Demonstration of Tar Removal from Paving Equipment and Ground Vehicles

Compliance Track @ E2S2, 12 May 2011 , # 12354

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Presentation Outline

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- Conclusions and Recommendations

BACKGROUND

- The Sustainable Painting Operations for the Total Army (SPOTA) working group evaluates solvents that will not impact the environment while cleaning the armament equipment.
- We were tasked to conduct a study and develop a methodology to evaluate environmentally friendly cleaners that would be effective in cleaning off road tar on military vehicles. We need to develop a guidance document (PWTB) for tar removal from ground vehicles and surfaces.
- Cleaning the road tar/asphalt is a standard practice prior to induction of a vehicle back in to service.
- Current practice is to use 40,000 psi water jet. Also some chemical solvents are used along with water jet and hand-wiping.

Problem/Relevance

Several ground vehicles need tar removal as part of the regular maintenance at depots.

Oil/bitumen spreaders and the clogged nozzles are a major problem often replacing with new components, cost about ~$10K-$15K per each spreader.

Current process uses high pressure water jet/steam jet cleaning. Energy and labor intensive.

Problem

It is a DoD problem. Removing Tar is a difficult job.
Red River Army Depot has about 25 vehicles for refurbishing.
Other equipment can also be recovered if a convenient solvent and process for removing tar/asphalt is available.

OBJECTIVE

- The overall objective of the study was to provide recommendations on the selection of commercially available, environmentally friendly cleaners for removing road tar/asphalt from Army ground vehicles and asphalt spreaders. Objective includes demonstration of the cleaning process to remove tar, asphalt and bitumen from the road paving spreaders and military ground vehicles at the maintenance facilities of the Red River Army Depot (RRAD), Texarkana, TX.

APPROACH

1. Develop criteria to rank commercial environmentally friendly solvent/cleaner systems for tar/asphalt removal.
2. Identify both cleaner products and methodologies.
3. Conduct laboratory coupon evaluations using select commercial products.
4. Develop a test protocol for selecting a cleaner for removal of tar/asphalt from ground vehicles.
5. Demonstrate select solvents at Red River Army Depot with immersion cleaning approach.
6. Prepare a guidance document with details for implementation, operation, and cost analysis

Criteria for Solvent Selection

The following criteria were considered for selecting a solvent for removing tar from vehicle surfaces:

1. *Effectiveness in removing the tar and fast drying*
2. *Shall have low VOCs*
3. *Shall have no or low content of HAPs*
4. *Shall have low toxicity*
5. *Shall have high flash point*
6. *Shall have low flammability*
7. *The ability to recycle the solvent*
8. *The cleaner residues must be biodegradable and easily treatable along with regular wastewater streams*
9. *Material compatibility, use of the solvent should not lead to corrosion or erosion, if possible provide corrosion protection layer*
10. *The cost of the solvent and the solvent requirement should be minimal.*

Literature Review

Laboratory standard testing protocols available in literature for tar removal from metal surfaces were reviewed. Search was conducted on multiple databases comprising of Scopus, Academic Search Premier (Ebsco), Academic Onefile (Gale), Web of Science-including Social Sciences, Medicine, Humanities, and Engineering.

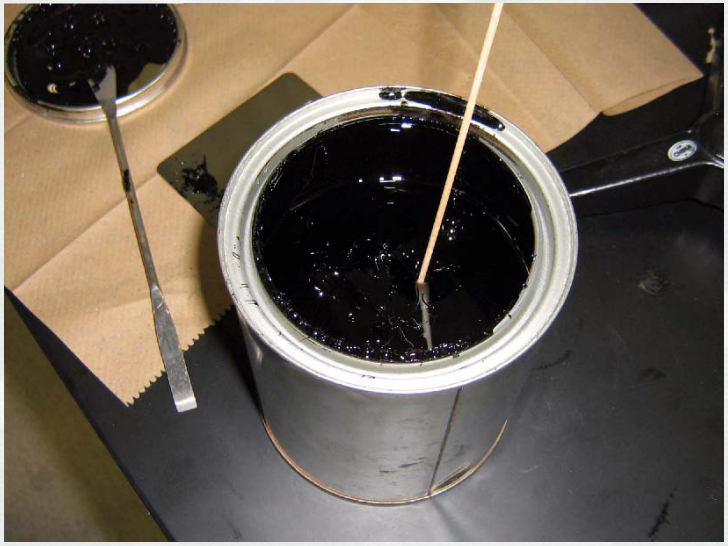
From the review of the literature it appears that the best performing solvents all have an appreciable ability to dissolve asphalt and asphalt compounds.

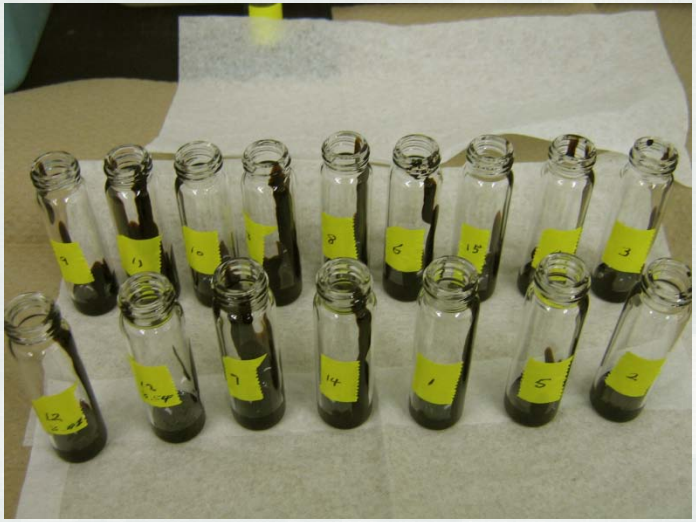
Both terpene-based compounds and vegetable oil esters appear to be especially favored due to their perceived environmental friendliness. The inclusion of surfactants appears to aid the process.

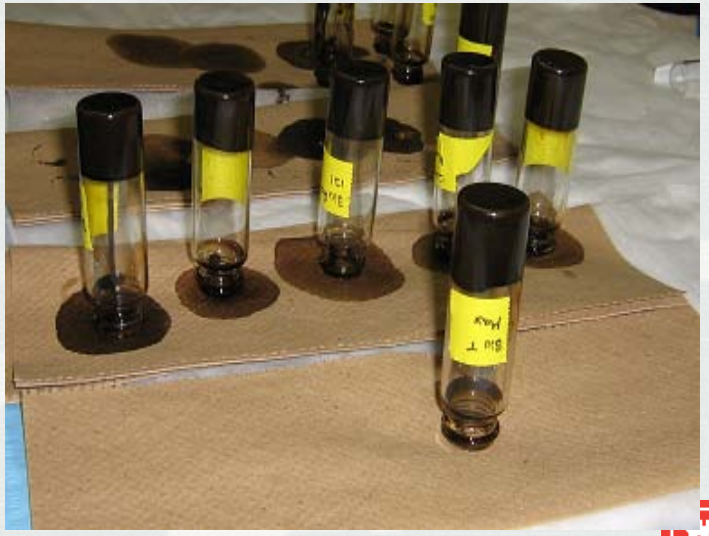
Laboratory Evaluation of Solvents

- Solubility of tar in cleaning solvents
- Coupon studies for cleaning efficiency
- Study operating parameters
  - Duration for cleaning
  - Temperature
  - Dilution
- Field samples (chains) cleaning

Tar Solubility Study







Solubility of the tar was obtained to rank the solvent systems

47 Commercial Tar Removal Solvents Are Reviewed

Solubility Results

Solvent Name	Bottle Weight, (g)	Bottle Weight with tar,(g)	Tar weight (g)	Bottle weight after 5 mL solvent (g)	Amount tar removed (g)	Percent Removed	Amount of tar removed per mL solvent (g/mL)	Cost per gallon**
Citri-Zip	12.64	17.13	4.49	16.95	0.18	4.01%	0.036	$58.85
BioAct 121	12.16	16.94	4.78	16.75	0.19	3.97%	0.038	$22.40
Citrus Soy Gold	12.64	16.60	3.96	16.45	0.15	3.79%	0.03	$28.73
Bio T Max	12.61	17.52	4.91	17.35	0.17	3.46%	0.034	$25.65
BioAct 105	12.75	17.56	4.81	17.40	0.16	3.33%	0.032	$16.92
Citrus King	12.16	17.23	5.07	17.07	0.16	3.16%	0.032	$39.00
BioAct MSO	12.20	17.30	5.10	17.14	0.16	3.14%	0.032	$22.18
BioAct 120	12.61	16.88	4.27	16.75	0.13	3.04%	0.026	$24.82
Full Force	12.70	17.33	4.63	17.19	0.14	3.02%	0.028	$39.00
Tuff Stuff	12.79	17.66	4.87	17.55	0.11	2.26%	0.022	$166.00*
Orange Oil Slicker	12.68	17.56	4.88	17.45	0.11	2.25%	0.022	$26.91
DS-104	12.60	17.72	5.12	17.61	0.11	2.15%	0.022	$30.82
Rid-O-Grease	12.69	17.29	4.60	17.20	0.09	1.96%	0.018	$56.00
Citri-Kote	12.69	17.01	4.32	16.93	0.08	1.85%	0.016	$36.50

Disclaimer: **ERDC-CERL or its sponsors do not promote or endorse any of the solvent cleaners or its manufacturers. Performance of individual cleaner is provided as guidance, but actual testing should be carried out by the end user.**

COUPON STUDY

- **Based on the literature review of the protocols, a modified protocol as described here was followed for this experimental study.**

- **Preparation of Test Strips**

  The assay used test strips of stainless steel with dimensions 4 in. x 6.0 in. x 1/50 in. Immersions in solvents were carried out by placing the strips in clamps and immersing two thirds of the total area of the strip. This provides a total uniform area of exposure of 12.0 sq in. The strips were desiccated and weighed with the clamp assembly so that the strip itself would not be handled.

- **The asphalt used in these experiments was a standard commercially available material labeled CRS-2. The strips were dried in an oven for 24 hours at 60 °C. At the end of the drying period, the strips were cooled to room temperature and weighed. A thin edge from the bottom of the strip where lip formation was seen was removed manually.**

Coupon Studies: Coupon preparation

Coupon as received

Asphalt coated coupon

Citrus-King at 75% conc.

Chain Results

Before

After

Solvent Selection

Recommendations

Solvent	Flash Point (ºF)	EPA regulated	Composition	Time (min)	Temp	Price	Producer	Phone	Percent Removed 5 mL Solvent/ Tar
Bio T Max	130	NO	D-Limonene	30-60	90ºF	$25.65	BioChem Systems	(800) 777-7870	3.46%
Citrus King	115	NO	Terpenes	30-60	90ºF	$39.00	Citrus Depot	(800) 424-8045	3.16%
BioAct MSO	117	NO	1-Methyl-4-(1-methylethenyl) -cyclohexene	30-60	90ºF	$22.18	Petroferm	(800) 367-9966	3.14%

Citrus King works well- cost is negotiated (~$20/gal), environmentally friendly

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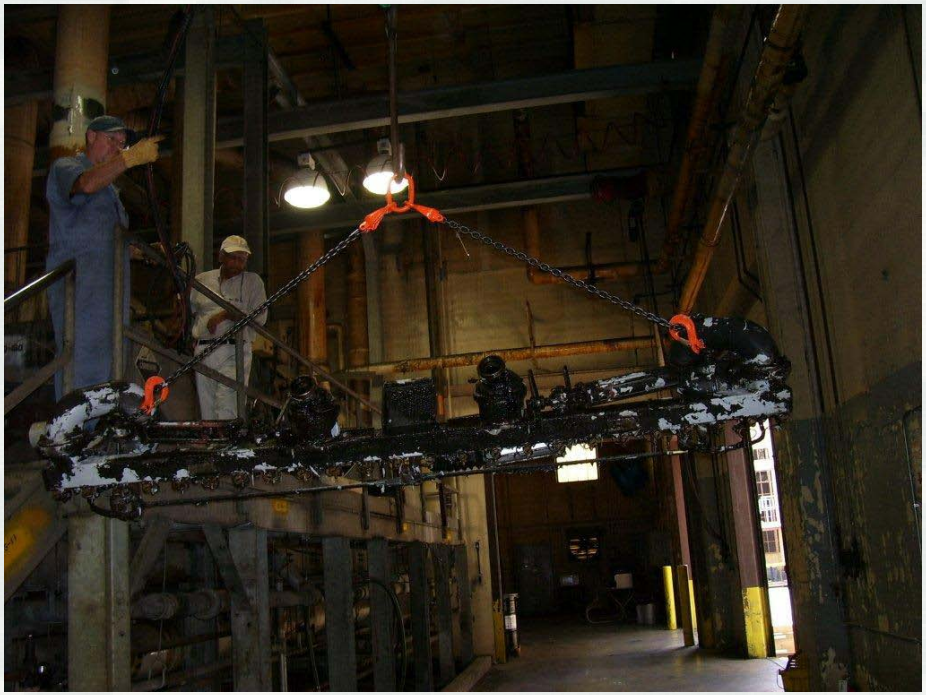
Demonstration At Red River Army Depot (TARDEC/TACOM) August 2010

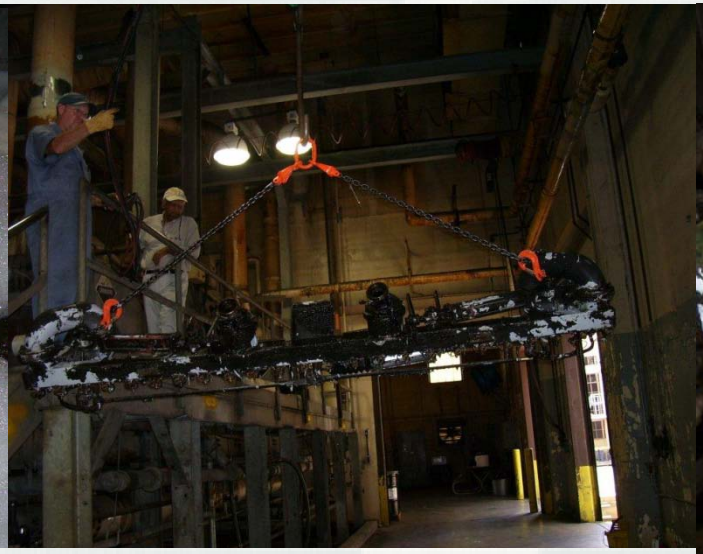
Two solvent systems Citrus-King and Simple Green. Citrus King Worked Great !

Demonstration At Red River Army Depot (TARDEC/TACOM), August 2010



Citrus King and Simple Green are Tested

Demonstration At Red River Army Depot (TARDEC/TACOM), August 2010



Simple Green foamed, effective in removing oils, grease and paint, but not tar

Citrus-King Performed Better

Demonstration At Red River Army Depot (TARDEC/TACOM), August 2010

Mr. Jerry Atchley (operator) was pleasantly surprised to see the clean part come out of the rinse tank

Mr. Ross Sutton (operator) identified that the water spray is just enough to do thorough cleaning after the dip cleaning

Mr. William Crow (in-charge for refurbishing) inspected and was extremely happy with the cleaning and functioning of the spreader.

Citrus-King Performed Better

Conclusions and Recommendation

This study revealed that at least two broad categories of solvent blends (terpene based solvents/esters, and blends of aliphatic hydrocarbons and esters assisted by surfactants) can remove asphalt from metal. Of the solvents tested, Citrus King worked well in all respects – time, (within 30~45 minutes), water rinsability, waste disposal of spent solvent (no special treatment is needed), the solvent can be diluted up to 50%. It appears to combine both functionality and was desirable environmental characteristics.

Implementation of the process is recommended.

Background Information

Tar and Asphalt

Asphalt: A brownish-black solid or semisolid mixture of bitumens obtained from native deposits or as a petroleum byproduct, used in paving, roofing, and waterproofing.

A dark bituminous substance found in natural beds and as residue from petroleum distillation; consists mainly of hydrocarbons

Tar: A dark sticky substance obtained by distilling organic matter such as coal, wood, or peat

Elemental analysis of select bitumen (Holleran et al. 2005)

Element	Weight percent otherwise as mentioned*			
	Mexican	Arkansas	Boscan (Venezuela)	California
Carbon (C)	83.77	85.78	82.9	86.77
Hydrogen H)	9.91	10.19	10.45	10.94
Nitrogen (N)	0.28	0.26	0.78	1.10
Sulfur (S)	5.25	3.41	5.43	0.99
Oxygen (O)	0.77	0.36	0.29	0.20
Vanadium (V)	180 ppm	7 ppm	1,380 ppm	4 ppm
Nickel (Ni)	22 ppm	0.4 ppm	109 ppm	6 ppm
* ppm = parts per million by weight				

Physical Properties of Asphalt

Summary of physical properties marathon petroleum asphalt.

Property	Value*
Appearance	Black-brown solid or semi-solid
Physical State	Liquid
Substance Type (Pure/Mixture)	Mixture
Color	Black-Brown
Odor	Tar
pH	Neutral
Boiling Point/Range (5-95%)	>700 F
Melting Point/Range	115-199 F
Specific Gravity	0.95-1.13
Density	7.9-9.4 lbs/gal
* Derived from the MSDS for Marathon Petroleum Asphalt.	

EXPERIMENTAL PROTOCOLS

There is no quantitative standardized procedure to compare the efficacy of these solvents.

The goal was to develop a standardized procedure that would yield quantitative and repeatable results.

Tar removal experiments were designed and conducted using a total of four commercial solvents. The four solvents were tested on metal coupons simulating the metal surfaces of military tactical and transport vehicles.

EXPERIMENTAL PROTOCOL

Assay

- The strips were immersed in the test solvents so that the entire asphalt coated areas were exposed to the solvent. The strips were withdrawn from the solution after 60 seconds and drained for 2 minutes. This was repeated two more times for a total of three solvent rinses. Following this the strips were washed in water. The strips were allowed to dry at room temperature for 2 hours and were desiccated overnight. The test strips were then reweighed. The data expressed in percent by weight of removal. The removal of a thin edge and the addition of a solvent and water rinse eliminated the lip formation and residues.

Evaluation of solvents

- Four solvents were chosen: (1) Diesel, (2) Bioclean, (3) Bio T Max, and (4) Axarel 32. Diesel was a reference solvent. Bioclean, Bio T Max, and Axarel 32 were selected as test solvents. Axarel 32 represented a different class of solvents without terpenes that is rinsable with water, easily recycled. It can be applied by a number of methods including immersion, pressure washing, and ultrasonic baths.
- A few other solvents including ethyl lactate, dibasic esters, and X-Force were tested with little success. An aqueous solution formulated with dioctylsulfosuccinate was also not effective.

ANOVA ANALYSIS

ANOVA analysis of test results

Groups	Count	Sum	Average	Variance		
Diesel	5	492.191	98.4382	0.129035		
Bioclean	6	595.0416	99.17359	0.8191		
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1.474919	1	1.474919	2.878427	0.124006	5.117357
Within Groups	4.611639	9	0.512404			
Total	*6.086558*	*10*				
Diesel	6	585.57	97.595	0.37747		
BioTMax	6	587.22	97.87	0.1942		
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	0.226875	1	0.226875	0.793727	0.393906	4.964591
Within Groups	2.85835	10	0.285835			
Total	*3.085225*	*11*				

DATA ANALYSIS AND INTERPRETATION

- Table lists the raw data for the four solvents tested. Note that the residual amounts of asphalt for both diesel and Bioclean were much improved compared to the trial results. This is attributable to the elimination of the lip formation observed previously.

Table. Raw data for the three solvents evaluated.

Solvent	Diesel	Bioclean	Diesel	BioTMax	Diesel	Axarel 32
	98.74	97.37	97.9	98.23	95.79	94.09
	98.44	99.64	97.57	97.33	94.09	94.48
	98.01	99.72	97.65	98.14		96.60
	98.16	99.58	96.52	97.89		95.53
	98.84	99.18	98.39	98.3		93.97
		99.55	97.54	97.33		97.27
Average %deviation	98.44	99.17	97.60	97.87	94.94	96.65
Std. Dev	0.36	0.91	0.61	0.44	1.20	1.36