ASSESSMENT, DEVELOPMENT AND DEMONSTRATION OF ALTERNATIVES TO VOC-EMITTING LUBRICANTS, VANISHING OILS AND RUST INHIBITORS

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DISCLAIMER

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EXECUTIVE SUMMARY

Metal working fluids are used by thousands of manufacturers in the country to make and repair metal parts. Examples of processes that use metal working fluids include stamping, cutting, forming, honing, cold heading, tube bending and deep drawing. Some of the metal working fluids are based on petroleum products and they are used as lubricants, vanishing oils and rust inhibitors. These products are often diluted with mineral spirits or kerosene and they result in VOC emissions. Other products are based on synthetic or semi-synthetic materials which include vegetable and water-based materials. In general, these materials have low VOC content.

The South Coast Air Quality Management District (SCAQMD) has jurisdiction over VOC emissions in the four county area including Los Angeles, Orange, Riverside and San Bernardino Counties. SCAQMD estimates the emissions from metal working operations in the South Coast Basin at 5.3 tons per day and these emissions are expected to increase to 6.1 tons per day by 2014.

The Institute for Research and Technical Assistance (IRTA) is a nonprofit organization established to assist industry in adopting alternative low-VOC, low toxicity alternatives. IRTA completed a project sponsored by U.S. EPA to identify, test and demonstrate low-VOC, safer alternative lubricants with eight facilities in the South Coast Basin. Five of the facilities used high VOC emitting lubricants and IRTA successfully found alternatives for their operations. More recently, with a grant from U.S. EPA, the SCAQMD contracted with IRTA to conduct a project to identify, test and demonstrate alternative low-VOC materials for vanishing oils and rust inhibitors. This report summarizes the results of the two projects.

IRTA worked with facilities in the two projects that used metal working fluids in a variety of different operations. Some of the facilities used VOC emitting lubricants; some used vanishing oils and some used rust inhibitors. IRTA identified and tested alternative low-VOC materials with the companies. The alternatives that proved effective included vegetable and water-based materials. Table E-1 shows the companies that participated in the two projects, the operations that use metal working fluids and the alternative that proved effective in each operations. Five of the facilities participating in the project elected to convert to the low-VOC alternatives.

IRTA analyzed and compared the costs of the original and alternative metal working fluids. The results indicated that five of the operations in Table E-1 would increase their costs through a conversion to the alternative materials and the others would reduce their costs through a conversion.

The SCAQMD lab is conducting an analysis of the VOC content of several of the products but the results were not available in time to include in this report. IRTA investigated the VOC content of the original metal working fluids and the alternatives without the test results based on other available information on VOC content. In general, the water-based and vegetable based materials have lower VOC content than the vanishing oils and petroleum based lubricants and rust inhibitors.

Table E-1
Results of the Metal Working Fluids Alternatives Projects

Company	Metal Working Fluid Type	Alternative(s)
S&H Machine, Inc.	Lubricant—Machines	Water-Based, Vegetable Based
Nelson Nameplate	Lubricant, Stamping	Vegetable Based
	Vanishing Oil--Stamping	Vegetable Based
	Vanishing Oil--Cutting	Vegetable Based
Fortner Engineering and Manufacturing, Inc.	Lubricant--Honing	Vegetable Based
Hydro-Aire	Lubricant--Honing	Vegetable Based
Weldcraft	Lubricant--Machines	Vegetable Based
Fred Rippy	Vanishing Oil—Stamping	Water-Based, Vegetable Based
Winders & LeBlanc, Inc.	Vanishing Oil--Forming	Water-Based
B & B Specialties, Inc.	Vanishing Oil--Machines	Vegetable Based
Dynaflex Products	Rust Inhibitor	Vegetable Based
Deltronic	Rust Inhibitor	Water-Based
Tracy Industries, Incl.	Rust Inhibitor	Water-Based
Robinson Helicopter Co.	Lubricant--Testing	Vegetable Based
	Rust and Corrosion Inhibitor	Water-Based

The California Department of Health Services Hazard Evaluation System & Information Service evaluated the toxicity of the metal working fluids based on the Material Safety Data Sheets. In general, the toxicity of the alternative vegetable and water-based materials is lower than the toxicity of the petroleum based metal working fluids with one exception. One of the water-based alternatives contains a chemical that is a carcinogen in very small quantities; it would be preferable if this product were reformulated without this chemical.

The results of this demonstration project indicate that alternative low-VOC materials for a variety of different types of metal working operations are available and cost effective. Companies using the high VOC products can convert to alternative vegetable and water-based materials to reduce their VOC emissions.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

I. INTRODUCTION AND BACKGROUND

There are thousands of manufacturers in the United States that use metal working fluids like lubricants, vanishing oils and rust inhibitors in their metal working processes. Independent machine shops manufacture parts for a variety of different types of metal operations. Many companies have captive machine shops that make parts for their production operations. Examples of the types of processes that use lubricants, vanishing oils or rust inhibitors are stamping, honing, deep drawing, forming, cold heading and tube bending.

About half of the metal working fluids used in metal working today are petroleum based materials. Some of these fluids are so-called vanishing oils. Vanishing oils are relatively high vapor pressure materials that are designed to evaporate from the part over a period of time. These oils are classified as Volatile Organic Compounds or VOCs that contribute to photochemical smog. Other lower vapor pressure lubricants are diluted with mineral spirits or kerosene to obtain the desired consistency for the operation being performed. In some cases, suppliers of these lubricants dilute them; in other cases, the companies using the fluids dilute them as they are used. The mineral spirits or kerosene in these fluids are classified as VOCs and, like vanishing oils, they contribute to smog. Some rust inhibitors, used to protect metals from corrosion, contain mineral spirits or kerosene and they also are VOCs.

Approximately half the metal working fluids are not based on petroleum products. These materials, called synthetic, semi-synthetic, polymer, water-based and vegetable based fluids are low or non-VOC emitting materials. The fluids are often diluted with water rather than mineral spirits or kerosene to obtain the desired consistency. These fluids can serve as alternatives to petroleum based metal working fluids.

VOC emissions from metal working fluid operations contribute substantially to the South Coast Air Basin's inventory. The South Coast Air Quality Management District (SCAQMD or District) is responsible for controlling air emissions in four counties including Los Angeles, Orange, San Bernardino and Riverside. The SCAQMD periodically adopts Air Quality Management Plans and the most recent plan calls for significant reductions in VOC emissions from metal working fluids by 2010 to help in achieving attainment status. The District currently controls VOC emissions from metal working fluid operations to some extent in Rule 442 "Usage of Solvents" but there is not currently a specific regulation that applies to these operations. Rule 442 specifies that companies shall not emit more than 833 pounds of VOCs per month from all VOC containing processes subject to the rule. This is a very high limit and most companies using VOC emitting metal working fluids would probably not exceed the limit.

The Institute for Research and Technical Assistance (IRTA), a nonprofit organization, was established in 1989 to assist industry in adopting safer alternatives to ozone depleting, chlorinated and other toxic and VOC solvents. IRTA staff members have worked with hundreds of facilities in the South Coast Basin to identify, test, develop and demonstrate alternatives. IRTA runs and operates the Pollution Prevention Center, a loose affiliation of local, state and federal governmental organizations and a large electrical utility.

IRTA completed a project sponsored by U.S. EPA in November 2004 that focused on alternative lubricants. The project involved working with eight companies that used VOC emitting or chlorinated paraffin lubricants in various types of metal working operations. Four of the five companies that used VOC emitting lubricants converted to the alternative low-VOC lubricants during the project. The SCAQMD received a grant from EPA to focus further on alternatives to VOC emitting materials used in other metal working operations. SCAQMD contracted with IRTA to conduct the project which involved identifying, testing and demonstrating alternative low-VOC materials as substitutes for vanishing oils and VOC emitting rust inhibitors. The results of the testing for both the IRTA/EPA project and the IRTA/EPA/SCAQMD project that focused on alternative low-VOC materials are presented here.

Participating Facilities

IRTA worked with five facilities that used VOC emitting lubricants during the earlier EPA project. During the current project which was sponsored by both SCAQMD and EPA, IRTA worked with eight facilities that used VOC emitting vanishing oils and rust inhibitors. Table 1-1 shows the list of facilities that participated in both projects.

Table 1-1
Facilities Participating in Metal Working Fluids Projects

Company	Project	Metal Working Fluid Type
S&H Machine, Inc.	EPA	Lubricant--Machines
Nelson Nameplate	EPA	Lubricant--Stamping, Vanishing Oil--Stamping
Fortner Engineering and Manufacturing, Inc.	EPA	Lubricant--Honing
Hydro-Aire	EPA	Lubricant--Honing
Weldcraft	EPA	Lubricant--Machines
Fred Rippy	SCAQMD, EPA	Vanishing Oil--Stamping
Nelson Nameplate	SCAQMD, EPA	Vanishing Oil--Cutting
Winders & LeBlanc, Inc.	SCAQMD, EPA	Vanishing Oil--Forming
B & B Specialties, Inc.	SCAQMD, EPA	Vanishing Oil--Machines
Dynaflex Products	SCAQMD, EPA	Rust Inhibitor
Deltronic	SCAQMD, EPA	Rust Inhibitor
Tracy Industries, Inc.	SCAQMD, EPA	Rust Inhibitor
Robinson Helicopter Co.	SCAQMD, EPA	Lubricant--Testing, Rust and Corrosion Inhibitor

The facilities that participated in the projects have a variety of different operations that use VOC emitting lubricants, vanishing oils or rust inhibitors. S&H Machine, Inc. is a machine shop that has several machines. Nelson Nameplate manufactures nameplates and has stamping machines for stamping out the nameplates and cutting presses for cutting adhesive backing. Fortner Engineering is a licensed Federal Aviation Administration repair station that has honing machines for repairing components like hydraulic flight controls, actuators and linkages for aircraft. Hydro-Aire manufactures braking systems, pumps and air locking devices for aircraft and uses honing machines in the manufacturing operations. Weldcraft manufactures welding torches and accessories and uses drilling/stamping machines to make the parts. Winders & LeBlanc is a machine shop that uses forming machines to make several different types of parts. B & B Specialties makes fasteners and specializes in forming and thread rolling. Dynaflex manufactures flexible exhaust connectors primarily for the heavy duty truck market. Deltronic manufactures plug and thread gages used by many companies for accurate measurement. Tracy Industries, Inc. remanufactures engines, calipers and motors. Robinson Helicopter Company manufactures small helicopters.

IRTA worked with the 12 companies listed in Table 1-1 on finding alternatives in various operations. Alternative lubricants were tested with six companies. Alternatives to vanishing oil were tested with four companies. Alternative rust inhibitors were tested with four companies.

Project Approach

The first step in the projects was to visit each of the participating facilities. During these visits, IRTA toured the facility and focused particularly on the metal working processes. IRTA discussed these processes and identified one or more of the processes where testing of alternative metal working fluids would be conducted.

The second step in the projects was to identify low-VOC alternatives that might be suitable for each of the metal working operations. This involved working with vendors that supply metal working fluids.

The third step in the projects was to conduct initial tests of alternatives that might be effective for the processes of focus. The initial testing generally involved testing one to five alternatives in the candidate processes. If a potential alternative performed well, IRTA and the facility structured a protocol for scaled-up testing.

The fourth step in the projects was to conduct more extensive or scaled-up testing in the candidate processes. IRTA provided the facility with alternative products over a range of one week to three months for the testing. In many cases, the alternatives were diluted with water and IRTA diluted them to the appropriate testing concentration.

The fifth step in the projects was to analyze and compare the cost and performance of the alternative and currently used metal working fluids. In some cases, analysis of additional processes like cleaning or blasting had to be included because the costs of these operations varied depending on the type of metal working fluid that was used.

The sixth step in the projects was to assist the companies in converting to the alternatives if they were interested in doing so. In five cases, the companies elected to convert to the alternatives that were tested.

IRTA prepared case studies for each of the participating facilities. These case studies were provided to the facilities for comments. All of the facilities approved the write-ups in this report.

Metal Working Fluid Performance

Performance of the low-VOC alternatives at each facility was evaluated on a case-by-case basis. In each instance, the plant personnel provided information on their requirements for the process. In all cases, it was important that the alternative perform as well as or better than the fluid used currently. As described above, IRTA and the plant personnel designed test protocols that would allow comparison of the alternative fluid performance for the operations conducted in a particular plant.

Cost Analysis

IRTA performed cost analysis for each of the alternatives that was successfully tested at the facilities participating in the project. The types of costs that were evaluated included:

- capital cost
- metal working fluid cost
- labor cost
- utilities cost
- cleaning cost
- related operation cost

These costs were evaluated and compared when the costs were different for the currently used fluid and the alternative fluids.

In a few cases, it was assumed that there would be a capital equipment requirement. In these instances, the cost of the capital equipment was spread over a 10 year period, which was assumed to be the life of the equipment. In one case, IRTA assumed a 12 year life for the equipment. The interest rate for the cost of capital was assumed to be four percent.

In virtually all cases, there was a difference in the cost of the current fluid and the cost of the alternative low-VOC fluid. In some cases, there was a difference in labor costs and, in these instances, the different costs were compared. In some cases, there was a difference in electricity costs and these were noted and compared. In three instances, there was a difference in the cleaning cost and this was noted. Finally, in a few instances, there was a difference in cost for related operations and these were determined.

Report Organization

Section II of this report provides detailed information on the testing and analysis that was performed for each of the companies participating in the project. The cost of the current and alternative process was evaluated and compared. Section III of the report presents information on the VOC content of the lubricants and the results of an evaluation of the toxicity of the metal working fluids performed by the California Department of Health Services Hazard Evaluation System & Information Service. Section IV summarizes the project findings. Appendix A includes MSDSs for the currently used and alternative low-VOC metal working fluids. Appendix B provides the stand alone case studies for four of the facilities that opted to convert to the alternatives.

II. ANALYSIS AND TESTING OF THE ALTERNATIVE LUBRICANTS

This section describes the alternative lubricants that were tested with each manufacturer. It provides information on the processes where the lubricants were tested. In most cases, the Material Safety Data Sheets (MSDSs) for the original lubricant are included in Appendix A. The MSDS for each alternative product that performed effectively is also included in the appendix. The description of the testing at each company includes a cost analysis and comparison of using the original and the alternative lubricants. In some cases, other collateral processes performed by the facility had to be changed to accommodate the use of the alternative lubricant and the costs of these changes are also included in the analysis.

S&H Machine, Inc.

S&H Machine is a small machine shop located in Burbank, California. The company machines parts for the aerospace industry. The parts machined by S&H Machine are made of aluminum and stainless steel. The company has 21 machine stations, which include several CNC lathes and mills. One of the stations is shown in Figure 2-1.

Figure 2-1. Machine Station at S&H Machine

In the past, S&H Machine used a petroleum-based lubricant that contained chlorinated paraffin extreme-pressure additives for machining their parts. The MSDS for this lubricant is shown in Appendix A. The company used mineral spirits to clean the parts. When the South Coast Air Quality Management District (SCAQMD) regulated the VOC content of cleaners used in batch loaded cold cleaning, S&H Machine purchased eight parts cleaners and began to use a water-based cleaner to clean their parts. At that stage, David Fisher, the owner of the company, began to examine alternative lubricants that would fit better with the water-based cleaners the company now used. After extensively researching the alternative lubricants, David Fisher converted the company's lubricant to a water miscible cutting and grinding lubricant. An MSDS for this lubricant is shown in Appendix A. S&H Machine used the new lubricant for a few years and then converted to a synthetic vegetable ester lubricant, which is being used today. An MSDS for the vegetable-based lubricant is shown in Appendix A.

In order to make the conversion from the petroleum based lubricant to the water miscible lubricant, S&H Machine had to purchase a mixer for mixing the lubricant and water at a cost of $432, a decanter used to separate tramp oils from the lubricant at a cost of $975 and a sump cleaner for cleaning out the machine sumps at a cost of $4,750. The company also had to purchase 15 oil skimmers used to skim the tramp oil from the surface of the lubricant; at a cost of $280 per skimmer, the total cost of the skimmers was $4,200. One of the skimmers is shown in Figure 2-2. The total capital cost amounted to $10,357. Installation of the new equipment required 15 hours of labor. Assuming a labor rate of $15 per hour, the installation labor cost was $225. The total capital and installation cost amounted to $10,582. When S&H Machine converted to the water miscible ester lubricant, no additional capital equipment was required. Had the company converted from the petroleum-based lubricant directly to the ester lubricant, they would have had the same capital equipment requirements as for the water miscible lubricant. Assuming a cost of capital of 2% and a 10 year life for the equipment, the annualized capital cost is $1,079.

Figure 2-2. Oil Skimmer at S&H Machine

S&H Machine used six drums per year of petroleum based lubricant. At a cost of $264 per drum, the total cost of the lubricant was $1,584 annually. The company used less lubricant, about five drums per year, of the water miscible lubricant. The higher cost of the lubricant, at $700 per drum, led to an annual lubricant cost of $3,500. At this stage, S&H Machine is using only three drums per year of the ester lubricant. At a cost of $1,134 per drum, the annual lubricant cost amounts to $3,402.

When S&H Machine used petroleum-based lubricants, the company performed no maintenance. With both the water miscible and the ester lubricant, the company must perform substantial maintenance to achieve peak performance and good part finish quality. S&H's owner estimates that four hours per week is required to pump the coolant out of the machines, refill the machines and decant the removed lubricant. In addition, once a year the water miscible lubricant must be changed out. This requires 10 employees who each spend four hours at this activity. Assuming a labor rate of $15 per hour, the total maintenance labor cost for using the water miscible and ester lubricants is $3,720 per year.

The water miscible and vegetable ester lubricants provide less lubricity than the petroleum-based lubricant. They do, however, serve as better coolants than the petroleum lubricant. As a result, S&H Machine can run the machines faster with the alternative lubricant. In effect, the efficiency of the operation has increased and the company can process more parts. To quantify this increase in efficiency, the machining labor using the petroleum and the alternative lubricant were compared. Eight operators machine parts for eight hours per day. Assuming each operator works 260 days per year and a labor rate of $15, the machining labor amounted to $249,600 annually. With the new lubricant, Mr. Fisher estimates that there has been a 10% increase in efficiency. This translates into a labor cost reduction of $24,960 per year. The machining labor cost is now $224,640.

When S&H Machine used petroleum-based lubricants, the only disposal costs involved disposal of the spent water-based cleaners. The company had eight parts cleaners each with a capacity of 15 gallons. The total of 120 gallons was disposed of three times per year. At a cost of $1 per gallon, the total cost of disposal amounted to $360 per year.

S&H Machine was able to reduce their cleaning requirements when they switched to the water miscible and ester lubricants. Four of the eight water-based parts cleaners were eliminated so disposal costs are half what they were previously. With the two alternative lubricants, however, there is also waste from decanting the lubricants. The cleaning system and decanting waste now amounts to 660 gallons per year. In addition, S&H Machine now changes out the lubricant and disposes of it once a year. Total disposal costs now amount to $1,025.

The labor required for cleaning was reduced when the company changed to the water miscible and ester lubricants. S&H Machine machines 85,549 parts annually. The company estimates that it requires 30 seconds less to clean each part now. Assuming a labor rate of $15 per hour, the cleaning labor cost has been reduced by $10,694 per year. S&H Machine also does not have to purchase detergent for four parts cleaners. Assuming each of the four parts cleaners required five gallons of detergent concentrate (one-third of the capacity), a detergent cost of $10 per gallon and that the parts cleaners are changed out three times per year, the cleaner cost has been reduced by $600 per year. By eliminating four of the parts cleaners, the electricity cost for heating the water-based cleaners has also been reduced. It is estimated that each parts cleaner carries an electricity cost of about $60 per year. Assuming that four parts cleaners have been eliminated, the cost savings are $240 annually. The total savings through eliminating four parts cleaners amounts to $11,534 annually.

When S&H Machine used the petroleum based lubricant and the mineral spirits as a cleaner, the mineral spirits, when it was spent, was poured in the machines and used to continually dilute the lubricant. When the company converted to water-based cleaning, mineral spirits had to be purchased separately to dilute the lubricant. S&H Machine estimates that the company purchased one drum every three months for this purpose. At a price of $148.50 per drum, the total annual cost of the mineral spirits amounted to $594.

When S&H Machine converted to the alternative lubricants, the mineral spirits was no longer necessary for dilution.

Table 2-1 shows the cost comparison for S&H Machine for the petroleum based lubricant, the water miscible lubricant and the ester lubricant. The values show that use of the water miscible and the ester lubricant reduces the cost substantially. Use of the ester lubricant, the lubricant currently used, reduced the cost to S&H Machine by 11% and is saving about $30,000 per year. When the company used the petroleum lubricant, the lubricant, maintenance and disposal costs were much lower. This is more than offset by the much higher cleaning cost and the machining labor cost with the petroleum lubricant.

Table 2-1
Annualized Cost Comparison for S&H Machine Lubricants

	Petroleum Lubricant	Water Miscible Lubricant	Ester Lubricant
Annualized Capital Cost	-	$1,079	$1,079
Lubricant Cost	$1,584	$3,500	$3,402
Maintenance Labor Cost	-	$3,720	$3,720
Machining Labor Cost	$249,600	$224,640	$224,640
Disposal Cost	$360	$1,025	$1,025
Cleaning Cost Change	$11,534	-	-
Mineral Spirits Oil Dilution Cost	$594	-	-
Total Cost	$263,672	$233,964	$233,866

S&H Machine is happy with the conversion. As mentioned earlier, the ester lubricant provides more cooling capability than the petroleum-based lubricant. A limitation of the new lubricant, however, is that it does not provide the same lubricity. For the tapping application, in particular, S&H Machine uses one of two machines that still rely on the petroleum based lubricant.

Nelson Nameplate—EPA Project

Nelson Nameplate is a small company with about 250 employees located in Los Angeles, California. The company, which was founded in 1946, manufactures nameplates made of stainless steel, aluminum and brass and membrane switches. An example of the nameplates manufactured by Nelson Nameplate is shown in Figure 2-3. As part of the manufacturing, several operations including stamping, coating, screen printing, lithographic printing and cleaning are required.

Nelson Nameplate is a very progressive company concerned about the environment and their workers. Several years ago, the company converted away from 1,1,1-trichloroethane (TCA), an ozone depleting solvent, to a water-based cleaning process. The company has also converted to alternative low-VOC cleanup materials in the screen and lithographic printing processes.


Figure 2-3. Nameplates Manufactured at Nelson Nameplate

IRTA began working with Nelson on their stamping process as part of a project sponsored by EPA Region IX. The company was using two lubricants in the process used to stamp out the nameplates. The first lubricant was a vanishing oil which the company diluted to 50% concentration with isopropyl alcohol. An MSDS for this lubricant is shown in Appendix A. The second lubricant was a petroleum-based oil. An MSDS for this lubricant is shown in Appendix A. One of Nelson's stamping machines is shown in Figure 2-4. The metal is precut in sheets of various sizes depending on the particular nameplate and prepared for printing. A single or multiple color print is applied to the metal. The large sheets of nameplates are stamped into smaller nameplates. The nameplates are then cleaned, inspected and packaged for shipping.

Figure 2-4. Stamping Machine at Nelson Nameplate

The lubricant used in the stamping process aids in increasing the accuracy of the cut and eliminating burrs. The lubricant must be compatible with the metals used to make the nameplates and also with the printing inks since they are applied before cleaning. In Nelson's process, the lubricant can remain on the nameplates for up to 72 hours before the nameplates are cleaned. Nelson wanted to examine alternative lubricants for two reasons. First, the company was finding increased rejects. After investigating, Nelson found that the lubricant that remained on the nameplates prior to cleaning was softening the printing inks. To resolve this, Nelson added another manufacturing step to bake and cure the ink a second time after cleaning. The company wanted to convert to an alternative lubricant to eliminate the second baking step. Second, Nelson wanted to adopt another lubricant to reduce their VOC emissions.

IRTA began testing alternative lubricants with Nelson. Two of the alternative lubricants were vegetable based and both softened the ink so they were unacceptable. The third alternative lubricant was a water-soluble lubricant and it was not acceptable because it left more burrs and rough edges on the metal. The fourth alternative lubricant that was tested was a vegetable-based oil that does not soften the ink. Nelson has converted to this lubricant in their stamping process. An MSDS for the lubricant is shown in Appendix A.

Nelson used up to one gallon per day of the vanishing oil that was blended with IPA. This analysis assumes that the use of the diluted lubricant amounted to one-half gallon per day. On this basis and assuming 260 days per year, the company used 130 gallons per year of the diluted lubricant. The cost of the vanishing oil was $11.42 per gallon and the company pays $4.93 per gallon for IPA. The annual cost of the vanishing oil lubricant blended with IPA is $1,063. Nelson estimates that the company used between a few ounces and one gallon per day of the second lubricant, the petroleum based oil. Assuming the company uses one-half gallon per day and that there are 260 days per year, use of the second lubricant amounted to 130 gallons per year. The cost of the second lubricant is $21 per gallon. On this basis, the annual cost of the second lubricant amounts to $2,730. The annual cost of the two lubricants is $3,793. Nelson converted to the vegetable ester lubricant about eight months ago and purchased 24 gallons during that time. This translates into an annual usage of 36 gallons per year. The cost of the vegetable ester lubricant is higher than the two original lubricants, at about $35 per gallon. The annual cost of using the new lubricant is $1,260.

With the conversion to the new lubricant, Nelson was able to eliminate the second ink-baking step. The company baked the nameplates in an oven for 20 minutes twice a week. The savings in energy from avoiding the baking is negligible. The labor required for the baking is estimated by Nelson at 40 minutes a week. Assuming a labor rate of $10 per hour, the savings from eliminating the baking step is $347 annually.

Table 2-2 shows the cost comparison for the original and new alternative lubricants. The values show that conversion to the alternative lubricant reduced Nelson's costs by about 70%. Although the cost of the new vegetable lubricant is much higher than the cost of the two original lubricants, use of the new lubricant is much lower. The change resulted in eliminating virtually all of the VOC emissions.

Table 2-2
Annualized Cost Comparison for Nelson Nameplate Lubricants

	Original Lubricants	Vegetable Ester
Lubricant Cost	$3,793	$1,260
Second Baking Labor Cost	$347	-
Total Cost	$4,140	$1,260

Fortner Engineering and Manufacturing, Inc.

Fortner is a small company with 50 employees located in Glendale, California. The company has been a licensed Federal Aviation Administration (FAA) repair station since 1968. Fortner repairs aircraft components like hydraulic flight controls, actuators and linkages for Boeing, Douglas and a number of airlines.

IRTA worked with Fortner in the past to assist the company in converting to water-based cleaning systems and acetone to replace a vapor degreaser that used 1,1,1-trichloroethane (TCA) and several batch loaded cold cleaners that used a VOC solvent. IRTA began work with Fortner again as part of a project sponsored by EPA Region IX on alternative lubricants. The project focus is on testing and demonstrating alternatives to VOC emitting lubricants and lubricants containing chlorinated paraffin extreme pressure additives. IRTA worked with Fortner to test alternatives to a petroleum based VOC emitting lubricant that the company used for honing operations on several substrates including aluminum, bronze, steel, stainless steel, nickel and chromium. Figure 2-5 shows one of the honing machines at Fortner. The MSDS for Fortner's VOC emitting honing oil is shown in Appendix A.

Figure 2-5. Honing Machine at Fortner

IRTA tested three alternatives with Fortner. One lubricant was a synthetic lubricant. The company found this lubricant to be sticky and it left a residue on the equipment. The parts were more difficult to clean and the lubricant was not easy to work with. The second lubricant, a water-soluble vegetable oil, had an odor the workers didn't like. The third lubricant was a vegetable-based oil that the workers liked. An MSDS for this lubricant is shown in Appendix A. IRTA arranged for Fortner to conduct scaled up testing for seven months in one machine. The company decided to convert to this lubricant.

Fortner uses between 10 and 15 gallons of lubricant in their three honing machines each year. The price of the petroleum-based lubricant used by the company for many years is currently $11.90 per gallon. Assuming a usage for this lubricant of 12 gallons per year, the annual cost of using the petroleum-based lubricant was $143. One of the Fortner employees that used the alternative lubricant indicated that he believes that less of the new vegetable-based lubricant is required. Assuming a usage for the new lubricant of nine gallons per year and based on its cost of $22.25 per gallon, the cost of purchasing the alternative lubricant is $200 annually.

The employees who tested the lubricant indicated that there are no labor changes in using the new lubricant. They also have experienced no change in the cleaning process in using the alternative. They prefer the new lubricant because it does not have the solvent odor the original lubricant had and because it does a good job on the parts.

Table 2-3 shows the annual cost comparison of the original and new alternative lubricant. Fortner's conversion to the vegetable based lubricant raises the annual cost by 40%. Use of the lubricant at this company is low, however, so the impact of the cost increase is minimal.

Table 2-3
Annualized Cost Comparison for Fortner Lubricants

	Petroleum Lubricant	Vegetable Lubricant
Lubricant Cost	$143	$200
Total Cost	$143	$200

Hydro-Aire

Hydro-Aire is a division of Crane located in Burbank, California. The company manufactures braking systems, pumps and air locking devices and is a subcontractor to Boeing. Hydro-Aire also repairs pumps used in military and commercial aircraft like the C-17 and C-130 transport.

When IRTA began working with Hydro-Aire on a lubricant project sponsored by EPA Region IX, the company was using a petroleum-based lubricant for their honing operations. An MSDS for this lubricant is shown in Appendix A. The employees did not like the odor of the lubricant and the company subsequently converted to a vegetable ester lubricant offered by the same supplier. The employees disliked the odor of this product as well.

Cleaning the honing oil has always been a problem for Hydro-Aire. The company wanted to find an alternative lubricant that was not petroleum-based, that did not have an objectionable odor and that was more easily cleaned. IRTA tested two different vegetable ester lubricants with the company. Hydro-Aire conducts honing on aluminum and stainless steel parts. The testing of alternative lubricants was performed primarily on aluminum because Hydro-Aire believes that honing of aluminum is more difficult. If the alternative lubricant worked for aluminum parts, it was reasoned that it would likely work for stainless steel parts as well. Figure 2-6 shows one of the machines where the testing was conducted.

Both of the alternative lubricants that were investigated were tested in a two-gallon recirculating reservoir system designed by IRTA. The reservoir could be placed inside the honing machine tray but did not require the entire lubricant tank to be changed out. The first alternative that was tested performed well at 100 percent concentration but cleaning the lubricant was still a major problem. The second alternative lubricant is a vegetable ester lubricant, which is water dilutable; it was selected because it is potentially easier to clean with Hydro-Aire's cleaning process. IRTA experimented to determine the optimal concentration of the lubricant. The first concentration tested was five percent; at this concentration the metal removed from the honed part built up on the honing stone and affected the honing adversely. At 15 percent, the honing was improved but was still not acceptable. At a 24 percent concentration, the build up was reduced and honing was improved but the microfinish of the part was rough. Finally, at about 33 percent concentration, there was virtually no build up and the finish was acceptable.

Figure 2-6. Honing Machine at Hydro-Aire

After the initial testing, IRTA helped Hydro-Aire change out their aluminum-honing machine and the company has been using the alternative lubricant for the last three months. Hydro-Aire has effectively converted to the alternative lubricant for processing the aluminum parts. An MSDS for this lubricant is shown in Appendix A.

IRTA analyzed and compared the cost of using the original petroleum based lubricant and the new alternative vegetable ester lubricant in the aluminum honing operation. The cost of the petroleum lubricant was $10.18 per gallon and the company used about one-half gallon each month. In addition, the 15 gallon capacity tank was changed out every six months. The cost of using 36 gallons of lubricant per year amounted to $366. Use of the alternative vegetable ester lubricant is also about one-half gallon per month. This lubricant is used at a concentration of 33 percent and two gallons of water must be added every two weeks to compensate for evaporation. The 15 gallon tank is also changed out twice a year. The price of the alternative lubricant is $15 per gallon. On this basis, the cost of purchasing 16 gallons of the alternative lubricant each year amounts to $240.

The alternative water dilutable lubricant is easier to clean than the original lubricant. With the petroleum lubricant, the parts were soaked in a parts cleaner, then washed in the parts cleaner with a brush. A picture of the parts cleaner is shown in Figure 2-7. The parts were blown off with compressed air. The parts were then soaked in acetone for three minutes and blown off with air again. The parts were then put through an automated precision ultrasonic cleaning system where they went through an alkaline wash step, a deionized water rinse step and a drying step. Figure 2-8 shows the ultrasonic cleaning system. Finally, the parts were blown off again and inspected. In most cases, the parts had to be put through the ultrasonic cleaning system a second time. With the new lubricant, the parts are washed with a brush in the parts cleaner and blown off with compressed air. The parts are then put through the ultrasonic cleaning system only once.

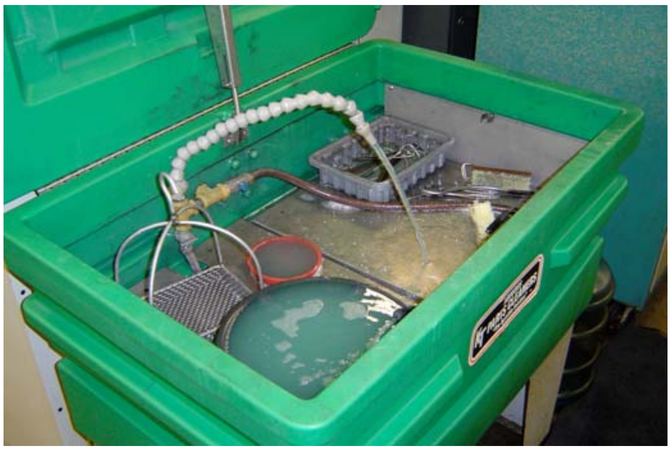
Figure 2-7. Parts Cleaner at Hydro-Aire

The machinist at Hydro-Aire hones 50 parts in an eight-hour shift or two batches of 25 parts each. The parts are cleaned in batches. The first step--the cleaning in the parts cleaner and acetone--required 50 minutes of employee time during a shift with the petroleum lubricant. The second step--cleaning in the ultrasonic system--required 34 minutes of the employee time during a shift. The total amount of time spent cleaning during a shift was 84 minutes. After conversion to the vegetable ester lubricant, the cleaning time was reduced to half the amount of time or 42 minutes per shift. On this basis, cleaning the petroleum lubricant required 364 hours per year and cleaning with the vegetable ester lubricant required half the amount of time or 182 hours per year. Assuming Hydro-Aire’s labor rate of $25 per hour, the cleaning cost of the petroleum lubricant amounted to $9,100 annually and the cleaning cost of the alternative lubricant amounts to $4,550.

Table 2-4 shows the annualized cost comparison of the petroleum and vegetable ester lubricants for the aluminum honing operation. The cost of the honing operation has been reduced by about half through adoption of the alternative lubricant.

IRTA also tested the lubricant in the stainless steel machines in a more limited way using the two-gallon recirculating system. The company is considering converting to the alternative lubricant in this honing operation as well. The company has two stainless steel honing machines and operates them each for two shifts. About 50 parts are processed during each shift for a total of 100 parts per day.

Figure 2-8. Ultrasonic Cleaning System at Hydro-Aire

Table 2-4
Annualized Cost Comparison for Hydro-Aire Lubricants in Aluminum Honing Operation

	Petroleum Lubricant	Vegetable Ester Lubricant
Lubricant Cost	$366	$240
Cleaning Cost	$9,100	$4,550
Total Cost	$9,466	$4,790

In the case of stainless steel, the concentration of the lubricant was optimal at 75 percent concentration. Assuming the two stainless steel honing machines would use twice as much lubricant as the aluminum machine, the cost of purchasing the petroleum lubricant is $732 per year. Because the concentration of the alternative lubricant required for stainless steel honing is higher, at 75 percent, the cost of the 57 gallons of the alternative vegetable ester lubricant would be $855 annually.

Twice as many parts are processed through the stainless steel honing operation as through the aluminum operation. During the testing, the stainless steel parts were again observed to be much easier to clean with the alternative lubricant. Assuming that the stainless steel parts require twice as much cleaning time as the aluminum parts and that adoption of the water dilutable lubricant would reduce the costs by half, the cost of cleaning with the petroleum lubricant is $18,200 annually. The cost of cleaning with the alternative vegetable ester lubricant is half the cost or $9,100 annually.

Table 2-5 shows the annualized cost comparison of the petroleum and vegetable ester lubricants for the stainless steel operation. Again, conversion to the alternative reduces the cost by about half.

Table 2-5
Annualized Cost Comparison for Hydro-Aire Lubricants in Stainless Steel Honing Operation

	Petroleum Lubricant	Vegetable Ester Lubricant
Lubricant Cost	$732	$855
Cleaning Cost	$18,200	$9,100
Total Cost	$18,932	$9,955

Weldcraft

Weldcraft is the world's leading manufacturer of Tungsten Inert Gas (TIG) welding torches and accessories. The company is located in Burbank, California. Weldcraft was founded in a residential garage as a welding torch repair shop. The aerospace customers wanted to get more life out of their welding torches. The company modified the torches to use a silicone rubber compound, which doesn't degrade like the old torches and the new torches are widely used today throughout the industry.

IRTA began work with the company as part of an EPA sponsored project on alternative lubricants. In conjunction with management, it was agreed that the work would focus on finding an alternative lubricant for the petroleum based lubricant used in a flooding system in the collet cell equipment. A collet holds the tungsten rod in the welding equipment. The collet cell equipment is a semi-automated machine that drills the collet, slots the length of the collet, redrills the collet and then stamps the part with the part number. Each station of the equipment has a lubricant spout and a steady flow of lubricant that "floods" the parts. The lubricant is collected in a pan and routed to a reservoir where it is recirculated through individual spouts on the machines. A picture of the cutting machine with flood lubrication is shown in Figure 2-9.

Figure 2-9. Flooding Lubrication at Weldcraft

Weldcraft was using a petroleum-based lubricant for the flooding operation. An MSDS for this lubricant is shown in Appendix A. IRTA decided to test an alternative vegetable ester lubricant in a near dry system. The MSDS for this lubricant is shown in Appendix A. The near dry approach minimizes the use of the lubricant; the lubricant is applied only at the point of contact with the part. A supply nozzle was positioned at each station. Each nozzle was supplied with lubricant through a centralized dispensing system through a flexible hose. The lubricant was mixed with air in the dispensing system. The near dry applicator was installed in one hour. A picture of a cutting machine with near dry lubrication is shown in Figure 2-10.

The alternative lubricant was tested for eight months at Weldcraft on one collet machine. Each collet machine processes 1,000 parts per day. Assuming the machine operates 260 days per year, each collet machine produces 260,000 parts per year. The alternative lubricant worked well but the drill life was reduced from one each 4,000 parts to one each 3,000 parts. On this basis, 65 drills were used each year with the petroleum lubricant and 87 drills were used each year with the vegetable ester lubricant. Weldcraft uses several different sizes of drills and the average cost of a drill is $5.65. On this basis, the cost of replacing drills with the petroleum lubricant is $367 annually and the cost of replacing drills with the vegetable ester lubricant is $492.

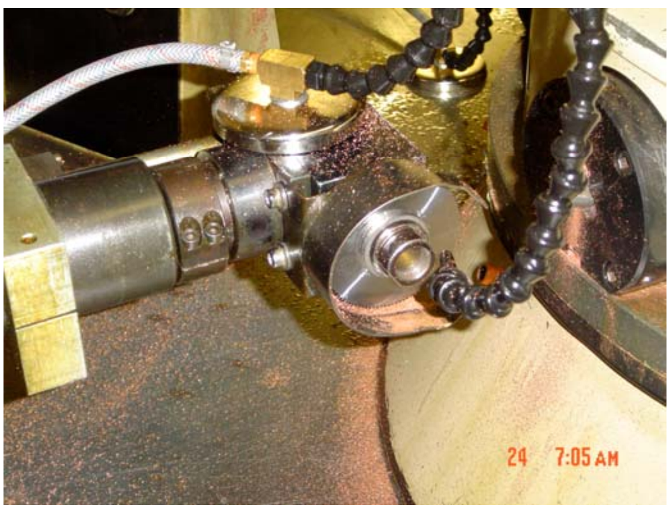

Figure 2-10 Cutting Machine with Near Dry Lubrication at Weldcraft

The flooding system requires half a gallon of the petroleum-based lubricant each week. It uses 26 gallons per year. In addition, the system, which has a capacity of 10 gallons, is cleaned and changed out completely once a year. Thus a total of 36 gallons of petroleum lubricant is used annually. At a cost of $4.68 per gallon, the total lubricant cost amounts to $168 per year. Over the eight-month testing phase, only one gallon of the vegetable ester lubricant was required. On this basis and assuming a cost of $52 per gallon, the annual cost of the vegetable ester lubricant would be $78. No cleaning or changeout of the lubricant is required in the case of the vegetable ester.

When the station is cleaned, the lubricant is discarded as waste. The cost for disposal of the petroleum based lubricant, at 65 cents per gallon, amounts to about $7 per year. The changout requires one hour. Assuming Weldcraft's labor rate of $17 per hour, the changeout labor cost is $17 annually.

Weldcraft has a leanjet cleaning system that is used to clean all the parts that are processed in the factory. The conditions are set to clean the most contaminated parts. Although in principle, the parts using the vegetable ester would be easier to clean because of the near dry conditions, no difference was noted during the testing phase.

Table 2-6 shows the annual cost comparison for Weldcraft's collet equipment. The annual costs of using the petroleum lubricant and the vegetable ester lubricant are comparable.

Table 2-6
Annualized Cost Comparison for Weldcraft's Collet Equipment Operation

	Petroleum Lubricant	Vegetable Ester Lubricant
Drill Replacement Cost	$367	$492
Lubricant Cost	$168	$78
Disposal Cost	$7	-
Changeout Labor Cost	$17	-
Total Cost	$559	$570

During the testing, Weldcraft was downsized and manufacturing engineering and technical support for a change was no longer a priority. The new management, under the circumstances, decided not to make a conversion at this time.

Fred R. Rippy, Inc.

Fred R. Rippy, Inc. is a small company in Whittier with 45 employees. The company manufactures motor and head laminations used in electronics applications for a variety of customers. Fred R. Rippy has several stamping machines that are used to stamp out the products in various forms. One of the stamping machines is shown in Figure 2-11.

Fred R. Rippy processes about five million parts annually. All of the laminations stamped out by the company are ferrous metal. Some of the parts are silicon steel and others are high cobalt material. Virtually all of the laminations rust very readily. A picture of one of the types of parts manufactured by the company is shown in Figure 2-12.

IRTA began work with Fred R. Rippy as part of a project sponsored by the South Coast Air Quality Management District (SCAQMD). The purpose of the project is to identify, test and demonstrate alternatives to VOC emitting lubricants and rust inhibitors.


Figure 2-11. Stamping Machine at Fred R. Rippy


Figure 2-12. Laminations Manufactured at Fred R. Rippy

The lubricant used by the company is a vanishing oil called Accu-Stamp Vanishing Oils (NM, PP, #11); an MSDS for this lubricant is shown in Appendix A. This lubricant, like other vanishing oils, is applied to the parts during stamping. The residue remains on the parts as they are further machined and processed to prevent rusting. The company uses automated magnetic systems to separate the parts during the machining. A picture of one of these systems is shown in Figure 2-13. Some of the parts are sent out for heat treating and the vanishing oil is designed to leave no significant ash on the parts after this annealing step.

IRTA tested several alternative low-VOC lubricants with Fred R. Rippy. The requirements were that the alternative have enough lubricity for the stamping process and that the alternative not interfere with use of the automated magnetic separation systems that are used throughout the plant. IRTA provided a number of alternative materials for testing. Some of these were vegetable based products, some were water based and some were both vegetable based and water dilutable. All but one of the water-based products left a stain on the parts and some of them interfered with the robotic magnet systems so the parts could not be separated. Some of the vegetable based products left the parts sticky and this was unacceptable.

Figure 2-13. Magnetic Separation System at Fred R. Rippy

Two alternatives, a vegetable based product called Soy Gold 2000 and a water soluble lubricant called NOCOR S2, did perform effectively. MSDSs for these alternatives are shown in Appendix A. Both products had enough lubricity for the stamping operation and performed well with the automated magnetic systems. The strong disadvantage of the soy product, however, is that, unlike vanishing oil, it does not evaporate. If this product were used, Fred R. Rippy would have to clean the parts before they are sent to heat treating. The water soluble lubricant left very little residue so it would not have to be cleaned before the parts were shipped. IRTA analyzed the costs of the soy based cleaner assuming Fred R. Rippy would have to clean the parts and the water soluble alternative assuming the company would not clean the parts.

IRTA worked with Fred R. Rippy several years ago to find an alternative cleaning system. The company had used a vapor degreaser with perchloroethylene (PERC) for several years for cleaning parts. At that time, the company carried a product line that had to be cleaned before annealing. IRTA assisted the company in adopting a conveyorized water-based cleaning system for cleaning 5,000 parts per day. At a later time, Fred R. Rippy changed their product mix and no longer needed to use the water-based cleaning system. The company still owns the system and could use it for cleaning parts if the alternative vegetable lubricant were adopted. A picture of the cleaning system is shown in Figure 2-14.

Figure 2-14. Cleaning System at Fred R. Rippy

Currently, Fred R. Rippy uses 300 gallons per year of the vanishing oil. The cost of the vanishing oil is $9.50 per gallon. The total annual cost of the lubricant is $2,850. During testing of the Soy Gold 2000 alternative, IRTA and Fred R. Rippy found that the company required about half the amount of lubricant or 150 gallons per year. The cost of the Soy Gold 2000 is about $8.50 per gallon. On this basis, the annual cost of the lubricant if Fred R. Rippy converted to the alternative would amount to $1,275. The water soluble lubricant performed effectively at a five percent concentration in water. The cost of the lubricant is $876 per drum or $15.93 per gallon. Taking into account the dilution and assuming the company would use 300 gallons per year, the cost of using the water soluble lubricant would be $239 annually.

As mentioned earlier, Fred R. Rippy processes about five million parts annually. If the company converted to the vegetable based alternative, they would have to clean about four million parts annually or about 15,000 parts per day. The conveyorized water-based cleaning system would have to operate 10.5 hours per day five days per week to clean the four million parts. The company would have to purchase an automated material handling system at a cost of $40,000 to avoid a high labor cost. Assuming a cost of capital of four percent and assuming the handling system has a useful life of 12 years, the annualized capital cost for the system amounts to $3,467.

During operation, the conveyorized cleaning system uses 46 kilowatt hours. Assuming the 10.5 hours per day of operation and an electricity cost of 18 cents per kilowatt, the annual electricity cost would be $22,604.

When the cleaning system was used in the past to clean the 5,000 parts per day, the water-based cleaning bath required changeout every three months. Because about 15,000 parts per day would now require cleaning, the cleaning bath would need changeout about every month. The cleaning bath has a capacity of 100 gallons and the cleaner is used at a 10 percent concentration. Assuming a cost of $10 per gallon for the cleaner concentrate, Fred R. Rippy would use 120 gallons of the cleaner each year. The annual cost of purchasing the cleaner would be $1,200.

The spent cleaning bath would be disposed of as hazardous water waste. The cost for this disposal amounts to about $2 per gallon. On this basis, assuming the bath would require changeout once a month, the annual cost of disposal would amount to $2,400.

Table 2-7 shows the annualized cost comparison for Fred R. Rippy for using the vanishing oil, the alternative vegetable based lubricant and the alternative water soluble lubricant. The values show that the cost of using the vegetable lubricant would increase Fred R. Rippy's cost by about $28,000 annually. The cost of using the water soluble lubricant would reduce Fred R. Rippy's current cost by 12 times. If the company decided to adopt a low-VOC alternative, the water soluble product would be the better choice.

Table 2-7
Annualized Cost Comparison for Fred R. Rippy Lubricants

	Vanishing Oil	Vegetable Lubricant	Water Soluble Lubricant
Capital Cost	-	$3,467	-
Lubricant Cost	$2,850	$1,275	$239
Electricity Cost	-	$22,604	-
Water-Based Cleaner Cost	-	$1,200	-
Disposal Cost	-	$2,400	-
Total Cost	$2,850	$30,946	$239

Nelson Nameplate—EPA/SCAQMD Project

Nelson Nameplate is a small company with about 260 employees located in Los Angeles, California. The company manufactures nameplates from aluminum, stainless steel and brass metal. Nelson also makes membrane switches, graphic overlays and polycarbonate and acrylic windows and lenses.

IRTA began work with Nelson as part of a project sponsored by the South Coast Air Quality Management District (SCAQMD) to investigate alternative low-VOC products for vanishing oil and rust inhibitors. IRTA worked with Nelson in the past to assist the company in finding an alternative to a vanishing oil used in some of the stamping machines.

Nelson had another operation that used a vanishing oil and the company and IRTA decided to test alternatives in that operation. Nelson uses a vanishing oil called Magnudraw Vanishing Oil to lubricate a cutting blade that is used to cut adhesive backed paper. An MSDS for the Magnudraw product is shown in Appendix A. A picture of the cutting blade is shown in Figure 2-15.

The purpose of the vanishing oil is to provide lubricity so the adhesive backed paper can be cut. Another purpose is to dissolve adhesive residue that can build up on the blade as cutting proceeds. A suitable alternative would have to meet these same standards.

Figure 2-15. Cutting Blade at Nelson Nameplate

IRTA tested a vegetable based material called Soy Gold 2500 with Nelson in the blade operation. An MSDS for this product is shown in Appendix A. This product performed well in short term initial testing. IRTA provided a larger quantity of the Soy Gold 2500 to Nelson and it continued to perform well during the longer term testing.

Nelson currently uses 30 gallons per year of the Magnadraw oil in the blade cutting operation. The cost of the high VOC oil is $9.76 per gallon. On this basis, the cost of using the oil in the cutting operation amounts to $293 annually.

During the testing, Nelson indicated that they used the same amount of the Soy Gold 2500. Assuming Nelson would purchase the soy in five gallon containers, the cost of the alternative low-VOC material would be $12.50 per gallon. On this basis, the annual cost of using the soy in the cutting operation would amount to $375.

Table 2-8 presents the annualized cost comparison of the vanishing oil used currently by Nelson and the alternative low-VOC soy product. The figures show that the cost of using the low-VOC material is 28 percent higher than the cost of using the vanishing oil.

Table 2-8
Annualized Cost Comparison for Nelson Nameplate Cutting Blade Lubricants

	Vanishing Oil	Soy Gold 2500
Lubricant Cost	$293	$375
Total Cost	$293	$375

Winders & LeBlanc Inc.

Winders & LeBlanc is a small company located in Cudahy, California. The company offers metal stamping and wire forming services to a range of different customers. Winders feeds steel, galvanized steel and aluminum wire to machines where the wire is formed into parts. A picture of one of the coils of wire is shown in Figure 2-16.


Figure 2-16. Feed Wire Coil at Winders & LeBlanc

Winders has traditionally used a vanishing oil called Ozonic 203 to provide some lubricity to the wire fed to the machines and to prevent rusting of the parts after they are formed. An MSDS for this product is shown in Appendix A. The vanishing oil leaves only a minimal residue on the parts.

IRTA began work with Winders as part of a project sponsored by the South Coast Air Quality Management District (SCAQMD) to investigate alternative low-VOC products for vanishing oil and rust inhibitors. The company has several machines and Winders and IRTA decided to work on alternatives to the vanishing oil for the machine that forms the fence ties. A picture of some of the fence ties is shown in Figure 2-17.


Figure 2-17. Fence Ties Manufactured at Winders & LeBlanc

The wire that is fed to the machine used to make the fence ties is lubricated with a cloth immersed in a small container of the vanishing oil. IRTA began testing with vegetable based lubricants because they have very low VOC content. The vegetable based lubricants were not successful because they were too oily and made the wire slip so it could not advance to the forming step.

IRTA then tested acetone and various acetone blends with small amounts of mineral spirits and water-based rust inhibitors at various concentrations in water. When a material performed successfully on the machine, the parts were collected and set outside under eaves to test for rusting. In all cases, parts formed with the baseline vanishing oil used currently were set outside with the alternatives. An alternative was judged to be successful if it provided as much as or more rust protection as the Ozonic 203.

The acetone and acetone/mineral spirits blends performed acceptably on the machine but did not provide sufficient rust protection. Several other water-based rust inhibitors that were tested also did not provide adequate rust protection. One product, Nocor E6, worked well on the machine and provided better rust protection than the baseline material. An MSDS for this product is shown in Appendix A.

IRTA tested the Nocor E6 at various concentrations in water. At 25 and 15 percent concentration, the material left too much of a residue on the parts and this was not acceptable. At 10 percent and five percent, the material left an acceptable level of residue. IRTA provided the company with a gallon of the material and it was used for a few days in scaled up testing. The product performed well in this testing.

Winders uses 600 gallons annually of Ozonic 203, the vanishing oil, for the fence tie machine. The cost of the product is $4.67 per gallon. On this basis, the annual cost of using the vanishing oil amounts to $3,082.

Although the company could use the alternative rust inhibitor at a five percent concentration, IRTA evaluated the cost of using it at 10 percent concentration to be conservative. During the scaled up testing, the technician indicated that about the same amount of the Nocor E6 and the vanishing oil were needed to process the parts. Under this assumption, 66 gallons of Nocor E6 would be required annually. The cost of the material is $13.24 per gallon. The annual cost of using the Nocor E6 would be $874.

Table 2-9 presents the annualized cost comparison of the vanishing oil used currently by Winders and the alternative low-VOC Nocor E6 product. The cost of using the low-VOC alternative is three and a half times less than the cost of using the vanishing oil. If the alternative product were used at a five percent concentration, the cost would be seven times lower.

Table 2-9
Annualized Cost Comparison for Winders & LeBlanc Inc. Lubricants

	Vanishing Oil	Nocor E6
Lubricant Cost	$3,082	$874
Total Cost	$3,082	$874

B&B Specialties, Inc.

B&B Specialties is located in Anaheim, California. The company has a 40,000 square foot manufacturing facility and employs 56 people. B&B Specialties manufactures commercial, military and aerospace fasteners or socket screws and specializes in cold forming and thread rolling. The fasteners are sold through a distribution sales network as standard and custom products. A picture of some of the fasteners made by B&B is shown in Figure 2-18.


Figure 2-18. Fasteners Manufactured at B&B Specialties

B&B uses wire in various different stainless steel and stainless steel alloy grades to make the fasteners. The first step in the process is cold heading which forms the blank. In this forming process, the wire is fed to the heading equipment. Figure 2-19 shows the wire feeding to one of B&B's machines. Cold heading involves applying force with a punch to the end of a metal blank contained in a die. In heading, a head is formed on a fastener. B&B uses a chlorinated paraffin lubricant that is not diluted with solvent for this purpose. The second step is to clean the lubricant from the formed parts. B&B uses a water-based cleaner for the parts cleaning. The third step, for one of the stainless steel types, is bead blasting. The fourth step is knurling. The fifth step is roll threading and the sixth and final step is cleaning.


Figure 2-19. Wire Feeding to Machine at B&B Specialties

As part of the process, B&B uses vanishing oil for several purposes. First, it is used to lubricate the tooling used in the forming processes. Second it is used to lubricate the wire feed when the chlorinated paraffin is too viscous. Third, it is sprayed on the die before the forming machines are operated. An MSDS for this product, called Stoddard Solvent, is shown in Appendix A. IRTA worked with B&B to test an alternative to the vanishing oil for these three applications. The company tested an alternative, a soy based product, and found it to perform well in all the applications. An MSDS for the soy product, called RP-291, is shown in Appendix A.

The company purchases 12 drums per year of the vanishing oil at $5.60 per gallon. The annual cost of purchasing the vanishing oil is $3,696. It is not clear whether less of the soy based material would be required because of its lower vapor pressure. The price of the soy product, if purchased in drum quantities, is $8.27 per gallon. Assuming for analysis purposes that the same amount of soy would be required, the annual cost to B&B of purchasing the soy would be $5,458.

Table 2-10 shows the cost comparison for the vanishing oil and the soy for B&B. The values indicate that the cost of using the low-VOC alternative are 48 percent higher than the cost of using the vanishing oil.

Table 2-10
Annualized Cost Comparison for B&B Specialties Lubricants

	Vanishing Oil	Soy Product
Oil Cost	$3,696	$5,458
Total Cost	$3,696	$5,458

Dynaflex Products

Dynaflex began manufacturing flexible exhaust connectors in 1974 in Los Angeles. Today, the company's major market is chrome stacks that are used in the heavy duty truck market. Dynaflex also manufactures a wide variety of stainless steel bellows type expansion joints used on heavy duty diesel engines for applications involving off road construction equipment, stationary engines and military equipment like the M113 tank.

As part of manufacturing commercial and military exhaust piping, Dynaflex has bending, expanding, flanging, hydraulic forming, convoluting and welding operations. The size of the tubes ranges from one-half inch to 12 inches in diameter. Many of the tubes have multiple bends at tight angles. A picture of some of the tubes processed by Dynaflex is shown in Figure 2-20.

Figure 2-20. Tubes Processed at Dynaflex.

Dynaflex brings in the raw material which is cut to the appropriate length. The tubes are formed in a hydraulic tube bender. A picture of one of the tube bending machines is shown in Figure 2-21. The employees use sticks to apply a heavy honey oil to the inside of the tubes prior to bending. This oil is not VOC emitting. The lubricant is removed with a water cleaning system. In most cases, the tubes are chrome plated or polished and they are packaged and shipped. Some of the tubes are stored at Dynaflex for up to a year before they are processed. A VOC emitting rust inhibitor is used to protect the stored tubes from corrosion. The tubes are taken from storage, cleaned and welded.

Figure 2-21. Tube Bending Machine at Dynaflex.

IRTA started work with Dynaflex as part of a South Coast Air Quality Management District (SCAQMD) project to examine and test low-VOC alternatives to high VOC rust inhibitors and vanishing oils. IRTA and Dynaflex designed a program to test alternatives to the VOC rust inhibitor used by the company currently.

An MSDS for Dynaflex's current rust inhibitor, a Chem Arrow product called Arrow 18690 Water Displacing Rust Preventative, is shown in Appendix A. A variety of alternative low-VOC rust inhibitors were tested during the project. The first test was to apply several alternative rust inhibitors and the baseline current rust inhibitor to panels and put them outside. Several of the alternatives did not perform well during this test. Two alternatives, one called Soy Gold 2000 and the other called RP 291, performed as well as the baseline rust inhibitor. MSDSs for these two products are shown in Appendix A.

Dynaflex wanted to make sure the panels that contained the two alternative rust inhibitors could be welded so a test was constructed. The panels were sand blasted to allow the rust inhibitors to penetrate into the material. Then the panels were immersed in the rust inhibitor. With the current rust inhibitor, the parts are cleaned before welding and also after welding to prevent any porosity in the weld. The results of the tests with the alternative rust inhibitors indicated that the welds were very good with no porosity and no cleaning was necessary because of the high weld temperature. Limited testing on production parts indicated that the process was effective.

IRTA analyzed the cost of using the alternative low-VOC rust inhibitors. The RP 291 is slightly lower in price than the Soy Gold 2000 so the RP 291 was selected for the analysis. Dynaflex believed, from the testing, that less of the alternative rust inhibitor would be required if it were substituted for the Chem Arrow product. The vapor pressure of the product is low, however, so IRTA decided to make the assumption that the same amount of the alternative rust inhibitor would be required.

Dynaflex currently uses one drum every two months or six drums per year of the Chem Arrow product. Assuming a drum contains 55 gallons and the cost of the current product is $6.98 per gallon, the annual cost of using the rust inhibitor amounts to $2,303. The cost of the RP 291 alternative rust inhibitor is $8.27 per gallon. Assuming the same amount of the product would be required, the cost of using the alternative rust inhibitor would be $2,729 annually.

Dynaflex indicated that there would be several benefits of using the alternative product. First, in handling the alternative product, Dynaflex believed that less of the alternative product would be required. Second, Dynaflex could avoid cleaning the parts before and after welding. This would lead to reduced cleaner purchase costs, labor costs for cleaning, utilities for running the cleaning system and disposal costs for the cleaning bath. Third, Dynaflex indicated that they could reduce shipping costs through adoption of the alternative. The shipping boxes are wet with the current lubricant and must be handled as hazardous waste. The alternative would not have this drawback. IRTA and Dynaflex were not able to quantify the benefits so they are not included in the cost analysis. As a result, the cost of using the alternative rust inhibitor is an overestimate of the actual cost.

Table 2-11 shows the annualized cost comparison for the current and low-VOC alternative rust inhibitors. The figures show that the cost of using the alternative rust inhibitor is 18 percent higher than the cost of using the current rust inhibitor. Again, this does not account for the reduced cleaning or shipping costs.

Table 2-11
Annualized Cost Comparison for Dynaflex Products Rust Inhibitors

	Current Rust Inhibitor	Low-VOC Rust Inhibitor
Rust Inhibitor Cost	$2,303	$2,729
Total Cost	$2,303	$2,729

<u>Deltronic</u>

Deltronic is a small company located in Santa Ana, California. The company manufactures thread and plug gages, optical comparators and video measurement inspection systems. Since 1955, the company has also provided services like centerless grinding and lapping to the computer, aerospace, military, medical and electrical industries. Deltronic works with various common metals as well as high strength alloy metals and exotic stainless steels. The company processes between 20,000 and 30,000 parts each month.

Many of the parts manufactured by Deltronic are made of steel. The gages are machined and Deltronic requires a rust inhibitor for the parts during subsequent processing. For many years, the company used a mineral spirits vanishing oil to provide rust inhibition for the parts. The parts were dipped in a tank containing the mineral spirits at various points during processing. A picture of this tank is shown in Figure 2-22.

Figure 2-22. Rust Inhibitor Tank at Deltronic

IRTA began work with Deltronic as part of a project sponsored by the South Coast Air Quality Management District (SCAQMD). The purpose of the project was to assist companies in testing alternative low-VOC vanishing oils and rust inhibitors. Deltronic agreed to participate in the project.

Deltronic needs to store parts on their shelves as work in process for six months to a year after grinding and the parts must not rust during that time. When IRTA began working with Deltronic, the company had already begun testing alternatives to reduce the plant's VOC emissions. Deltronic had gotten good results with an alternative product called Trim Nocor E12. An MSDS for this product is shown in Appendix A. Deltronic and IRTA tested additional alternatives that were generally water-based and vegetable based rust inhibitors. The testing involved two approaches. First, several of the water-based rust inhibitors were applied to the parts and the parts were placed in a humidity chamber. The humidity chamber accelerates the rusting and it is more convenient than waiting months to determine the results. Second, several of the water-based and vegetable based rust inhibitors were applied to the parts and the parts were placed on the shelf at Deltronic.

Two products performed well in the humidity chamber testing but did not perform well in the shelf testing. The Nocor E12 product performed better than the other water-based and vegetable based alternatives in the several months of shelf testing. Deltronic planned to continue to use this alternative. At that stage, the rust inhibitor supplier indicated that the company planned to discontinue the E12 product and that there was a replacement product called Nocor E6. An MSDS for the Nocor E6 product is shown in Appendix A. IRTA and Deltronic performed several months of shelf testing of the Nocor E12 and the Nocor E6 to compare the rust protection of the two products. There appeared to be no difference so Deltronic decided to convert to Nocor E6.

As mentioned above, Deltronic historically used mineral spirits for rust protection for the gages. Use of the mineral spirits for this purpose amounted to 100 gallons per year. The cost of the mineral spirits was $3.64 per gallon. On this basis, the annual cost of the mineral spirits amounted to $364.

Deltronic had converted to Nocor E12 and used it for 15 months during the testing of alternatives. The Nocor E12 is a water-based rust inhibitor and the company diluted it with water during use. During the 15 months the company used the material, they used 24 gallons which leads to an annual use of 19.2 gallons. The cost of Nocor E12 was $12.69 per gallon if it is purchased on a drum basis. The annual cost of the Nocor E12 amounts to $244. Because the Nocor E12 product has been discontinued, the company will use Nocor E6 instead. The cost of the Nocor E6 is $13.24 per gallon, again on a drum basis. Assuming the company would use the same amount of E6 as E12, the annual cost of the E6 is $254.

The conversion from the mineral spirits rust inhibitor to the water-based rust inhibitors would not involve any capital purchases. The same tank could be used to hold the rust inhibitor. No increase in labor cost or electricity cost would occur.

Table 2-12 presents the annualized cost comparison for the mineral spirits, the Nocor E12 and the Nocor E6. The cost of using the Nocor E6 is 30 percent lower than the cost of using the mineral spirits.

Table 2-12
Annualized Cost Comparison for Deltronic Rust Inhibitors

	Mineral Spirits	Nocor E12	Nocor E6
Rust Inhibitor Cost	$364	$244	$254
Total Cost	$364	$244	$254

Tracy Industries, Inc.

Tracy Industries is located in Whittier, California. The company remanufactures automotive engines, disk brake calipers and window lift motors. During typical production, Tracy Industries processes 65 engines and 550 calipers per day. A picture of an engine after processing is shown in Figure 2-23. A picture of several calipers is shown in Figure 2-24.

Figure 2-23. Engine After Processing at Tracy Industries, Inc.

When the assemblies, which are made of cast iron, come in from the field, they are disassembled. They are then placed in an oven at a temperature of 750 degrees F for nine hours to evaporate off the organic contamination. Then they are processed through a "wheelabrator" and blasted with steel shot to remove residual ash. A picture of the wheelabrator is shown in Figure 2-25. The parts then go through various processes. At the end of the processing, a rust inhibitor is applied to the parts to prevent rusting. The parts are then put into plastic envelopes for shipment.

IRTA began work with Tracy Industries as part of a project sponsored by the South Coast Air Quality Management District (SCAQMD). The aim of the project was to test and demonstrate alternative low-VOC vanishing oils and rust inhibitors. Tracy Industries was using a high VOC content rust inhibitor diluted with water and wanted to test alternative low-VOC rust inhibitors as part of the project.


Figure 2-24. Calipers Remanufactured at Tracy Industries, Inc.

Figure 2-25. Wheelabrator at Tracy Industries, Inc.

IRTA and Tracy Industries tested a variety of alternative rust inhibitors in the course of the project. It eventually became obvious that the success of a rust inhibitor and the quality of the blasting operation were intimately tied together. If the blasting operation removed all of the rust remaining in the micropores of the metal, then any rust inhibitor that was applied to the assembly would successfully prevent rusting. In contrast, if the blasting operation did not remove all of the rust in the metal micropores, then almost any rust inhibitor that was applied to the assembly would not keep it from rusting. This was an important conclusion because it prompted Tracy Industries to modify the blasting operation so it could more effectively remove all traces of rust from the assemblies. A picture of calipers returned to the wheelabrator for additional blasting (because of rust) is shown in Figure 2-26.

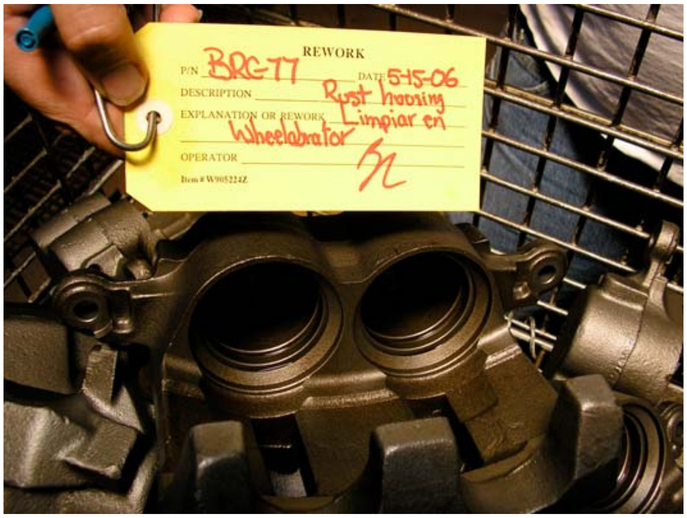

Figure 2-26. Calipers Returned to Wheelabrator at Tracy Industries, Inc.

Tracy Industries and IRTA also tested a rust remover that the company could use in the event that the blasting operation was not completely effective in eliminating the micropore rusting. An MSDS for this product is shown in Appendix A. Although the company is still using the original rust inhibitor, this rust remover could serve as a low-VOC alternative.

The cost analysis involves comparing the use of the original rust inhibitor and the less aggressive blasting operation on the one hand with the use of the rust remover and the more aggressive shot blasting process on the other hand. With the new processes, there has been a change in the electricity cost, the labor cost and the steel shot cost. The analysis also includes a comparison of the cost of the original rust inhibitor and the rust remover.

The original rust inhibitor was used in a 10 percent concentration in water. Tracy Industries uses 220 gallons per year of the material. Assuming a cost of $10 per gallon for the product, the annual cost of using the rust inhibitor amounts to $2,200. The new product, the rust remover, would be used at a concentration of 100 percent. Tracy estimates that the only loss is through dragout of about one gallon per day. Assuming the company operates five days per week and 52 weeks per year, use of the rust remover would be 260 gallons per year. At a cost of $7 per gallon, the cost of using the rust remover would be $1,820 annually.

The optimization of the steel shot blasting operation resulted in several changes. The volume of steel shot required has decreased from 13,636 pounds per year to 10,938 pounds per year. The price of the shot has declined from $3.20 per pound to $1.10 per pound. The annual cost of using the steel shot was about $43,635 in the past; it now amounts to about $12,032.

In the past, Tracy Industries blasted each group of parts for 10.4 minutes. With the new procedure, the blast time for each group now amounts to eight minutes. This reduction in blasting time has reduced the labor and the electricity requirements. Tracy Industries estimates that the new process has led to a 15 percent decrease in labor. Assuming a labor rate of $14 per hour and that the worker previously worked eight hours per day five days per week and 52 weeks per year on the blasting operation, the annual blasting labor cost was $29,120. With the new process, the labor cost is $24,752 annually.

The blasting equipment uses two 25 horsepower motors. These motors operated for 10.4 minutes per cycle during the original blasting operation. This translates to about five cycles or 52 minutes per hour. Assuming an eight hour work day, the motors were operated for 6.93 hours per day. The cycle time is now shorter at eight minutes, 77 percent of the original cycle time. Thus the motors now operate for 5.33 hours per day. Assuming an electricity cost of 12 cents per kW, the electricity cost of blasting was $8,065 originally and is now lower at $6,203.

Table 2-13 shows the annualized cost comparison for the operation before and after the shot blasting and rust processes were changed. The figures show that the cost of the operation with optimized blasting procedures and use of the rust remover is 46 percent lower than the cost of the operation with the original blasting procedures and use of the rust inhibitor.

Table 2-13
Annualized Cost Comparison for Tracy Industries, Inc. Rust Inhibitors

	High VOC Rust Inhibitor	Low VOC Rust Remover
Rust Inhibitor/Remover Cost	$2,200	$1,820
Steel Shot Cost	$43,635	$12,032
Labor Cost	$29,120	$24,752
Electricity Cost	$8,065	$6,203
Total Cost	$83,020	$44,807

Robinson Helicopter Company

Robinson Helicopter is located in Torrance, California. The company has 1,200 employees and is currently the world's leading producer of civil helicopters. The company manufactures small two and four seat helicopters for corporations and individuals and also provides parts and accessories, engine overhauls and helicopter repairs.

IRTA began work with Robinson on a project sponsored by the South Coast Air Quality Management District (SCAQMD). The aim of the project was to test and demonstrate alternative low-VOC vanishing oils and rust inhibitors.

IRTA worked with Robinson on three different types of operations. The first operation is spring/coil lubrication. Robinson currently uses an aerosol based vanishing oil called LPS 2 Industrial Strength Lubricant to lubricate a coil that is sealed in an outer casing. The MSDS for LPS 2 is shown in Appendix A. A picture of the coil is shown in Figure

2-27. The Robinson employees lubricate the coil before sealing it in an outer casing and they operate the coil to determine if the lubricant is effective. If the coil is not lubricated sufficiently, it will make a noise; if it is lubricated properly, it does not make a noise.

Figure 2-27. Coil at Robinson Helicopter Co.

IRTA tested several alternatives with Robinson and all of them performed well. IRTA compared the cost of one of these, a vegetable based material called Soy Gold 2500, as the low-VOC alternative to the LPS 2 vanishing oil in the spring coil operation. An MSDS for this alternative is shown in Appendix A. Robinson currently uses one can of the LPS 2 annually for spring coil lubrication. The cost of the vanishing oil is $4.66 per 16 ounce can. The cost of the alternative, Soy Gold 2500, is $12.50 per gallon. Assuming 16 ounces of the Soy Gold 2500 would be required, the annual cost of the alternative would be $1.56.

Table 2-14 presents the cost comparison for the spring coil operation. The figures show that the cost of using the alternative is lower than the cost of using the vanishing oil.

Table 2-14
Annualized Cost Comparison for Spring Coil Operation at Robinson Helicopter

	Vanishing Oil	Vegetable Lubricant
Lubricant Cost	$4.66	$1.56
Total Cost	$4.66	$1.56

The second operation IRTA and Robinson worked on was general rust inhibition for steel in the plant. Several fixed tools in the form of steel blocks must be maintained with a rust inhibitor regularly. The employees apply the rust inhibitor to the tools in a spray bottle. Robinson currently uses LPS 2 Industrial Strength Lubricant for this purpose. Initial alternatives testing was conducted by fabricating seven steel panels and placing them in a clean, dry area in the plant for about two weeks. Two vanishing oils used by Robinson were tested. These included LPS 2 and LPS 3 Heavy Duty Rust Inhibitor. An MSDS for the LPS 3 product is shown in Appendix A. The other five panels were covered with various alternative low-VOC materials. The best performing lubricant was

LPS 3 but the company uses LPS 2 for this operation. The LPS 2 panel had some evidence of rust after the two week period. The best performing alternatives, which had mild rust, were a 50 percent and 25 percent concentration of a water-based rust inhibitor called NOCOR E6. IRTA provided a larger amount of the 50 percent mixture of NOCOR E6 to the employees and they used it for a few weeks. It performed well and appeared to provide good rust protection for the steel tools.

Robinson uses 414 cans per year of LPS 2 as a rust inhibitor for the steel tool surfaces annually. Assuming the cost of a six ounce can is $4.66, the annual cost of using this rust inhibitor is $1,929. The cost of the low-VOC alternative, NOCOR E6, is $13.64 per gallon. Assuming the same amount of the alternative would be required and that it is diluted by 50 percent with water, 26 gallons of the NOCOR product would be required. The annual cost of the alternative is $355.

Table 2-15 shows the cost comparison of the rust inhibitors for the steel tooling. The values show that the cost of using the low-VOC rust inhibitor is 5.4 times lower than the cost of using the current product.

Table 2-15
Annualized Cost Comparison for Maintenance of Steel Tooling at Robinson Helicopter

	High VOC LPS 2 Rust Inhibitor	Low-VOC NOCOR E6 Rust Inhibitor
Rust Inhibitor Cost	$1,929	$355
Total Cost	$1,929	$355

The third operation IRTA and Robinson worked on was corrosion inhibition of aluminum contacts in the wiring system of the helicopters. Robinson uses LPS 3 Heavy Duty Rust Inhibitor for this purpose. To simulate this operation, IRTA and Robinson prepared aluminum panels treated with LPS 2, LPS 3 and five potential alternatives. After 144 hours, the LPS 2 showed evidence of corrosion but LPS 3 did not. All of the alternatives showed some evidence of corrosion. Only mild corrosion was found on one of the alternatives, the NOCOR E6 at a 50 and 25 percent concentration in water. IRTA and Robinson decided to conduct additional salt spray chamber testing with LPS 3 and two alternative low-VOC materials, NOCOR E6 at 50 percent and at 100 percent. After about 10 weeks, none of the panels had any evidence of corrosion. All three of the rust inhibitors performed exceptionally well in this test.

IRTA compared the cost of using the LPS 3 with the cost of using the 50 and 100 percent concentrations of the low-VOC rust inhibitor. Robinson estimates that 182 cans of LPS 3 are used each year for rust inhibiting the aluminum contacts. The cost of the LPS 3 is $5.99 per 16 ounce can. On this basis, the cost of using the LPS 3 is $1,090 annually. The cost of the NOCOR E6 is $13.64 per gallon. Assuming the same volume (22.75 gallons) of the 100 and 50 percent product would be required, the annual cost of the 100 percent NOCOR E6 would amount to $310 and the annual cost of the 50 percent product would be $155.

Table 2-16 shows the annualized cost comparison for the aluminum corrosion inhibition operation. The values show that the cost of using the low-VOC alternatives is much lower than the cost of using the current product.

Table 2-16
Annualized Cost Comparison for Aluminum Wiring Corrosion Protection at Robinson Helicopter

	High VOC LPS 3 Corrosion Inhibitor	Low-VOC 100% Corrosion Inhibitor	Low-VOC 50% Corrosion Inhibitor
Rust Inhibitor Cost	$1,090	$310	$155
Total Cost	$1,090	$310	$155

Robinson Helicopter Company found this study to be both interesting and educational.

III. HEALTH AND ENVIRONMENTAL CHARACTERISTICS OF LUBRICANTS, VANISHING OILS AND RUST INHIBITORS

This section focuses on the VOC content and the toxicity of some of the original materials used by the facilities participating in the project and some of the alternatives that IRTA and the facilities tested. The Department of Health Services Hazard Evaluation System & Information Service (HESIS) performed the toxicity evaluation based on the MSDSs for the products.

VOC Content of Original and Alternative Materials

The SCAQMD laboratory is testing some of the original products and some of the alternative products for VOC content. Some of the lubricants and rust inhibitors have a very high VOC content. A test like EPA Test Method #24 is an appropriate way to test the VOC content of these high VOC products. In contrast, this test method is not appropriate for testing the VOC content of water-based or very low vapor pressure lubricants or rust inhibitors. Another method based on gas chromatography/mass spectrometry (GC/MS) is the method that should be used for these materials. The results of the SCAQMD laboratory analysis were not completed in time to include them in this report.

Comments about the VOC content of some of the products can be made even without the results of the laboratory testing. Very few of the MSDSs in Appendix A list a VOC content for the products. In some cases, the MSDSs provide a value for “percent volatile.” In many cases, however, the supplier dilutes the product with mineral spirits or kerosene before it is shipped or the user dilutes it before it is used. An example is the Sunnen products used at Fortner Engineering and Hydro-Aire. IRTA discussed the VOC content of this honing oil with the Sunnen chemist and he indicated that the company dilutes the products to 50 percent honing oil and 50 percent mineral spirits. Thus the VOC content of the product is likely to be in the neighborhood of 300 to 350 grams per liter when it is used even if the honing oil itself has zero VOC content.

The vanishing oils used at Nelson Nameplate, Fred Rippy, Winders & LeBlanc and B & B Specialties are virtually 100 percent VOC; this implies they would have a VOC content in the neighborhood of 650 grams per liter. The MSDS for the LPS 3 aerosol product used at Robinson Helicopter as a rust inhibitor lists a VOC content of 577 grams per liter for the material.

The alternative vegetable based products that were tested and, in some cases, adopted by the participating facilities are likely to have minimal VOC content. The VOC content of three products that were tested, Soy Gold 2000, Soy Gold 2500 and RP-291, was evaluated by the SCAQMD lab. All three products have a VOC content less than 25 grams per liter. Other vegetable based materials were adopted and/or tested at S&H Machine, Nelson Nameplate, Fortner, Hydro-Aire and Weldcraft. Although the VOC content for these materials is unknown, it is likely to be low since these materials are similar to the other vegetable based materials that have been tested.

Alternative water-based lubricants were tested at several facilities including S&H Machine, Fred Rippy, Winders & LeBlanc, Deltronic, Tracy Industries and Robinson Helicopter. These products were generally used in diluted form. At Fred Rippy, for instance, the NOCOR S2 was diluted to 95 percent water and five percent of the product. At Robinson Helicopter, the NOCOR E6 was diluted to 75 percent water and 25 percent of the product. Thus, even if the product concentrate has a high VOC content, the VOC content of the product when it is used would be relatively low.

Toxicity of Original Products

As mentioned above, HESIS examined the toxicity of some of the materials used by the participating facilities based on the ingredients listed on the MSDSs. This subsection summarizes the HESIS evaluation.

The vanishing oils used by B & B Specialties and Fred Rippy both contain Stoddard solvent. This solvent is a mixture of straight and branched chain paraffins, naphthenes and aromatic hydrocarbons. Consistent with other organic solvents, it is a central nervous system toxicant and a skin and respiratory tract irritant. Overexposure to solvent based lubricants and rust inhibitors affects the central nervous system (brain), causing nausea, dizziness, clumsiness, drowsiness and other effects like those of being drunk. Overexposure for months or years can cause long-lasting and possibly permanent damage to the nervous system, known as toxic encephalopathy. The symptoms of long-term health effects include fatigue, sleeplessness, poor coordination, difficulty in concentrating, loss of short-term memory and personality changes such as depression, anxiety and irritability. Solvent based products can also irritate the eyes, nose, throat and skin. Skin contact can cause dermatitis. The American Governmental Industrial Hygienists (ACGIH) Threshold Limit Value (TLV) of 100 ppm is set to minimize ocular and dermal irritation, de-fatting of the skin, nausea, narcosis and possible kidney damage. There is no Cal/OSHA Permissible Exposure Limit (PEL) for Stoddard solvent.

Magnadraw Vanishing Oil, used by Nelson Nameplate, is composed primarily of solvent naphtha (petroleum), heavy alkylate. The toxicity of this material is consistent with that of other organic solvents like Stoddard solvent described above. There is no ACGIH TLV for this chemical and it is not regulated by Cal/OSHA.

LPS 2 and LPS 3, the aerosol products used by Robinson Helicopter, contain distillates (petroleum), hydrotreated light and petroleum oil as major ingredients. Again, these materials would have the same solvent toxicity as Stoddard solvent described above. The two chemicals do not have ACGIH TLVs or Cal/OSHA PELs.

Ozonic 203, used by Winders & LeBlanc, contains heavy normal paraffins (petroleum). No toxicity information is available on this chemical but the potential health hazards should be consistent with the solvent toxicity described for Stoddard solvent above. There is no ACGIH TLV or Cal/OSHA PEL for the chemical.

The major ingredients in the rust inhibitor used by Dynaflex, Arrow 18690, are solvent naphtha (petroleum), medium aliphatic and distillates (petroleum), hydrotreated light. These materials have the general solvent toxicity as discussed above for Stoddard solvent. The primary adverse health effects of inhalation overexposure are on the central nervous system and the respiratory system. Skin exposure can cause dermatitis. Solvent naphtha (petroleum), medium aliphatic has been tested by the National Toxicology Program and the results indicate that it is not reasonably anticipated to cause cancer in humans. There was some evidence of cancer in male rats, no evidence in female rats, no evidence in male mice and equivocal evidence in female mice. None of the chemicals in this product is regulated by Cal/OSHA and none has an ACGIH TLV.

<u>Toxicity of Alternative Products</u>

HESIS evaluated the toxicity of Soy Gold 2500 and RP-291, two of the vegetable based materials tested as alternatives at Nelson Nameplate, Robinson Helicopter, B & B Specialties and Dynaflex. These materials contain fatty acid esters and there are no hazardous ingredients listed on the MSDS. Fatty acid esters have low volatility and they are lower in toxicity than other organic solvents.

NOCOR E6 is the alternative tested at Winders & LeBlanc, Deltronic and Robinson Helicopter. This material contains petroleum oil. The American Petroleum Institute's (API's) submission to the EPA High Production Volume Challenge Program indicates that this CAS number corresponds to crude oil. According to API, it is "a complex mix of hydrocarbons." It consists predominantly of aliphatic, alicyclic and aromatic hydrocarbons. It may also contain small amounts of nitrogen, oxygen and sulfur compounds. It encompasses light, medium and heavy petroleums as well as oils extracted from tar sands. Data submitted by API indicate that the chemical composition of crude oils can vary widely depending on their origin. For example, the aromatics content can be as high as 50 percent. API submitted existing toxicity data and plans to conduct chronic toxicity studies. The symptoms and health effects of the material are consistent with solvent toxicity. There is no Cal/OSHA PEL and no ACGIH TLV for the material.

NOCOR S2, which was tested by Fred Rippy, contains 10 to 20 percent triethanolamine and one to 10 percent monoethanolamine. Triethanolamine has been identified as causing occupational asthma by the Association of Environmental and Occupational Health Clinics. The ACGIH TLV of five milligrams per meter cubed is based on minimizing the potential for eye and skin irritation, contact dermatitis and triethanolamine induced injury to the liver, kidneys and nerve fibers seen in test animals. The Cal/OSHA PEL is the same as the TLV. Based on cancer tests conducted in mice, the National Toxicology Program concluded that triethanolamine caused liver tumors in female mice and may have caused a slight increase in hemangiosarcomas of the liver in male mice. Monoethanolamine is an eye and skin irritant in animals and the ACGIH

TLV of three ppm was set to minimize skin and eye irritation in workers. The Cal/OSHA PEL for monoethanolamine is the same as the TLV.

NOCOR E6 and NOCOR S2 are water-based lubricants. Both materials have some toxicity, particularly NOCOR S2, which is a carcinogen. The NOCOR E6 was diluted with water during the testing to between 10 and 25 percent. Using the material in dilute form should reduce the toxicity. The NOCOR S2 was diluted to five percent during the testing. The concentration of triethanolamine, the carcinogen, in the diluted material would be no more than one percent. Again, the toxicity would be minimized. Even so, it would be preferable if the NOCOR S2 were reformulated to eliminate triethanolamine.

Conclusions on Toxicity

In general terms, the alternatives that were tested by IRTA during this project are fatty acid esters and water diluted materials. The fatty acid esters are lower in toxicity than other organic solvents. The water diluted materials are generally used at low concentrations so their toxicity is minimized. With the exception of NOCOR S2, which contains a carcinogen, the alternatives are generally lower in toxicity than the original lubricants and rust inhibitors used by the participating facilities.

IV. SUMMARY AND CONCLUSIONS

This document presents the results of two projects that focused on low-VOC, low toxicity alternatives to the high VOC lubricants, vanishing oils and rust inhibitors used today. One of the projects was sponsored by EPA and the other was sponsored by EPA and SCAQMD. The EPA project involved identifying, testing and demonstrating alternatives for lubricants and the EPA/SCAQMD project involved identifying, testing and demonstrating alternatives for vanishing oils and rust inhibitors.

During the two projects, IRTA worked with 12 facilities in the South Coast Basin that use metal working fluids in their operations. IRTA tested alternatives with the 13 facilities in 15 different operations where VOC emitting products were used. IRTA found effective alternatives in all cases. The low-VOC alternatives were generally vegetable based or water-based products. IRTA analyzed the costs of using the current products and compared them to the cost of using the alternative products. The SCAQMD lab is analyzing the VOC content of some of the current and alternative products. HESIS assisted IRTA in evaluating the toxicity of the current and alternative products.

Table 4-1 summarizes the results of the tests of the alternative metal working fluids. The operations represent a range of different types of processes that use lubricants, vanishing oils and rust inhibitors. The table indicates that most of the alternatives that proved to be effective are vegetable based. Some of the alternatives that performed well were water-based products. Five of the facilities, S&H Machine, Nelson Nameplate, Fortner, Hydro-Aire and Deltronic, converted to the low-VOC alternatives.

IRTA conducted a cost analysis and comparison of the current and alternative metal working fluids. The results indicated that the costs would increase for five of the participating facilities/operations in Table 4-1 and that the costs would be reduced for the other facilities/operations.

The VOC content of a few of the vegetable based alternative products in Table 4-1 is less than 25 grams per liter. The VOC content of the other vegetable based products, since they are similar, is likely to be very low as well. The water-based products are most often diluted with water when they are used; as a consequence, the VOC content of these products is also likely to be low. The SCAQMD lab is testing the VOC content of some of the current and alternative products but the results were not completed in time to include them in this report.

HESIS assisted IRTA in evaluating and comparing the toxicity of the current and alternative products based on their MSDSs. In general, the alternatives appear to be lower in toxicity than the high VOC products with one exception. The exception is a product which contains a small amount of a carcinogen and it would be preferable if it were reformulated to exclude this component.

Table 4-1
Results of the Metal Working Fluids Alternatives Projects

Company	Metal Working Fluid Type	Alternative(s)
S&H Machine, Inc.	Lubricant—Machines	Water-Based, Vegetable Based
Nelson Nameplate	Lubricant, Stamping	Vegetable Based
	Vanishing Oil--Stamping	Vegetable Based
	Vanishing Oil--Cutting	Vegetable Based
Fortner Engineering and Manufacturing, Inc.	Lubricant--Honing	Vegetable Based
Hydro-Aire	Lubricant--Honing	Vegetable Based
Weldcraft	Lubricant--Machines	Vegetable Based
Fred Rippy	Vanishing Oil—Stamping	Water-Based, Vegetable Based
Winders & LeBlanc, Inc.	Vanishing Oil--Forming	Water-Based
B & B Specialties, Inc.	Vanishing Oil--Machines	Vegetable Based
Dynaflex Products	Rust Inhibitor	Vegetable Based
Deltronic	Rust Inhibitor	Water-Based
Tracy Industries, Incl.	Rust Inhibitor	Water-Based
Robinson Helicopter Co.	Lubricant--Testing	Vegetable Based
	Rust and Corrosion Inhibitor	Water-Based

Many companies in the Basin are using high VOC metal working fluids. The results of the field testing and analysis demonstrate that these companies can convert to alternative metal working fluids that are vegetable or water-based products.