An AMERICAN RESEARCH PRODUCTS White Paper

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PRACTICAL APPLICATION OF NON-CHLORINATED ULTRA LOW VOC METALWORKING FLUIDS USING RENEWABLE RESOURCE BASED TECHNOLOGY

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Introduction

The use of chlorinated paraffin as extreme pressure additives in metalworking fluids has experienced a long history and established CP's as a highly effective additive in many applications. In particular, CP's have shown great usefulness in applications involving the most difficult materials to work such as Inconel and various grades of Stainless Steel or other well known metals of low machinability.

However, CP's also have long been targeted by many state and federal agencies. Among these are The United States Environmental Protection Agency and the State of California EPA. These agencies may restrict the use of CP's in metalworking fluids due to the environmental, health and safety risks associated with such products.

In 2007, The California "Green Chemistry Initiative" (AB 1879 & SB 509) was signed into law. The law seeks to identify and remove substances deemed toxic or harmful to the environment or which present a health risk. It also promotes the development of safer technology based on sustainable resources as viable replacements and alternatives. The California Department of Toxic Substance Control (DTSC) has been charged with the task of assembling a list of chemicals and substances for elimination or restriction.

In addition, The South Coast Air Quality Management District proposed Rule 1144 establishing limits on metalworking products restricting the emission level of volatile organic compounds found in such products. VOC's contribute to air pollution and smog. Rule 1144 was adopted and passed by the Governing Board of Supervisors on July 9th, 2010.

Clearly, we can be reasonably certain there is a need for new technology to enter into the marketplace. This new technology must meet the requirements of any law or regulation and provide industrial manufacturers with cost effective alternatives which provide the same level of performance as that of conventional chlorinated products or those which are found to contain excessive VOC emissions.

It should be acknowledged, there are available products commonly referred to as "bio based" that perform well. These products generally are quite expensive in comparison with conventional products currently in use. It should also be noted that most of the bio-based products were initially developed for minimum quantity lubrication applications or MQL. In these applications small quantities are applied to the tool piece working area rather than flooding the tool. In these applications they work remarkably well and can be cost justified. In applications that require flooding of the work they are highly cost prohibitive and thus are not viable alternatives.

American Research Products Inc.

American Research Products Inc. is a manufacturer and supplier of metalfinishing and metalworking products. Located in Southern California we naturally have a vested interest in supplying the local manufacturing community with performance proven and full regulatory compliant products. Early in 2009, we recognized the emerging needs outlined in the introduction and engaged in development efforts with a focus on bio-based raw materials.

Furthermore, such materials would be sourced to the extent possible from domestic suppliers. This paper will detail our technology development and field test results of a broad product line based on renewable and sustainable resources.

Our design charter was specifically developed with the following requirements.

Primary Requirements

- Free of Chlorinated Paraffin.
- 50 grams per liter VOC or less.
- Flashpoint 400 degrees Fahrenheit or greater.
- Cost competitive on a unit cost basis with conventional products.
- Field tests must attain equal performance to incumbent competitive products.

Secondary Requirements

- Multiple Domestic Sources of Raw Materials Identified.
- Meet Federal Guidelines for Bio-Based Products.
- Meet Low Toxicity, Non Hazardous DOT Standards.

Case Study # 1 AF, Bio-Based Straight Oil

Field Trial #1: Start Date: October, 2009

Company: Aerospace Fasteners, Southern California
Industry: Aerospace Fasteners
Part Description: Cold Formed Nut
Application: Tapping four sizes: 10/32.....1/4-28.....5/16-18.....3/8-24
Make/Model: Vibratory Fed, Automatic Tapper
Tooling: 3 flute straight cut HSS, titanium nitride coated
Material: Aluminum 7050 Grade
Competitive Product: Brand X

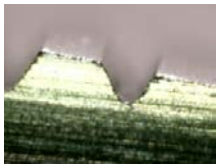
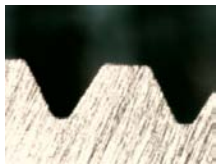
Process Description

Material worked in this manufacturing cell is of aluminum alloy grade 7050 and has been formed by cold heading to a typical hex nut configuration. Cold formed parts are then pre-drilled and moved to tapping. Parts are tapped in various thread diameters using Ti-nitride coated three flute cut taps

Application Details

The operation is high speed automatic tapping No change in program, tooling or setup. Machine was charged with Bio-Based Oil. Parts are cold headed and pre-drilled. Fed by vibratory feeder parts are tapped automatically. Cutting oil is applied via flood method. Parts are inspected by operator visually under magnification and checked by certified go and no-go gauge. Parts are also inspected by bi-section at 50x - 100x magnification for thread profile. Production rates up to 10,000 parts per shift. Taps are changed under SOP routinely at 10,000 per tap. However, one shift ran out to 13,400 parts for trial data purposes logging an increase of 30%.



TOTAL PRODUCTION: 876,000

Cost Analysis

Conventional Oil Unit Cost Calculation
gals x $13.50 p.g / Units Produced
60 gal x $13.50 = $810.00 / 876,000 = **$0.00092**

Bio Based Oil Unit Cost Calculation
gals x $14.00 p.g / Units Produced
60 gal x $14.00 = $840.00 / 876,000 = **$0.00095**

Conclusion: Successful. Results indicate equal performance and cost. Excellent surface finish and thread profile. Potential for improved tool life.

Case Study # 2 AF, Bio-Based Straight Oil
Field Trial #2: Start Date: March, 2009
Company: Aerospace Fasteners, Southern California
Industry: Aerospace Fasteners
Part Description: Collars, Sleeves, Spherical Washers
Application: Multi Spindle Screw Machine
Make/Model: Acme Gridley, RA-6
Tooling: Carbide, HSS Titanium Nitride coated
Material: Titanium Grade 5 and Grade 9
Competitive Product: Brand X

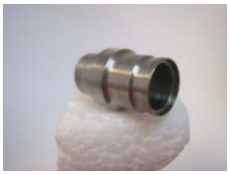
Process Description

The operation is automatic screw machine. Material worked is Titanium Grades 5 and 9. Bar stock material is feed into the machine spindles and at each tool station a specific metal removal operation is performed. Tools consist of form tools, drills, broaches, reamers, chamfering, cut-off etc. Any number of tool stations may be employed with as many as 24 tools involved in a progressive machining operation. Cutting oil is supplied in high volume via flood delivery.

Application Details

The trial machine is an Acme Gridley RA-6. This is an older style machine in which ingression of lubricating oil is typical. The Bio-Based Oil is formulated to be used as the lubricating oil and cutting oil to avoid any degradation of performance. Machine was charged with BBO. No changes in tooling, speeds or feed rates. Normal tool life was recorded on all stations with drills logging 120,000 parts per drill. Operators did report and log fewer (1-2) adjustments were required on the parting or cut-off tool. This tool normally would require 3-4 adjustments per shift due to wear.



TOTAL PRODUCTION: 502,000

Cost Analysis

Brand X Oil Unit Cost Calculation
gal x $14.00 p.g / Units Produced
220gal x $14.00 = $3080.00 / 502,000 = **$0.0061**

Bio-Based Oil Unit Cost Calculation
gal x$14.00 p.g / Units Produced
220gal x $14.00 = $3080.00 / 502,000 = **$0.0061**

Conclusion: Successful. Results indicate equal performance and cost. Excellent surface finish and part quality. Potential for improved tool life.

Case Study # 3 AF, Bio-Based Straight Oil

Field Trial #3: Start Date: March, 2009

Company: Aerospace Fasteners, Southern California
Industry: Aerospace Fasteners
Part Description: Cold Formed Nut
Application: Tapping four sizes: 5/8”-18.....3/4”-16.....1”-12
Make/Model: Speedy Cut Manual Feed, Automatic Tapper
Tooling: 4 flute straight cut HSS, titanium nitride coated
Material: Inconel 718, A286 Stainless Steel, Wastalloy
Competitive Product: Brand X

Process Description

Materials worked in this manufacturing cell are some of the most difficult to machine materials. Inconel 718, A286 S.S and Wastalloy formed by cold heading to a typical hex nut configuration. These materials are known to work harden during forming and must be solution heat treated to reduce the hardness level for subsequent drilling and tapping. Cold formed parts are pre-drilled and moved to tapping. Parts are tapped in various thread diameters using Ti-nitride coated 4 flute cut taps

Application Details

The operation is performed by manually loading parts into the automatic tapping machine. No change in program, tooling or setup. Machine was charged with Bio-Based Oil. Parts are cold headed and pre-drilled. Cutting oil is applied via flood method. All Parts are inspected by operator visually under magnification and checked by certified go and no-go gauge. Parts are also inspected by bi-section at 50x - 100x magnification for thread profile. Production rates up to 1000 parts per shift. Taps are changed when inspection indicates poor thread profile, roughness or gauge check.

TOTAL PRODUCTION: 2,441

Cost Analysis

Brand X Oil Unit Cost Calculation
gals x $13.60 p.g / Units Produced
40gal x $13.60 = $544.00 / 2441 = **$0.223**

Bio-Based Oil Unit Cost Calculation
gals x $14.00 p.g / Units Produced
40gal x $14.00 =$560.00 / 2441 = **$0.229**

Amerilube 40 Tapping Test A286 & Inconel 718				
Date: 10/29/2010 THRU 11/15/2010				
Date	**Size**	**Tap**	**Material**	**# of Parts**
29-Oct	5/8 18	H9 4FL	A286	186
5-Nov	5/8 18	H9 4FL	A286	63
5-Nov	5/8 18	H9 4FL	A286	113
5-Nov	5/8 18	H9 4FL	A286	55
5-Nov	5/8 18	H9 4FL	A286	55
6-Nov	5/8 18	H9 4FL	A286	190
6-Nov	5/8 18	H9 4FL	A286	112
			Total parts	**774**
			Avg P.Per Tap	**258**
8-Nov	3/4 16	H11 6FL	Inconel	84
8-Nov	3/4 16	H11 6FL	Inconel	77
8-Nov	3/4 16	H11 6FL	Inconel	78
8-Nov	3/4 16	H11 6FL	Inconel	76
8-Nov	3/4 16	H11 6FL	Inconel	146
8-Nov	3/4 16	H11 6FL	Inconel	27
9-Nov	3/4 16	H11 6FL	Inconel	90
9-Nov	3/4 16	H11 6FL	Inconel	52
9-Nov	3/4 16	H11 6FL	Inconel	50
9-Nov	3/4 16	H11 6FL	Inconel	120
9-Nov	3/4 16	H11 6FL	Inconel	107
9-Nov	3/4 16	H11 6FL	Inconel	115
			Total parts	**1022**
			Avg P.Per Tap	**511**
12-Nov	5/8 18	H9 4FL	A286	100
12-Nov	5/8 18	H9 4FL	A286	100
12-Nov	5/8 18	H9 4FL	A286	100
15-Nov	5/8 18	H9 4FL	A286	200
15-Nov	5/8 18	H9 4FL	A286	30
15-Nov	5/8 18	H9 4FL	A286	115
			Total parts	**645**
			Avg P.Per Tap	**322**

Conclusion: Successful. Results indicate equal performance and cost. Tool life and average part per tap statistically equal to historical performance using petroleum based chlorinated cutting oil.

Case Study # 4 AMF, Bio-Based Soluble Oil

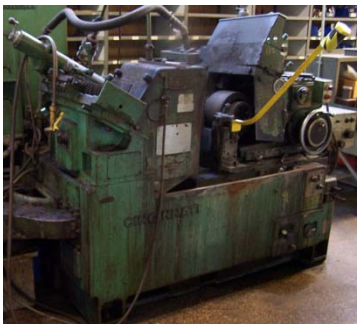
Field Trial: Start Date: March, 2009
Company: Aerospace / Marine Fasteners, Southern California
Industry: Aerospace, Marine Fasteners
Part Description: Bar Stock and various Finished Parts
Application: Centerless Grinding
Make/Model: Cincinnati Milacron
Tooling: Radiac GA54-M19-B6H Grinding Wheel
Material: 17-4, Stainless Steel, 4130 C.S, 2024, 6061, 7075 Aluminum
Competitive Product: Brand X Soluble Oil

Process Description

The cell consists of 4 Cincinnati Milacron Centerless Grinders. One machine is dedicated to finish grinding of bar stock to the desired outside diameter (O.D). This machine performs a very high degree of metal removal due to the number of linear feet of bar stock fed through it. The grinding coolant must have excellent settling properties to allow grinding swarf to separate during the fluid cycle. The remaining machines generally perform finish grinding of individual parts in various process stages. The bio-based soluble oil was tested in both operations. Machines are cleaned and recharged every 6 weeks.

Application Details

Machines were cleaned of all previous coolant and swarf and charged with Bio-based Soluble Oil at a concentration of 5%. No changes in wheel type, speed, feed or cycle times were made. Machines were placed back into production.



TOTAL PRODUCTION: 40,000

Cost Analysis

Brand X Soluble Oil Unit Price Calculation
gals x $17.50 p.g / Units Produced
110gal x $17.50 = $1,925.00 / 40,000 = **$0.048**

Bio-Based Soluble Oil Unit Price Calculation
gals x $15.09 p.g / Units Produced
75gal x $15.09 = $1,659.90 / 40,000 = **$0.041**

Conclusion: Successful. Better surface finish and lower cost. Equal sump life and equal wheel life.

Case Study # 5 AMF, Bio-Based Straight Oil
Field Trial: Start Date: May, 2011
Company: Aerospace / Marine Fasteners, Southern California
Industry: Aerospace / Marine Fasteners
Part Description: Pin
Application: Swiss Style Screw Machine
Make/Model: STAR
Tooling: Carbide, HSS Titanium Nitride coated
Material: 17-4 Stainless Steel, 4130 Steel
Competitive Product: Brand X

Process Description
The operation is automatic screw machine. Materials worked are 17-4 S.S and 4130 high carbon steel. Bar stock material is feed into the machine spindle and at each tool station a specific metal removal operation is performed. Tools consist of form tools, gun drills, knurling, reamers, chamfering, cut-off etc. Any number of tool stations may be employed in a progressive machining operation. Cutting oil is supplied in high volume via high pressure (200 psi) flood delivery.

Application Details
The trial machine is a STAR Turn. This is a modern CNC style machine. Machine was charged with BBO. No changes in tooling, speeds or feed rates. The gun drills used for deep hole drilling are the focus of tool performance.



TOTAL PRODUCTION: 9,600
Cost Analysis
Brand X Oil Unit Cost Calculation
gal x $18.00 p.g / Units Produced
75 gal x $18.00 = $1350.00 / 9,600 = **$0.14**

Bio-Based Oil Unit Cost Calculation
gal x $14.50 p.g / Units Produced
75 gal x $14.50 = $1087.50 / 9,600 = **$0.11**

Conclusion: Successful. Results indicate equal performance and lower cost. Excellent surface finish and part quality.

Case Study # 6 AGI, Bio-Based Straight Oil
Field Trial: Start Date: Oct, 2010
Company: Auto & Transportation Fasteners, Southern California
Industry: Transportation & General Industrial Fasteners
Part Description: Blind Fastener
Application: Cold Heading
Make/Model: SACMA
Tooling: Carbide, HSS Titanium Nitride coated
Material: 1018 & 1022 CRS, 302 Stainless Steel
Competitive Product: Brand X

Process Description

The company manufactures fasteners by cold forming or "heading". This process involves deformation entirely and operates at rapid production rates. Between 3 and 5 hits are required for full formation. Extremely high pressures and temperatures are experienced during the heading process and tool wear or metal pickup on tooling must be avoided. This operation would traditionally use sulphonated-chlorinated petroleum oil. Recent machines added to production restricted the use of chlorinated oil. A product using active sulphur has been in service. There is a normal ingression of lubricating oil into the heading oil.

Application Details

The operation is performed by manually loading parts into the automatic tapping machine. No change in program, tooling or setup. Machine was charged with Bio-Based Oil. Parts are cold headed and pre-drilled. Cutting oil is applied via flood method. All Parts are inspected by operator visually under magnification and checked by certified go and no-go gauge. Parts are also inspected by bi-section at 50x - 100x magnification for thread profile. Production rates up to 1000 parts per shift. Taps are changed when inspection indicates poor thread profile, roughness or gauge check.

Bio-Based Oil X40H-HEADING OIL TEST	
DATE: 10/28/10 THRU 12/10/10	
PART NUMBER	QUANTITY
AKS4-8125-3.8	239,000
AVKP4257	127,000
AKS4-616-150	110,000
AKS3T-1015-3.8	47,000
AKS4-1015-7.9	34,000
AVK2214	71,000
ALS4-518-312	211,000
ALS4-616-312	97,000
ALS4-518-150	210,000
ALS4-8125-3.8	410,000
ALS4-616-150	131,000
ALS4-1015-3.8	255,000
ALM5-1015-3.8	10,000
ALS4-8125-11.1	42,000
ALS4-8125-7.9	141,000
AVK4166	59,000
AVKP3602	100,000
ALS4-8125-7.9	104,000
ALM9T-518-150	39,000
ALA1-8125-3.8	63,000
ALA1-616-150	58,000
ALA1-616-312	16,000
ALA1-8125-7.9	22,000
ALA1-518-312	22,000
AKS4-8125-7.9	196,000
AKS4-8125-3.8	369,000
AKM5-8125-7.9	70,000
ALM5-1015-7.9	23,000

TOTAL PRODUCTION: 3,037,000

Cost Analysis

Brand X Unit Cost Calculation
gals x $9.00 p.g / Units Produced
150 gal x $9.00 = $1350.00 / 3,037,000 = **$0.0004**

Bio-Based Oil Unit Cost Calculations
gals x $13.50 p.g / Units Produced
150 gal x $13.50 = $2025.00 / 3,037,000 = **$0.0006**

Conclusion: Successful. Results indicate equal performance and cost.

Case Study # 7 MD, Bio-Based Straight Oil X30

Field Trial: Start Date: February, 2010
Company: Opti-Surgical, Irvine California
Industry: Medical Device
Part Description: Surgical Eye Needle
Application: Swiss Style Screw Machine
Make/Model: Citizen Cincom B12
Tooling: Carbide
Material: Titanium, Grade 5
Competitive Product: Brand X

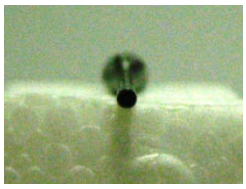
Process Description

Opti-Surgical produces surgical eye needles from titanium bar stock. Operations include drilling, turning, single point threading. During the process a .036 diameter hole 13/16ths deep is drilled using a carbide drill. Dimensional accuracy and surface finish are critical. Tool life using Swiss Silver historically recorded 400-500 parts per drill.

Application Details

Machine was charged with chlorine and sulphur free Bio-Based Oil. No program changes were made and no changes in tool type, speeds or feed rates. Surface finish improved. Tool life has increased by 15-20% or an additional 100 parts per tool. Bio-Based Oil continues to run in production. Over 200,000 parts produced.



TOTAL PRODUCTION: 200,000

Cost Analysis

Brand X Unit Cost Calculation
gals x $18.00 p.g / Units Produced
40gal x $18.00 = $720.00 / 200,000 = **$0.0036**

Bio-Based Oil Unit Cost Calculation
gals x $16.00 p.g / Units Produced
40gal x $16.00 = $640.00/200,000 = **$0.0032**

Conclusion: Successful. Product exhibited better performance and equal cost. Increased tool life confirmed. Excellent surface finish and part quality. This unit is approaching two years of continuous operation.

Case Study # 8 ST, Long Term Rust Preventative

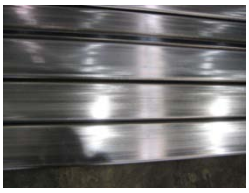
Field Trial: Start Date: February, 2009
Company: Vest Incorporated, Los Angeles, California
Industry: Welded Steel Tube Products
Part Description: 2 x 2 Mechanical
Application: Mill #6
Make/Model: YODER M-2
Tooling: Heat Treated Steel Rolls
Material: Hot Rolled Pickled & Oil
Competitive Product: Brand X

Process Description

Vest manufactures steel tube products of round, square, rectangular configurations up to 10 in. with wall thickness ranging from .035 to .625 in. Coiled steel stock is fed into the mill and rolls progressively form the configuration as it passes through multiple roll form stands. The seam is welded and finished by scarfing and continues through a cooling stage. Tube exits cooling and rust preventative is applied via flood application. Tube of any desired length is sheared and conveyed to an accumulation table and stacked into bundles. These bundles contain any number of tubes from 40 to over 100.

Application Details

Rust preventative is applied by flooding. RP run off from tube carries residual mill coolant which enters the RP basin. RP indicated excellent de-watering characteristics. Mill coolant could easily be decanted from RP flood basin.




TOTAL PRODUCTION: Continuous

Cost Analysis

Brand X Unit Cost Calculation
$13.50 p.g / 16000 sq.ft per gal
$13.50 / 16000 = **$0.00085**

RP Unit Cost Calculations
$12.63 p.g / 16000 sq.ft per gal
$12.63 / 16000 = **$0.00079**

Conclusion: Successful. Original test bundle exhibited excellent condition. Product exhibited better performance and lower unit cost. Increased corrosion protection observed on internal tubes exposed to captive coolant.

Summary of Performance Data

4 Industrial Segments

- Aerospace & Marine Fasteners.
- Automotive & General Industrial Fasteners.
- Medical Devices.
- Steel Tube Products.

Applications & Process's

- Milling
- Drilling
- Turning
- Tapping
- CNC Machining
- Centerless Grinding
- Cold Heading / Forming
- Deep Hole / Gun Drilling
- Rust & Corrosion Prevention
- High Pressure Fluid Delivery Systems
- Screw Machining Conventional & Swiss Style

Materials and Alloy's

- Aluminum, 6061, 7050
- Inconel 718
- Stainless Steel, A286, 17-4, 18-8, 302
- Titanium, Grade 5 (Ti 6AL-4V) and Grade 9 (Ti 3AL-V2.5)

Economic and Production Data

- Tool Life equivalent / slightly better compared to Petroleum based product in use.
- Statistically equivalent cost per unit compared to Petroleum based product in use.
- Over 4 million parts produced.
- No process changes required.

Health, Safety and Environmental Benefits

- Low Toxicity.
- Ultra Low VOC's.
- High Biodegradability.
- Free of Chlorinated Paraffin's.
- Reduced Dependence on Foreign Oil.
- Waste potentially characterized as Non-Hazardous.
- Domestic Green Renewable Resource Based Technology.
- Aligns with State of CA GHG, SCAQMD 1144, and CA Green Chemistry Initiative.

Conclusion

Based on South Coast Air Quality Management District analysis for VOC emission potential (see attachment “A”) and additional tests conducted by Ceway Chemical Services using ASTM E1868-10 (see attachment “B”). Product technology utilizing organic base oils are confirmed as having ultra low emissions of volatile organic compounds. Furthermore, the case studies documented and provided in this paper indicate the products deployed in all of the field trials were successful in each of the practical applications run. These were real time; actual production settings with high volume quantities run in long term sustained operations. All of the finished goods produced were passed in each manufacturer’s Quality & Assurance specifications.

No special handling procedures or precautions were required. Nor were there any deviations to Standard Operating Practices in set-up, tooling, cycle times or feed rates. All products were in every case cost effective and economical both in unit cost and in cost per part in direct comparison with petroleum based technology and in some cases more cost efficient than the incumbent product.

American Research Products Inc. initiated an effort to successfully develop and deploy bio-based product technology formulated with environmentally safer materials sourced from domestic renewable resources. And to the extent possible convincingly illustrate such products are cost effective, fit for purpose, safe and compliant with applicable regulations. They can and are ready to serve the manufacturing community across all industries.

- Free of Chlorinated Paraffin.
- 50 grams per liter VOC or less.
- Flashpoint 400 degrees Fahrenheit or greater.
- Cost competitive on a unit cost basis with conventional products.
- Field tests must attain equal performance to incumbent competitive products.

All of the original design charter basic characteristics were achieved and all of the case studies documented here are considered successful in their respective applications.