is a skin, eye, and mucous membrane irritant. Avoid inhalation of dust. It is a mild allergen.</p>				
Section 2. Ingredients and Occupational Exposure Limits				
Sodium lauryl sulfate*				
1989 OSHA PEL	1990-91 ACGIH TLV	1988 NIOSH REL	1995-86 Toxicity Data†	
None established	None established	None established	Human, skin: 25 mg administered over 24 hr produces mild irritation Rat, oral, LD ₅₀ : 1288 mg/kg	
<p>*A typical composition is 92% sodium alkyl sulfates, 2.5% free fatty alcohols, and 5.5% combined sodium sulfate and sodium chloride. † See NIOSH, RTECS (WT1050000), for additional irritative, mutative, reproductive, and toxicity data.</p>				
Section 3. Physical Data				
Molecular Weight: 288.38		Relative Density (15 °C/4 °C): 0.35 g/cm ³		
pH (1% Solution): 8 to 10		Water Solubility: Soluble; 1 g dissolves in 10 ml of water (an opalescent solution)		
Appearance and Odor: White or cream-colored crystals with a faint odor of fatty substances.				
Section 4. Fire and Explosion Data				
Flash Point: >200 °F (93.4 °C), CC		Autoignition Temperature: None reported		LEL: None reported UEL: None reported
Extinguishing Media: Use water or foam to fight fires involving sodium lauryl sulfate.				
Unusual Fire or Explosion Hazards: Sodium lauryl sulfate can produce sulfur dioxide and carbon monoxide under combustion.				
Special Fire-fighting Procedures: Since fire may produce toxic fumes, wear a self-contained breathing apparatus (SCBA) with a full facepiece operated in the pressure-demand or positive-pressure mode. Be aware of runoff from fire control methods. Do not release to sewers or waterways.				
Section 5. Reactivity Data				
Stability/Polymerization: Sodium lauryl sulfate is stable at room temperature in closed containers under normal storage and handling conditions. Hazardous polymerization cannot occur.				
Chemical Incompatibilities: Sodium lauryl sulfate is inert to most chemicals other than mineral acids.				
Conditions to Avoid: Avoid high temperatures and acidic conditions.				
Hazardous Products of Decomposition: Thermal oxidative decomposition of sodium lauryl sulfate can produce sulphur dioxide and carbon monoxide.				

No. 731 Sodium Lauryl Sulfate 11/90

Section 6. Health Hazard Data

Carcinogenicity: The NTP, IARC, and OSHA do not list sodium lauryl sulfate as a carcinogen.

Summary of Risks: Sodium lauryl sulfate is an eye, skin, and mucous membrane irritant, and may directly or indirectly produce irritation since it increases skin permeability (stratum corneum) not only to medicaments, but to noxious agents too. This mild allergen may produce sensitizing reactions. Experimental studies on laboratory animals show sodium lauryl sulfate causes teratogenic and reproductive effects.

Medical Conditions Aggravated by Long-Term Exposure: None reported.

Target Organs: Skin, eyes, and mucous membranes.

Primary Entry Routes: Inhalation.

Acute Effects: Dust inhalation causes sneezing, coughing, and nose and throat irritation. Dust also irritates eyes and may cause burns on prolonged contact. Prolonged occupational dermal contact can cause skin irritation. Ingestion results in nausea, vomiting, stomach irritation, and diarrhea.

Chronic Effects: Continued exposure to sodium lauryl sulfate solution can defat and crack the skin.

FIRST AID

Eyes: Gently lift the eyelids and flush immediately and continuously with flooding amounts of water until transported to an emergency medical facility. Consult a physician immediately.

Skin: Quickly remove contaminated clothing. Rinse with flooding amounts of water for at least 15 min. For reddened or blistered skin, consult a physician. Wash affected area with soap and water.

Inhalation: Remove exposed person to fresh air and support breathing as needed.

Ingestion: Never give anything by mouth to an unconscious or convulsing person. If ingested, have that *conscious* person immediately drink 4 to 8 oz. of milk or water. Spontaneous vomiting occurs normally within 1 hr of ingesting a toxic dose. Consult a physician if large amounts are ingested.

After first aid, get appropriate in-plant, paramedic, or community medical support.

Section 7. Spill, Leak, and Disposal Procedures

Spill/Leak: Notify safety personnel. Cleanup personnel should protect against dust inhalation and skin or eye contact. Avoid creating airborne dust conditions. Carefully scoop spilled dry material into a suitable container (with a secure lid) for disposal or reclamation. Absorb liquid spills on fire retardant-treated sawdust or diatomaceous earth and scrape into appropriate containers for disposal. For large spills, dike far ahead of large spill to contain. Follow applicable OSHA regulations (29 CFR 1910.120).

Disposal: Contact your supplier or a licensed contractor for detailed recommendations. Follow applicable Federal, state, and local regulations.

Sodium lauryl sulfate is biodegradable on activation with sewage sludge.

EPA Designations

RCRA Hazardous Waste (40 CFR 261.33): Not listed

CERCLA Hazardous Substance (40 CFR 302.4): Not listed

SARA Extremely Hazardous Substance (40 CFR 355): Not listed

SARA Toxic Chemical (40 CFR 372.65): Not listed

OSHA Designations

Air Contaminant (29 CFR 1910.1000, Subpart Z): Not listed

Section 8. Special Protection Data

Goggles: Wear protective eyeglasses or chemical safety goggles, per OSHA eye- and face-protection regulations (29 CFR 1910.133).

Respirator: Seek professional advice prior to respirator selection and use. Follow OSHA respirator regulations (29 CFR 1910.134) and, if necessary, wear a NIOSH-approved respirator. For emergency or nonroutine operations (cleaning spills, reactor vessels, or storage tanks), wear an SCBA. *Warning! Air-purifying respirators do not protect workers in oxygen-deficient atmospheres.*

Other: Wear impervious gloves, boots, aprons, and gauntlets to prevent prolonged or repeated skin contact.

Ventilation: Provide general and local exhaust ventilation systems to maintain airborne concentrations that promote worker safety and productivity. Local exhaust ventilation is preferred since it prevents contaminant dispersion into the work area by controlling it at its source.⁽¹⁰⁹⁾

Safety Stations: Make available in the work area emergency eyewash stations, safety/quick-drench showers, and washing facilities.

Contaminated Equipment: Never wear contact lenses in the work area: soft lenses may absorb, and all lenses concentrate, irritants. Remove this material from your shoes and equipment. Launder contaminated clothing before wearing.

Comments: Never eat, drink, or smoke in work areas. Practice good personal hygiene after using this material, especially before eating, drinking, smoking, using the toilet, or applying cosmetics.

Section 9. Special Precautions and Comments

Storage Requirements: Store in tightly closed containers in a cool (<140 °F (60 °C)), dry, well-ventilated area away from all heat and ignition sources. Protect containers against physical damage. To prevent static sparks, electrically ground and bond all equipment used in shipping, receiving, or transferring operations in production and storage areas.

Engineering Controls: Avoid dust inhalation and skin or eye contact. Use appropriate personal protective gear such as protective gloves and aprons, dust masks, and face shields. Avoid use in confined areas. Institute a respiratory protection program that includes regular training, maintenance, inspection, and evaluation. Avoid creating airborne dust conditions. Practice good personal hygiene and housekeeping procedures.

Transportation Data (49 CFR 172.101, .102): Not listed

MSDS Collection References: 1, 73, 101, 103, 124, 126, 127, 132, 136, 139

Prepared by: MJ Allison, BS; Industrial Hygiene Review: DJ Wilson, CIH; Medical Review: AC Darlington, MD; Edited by: JR Stuart, MS

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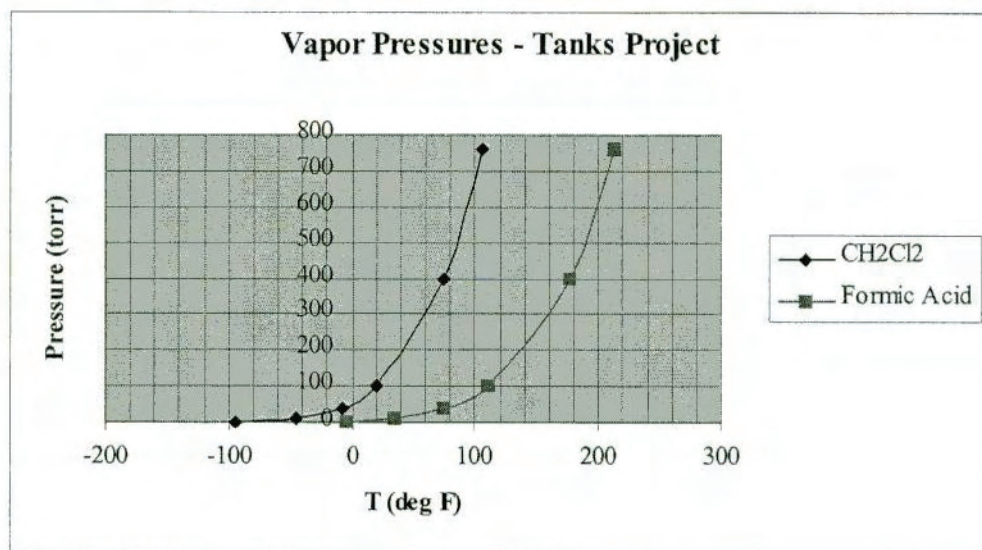
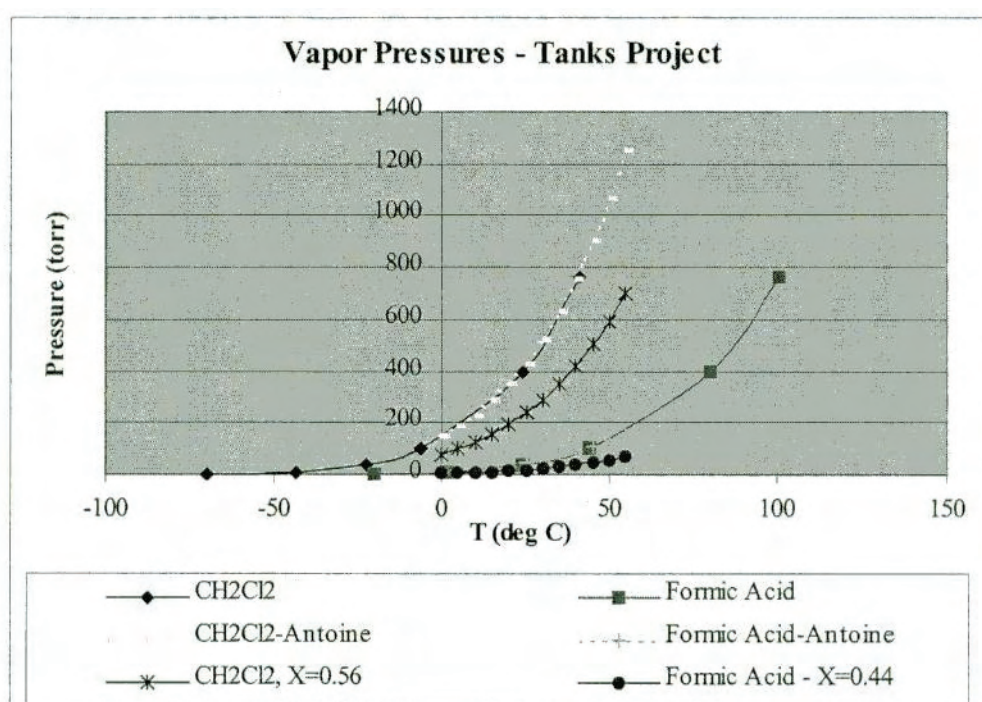
Appendix E: Vapor Pressure of Methylene Chloride and Formic Acid

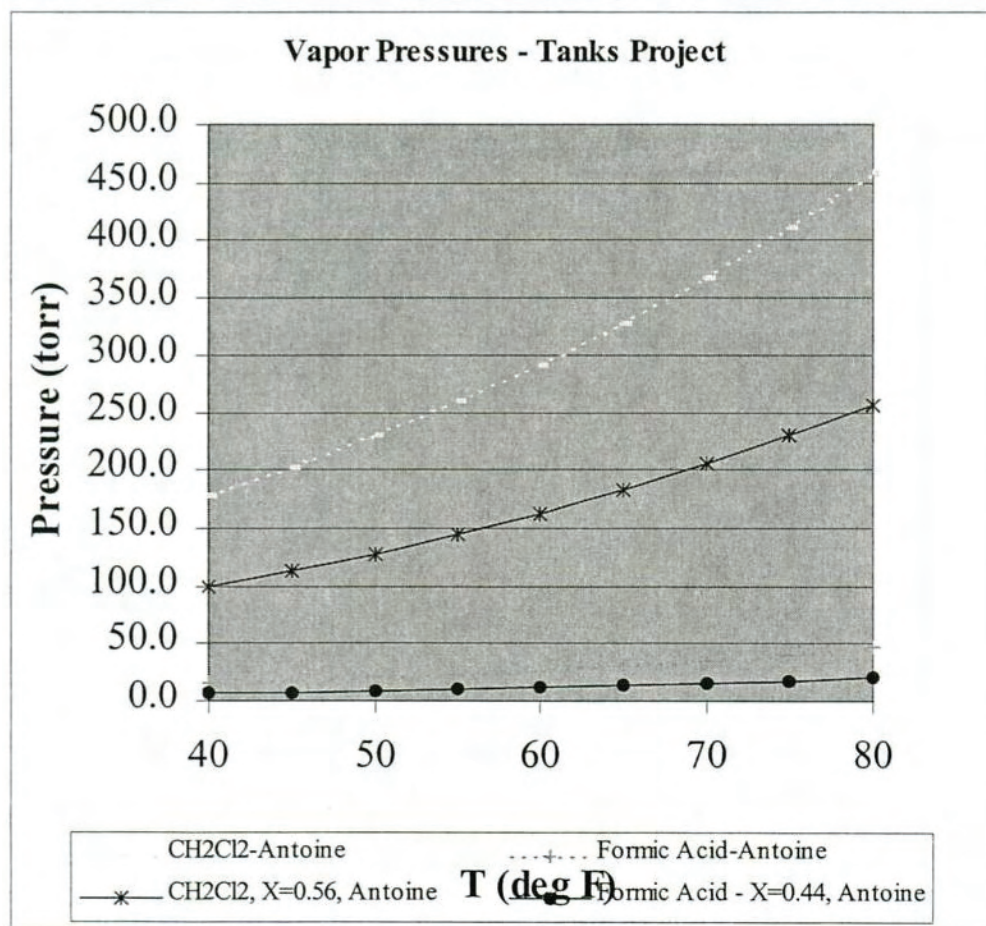
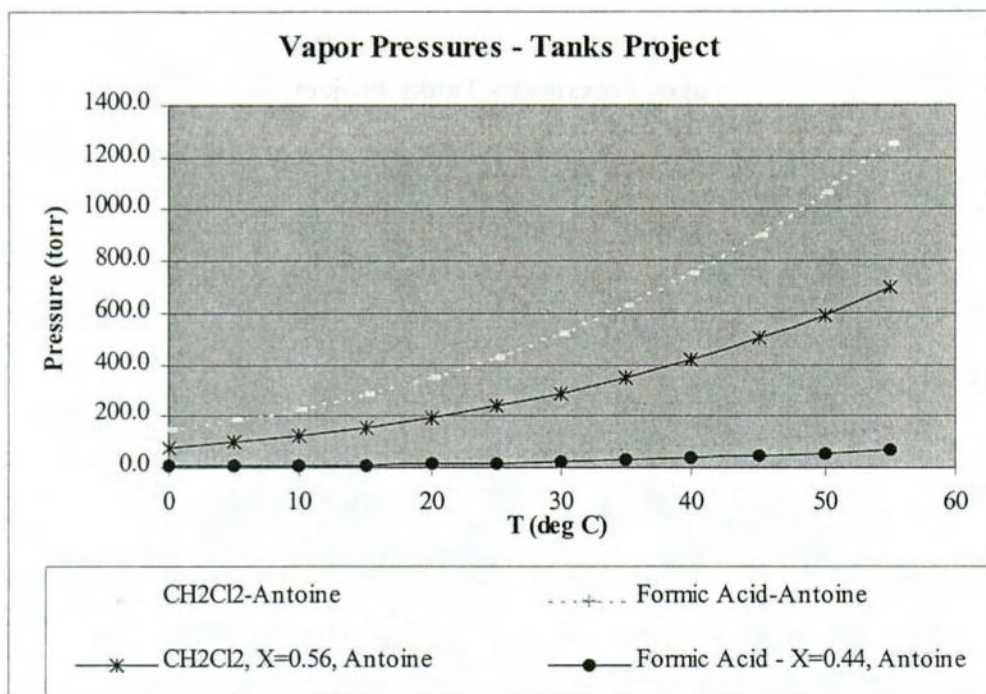
VAPOR PRESSURE OF METHYLENE CHLORIDE AND FORMIC ACID CHARTS AND CALCULATION

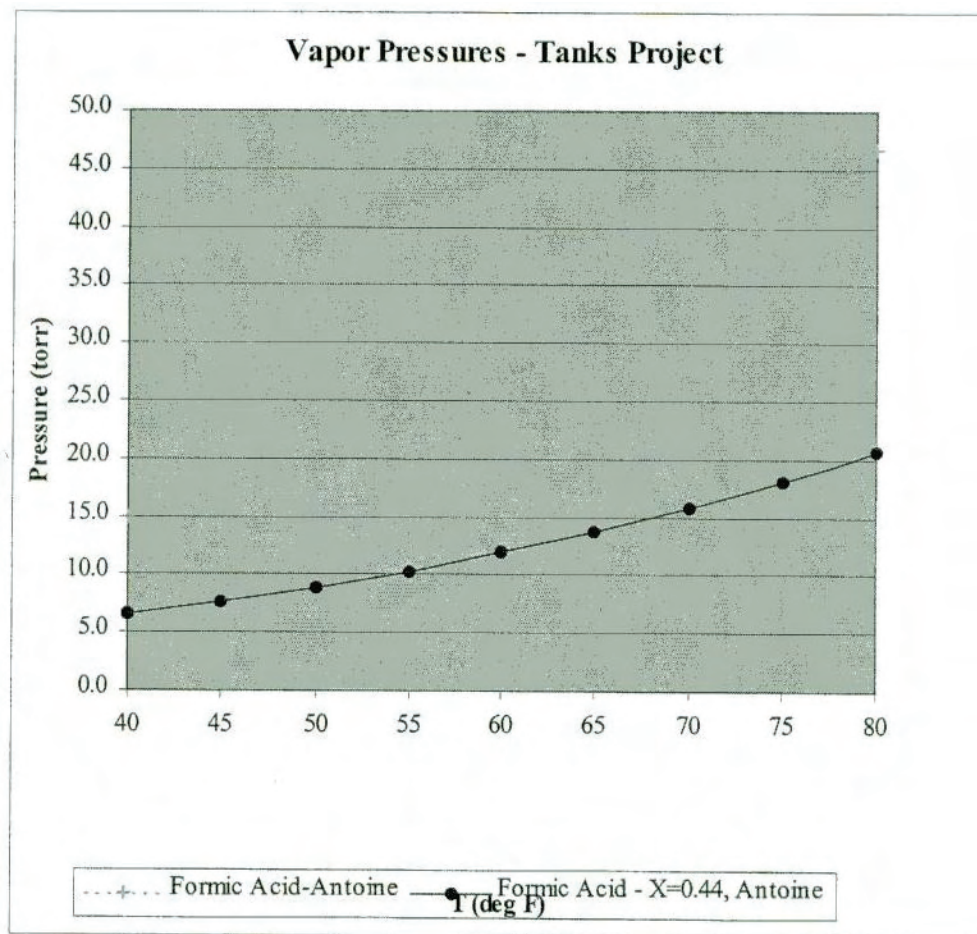
The following spreadsheets show vapor pressure as a function of temperature for methylene chloride and formic acid, individually and in a 70/30 (w/w) mixture.

Both experimental data and Antoine constants for methylene chloride and formic acid were found. As shown in the graphs, curves calculated from the Antoine constants and the experimental data are in close agreement. Therefore, the Antoine constants were used to calculate vapor pressure as a function of temperature. This is deemed to be more accurate than interpolating the not very well-spaced experimental values.

Next, Raoult's law was used to calculate the vapor pressures in a mixture, assuming that methylene chloride and formic acid were fully miscible and would behave ideally (i.e., the vapor pressure of methylene chloride above a solution would be equal to its mole fraction times its vapor pressure above the pure liquid, same for formic acid).







Methylene Chloride, formic acid solution

	%(w/w)	f.w.	Moles 100g basis	X
Methylene chloride	70	84.93	0.8242	0.5584
Formic acid	30	46.03	0.6517	0.4416
Total	100		1.4760	1.00

Methylene chloride

T (deg F)	T (deg C)	T (K)	1/T (K)	P (torr)
-94	-70	203.15	0.004922	1
-45.94	-43.3	229.85	0.004351	10
-8.14	-22.3	250.85	0.003986	40
20.66	-6.3	266.85	0.003747	100
75.38	24.1	297.25	0.003364	400
105.26	40.7	313.85	0.003186	760

Formic Acid

T (deg F)	T (deg C)	T (K)	1/T (K)	P (torr)
-4	-20	253.15	0.003950	1
35.78	2.1	275.25	0.003633	10
75.2	24	297.15	0.003365	40
110.84	43.8	316.95	0.003155	100
176.54	80.3	353.45	0.002829	400
213.08	100.6	373.75	0.002676	760

Methylene Chloride, Antoine Equation (-40 C to +40 C)

A=	7.4092	B=	1325.9	C=	252.6
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$$\log 10 p = A - B / (T + C)$$

T (deg C)	log P _o (torr)	P _o (torr)	P _x (torr)
0	2.160	144.6	80.75
5	2.262	182.8	102.10
10	2.360	229.1	127.95
15	2.454	284.7	158.99
20	2.545	351.0	196.00
25	2.633	429.4	239.81
30	2.717	521.7	291.32
35	2.799	629.5	351.51
40	2.878	754.7	421.43
45	2.954	899.3	502.17
50	3.028	1065.4	594.94
55	3.099	1255.3	700.96

T (deg F)	T (deg C)	log P _o (torr)	P _o (torr)	P _x (torr)
40	4.4	2.251	178.2	99.52
45	7.2	2.306	202.3	112.99
50	10.0	2.360	229.1	127.95
55	12.8	2.413	258.8	144.51
60	15.6	2.465	291.5	162.80
65	18.3	2.515	327.6	182.95
70	21.1	2.565	367.3	205.12
75	23.9	2.614	410.9	229.44
80	26.7	2.661	458.6	256.08

Formic Acid, Antoine Equation (-40 C to +40 C)

A=	7.5818	B=	1699.2	C=	260.7
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$$\log 10 p = A - B / (T + C)$$

T (deg C)	log P _o (torr)	P _o (torr)	P _x (torr)
0	1.064	11.6	5.12
5	1.187	15.4	6.79
10	1.305	20.2	8.91
15	1.419	26.2	11.58
20	1.528	33.8	14.91
25	1.634	43.1	19.02
30	1.737	54.5	24.08
35	1.835	68.5	30.23
40	1.931	85.3	37.67
45	2.023	105.5	46.60
50	2.113	129.7	57.26
55	2.199	158.3	69.90

T (deg F)	T (deg C)	log P_o (torr)	P_o (torr)	P_x (torr)
40	4.4	1.173	14.9	6.58
45	7.2	1.240	17.4	7.67
50	10.0	1.305	20.2	8.91
55	12.8	1.368	23.4	10.32
60	15.6	1.431	27.0	11.91
65	18.3	1.492	31.1	13.72
70	21.1	1.552	35.7	15.75
75	23.9	1.611	40.8	18.03
80	26.7	1.669	46.6	20.60

Appendix F: Test Plan for Studying the Effect of Chilling on Stripping

TEST PLAN FOR CHILLED STRIPPING SOLUTION

The test plan was implemented by MSE personnel, with the following digressions:

1. All the paint coupons were cut to a size of 4 x 3 in.
2. During the Vapor Pressure Testing, the flasks were left to stabilize and obtain equilibrium for 1 hour instead of 10-15 minutes.
3. The tests were stopped at 70 °F due to the inconclusive results.

A modification of the test was designed and implemented. The modification included the following:

1. The flasks were left to stabilize and obtain equilibrium for 2 hours.
2. The gas was drawn ¼ in. from the solution top.
3. The tests were repeated for 40 °F, room temperature, and 80 °F.

TEST PLAN FOR CHILLED METHYLENE CHLORIDE

STRIPPING SOLUTION

The following test procedure was performed by MSE in an attempt to determine the effect that chilling has on methylene chloride-based stripping operations. Parameters to be examined include the off-gas emission concentration of the methylene chloride, and the effectiveness of the stripping ability. The testing parameters have been set up to comply with the needed requirements of Anniston Army Depot for their stripping.

BACKGROUND:

Anniston Army Depot (ANAD) uses vats of solution at their site for stripping. This stripping solution consists of methylene chloride, formic acid and aromatic hydrocarbon & beeswax.

The parts to be stripped are lowered into the vats in a 36-in. cubed cage via a crane system. The vats are open to the air. The off gas emission from the solution is captured by a push system that uses a blower to push air across the top of the open vat and into the pull discharge at the opposite side of the vat. The emissions are discharged into the ambient air.

The methylene chloride concentration in the off gas needs to stay within the national emission standards for hazardous air pollutants (NESHAP) requirements. ANAD is currently exceeding the NESHAP limits. Upcoming enforcement of these NESHAP emission standards could result in fines for violations if the emissions are not reduced. Ways to reduce the emissions are being investigated.

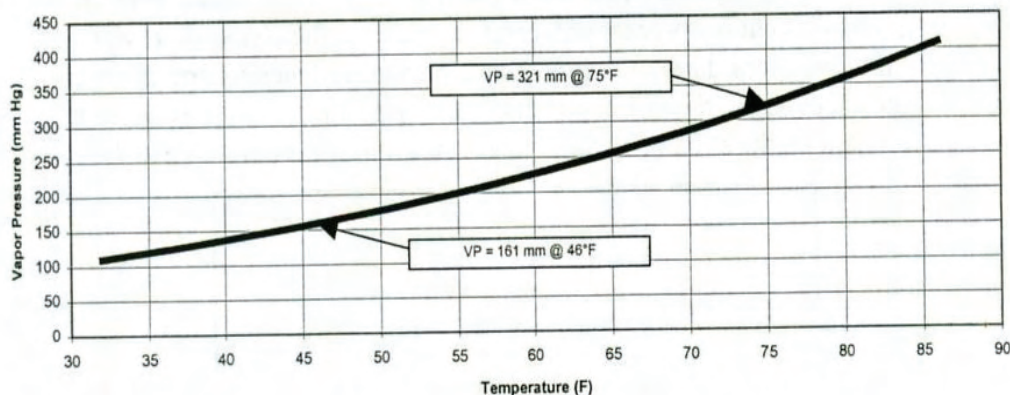
GOAL:

This test is being done to determine if lowering the temperature of the solution will be a viable alternative to their existing operation, which is an ambient temperature of 70°F 80°F.

To be a viable alternative, the stripper would need to be effective in stripping within a time range of 30 minutes or less while reducing or eliminating the methylene chloride emission concentration.

Theoretical vapor pressure calculations show that lowering the liquid temperature from 75°F to 46°F reduces the vapor pressure by 50 percent. This reduction in vapor pressure would likely result in lower concentrations in the off gas emissions. See Figure 1.

Figure 1. Theoretical Vapor Pressure
Binary Mixture - Dichloromethane and Formic Acid
Calculated using Antoine Equation



This sampling project is to make the following determinations:

1. Confirm the theoretical calculations of the vapor pressure.
 - The first set of vapor pressure tests will use a sample of the stripping solution that ANAD is currently using in their stripping process.
 - The second set of vapor pressure tests will use a methylene chloride / formic acid solution which excludes the aromatic hydrocarbons (beeswax). The beeswax is used in the stripping solution to inhibit emissions from the solution. This second set of vapor pressure testing will help in determining whether lower temperatures will eliminate the need for the beeswax in reducing methylene chloride emissions.
2. Evaluate the emission vapor pressure of the stripping solution at a temperature range of 40°F to 80°F. Compare these different vapor pressures to the vapor pressure found at 75°F (the approximate temperature used at ANAD during their stripping operations). The vapor pressure reflects the tendency of the solution to become a vapor. The methylene chloride emission concentration is proportional to the vapor pressure of the methylene chloride.
3. Determine the time it takes to completely strip the paint at each temperature.

PREPARATION:

ANAD is preparing 20 paint coupons consisting of 16-gauge carbon steel sheet metal painted by ANAD with the same chemical agent resistive compound (CARC) paint that is used on the actual parts ANAD is responsible for stripping. Each paint coupon is to be approximately 4" x 6".

The paint coupons are to be shipped by ANAD to the MSE Technology Applications, Inc. (MSE) site. The laboratory facility at MSE shall set up and perform the test.

When the paint coupons are received by MSE, score the backs of the paint coupons with a vertical center line starting approximately one inch from the top and ending at approximately one inch from the bottom. Make sure the scoring extends past the paint and into the metal. See Figure 2. This scoring will give MSE a reference point in determining if MSE's cutting process will create a "flaw" in the coupons. If visible inspections of the coupons during testing reflect a greater tendency to strip at the cut edges than the uncut edges, then MSE can discount that tendency in the evaluation process, blaming it on the stripper's ability to get underneath the paint due to the cut.

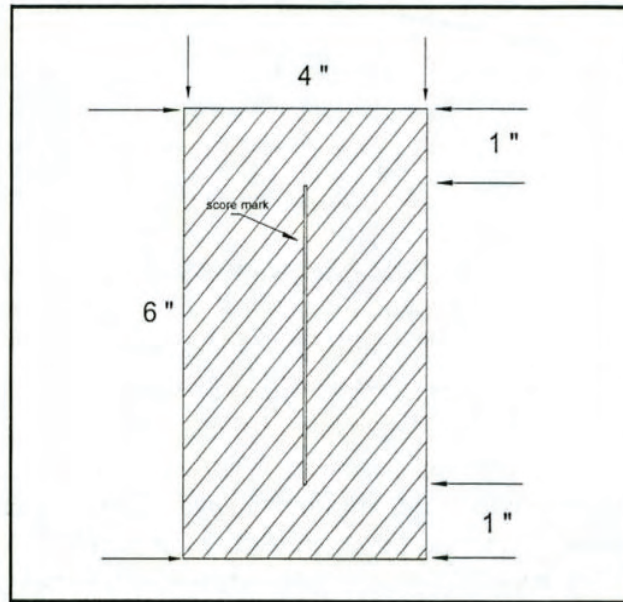


Figure 2. Scoring the Paint Coupons

MSE shall cut the 16 paint coupons into 32 coupons, each of them should be 4"x 3", leaving four 4"x 6" coupons intact. Drill a small hole (large enough to insert a thin stainless steel wire through) in top center of each paint coupon, including the 4" x 6" coupons.

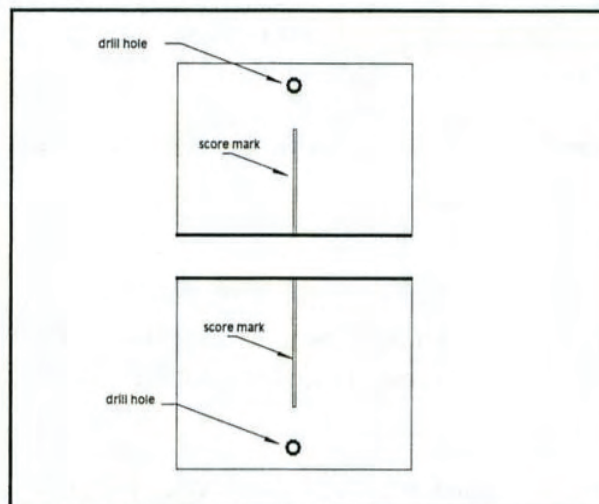


Figure 3. Cutting and Drilling the Paint Coupons

SETUP:

1200 mL clear beaker
600 mL clear beaker
500 ml capacity Erlenmeyer flasks
Water Bath
Syringe and Needle
Gas Chromatograph (GC)
Digital Thermometer
Stopper or Teflon Tape
Methylene Chloride / Formic Acid solution (See Safety Guidelines and MSDS)
Hood
Thin stainless steel wire
Wire holding device (see test engineer)

SAFETY:

Proper personal protective equipment shall be worn while handling the stripping solution and methylene chloride / formic acid solution. This shall minimally consist of Neoprene gloves, splash proof goggles and an apron. The stripping solution and methylene chloride / formic acid solution shall only be poured and handled in a hooded system with exhaust fans. Wash hands with soap and water after contact. Avoid breathing the vapors.

See the Material Safety Data Sheet (MSDS) attached.

PROCEDURE:**VAPOR PRESSURE TESTING FOR THE STRIPPING SOLUTION
(INCLUDING AROMATIC HYDROCARBONS).**

Caution: It is important to be consistent in selecting the same sampling point location for each test.

1. Pour 200 ml of stripping solution in each of three (3) 500 ml capacity Erlenmeyer flasks.
2. Place thermocouple in flask and cover top of flask with Teflon tape allowing some air to enter flask.
3. Place flasks in water bath and chill to a temperature of approximately 40 °F. Let set at this temperature for 10 - 15 minutes to stabilize and to allow vapor pressure to build up prior to taking a sample.
4. Measure and record the temperature on the data sheet within 0.1 °F of labeling the data sheets with the sample number.
5. Insert a needle with syringe through the top positioning the needle point $\frac{1}{2}$ inch above the stripping solution leaving the flask in the water bath. Pull a volume of the gaseous solution into the syringe.

6. Insert the captured gas in the syringe into the gas chromatographer mass spectrometer (GCMS). Measure and record the concentration of the methylene chloride and the formic acid in the sample.
7. Warm the water bath to 45°F.
8. Repeat Steps 4 through 6, recording on the data sheet.
9. Repeat for 50°F, 60°F, 70°F and 80°F.

VAPOR PRESSURE TESTING FOR METHYLENE CHLORIDE / FORMIC ACID SOLUTION (EXCLUDING AROMATIC HYDROCARBONS).

Caution: It is important to be consistent in selecting the same sampling point location for each test.

(Note: this vapor pressure test may be performed concurrently with the stripping solution vapor tests if there is enough room in the water bath for four Erlenmeyer flasks instead of just two.)

1. Perform Steps 1 through 9 under Vapor Pressure Testing for the stripping solution (including aromatic hydrocarbons) substituting the methylene chloride/formic acid solution for the stripping solution.
2. Measure and record all data on the data sheets including the sample numbers.

Note: If there are no changes for the vapor pressure for lower temperatures compared to the stripping solution, there is no need to continue with the lower temperatures for this methylene chloride testing.

STRIPPING TESTS AT SPECIFIC TEMPERATURES

(This test will determine how well the stripping action works at the different temperatures. Caution: It is important to closely watch the time intervals for checking the progress of the stripping for each test and to be consistent raising or lowering the coupon in the same manner.)

1. Under an exhaust hood, pour 400 mL of stripping solution into a clear 600 mL beaker.
2. Place the beaker in a water bath until a temperature of 80°F is reached. Let set in the water bath 10 minutes prior to inserting the paint coupon.
3. Measure and record the exact temperature on the data sheet within 0.1 °F.
4. Insert a stainless steel wire through the hole in the top of the paint coupon.
5. Holding onto the stainless steel wire, lower one 4"x3" paint coupon into the beaker and hook the top of the wire to a holding device above, holding the paint coupon in place in the stripping solution. Immediately, record the time on the data sheet.

STRIPPING TESTS ACTUAL TESTING

6. **FIRST TEST:** Slowly, and with as little turbulence as possible, pull the paint coupon from the beaker at 10-minute intervals (or visually inspect through the beaker if possible) recording “YES” or “NO” as to whether 100% of the paint has been stripped. Record each finding and time increment.
 - a. If “YES” has been obtained.
 - i. **SECOND TEST:** Repeat process at the same temperature reducing to 5-minute increments 10 minutes before the earliest “YES” appeared on the first test. *(This is to try to pin down within (+/-) 5 minutes how long it takes to do a 100% strip.)*
 - ii. **THIRD TEST:** When the time has been determined on the second test, repeat process a third time reducing to 5-minute increments 10 minutes before the earliest “YES” appeared on the second test at this temperature. *(This test will be done to confirm how long it takes to do a 100% strip.)*
 - iii. When “YES” has been obtained again, repeat until the same time is received on two consecutive test, then place the used stripping solution in a labeled disposal container. Go on to the next sample.
 - b. If “NO”, replace the paint coupon in the stripping solution and proceed through the next time increment until “YES” is obtained, or until 40 minutes has passed.
 - c. If a testing period of 40 minutes has passed, document the data sheet. For example:
“Over 40 minutes has passed and visually it appears 75% is stripped off of the part.”

Note: This test is stopped because ANAD had advised that they cannot go beyond a 30-minute stripping time, therefore, this temperature is a failure.

- d. When test is complete, place the used stripping solution in a labeled disposal container.
- e. Proceed to the next sample.

Repeat FIRST, SECOND, and THIRD Stripping Tests at Specific Temperatures for the following temperatures:

1. 75° F,
2. 70° F,
3. 60 °F,
4. 50 °F,
5. 40 °F.

Note: Use judgment on whether to continue with the tests. For example:

If 100% is stripped, then the test is complete.

If a time limit of 30-40 minutes has been passed, then the test should be stopped as it has gone beyond the parameters of acceptability.

If a temperature of 60 °F does not strip 100% within the 40-minute time range, then it is assumed that a temperature of less than 60 °F also will not and all further tests may be aborted.

If two stripping tests for the same temperature reflect a sizeable difference in stripping time, repeat the test a third time.

See testing engineer for any questions.

7. Once the 4" x 3" paint coupon test have been completed have the test engineer determine which temperature(s) are to have the next tests performed on.
8. Under an exhaust hood, pour 1200 mL of stripping solution into an 1800 mL beaker.
9. Repeat *STRIPPING TESTS ACTUAL TESTING* Steps through 6 for this selected temperature, while using a 4" x 6" paint coupon instead of the 4" x 3" coupons. Note: This test is to determine if there are any differences in testing with the 4" x 3" (cut by MSE) coupons compared to the 4" x 6" (uncut by MSE) coupons. This is to rule out any effects the pre-cutting of the painted coupons may have on the stripping time.
10. Document findings.

ANALYSIS:

Immediately upon receiving the syringe sample, insert the sample into the GC for analysis to determine the concentration. This should be done immediately, making sure the methylene chloride does not condense in the syringe. Record on corresponding data sheets.

Appendix G: Results of Vapor Pressure Tests for Methylene Chloride-Based Solutions at Various Temperatures

Tests at the MSE site in Butte, MT, were performed to try to confirm the theoretical calculations of the vapor pressure's effect from chilled temperatures. These vapor pressures tests used the methylene chloride-based solution that ANAD is currently using in their stripping process.

Testing Procedure and Results

In Appendix G is the Test Plan for Chilled Stripping Solution. This test plan proved to be inadequate to produce the results necessary. In this test, the solution was chilled to various temperatures down to 40 °F, and samples of the stripper's emissions were collected using a syringe. This vapor sample was injected into a gas chromatograph mass spectrometer (GCMS) and recorded. The results of the first series of tests were inconclusive.

The test plan was modified and the modified test was implemented with the solvent at the following three temperatures: room temperature, 40 °F, and at 80 °F. The results of these modified tests were inconclusive. These results are found in this Appendix.

Future Testing

Future testing needs to be designed simulating more of the actual conditions at ANAD. A different approach should be taken for future testing. Rather than trying to measure the off-gas emissions from the solution, measuring the reduction in solution volume by weight would give better results, however project time and funding constraints did not allow further testing.

A suggestion for future testing which may result in more substantial data would be as follows:

To measure the emissions of the solution at room temperature:

- Place a measured volume by weight amount of solution in an Erlenmeyer flask. Record.
- Leave the top of the Erlenmeyer flask open to the ambient air.
- Blow air across the top of the Erlenmeyer flask for 10 hours in order to obtain equilibrium.
- Measure the volume by weight of the amount of solution in the Erlenmeyer flask. Record.
- Find the difference in volume by weight. This difference represents solution emissions at room temperature.

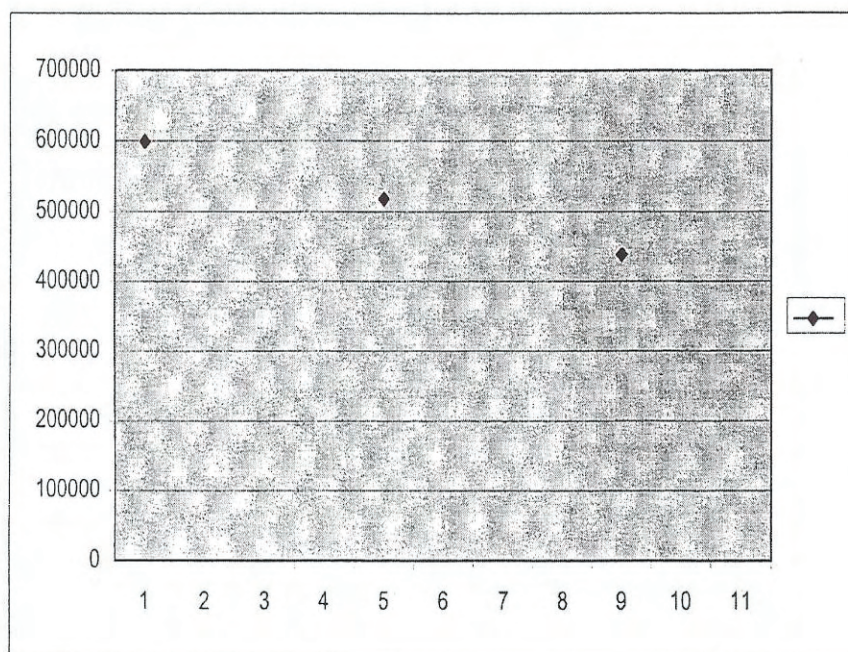
To measure the emissions of the solution at 40 °F temperature:

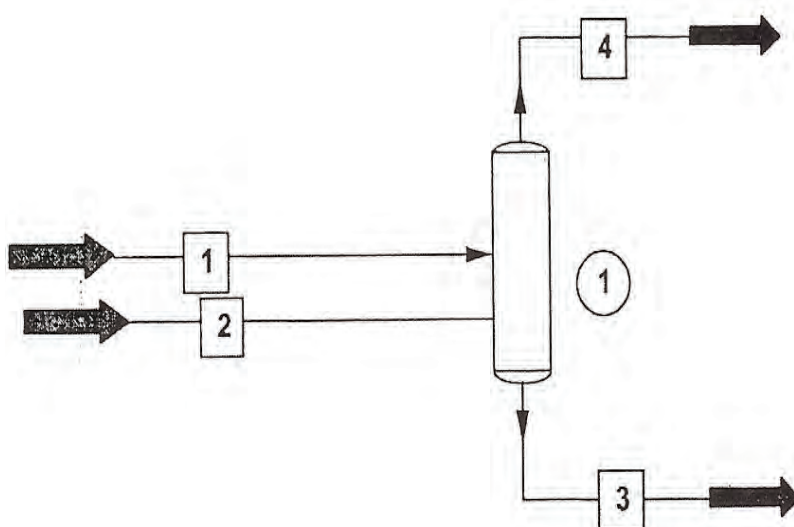
- Place a measured volume by weight amount of solution in an Erlenmeyer flask. Record.
- Leave the top of the Erlenmeyer flask open to the ambient air.
- Chill the flask to 40 °F.
- Blow air across the top of the chilled Erlenmeyer flask for 10 hours in order to obtain equilibrium.
- Measure the volume by weight of the amount of solution in the Erlenmeyer flask. Record.
- Find the difference in volume by weight. This difference represents solution emissions at 40 °F.

To measure the emissions of the solution at 80 °F temperature:

- Place a measured volume by weight amount of solution in an Erlenmeyer flask. Record.
- Leave the top of the Erlenmeyer flask open to the ambient air.
- Heat the flask to 80 °F.
- Blow air across the top of the heated Erlenmeyer flask for 10 hours in order to obtain equilibrium.
- Measure the volume by weight of the amount of solution in the Erlenmeyer flask. Record.
- Find the difference in volume by weight. This difference represents solution emissions at 80 °F.

Sample id.	actual temp	meth chlor area	Average
40 F	40.8	635943	599151
40 F	41	587394	
40 F	40.9	574116	
room temp	70.1	537716	517588
room temp	70.3	494386	
room temp	70.3	520662	
80 F	80.1	431459	437482.7
80 F	80	426002	
80 F	80.1	454987	





Stream No.	1	2	3	4
Name	Stripper	air	VAT	Vapor
- - Overall - -				
Molar flow lbmol/h	1.3810	0.3466	1.2883	0.4393
Mass flow lb/h	100.0000	10.0000	92.3726	17.6274
Temp F	40.0000	75.0000	40.0000	40.0000
Pres psia	14.5000	14.5000	14.5000	14.5000
Vapor mole fraction	0.0000	1.000	0.0000	1.000
Average mol wt	72.4116	28.8508	71.6993	40.1287
Component mole %				
Dichloromethane	59.680814	0.000000	57.265472	19.673198
Formic Acid	39.331892	0.000000	41.674533	1.426142
n-HEXACOSANE	0.987297	0.000000	1.058307	0.000000
Oxygen	0.000000	20.999999	0.000582	16.568460
Nitrogen	0.000000	78.999996	0.001094	62.332201

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Job Name: MARSHAL Date: 09/05/2003 Time: 13:37:46

FLOWSHEET SUMMARY

Equipment	Label	Stream Numbers
1 FLAS		1 2 -4 -3

Stream Connections

Stream	Equipment
	From To
1	1
2	1
3	1
4	1

Calculation mode : Sequential

Flash algorithm : Normal

Equipment Calculation Sequence

1

No recycle loops in the flowsheet.

COMPONENTS

	ID #	Name
1	222	Dichloromethane
2	223	Formic Acid
3	1770	n-HEXACOSANE
4	47	Oxygen
5	46	Nitrogen

THERMODYNAMICS

K-value model : UNIFAC
No correction for vapor fugacity
Enthalpy model : Latent Heat
Liquid density : Library

* Component ID 47 does not have UNIFAC subgroups.

* Component ID 46 does not have UNIFAC subgroups.

CHEMCAD 5.3.0

Page 2

Job Name: MARSHAL Date: 09/05/2003 Time: 13:37:46

Overall Mass Balance	lbmol/h		lb/h	
	Input	Output	Input	Output
Dichloromethane	0.824	0.824	70.000	70.000
Formic Acid	0.543	0.543	25.000	25.000
n-HEXACOSANE	0.014	0.014	5.000	5.000
Oxygen	0.073	0.073	2.329	2.329
Nitrogen	0.274	0.274	7.671	7.671
Total	1.728	1.728	110.000	110.000

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Job Name: MARSHAL Date: 09/05/2003 Time: 13:37:46

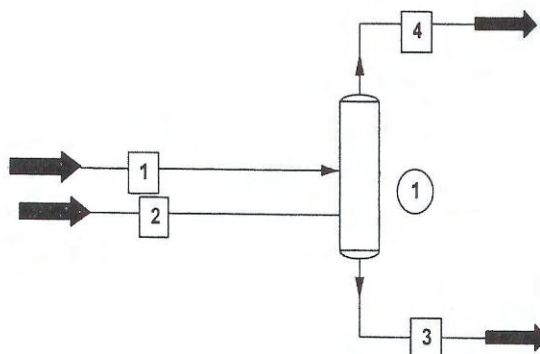
EQUIPMENT SUMMARIES

Flash Summary

Equip. No.	1
Name	
Flash Mode	2
Param 1	40.0000
Param 2	14.5000
Heat duty MMBtu/h	0.0011

K values:

Dichloromethane	0.344
Formic Acid	0.034
n-HEXACOSANE	2.472E-010
Oxygen	28448.229
Nitrogen	56998.914



Stream No.	1	2	3	4
Name	Stripper	air	VAT	Vapor
- - Overall - -				
Molar flow lbmol/h	1.3810	0.3466	1.1258	0.6018
Mass flow lb/h	100.0000	10.0000	79.1526	30.8474
Temp F	40.0000	75.0000	70.0000	70.0000
Pres psia	14.5000	14.5000	14.5000	14.5000
Vapor mole fraction	0.0000	1.000	0.0000	1.000
Average mol wt	72.4116	28.8508	70.3103	51.2548
Component mole %				
Dichloromethane	59.680814	0.000000	52.435273	38.862744
Formic Acid	39.331892	0.000000	46.352768	3.547488
n-HEXACOSANE	0.987297	0.000000	1.211139	0.000000
Oxygen	0.000000	20.999999	0.000284	12.093637
Nitrogen	0.000000	78.999996	0.000528	45.496130

CHEMCAD 5.3.0

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Job Name: MARSHAL Date: 09/05/2003 Time: 13:37:46
 FLOW SUMMARIES

Stream No.	1	2	3	4
Stream Name	Stripper	air	VAT	Vapor
Temp F	40.0000	75.0000	40.0000	40.0000
Pres psia	14.5000	14.5000	14.5000	14.5000
Enth MMBtu/h	-0.14271	-4.6673E-006	-0.13692	-0.0046861
Vapor mole fraction	0.00000	1.0000	0.00000	1.0000
Total lbmol/h	1.3810	0.3466	1.2883	0.4393
Flowrates in lbmol/h				
Dichloromethane	0.8242	0.0000	0.7378	0.0864
Formic Acid	0.5432	0.0000	0.5369	0.0063
n-HEXACOSANE	0.0136	0.0000	0.0136	0.0000
Oxygen	0.0000	0.0728	0.0000	0.0728
Nitrogen	0.0000	0.2738	0.0000	0.2738

CHEMCAD 5.3.0

Page 1

Job Name: MARSHAL Date: 09/05/2003 Time: 13:39:00

FLOWSHEET SUMMARY

Equipment	Label	Stream Numbers
1	FLAS	1 2 -4 -3

Stream Connections

Stream	Equipment From	To
1		1
2		1
3	1	
4	1	

Calculation mode : Sequential

Flash algorithm : Normal

Equipment Calculation Sequence

1

No recycle loops in the flowsheet.

COMPONENTS

	ID #	Name
1	222	Dichloromethane
2	223	Formic Acid
3	1770	n-HEXACOSANE
4	47	Oxygen
5	46	Nitrogen

THERMODYNAMICS

K-value model	:	UNIFAC
		No correction for vapor fugacity
Enthalpy model	:	Latent Heat
Liquid density	:	Library

* Component ID 47 does not have UNIFAC subgroups.

* Component ID 46 does not have UNIFAC subgroups.

CHEMCAD 5.3.0

Page 2

Job Name: MARSHAL Date: 09/05/2003 Time: 13:39:00

Overall Mass Balance	lbmol/h		lb/h	
	Input	Output	Input	Output
Dichloromethane	0.824	0.824	70.000	70.000
Formic Acid	0.543	0.543	25.000	25.000
n-HEXACOSANE	0.014	0.014	5.000	5.000
Oxygen	0.073	0.073	2.329	2.329
Nitrogen	0.274	0.274	7.671	7.671
Total	1.728	1.728	110.000	110.000

CHEMCAD 5.3.0

Page 3

Job Name: MARSHAL Date: 09/05/2003 Time: 13:39:00

EQUIPMENT SUMMARIES

Flash Summary

Equip. No.	1
Name	
Flash Mode	2
Param 1	70.0000
Param 2	14.5000
Heat duty MMBtu/h	0.0042

K values:

Dichloromethane	0.741
Formic Acid	0.077
n-HEXACOSANE	6.889E-009
Oxygen	42521.547
Nitrogen	86096.742

CHEMCAD 5.3.0

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Job Name: MARSHAL Date: 09/05/2003 Time: 13:39:00
 STREAM PROPERTIES

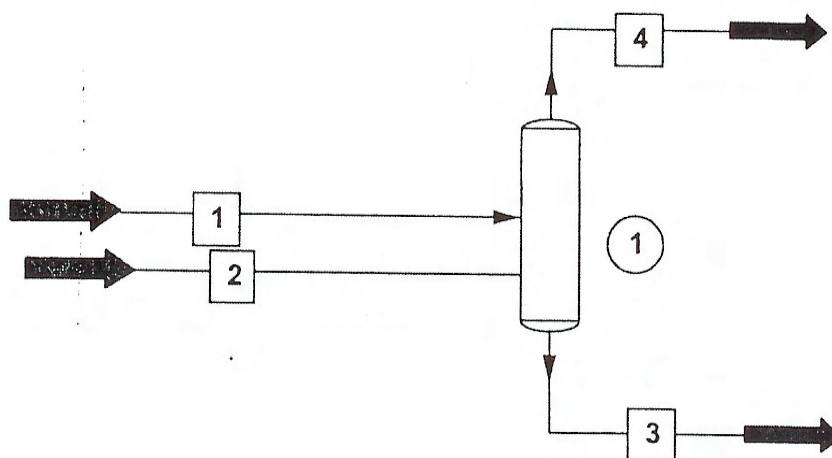
Stream No.	1	2	3	4
Name	Stripper	air	VAT	Vapor
- - Overall - -				
Molar flow lbmol/h	1.3810	0.3466	1.1258	0.6018
Mass flow lb/h	100.0000	10.0000	79.1526	30.8474
Temp F	40.0000	75.0000	70.0000	70.0000
Pres psia	14.5000	14.5000	14.5000	14.5000
Vapor mole fraction	0.0000	1.000	0.0000	1.000
Enth MMBtu/h	-0.14271	-4.6673E-006	-0.12541	-0.013073
Tc F	545.6796	-223.2906	564.3182	196.1832
Pc psia	1024.1671	522.8010	1064.5623	1707.1316
Std. sp gr. wtr = 1	1.272	0.866	1.256	1.135
Std. sp gr. air = 1	2.500	0.996	2.428	1.770
Degree API	-20.2598	31.9273	-18.8818	-6.8779
Average mol wt	72.4116	28.8508	70.3103	51.2548
Actual dens lb/ft3	80.0988	0.0729	77.4932	0.1317
Actual vol ft3/hr	1.2485	137.1171	1.0214	234.1455
Std liq ft3/hr	1.2604	0.1852	1.0100	0.4356
Std vap 60F scfh	524.0580	131.5312	427.2019	228.3873
- - Vapor only - -				
Molar flow lbmol/h		0.3466		0.6018
Mass flow lb/h		10.0000		30.8474
Average mol wt		28.8508		51.2548
Actual dens lb/ft3		0.0729		0.1317
Actual vol ft3/hr		137.1171		234.1455
Std liq ft3/hr		0.1852		0.4356
Std vap 60F scfh		131.5312		228.3873
Cp Btu/lbmol-F		6.9674		9.1233
Z factor		0.9998		0.9926
Visc cP		0.01826		0.01321
Th cond Btu/hr-ft-F		0.0147		0.0087
- - Liquid only - -				
Molar flow lbmol/h	1.3810		1.1258	
Mass flow lb/h	100.0000		79.1526	
Average mol wt	72.4116		70.3103	
Actual dens lb/ft3	80.0988		77.4932	
Actual vol ft3/hr	1.2485		1.0214	
Std liq ft3/hr	1.2604		1.0100	
Std vap 60F scfh	524.0580		427.2019	
Cp Btu/lbmol-F	25.1840		25.9175	
Z factor	0.0036		0.0035	
Visc cP	0.9925		0.8549	
Th cond Btu/hr-ft-F	0.0999		0.1005	
Surf tens dyne/cm	32.7955		30.8591	

CHEMCAD 5.3.0

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Job Name: MARSHAL Date: 09/05/2003 Time: 13:39:00
FLOW SUMMARIES

Stream No.	1	2	3	4
Stream Name	Stripper	air	VAT	Vapor
Temp F	40.0000	75.0000	70.0000	70.0000
Pres psia	14.5000	14.5000	14.5000	14.5000
Enth MMBtu/h	-0.14271	-4.6673E-006	-0.12541	-0.013073
Vapor mole fraction	0.00000	1.0000	0.00000	1.0000
Total lbmol/h	1.3810	0.3466	1.1258	0.6018
Flowrates in lbmol/h				
Dichloromethane	0.8242	0.0000	0.5903	0.2339
Formic Acid	0.5432	0.0000	0.5218	0.0214
n-HEXACOSANE	0.0136	0.0000	0.0136	0.0000
Oxygen	0.0000	0.0728	0.0000	0.0728
Nitrogen	0.0000	0.2738	0.0000	0.2738



Stream No.	1	2	3	4
Name	Stripper	air	VAT	Vapor
- - Overall - -				
Molar flow lbmol/h	1.3810	0.3466	1.0174	0.7102
Mass flow lb/h	100.0000	10.0000	70.4405	39.5595
Temp F	40.0000	75.0000	80.0000	80.0000
Pres psia	14.5000	14.5000	14.5000	14.5000
Vapor mole fraction	0.0000	1.000	0.0000	1.000
Average mol wt	72.4116	28.8508	69.2328	55.7050
Component mole %				
Dichloromethane	59.680814	0.000000	48.602706	46.423778
Formic Acid	39.331892	0.000000	50.056607	4.769738
n-HEXACOSANE	0.987297	0.000000	1.340074	0.000000
Oxygen	0.000000	20.999999	0.000215	10.249238
Nitrogen	0.000000	78.999996	0.000401	38.557249

CHEMCAD 5.3.0

Job Name: MARSHAL Date: 09/05/2003 Time: 13:39:41

FLOWSHEET SUMMARY

Equipment	Label	Stream Numbers
1	FLAS	1 2 -4 -3

Stream Connections

Page 1

Stream	Equipment
	From To
1	1
2	1
3	1
4	1

Calculation mode : Sequential

Flash algorithm : Normal

Equipment Calculation Sequence

1

No recycle loops in the flowsheet.

COMPONENTS

	ID #	Name
1	222	Dichloromethane
2	223	Formic Acid
3	1770	n-HEXACOSANE
4	47	Oxygen
5	46	Nitrogen

THERMODYNAMICS

K-value model : UNIFAC
No correction for vapor fugacity
Enthalpy model : Latent Heat
Liquid density : Library

* Component ID 47 does not have UNIFAC subgroups.

* Component ID 46 does not have UNIFAC subgroups.

CHEMCAD 5.3.0

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Job Name: MARSHAL Date: 09/05/2003 Time: 13:39:41

EQUIPMENT SUMMARIES

Flash Summary

Equip. No.	1
Name	
Flash Mode	2
Param 1	80.0000
Param 2	14.5000
Heat duty MMBtu/h	0.0059

K values:

Dichloromethane	0.955
Formic Acid	0.095
n-HEXACOSANE	2.564E-008
Oxygen	47665.039
Nitrogen	96259.680

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Page 4

Job Name: MARSHAL Date: 09/05/2003 Time: 13:39:41
 STREAM PROPERTIES

Stream No.	1	2	3	4
Name	Stripper	air	VAT	Vapor
- - Overall - -				
Molar flow lbmol/h	1.3810	0.3466	1.0174	0.7102
Mass flow lb/h	100.0000	10.0000	70.4405	39.5595
Temp F	40.0000	75.0000	80.0000	80.0000
Pres psia	14.5000	14.5000	14.5000	14.5000
Vapor mole fraction	0.0000	1.000	0.0000	1.000
Enth MMBtu/h	-0.14271	-4.6673E-006	-0.11784	-0.018958
Tc F	545.6796	-223.2906	574.6925	251.8156
Pc psia	1024.1671	522.8010	1088.3575	1635.7902
Std. sp gr. wtr = 1	1.272	0.866	1.248	1.174
Std. sp gr. air = 1	2.500	0.996	2.390	1.923
Degree API	-20.2598	31.9273	-18.0869	-10.9368
Average mol wt	72.4116	28.8508	69.2328	55.7050
Actual dens lb/ft3	80.0988	0.0729	76.4204	0.1408
Actual vol ft3/hr	1.2485	137.1171	0.9218	280.9489
Std liq ft3/hr	1.2604	0.1852	0.9052	0.5404
Std vap 60F scfh	524.0580	131.5312	386.0987	269.4904
- - Vapor only - -				
Molar flow lbmol/h		0.3466		0.7102
Mass flow lb/h		10.0000		39.5595
Average mol wt		28.8508		55.7050
Actual dens lb/ft3		0.0729		0.1408
Actual vol ft3/hr		137.1171		280.9489
Std liq ft3/hr		0.1852		0.5404
Std vap 60F scfh		131.5312		269.4904
Cp Btu/lbmol-F		6.9674		9.6270
Z factor		0.9998		0.9906
Visc cP		0.01826		0.01283
Th cond Btu/hr-ft-F		0.0147		0.0080
- - Liquid only - -				
Molar flow lbmol/h	1.3810		1.0174	
Mass flow lb/h	100.0000		70.4405	
Average mol wt	72.4116		69.2328	
Actual dens lb/ft3	80.0988		76.4204	
Actual vol ft3/hr	1.2485		0.9218	
Std liq ft3/hr	1.2604		0.9052	
Std vap 60F scfh	524.0580		386.0987	
Cp Btu/lbmol-F	25.1840		26.2620	
Z factor	0.0036		0.0035	
Visc cP	0.9925		0.8318	
Th cond Btu/hr-ft-F	0.0999		0.1016	
Surf tens dyne/cm	32.7955		30.3666	

CHEMCAD 5.3.0

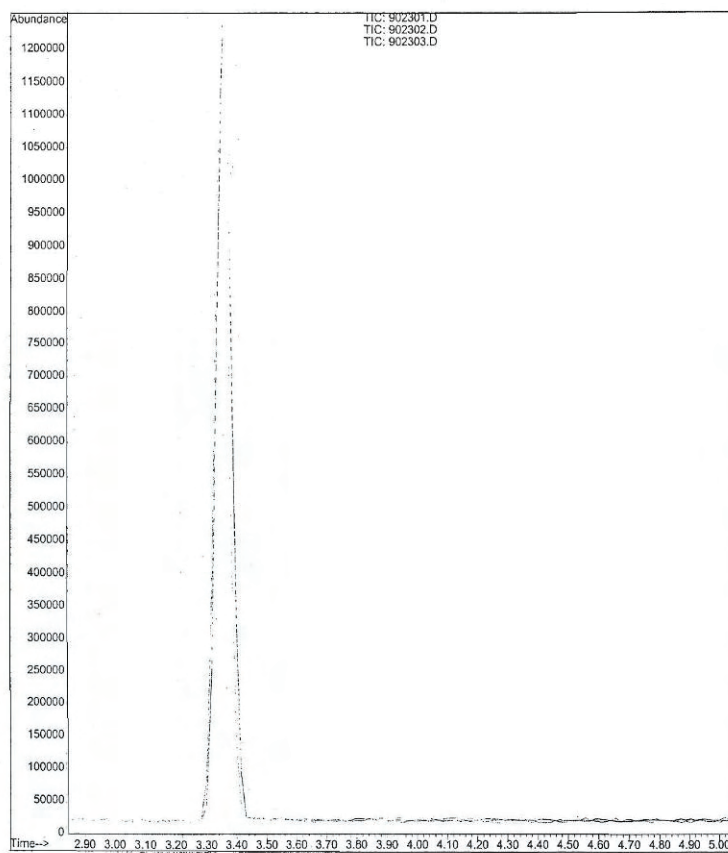
Page 5

Job Name: MARSHAL Date: 09/05/2003 Time: 13:39:41

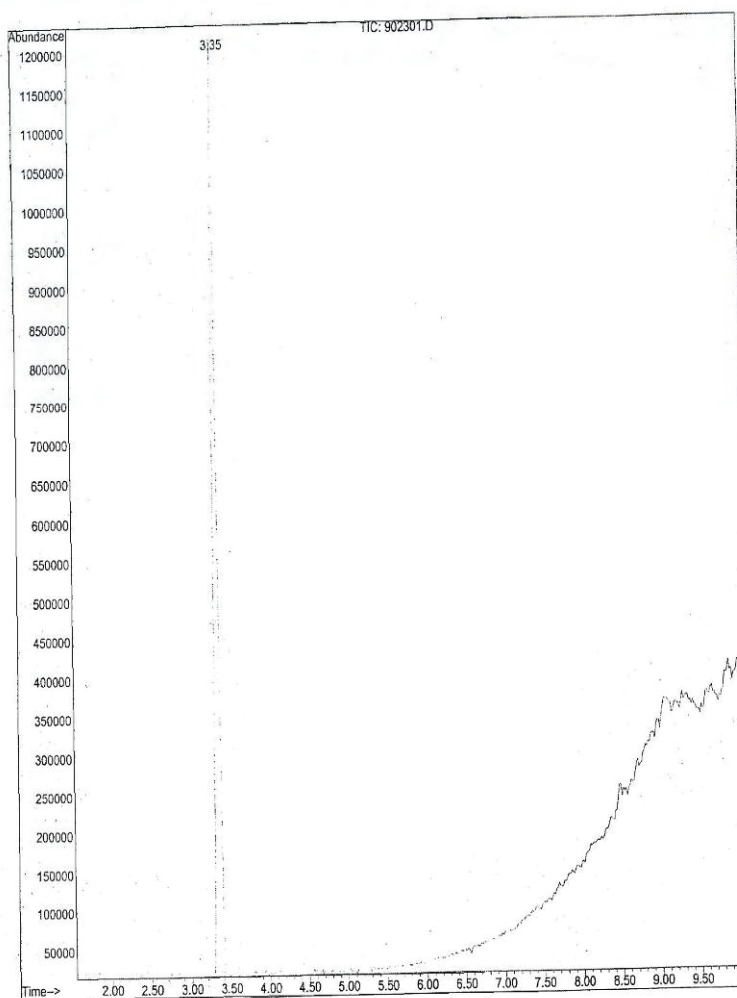
FLOW SUMMARIES

Stream No.	1	2	3	4
Stream Name	Stripper	air	VAT	Vapor
Temp F	40.0000	75.0000	80.0000	80.0000
Pres psia	14.5000	14.5000	14.5000	14.5000
Enth MMBtu/h	-0.14271	-4.6673E-006	-0.11784	-0.018958
Vapor mole fraction	0.00000	1.0000	0.00000	1.0000
Total lbmol/h	1.3810	0.3466	1.0174	0.7102
Flowrates in lbmol/h				
Dichloromethane	0.8242	0.0000	0.4945	0.3297
Formic Acid	0.5432	0.0000	0.5093	0.0339
n-HEXACOSANE	0.0136	0.0000	0.0136	0.0000
Oxygen	0.0000	0.0728	0.0000	0.0728
Nitrogen	0.0000	0.2738	0.0000	0.2738

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Operator : RTR
Acquired : 3 Sep 2003 9:40 using AcqMethod
Instrument : GC/MS Ins
Sample Name: 100k Meth CH1 std
Misc Info :
Vial Number: 1



File : C:\HPCHEM\1\DATA\902301.D
Operator : RTR
Acquired : 3 Sep 2003 9:40 using AcqMethod
Instrument : GC/MS Ins
Sample Name: 100k Meth CH1 std
Misc Info :
Vial Number: 1



TIC: 902301.D

100k Meth CH1 std

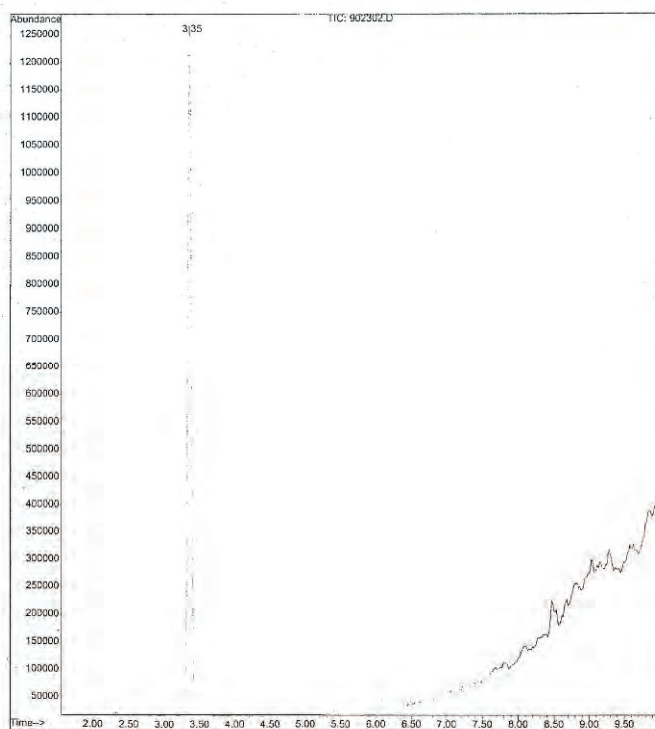
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TIC: 902301.D

100k Meth CH1 std

Peak#	Ret Time	Type	Width	Area	Start Time	End Time
1	3.348	rm	0.149	3956241	3.282	3.431

File : C:\HPCHEM\1\DATA\902302.D
Operator : RTR
Acquired : 3 Sep 2003 10:17 using AcqMethod
Instrument : GC/MS Ins
Sample Name: 100k Meth CH1 std
Misc Info :
Vial Number: 1

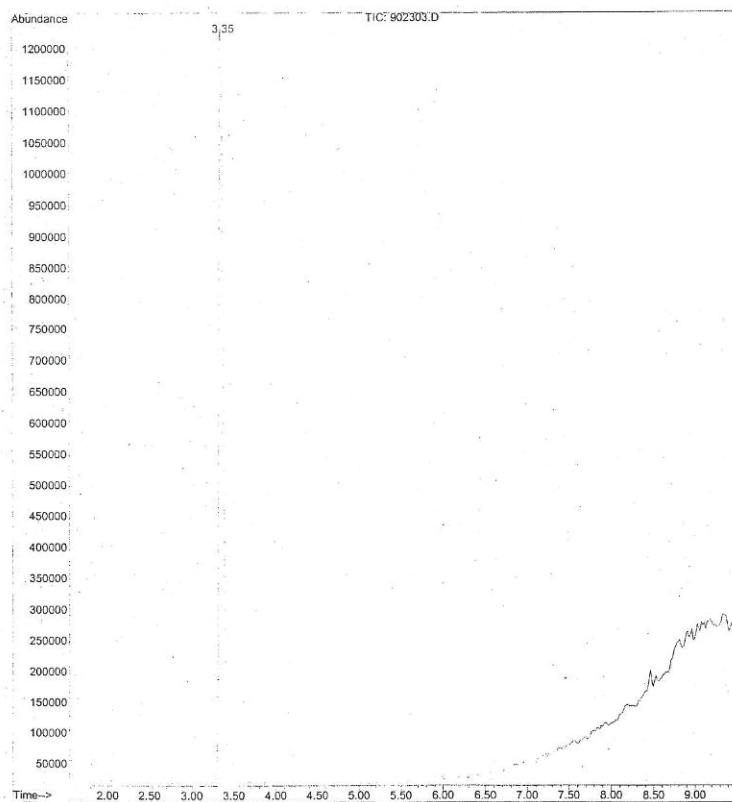


TIC: 902302.D

100k Meth CH1 std

Peak#	Ret Time	Type	Width	Area	Start Time	End Time
1	3.348	rm	0.116	4238209	3.298	3.414

File : C:\HPCHEM\1\DATA\902303.D
Operator : RTR
Acquired : 3 Sep 2003 10:44 using AcqMethod
Instrument : GC/MS Ins
Sample Name: 100k Meth CH1 std
Misc Info :
Vial Number: 1

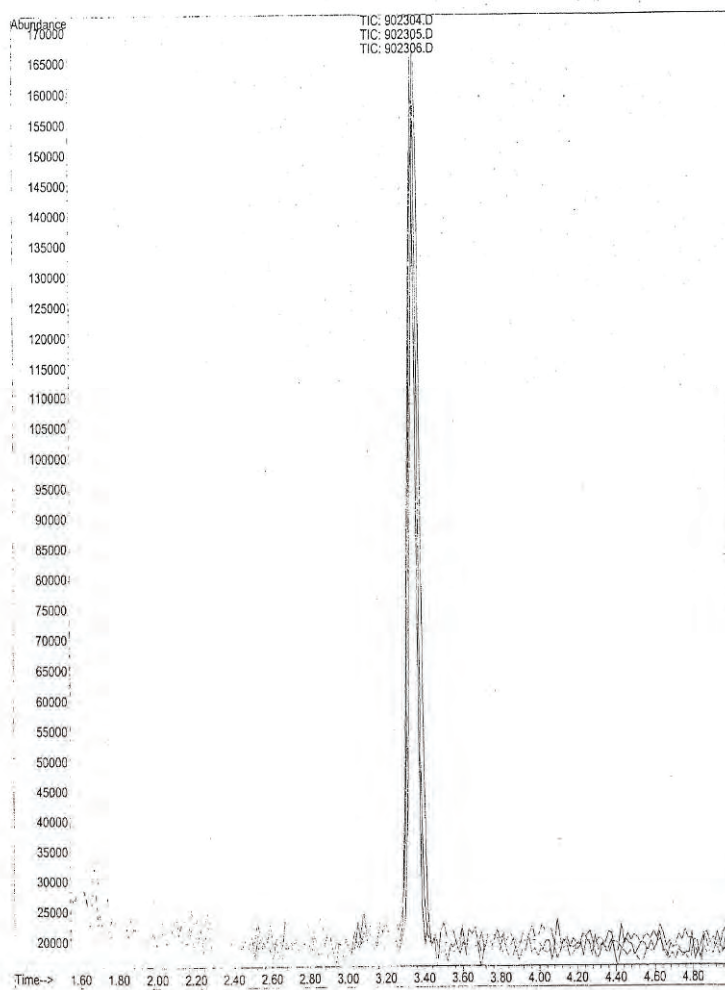


TIC: 902303.D

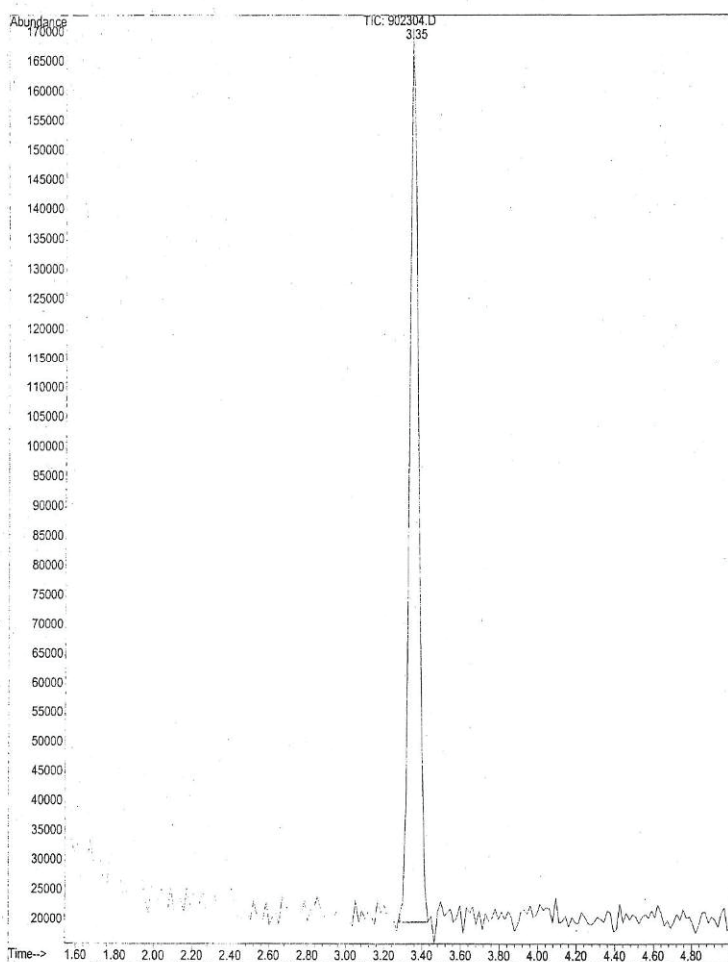
100k Meth CH1 std

Peak#	Ret Time	Type	Width	Area	Start Time	End Time
1	3.348	rm	0.166	4352124	3.282	3.447

File : C:\HPCHEM\1\DATA\902304.D
Operator : RTR
Acquired : 3 Sep 2003 11:18 using AcqMethod :
Instrument : GC/MS Ins
Sample Name: 10k Meth CH1 std
Misc Info :
Vial Number: 1



File : C:\HPCHEM\1\DATA\902304.D
Operator : RTR
Acquired : 3 Sep 2003 11:18 using AcqMethod
Instrument : GC/MS Ins
Sample Name: 10k Meth CHl std
Misc Info :
Vial Number: 1

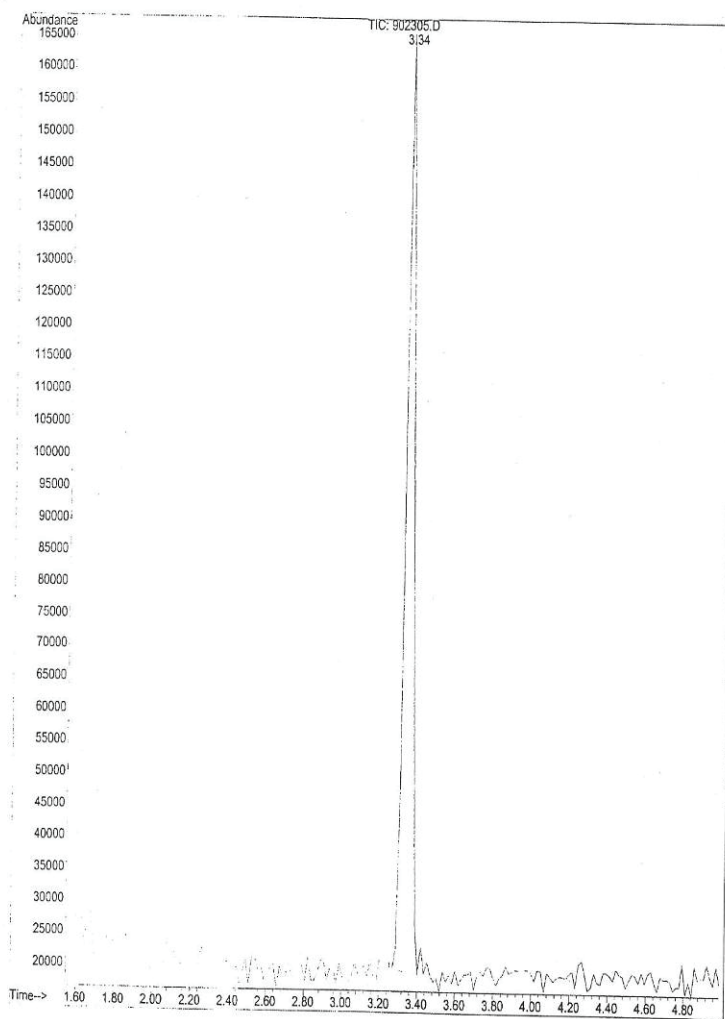


TIC: 902304.D

10k Meth CHl std

Peak#	Ret Time	Type	Width	Area	Start Time	End Time
1	3.349	rm	0.116	467371	3.300	3.415

File : C:\HPCHEM\1\DATA\902305.D
Operator : RTR
Acquired : 3 Sep 2003 11:25 using AcqMethod
Instrument : GC/MS Ins
Sample Name: 10k Meth CH1 std
Misc Info :
Vial Number: 1

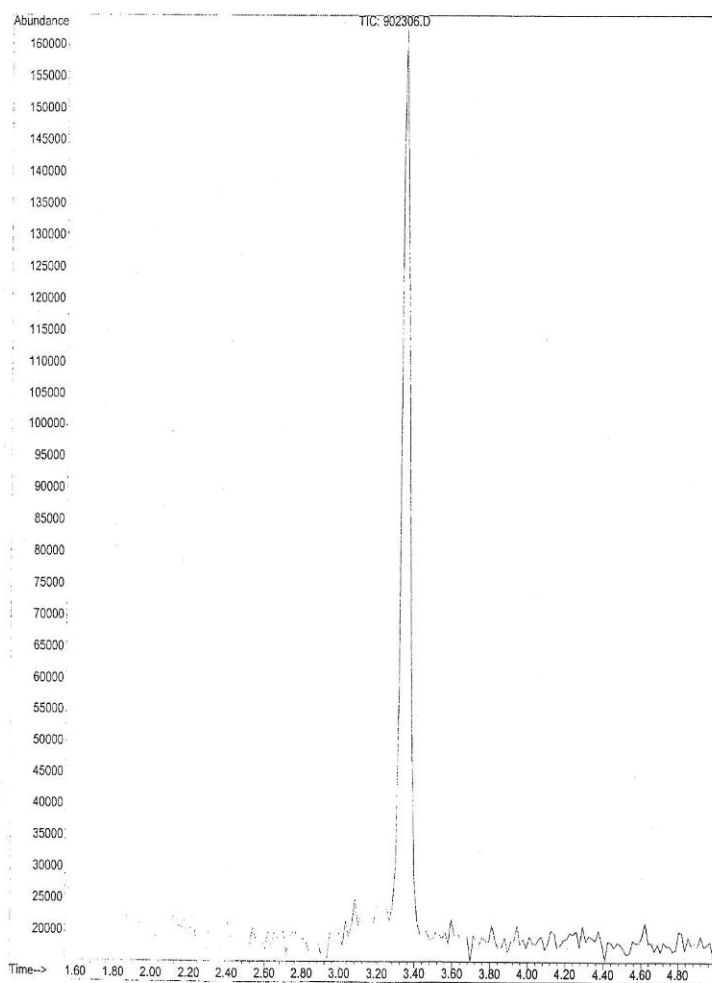


TIC: 902305.D

10k Meth CH1 std

Peak#	Ret Time	Type	Width	Area	Start Time	End Time
1	3.337	rm	0.132	434756	3.270	3.403

File : C:\HPCHEM\1\DATA\902306.D
Operator : RTR
Acquired : 3 Sep 2003 11:35 using AcqMethod
Instrument : GC/MS Ins
Sample Name: 10k Meth CH1 std
Misc Info :
Vial Number: 1

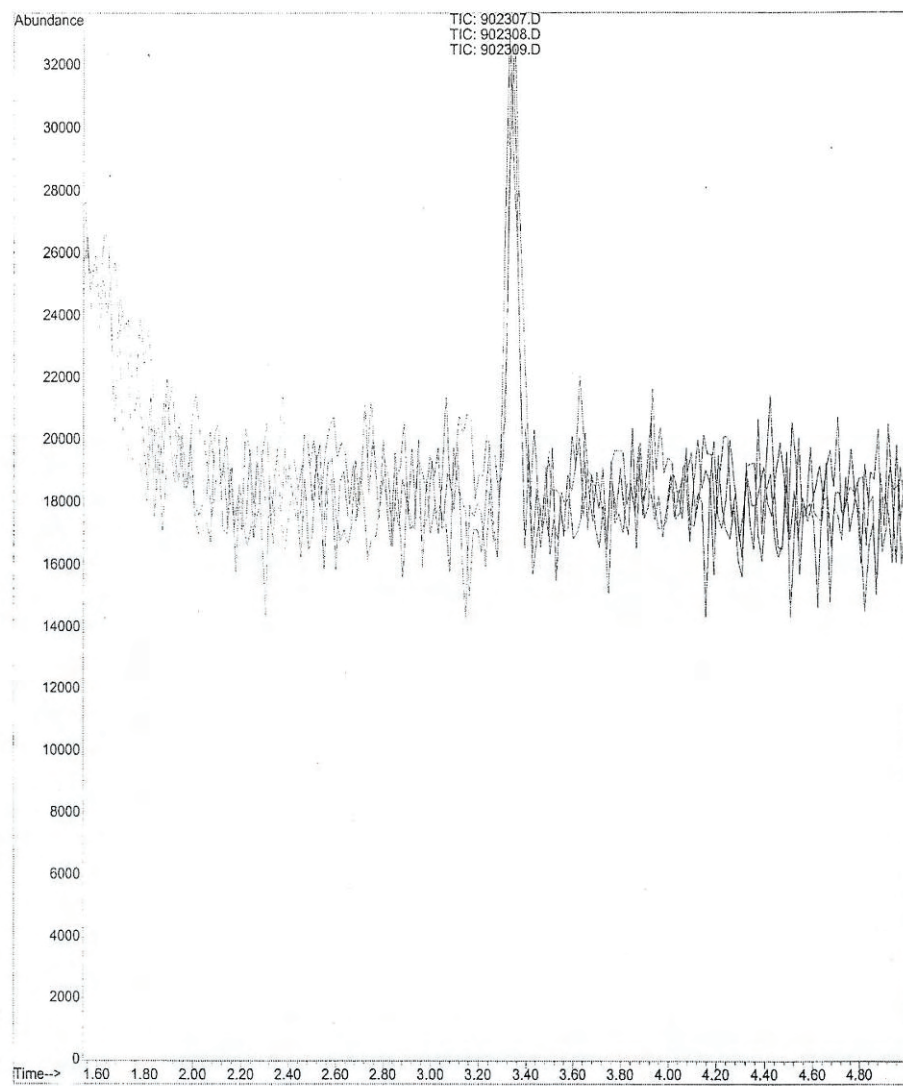


TIC: 902306.D

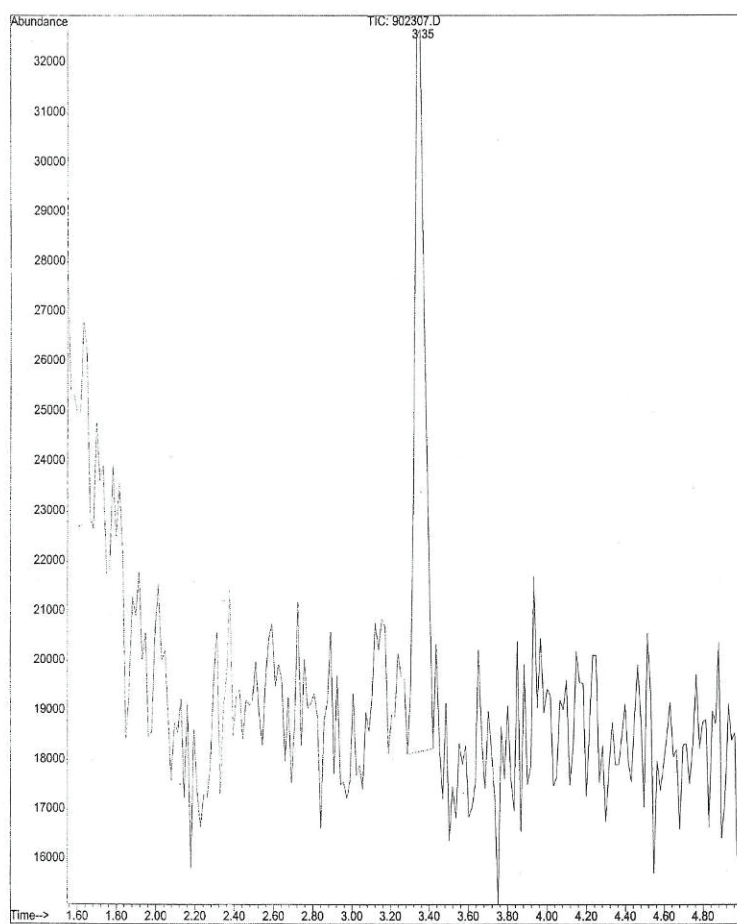
10k Meth CH1 std

Peak#	Ret Time	Type	Width	Area	Start Time	End Time
1	3.347	rm	0.16	445495	3.264	3.430

File : C:\HPCHEM\1\DATA\902307.D
Operator : RTR
Acquired : 3 Sep 2003 11:47 using AcqMethod
Instrument : GC/MS Ins
Sample Name: 1k Meth CH1 std
Misc Info :
Vial Number: 1



File : C:\HPCHEM\1\DATA\902307.D
Operator : RTR
Acquired : 3 Sep 2003 11:47 using AcqMethod
Instrument : GC/MS Ins
Sample Name: 1k Meth CH1 std
Misc Info :
Vial Number: 1

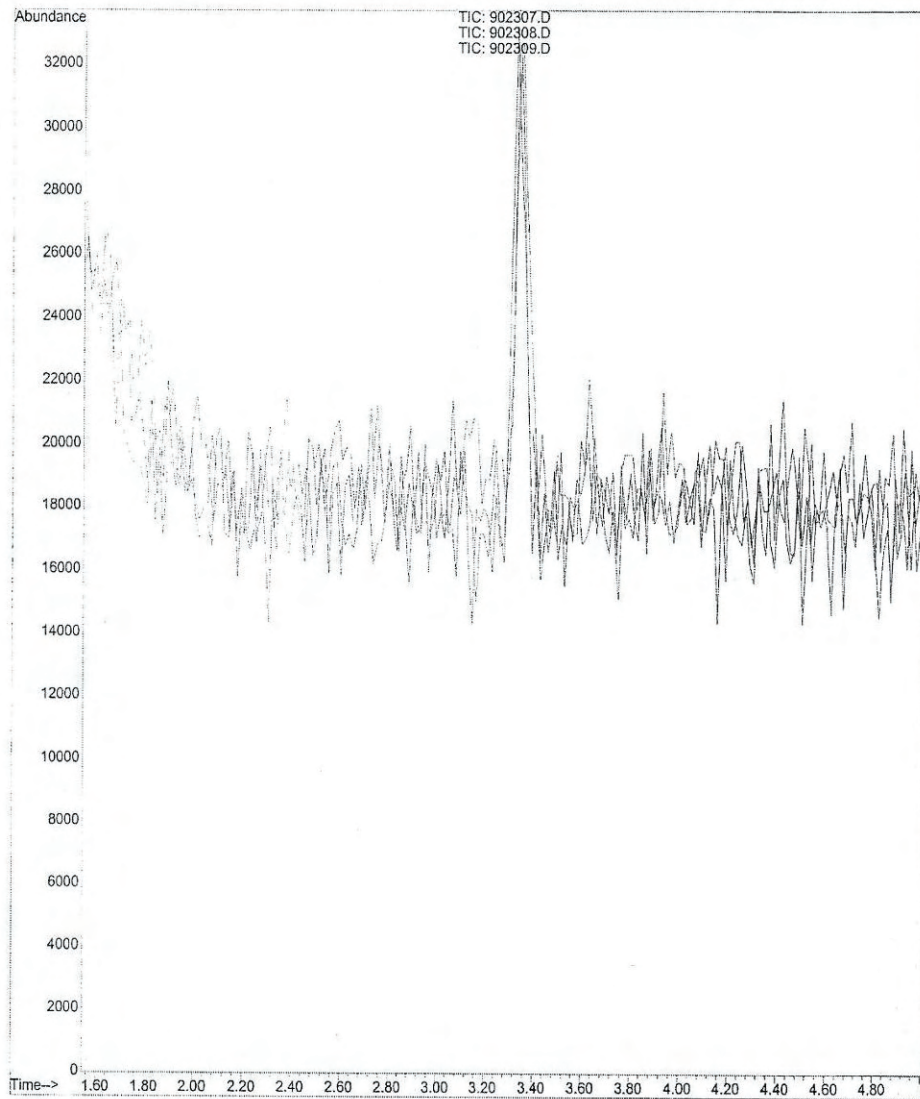


TIC: 902307.D

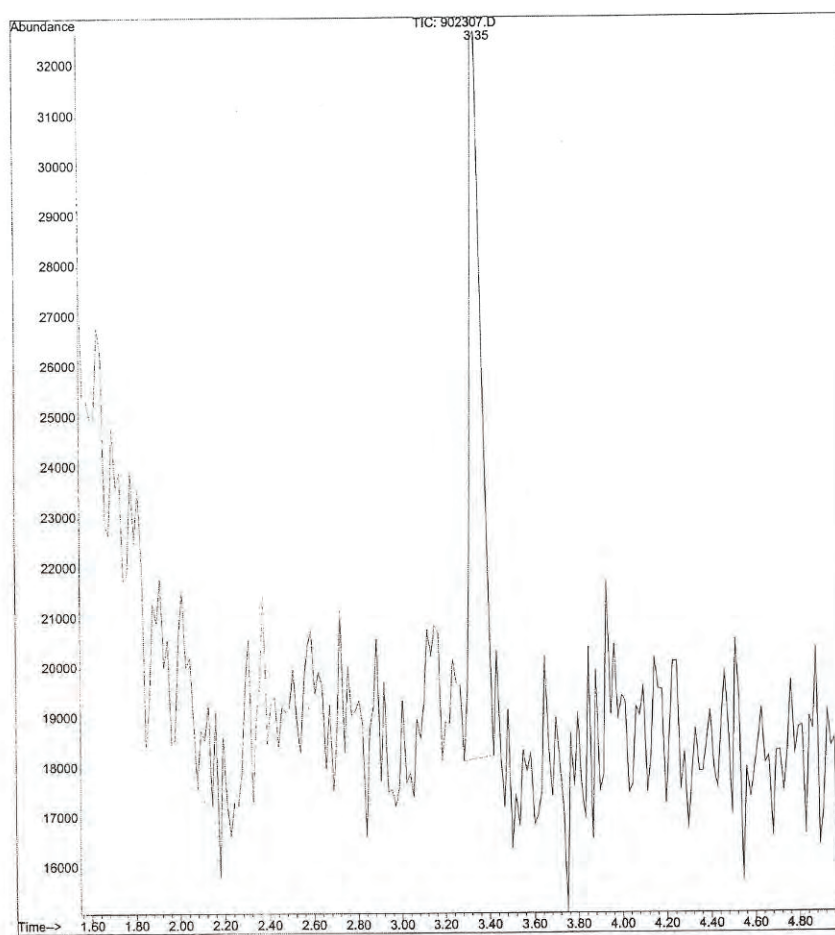
1k Meth CH1 std

Peak#	Ret Time	Type	Width	Area	Start Time	End Time
1	3.354	rm	0.132	54792	3.288	3.420

File : C:\HPCHEM\1\DATA\902307.D
Operator : RTR
Acquired : 3 Sep 2003 11:47 using AcqMethod
Instrument : GC/MS Ins
Sample Name: 1k Meth CH1 std
Misc Info :
Vial Number: 1



File : C:\HPCHEM\1\DATA\902307.D
Operator : RTR
Acquired : 3 Sep 2003 11:47 using AcqMethod
Instrument : GC/MS Ins
Sample Name: 1k Meth CH1 std
Misc Info :
Vial Number: 1

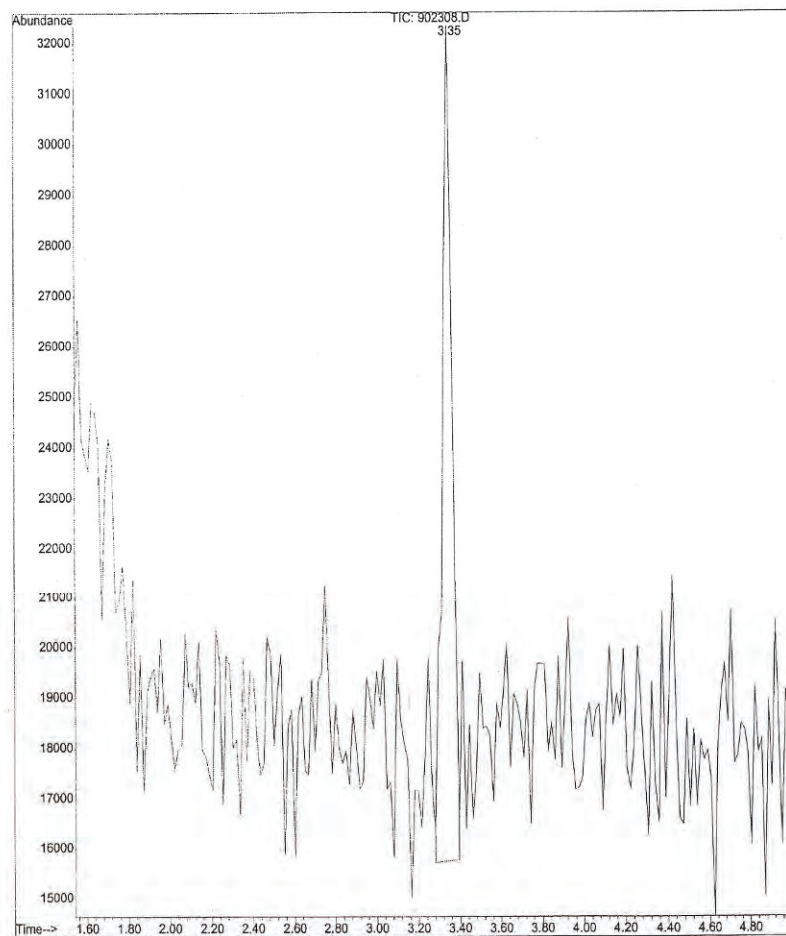


TIC: 902307.D

1k Meth CH1 std

Peak#	Ret Time	Type	Width	Area	Start Time	End Time
1	3.354	rm	0.132	54792	3.288	3.420

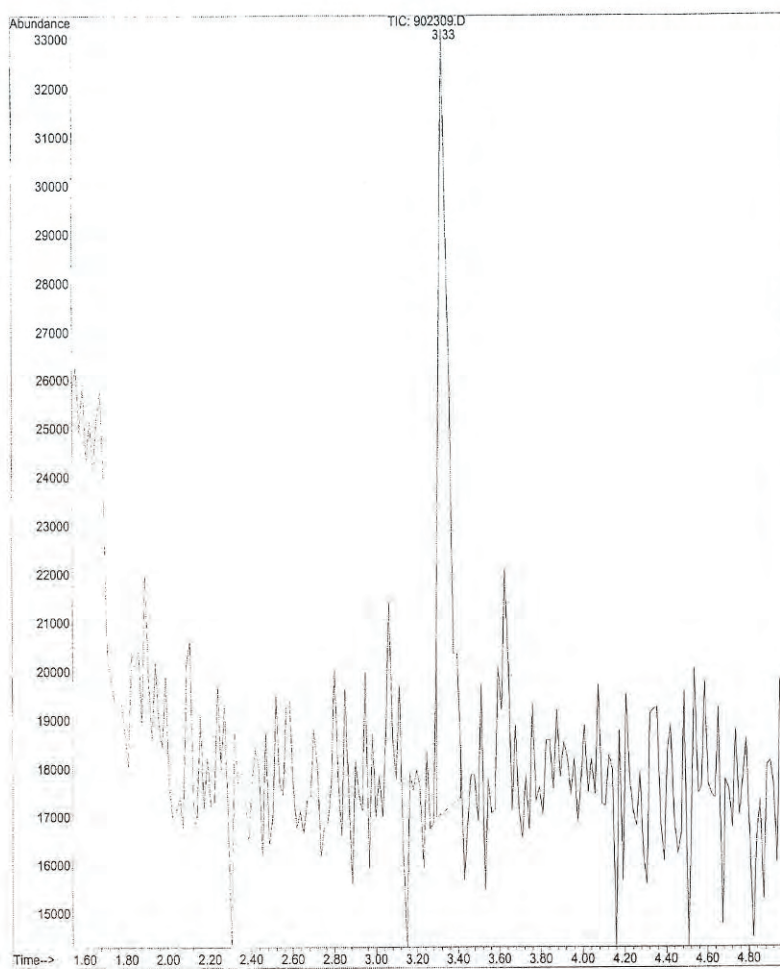
File : C:\HPCHEM\1\DATA\902308.D
Operator : RTR
Acquired : 3 Sep 2003 11:57 using AcqMethod
Instrument : GC/MS Ins
Sample Name: 1k Meth CH1 std
Misc Info :
Vial Number: 1



1k Meth CH1 std

Peak#	Ret Time	Type	Width	Area	Start Time	End Time
1	3.347	rm	0.116	55600	3.281	3.397

File : C:\HPCHEM\1\DATA\902309.D
Operator : RTR
Acquired : 3 Sep 2003 12:17 using AcqMethod
Instrument : GC/MS Ins
Sample Name: 1k Meth CH1 std
Misc Info :
Vial Number: 1

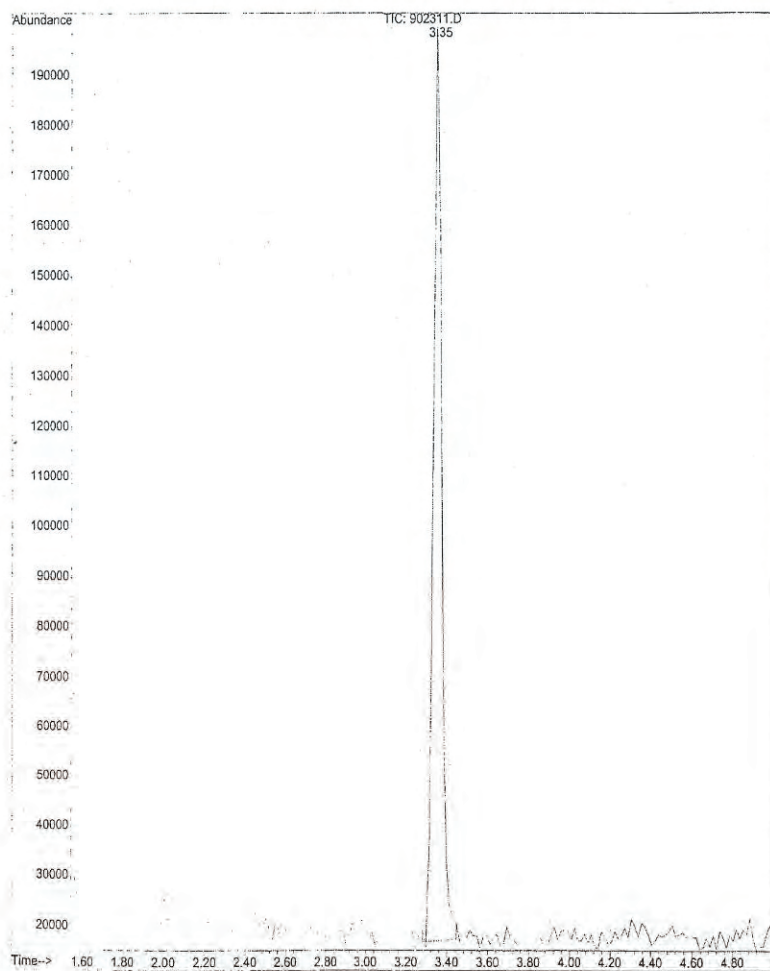


TIC: 902309.D

1k Meth CH1 std

Peak#	Ret Time	Type	Width	Area	Start Time	End Time
1	3.332	rm	0.116	54078	3.299	3.414

File : C:\HPCHEM\1\DATA\902311.D
Operator : RTR
Acquired : 3 Sep 2003 13:34 using AcqMethod
Instrument : GC/MS Ins
Sample Name: room temp
Misc Info :
Vial Number: 1

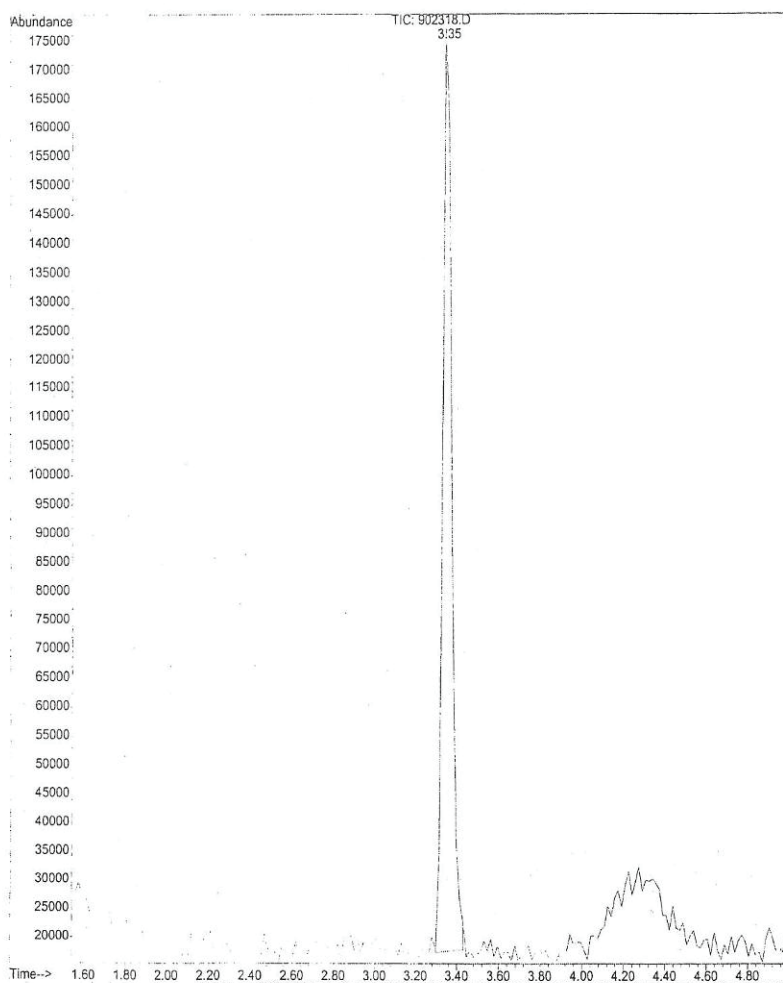


TIC: 902311.D

room temp

Peak#	Ret Time	Type	Width	Area	Start Time	End Time
1	3.346	rm	0.166	520662	3.280	3.446

File : C:\HPCHEM\1\DATA\902318.D
Operator : RTR
Acquired : 3 Sep 2003 14:45 using AcqMethod
Instrument : GC/MS Ins
Sample Name: room temp
Misc Info :
Vial Number: 1

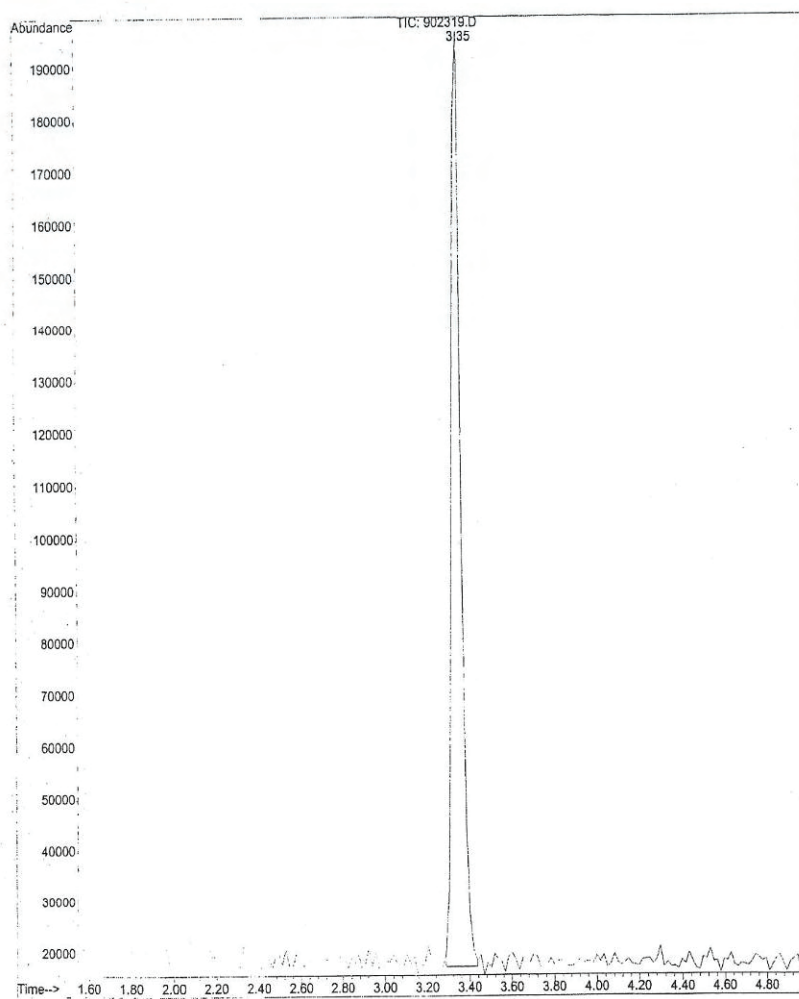


TIC: 902318.D

room temp

Peak#	Ret Time	Type	Width	Area	Start Time	End Time
1	3.347	rm	0.132	494386	3.298	3.430

File : C:\HPCHEM\1\DATA\902319.D
Operator : RTR
Acquired : 3 Sep 2003 15:14 using AcqMethod
Instrument : GC/MS Ins
Sample Name: room temp
Misc Info :
Vial Number: 1

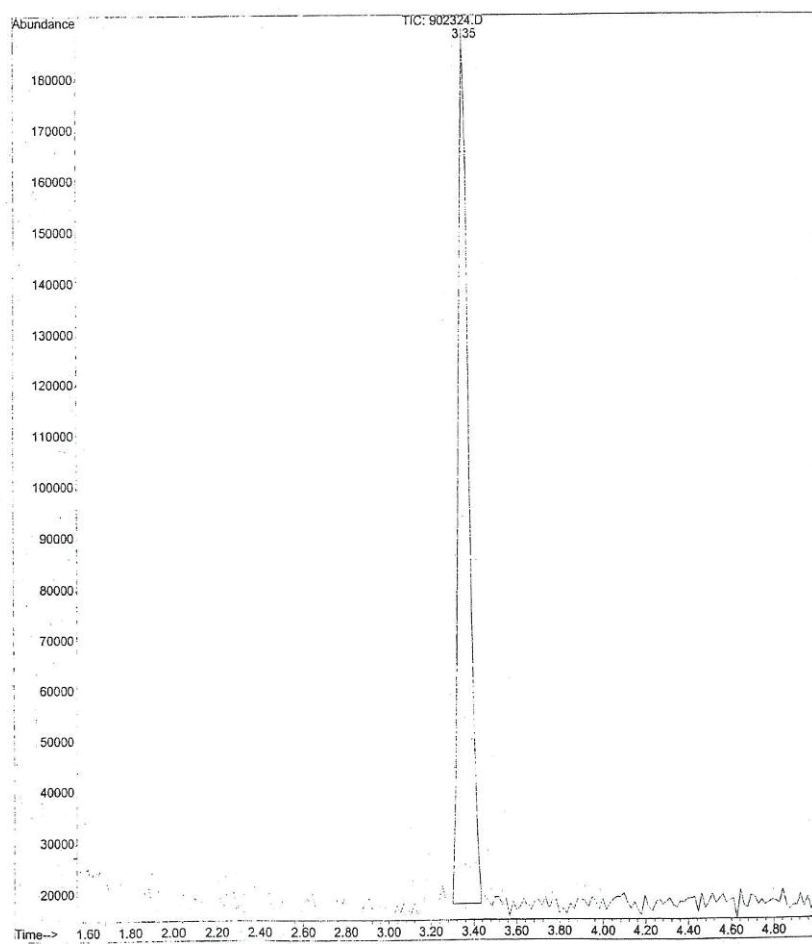


TIC: 902319.D

room temp

Peak#	Ret Time	Type	Width	Area	Start Time	End Time
1	3.353	rm	0.149	537716	3.287	3.436

File : C:\HPCHEM\1\DATA\902324.D
Operator : RTR
Acquired : 3 Sep 2003 17:03 using AcqMethod
Instrument : GC/MS Ins
Sample Name: 40 F
Misc Info :
Vial Number: 1

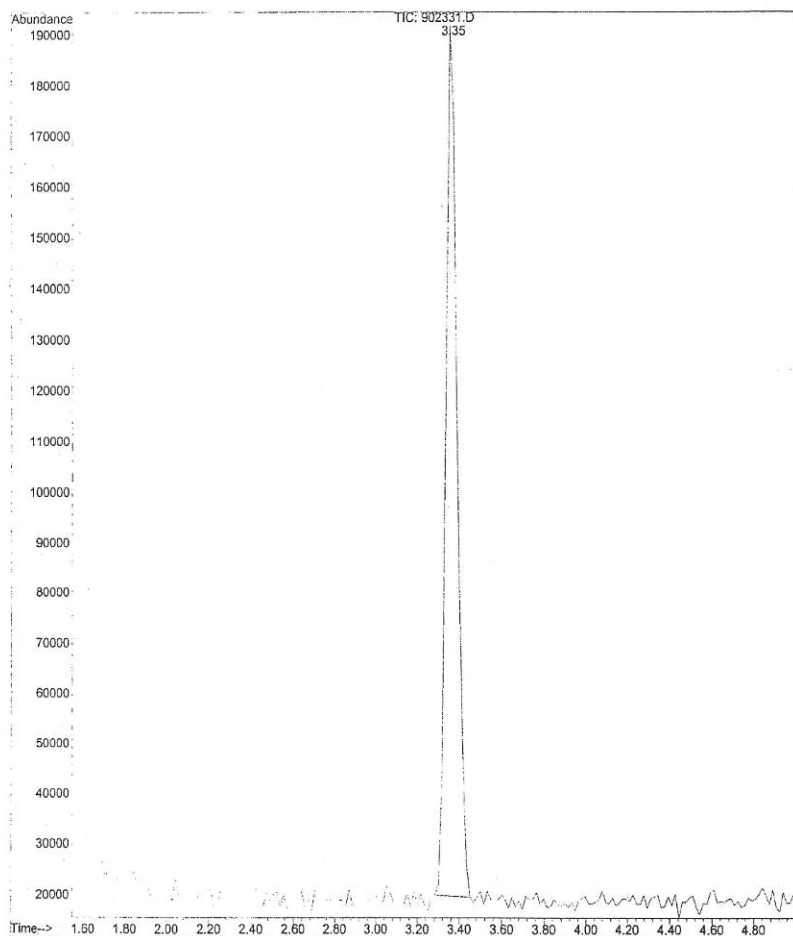


TIC: 902324.D

40 F

Peak#	Ret Time	Type	Width	Area	Start Time	End Time
1	3.352	rm	0.132	574116	3.302	3.435

File : C:\HPCHEM\1\DATA\902331.D
Operator : RTR
Acquired : 4 Sep 2003 10:40 using AcqMethod
Instrument : GC/MS Ins
Sample Name: 40 F
Misc Info :
Vial Number: 1

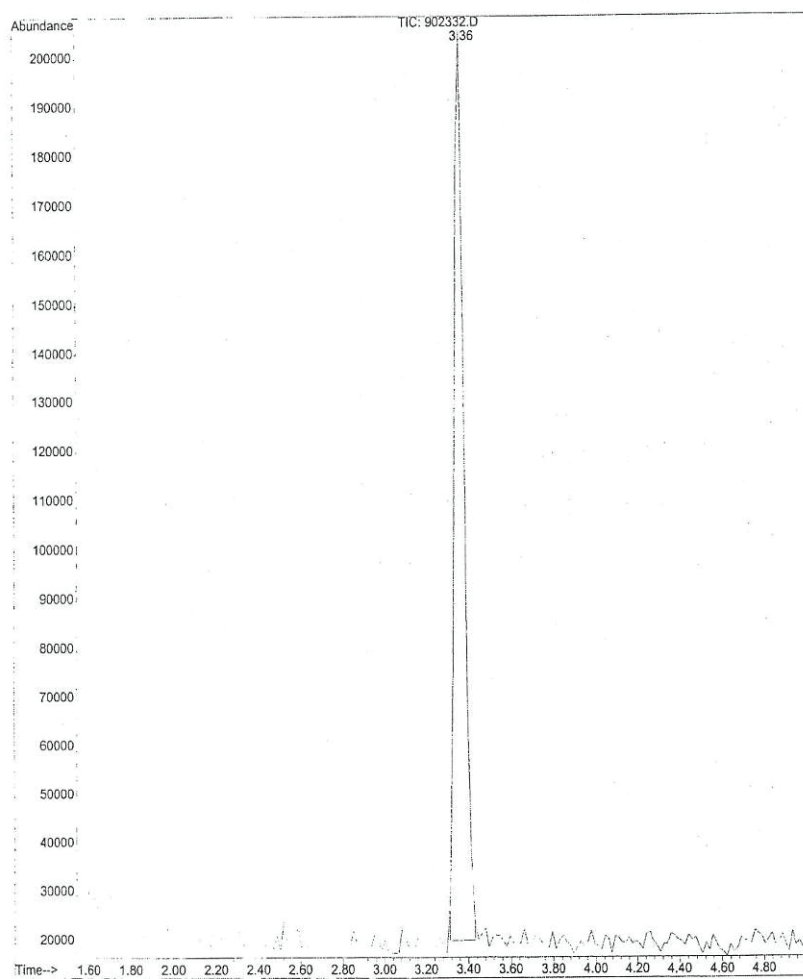


TIC: 902331.D

40 F

Peak#	Ret Time	Type	Width	Area	Start Time	End Time
1	3.350	rm	0.132	635943	3.301	3.433

File : C:\HPCHEM\1\DATA\902332.D
Operator : RTR
Acquired : 4 Sep 2003 11:03 using AcqMethod
Instrument : GC/MS Ins
Sample Name: 40 F
Misc Info :
Vial Number: 1

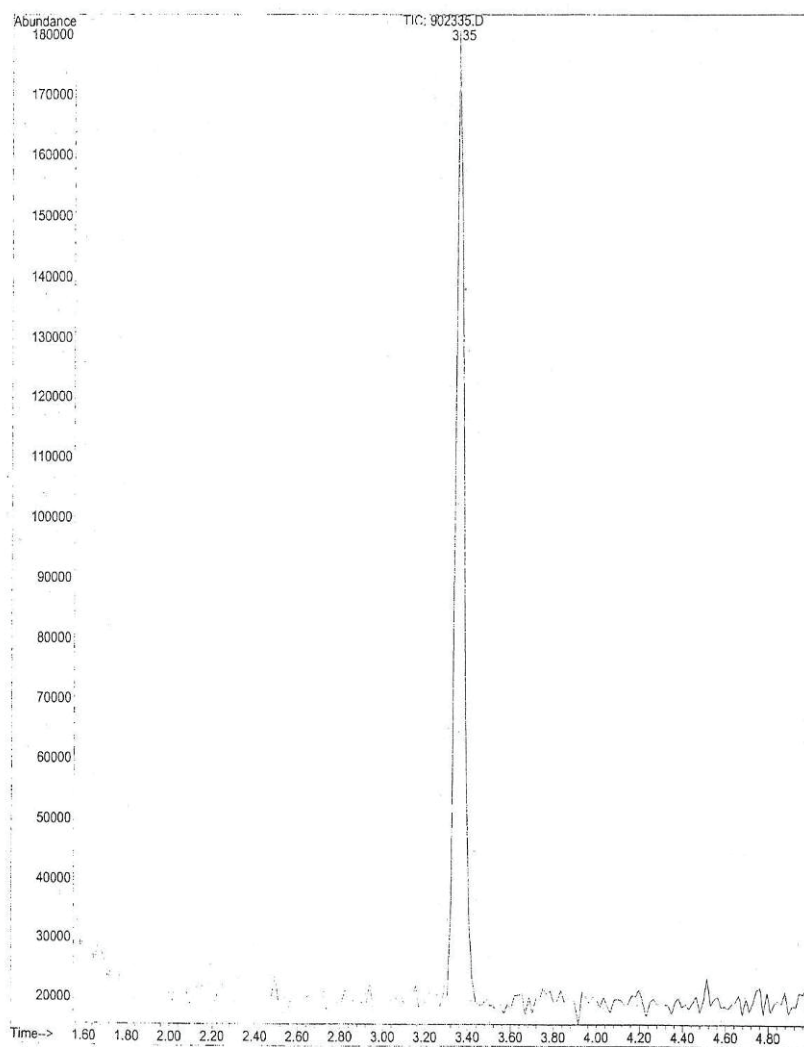


TIC: 902332.D

40 F

Peak#	Ret Time	Type	Width	Area	Start Time	End Time
1	3.364	rm	0.116	587394	3.315	3.431

File : C:\HPCHEM\1\DATA\902335.D
Operator : RTR
Acquired : 4 Sep 2003 12:18 using AcqMethod
Instrument : GC/MS Ins
Sample Name: 80 F
Misc Info :
Vial Number: 1

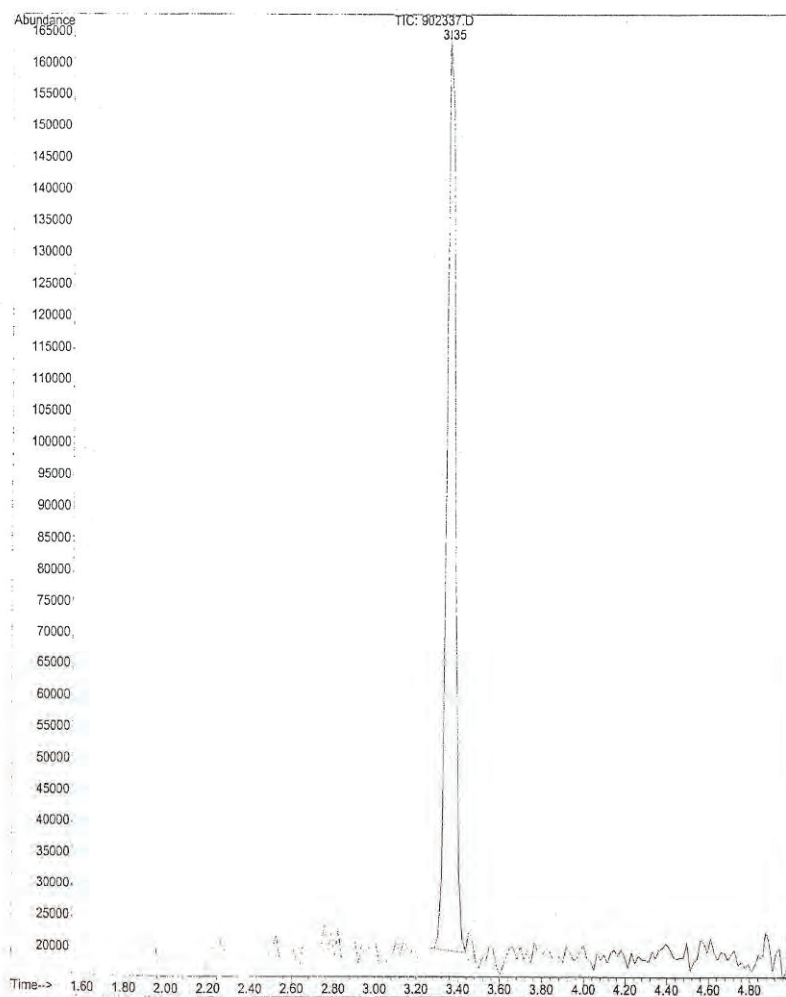


TIC: 902335.D

80 F

Peak#	Ret Time	Type	Width	Area	Start Time	End Time
1	3.353	rm	0.132	454987	3.304	3.436

File : C:\HPCHEM\1\DATA\902337.D
Operator : RTR
Acquired : 4 Sep 2003 12:46 using AcqMethod
Instrument : GC/MS Ins
Sample Name: 80 F
Misc Info :
Vial Number: 1

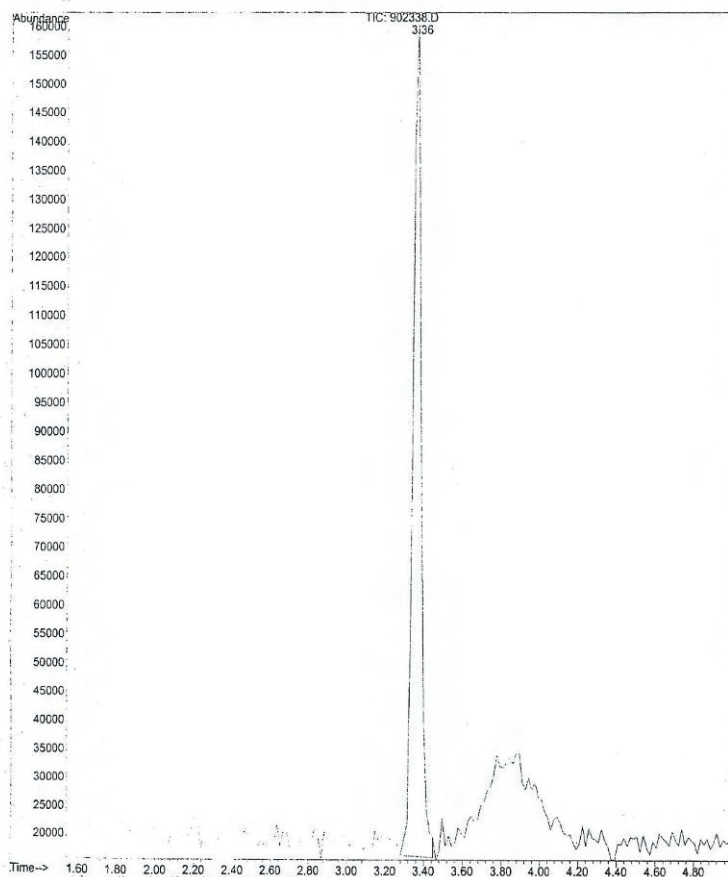


TIC: 902337.D

80 F

Peak#	Ret Time	Type	Width	Area	Start Time	End Time
1	3.353	rm	0.149	426002	3.286	3.435

File : C:\HPCHEM\1\DATA\902338.D
Operator : RTR
Acquired : 4 Sep 2003 13:03 using AcqMethod
Instrument : GC/MS Ins
Sample Name: 80 F
Misc Info :
Vial Number: 1



TIC: 902338.D

80 F

Peak#	Ret Time	Type	Width	Area	Start Time	End Time
1	3.364	rm	0.166	431459	3.281	3.447

Appendix H: Data Sheets of Stripping Tests and Chilled Temperatures

SOURCE SAMPLING FIELD DATA SHEET

PROJECT				SHEET <u>1</u> OF <u>2</u>		REMARKS:	
SAMPLING LOCATION <u>M80 SITE</u>							
TEST ENGINEER <u>Kim McClafferty</u>							
DATE <u>8-4-03</u>							
SAMPLE	Trial Number	COLOR (Green or White)	EXACT TEMPERATURE (F)	CLOCK TIME ME PM	SAMPLING TIME (min)	STRIPPED 100% (Yes or No)	Comments
Water Bath only			80.2 DEWATER				Fluid in @ 1:40
M80-1	1	green	79.9	2:09pm	0 5 7.5	NO NO YES	90% dense clumps - flaking off Total strip in layers
M80-2	2	Green	79.9	2:13	0 3 5 7.5	NO NO NO YES	starting to strip 90% - blistering, clumps Total strip
M80-3	3	white	79.9	2:25	0 5 7.5	NO NO YES	95% almost completely flaked off stripped
M80-4	4	white	79.9	2:38	0 5 7.5	NO NO YES	95% - almost completely flaked off stripped
* Discarded NPX + Put New NPX in							
M85-1	1	green	75.1	3:15	0 5 7.5 10	NO NO NO YES	Fluid @ temp @ 3:14 pm 95% one side stripped but not other Front 100% Back 95% stripped 100% Both sides
M85-2	2	green	75.1	3:30	0 5 7.5	NO NO YES	Both sides 95% Both sides 100% stripped
M85-3	3	green	75.1	3:40	0 5 7.5	NO NO YES	95% stripped 100% stripped

SOURCE SAMPLING FIELD DATA SHEET

PROJECT				SHEET 1 OF 4			
SAMPLING LOCATION <u>MUSE SITE</u>				REMARKS:			
TEST ENGINEER <u>Kim McCafferty</u>							
DATE <u>8-5-03</u>							
SAMPLE	Trial Number	COLOR (Green or White)	EXACT TEMPERATURE (F)	CLOCK TIME (any)	SAMPLING TIME (min)	STRIPPED 100% (Yes or No)	Comments
MC70-1	1	Green	70.1	9:58	0	NO	
					5	YES	Stripped fast!
MC70-2	2	Green	70.1	10:08	0	NO	
					2.5	NO	20% stripped
					5	NO	Front 100% stripped Back 50% stripped
					7.5	NO	" " " Back 75% "
					10	YES	100% both sides
MC70-3	3	Green	70.1	10:22	0	NO	
					2.5	NO	20% stripped
					5	YES	Both sides 100% stripped
MC70-4	4	Green	70.1	10:30	0	NO	
					2.5	NO	front 90% stripped Back 50% stripped
					5	NO	" 100% " " 90% " "
					7.5	YES	Both 100% stripped
MC70-5	5	Green	70.1	10:40	0	NO	
					2.5	NO	one side 90% stripped - other side 75% stripped
					5	YES	100% stripped
MC70-6	6	White	70.1	10:47	0	NO	
					2.5	NO	front 50% Back 20%
					5	YES	100% stripped
MC70-7	7	White	70.1	10:55	0	NO	
					2.5	NO	50% only on both sides
					5	YES	100% stripped
<p>Chy'd 1 for Next Test</p>							

max concentration possibly too large - could have created higher stripping time

note: white paint strips by being permeated green paint strips in layers.

SOURCE SAMPLING FIELD DATA SHEET

PROJECT
SAMPLING LOCATION MOE SITE
TEST ENGINEER Kia McClellan
DATE 8-5-23

SHEET 2 OF 4
REMARKS:

MOE-1 1 Green 60.4 12:18 0 20% stripping
2.5 10%
5 0%
7.5 100% stripped

MOE-2 2 Green 60.4 12:28 0 20% stripped
2.5 10%
5 0%
7.5 100% stripped

MOE-3 3 White 60.8 12:39 0 20% stripping front - 10% Back
2.5 0%
5 0%
7.5 100% stripped

MOE-4 4 White 60.4 12:49 0 90% Front - 20% Back
2.5 10%
5 100% stripped

MOE-5 5 White 60.8 12:56 0 10%
2.5 0%
5 100% stripped Both sides

Org'd FOR NEXT TEST

SOURCE SAMPLING FIELD DATA SHEET

PROJECT <u>Chilled NPX Stripping Solution</u>					SHEET <u>3</u> OF <u>4</u>		
SAMPLING LOCATION <u>BASE SITE</u>					REMARKS:		
TEST ENGINEER <u>K. M. McClellan</u>							
DATE <u>8-5-03</u>							

SAMPLE	Trial Number	COLOR (Green or White)	EXACT TEMPERATURE (F)	CLOCK TIME (pm)	SAMPLING TIME (min)	STRIPPED 100% (Yes or No)	Comments
MC50-1	1	Green	50.2	1:51	0	No	
					2.5	No	Front 50% Back 10%
					5	Yes	100% stripped
MC50-2	2	Green	50.3	2:00	0	No	
					2.5	No	20% stripped
					5	No	Front stripped 100% - Back 50%
					7.5	Yes	100% stripped
MC50-3	3	Green	50.3	2:10	0	No	
					2.5	No	20% stripped
					5	No	Back 80% stripped - Front 50%
					7.5	No	100%
MC50-4	4	White	50.2	2:23	0	No	
					2.5	No	Front 50% - Back 10%
					5	No	" 90% - " 50%
					7.5	No	Front 100% - Back 90%
					10	Yes	100% stripped
MC50-5	5	White	50.2	2:36	0	No	
					2.5	No	Front 20% - Back 10%
					5	No	" 80% - " 50%
					7.5	No	Front 100% - Back 90%
					10	Yes	100% stripped
Chg'd for next test							

SOURCE SAMPLING FIELD DATA SHEET

PROJECT <u>Chilled NPX Stripping Solution</u> SAMPLING LOCATION <u>M3 SITE</u> TEST ENGINEER <u>Kim McCafferty</u> DATE <u>8-9-03</u>							
SHEET <u>4</u> OF <u>4</u> REMARKS: _____ _____ _____							
SAMPLE	Trial Number	COLOR (Green or White)	EXACT TEMPERATURE (F)	CLOCK TIME (PM)	SAMPLING TIME (min)	STRIPPED 100% (Yes or No)	Comments
MC40-1	1	Green	40.4	3:15	0	No	Front 40% - Back 10% Front 70% - Back 50% 100% stripped.
					2.5	No	
					5	No	
					7.5	yes	
MC40-2	2	Green	40.4	3:21	0	No	Front 20% - Back 10% Front 50% - Back 10% Front 95% - Back 10% Front 100% - Back 75% 100% stripped (10% Both sides)
					2.5	No	
					5	No	
					7.5	No	
					10	No	
MC40-3	3	Green	40.3	3:39	0	yes	Front 50% - Back 10% Front 75% - Back 10% Front 100% - Back 95% 100% stripped
					2.5	No	
					5	No	
					7.5	No	
					10	No	
MC40-4	4	White	40.3	3:54	0	No	

- Power fluctuation concerning water Bath.

