Viscon Multi Media Evaluation
(Tier I)

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Multi Media Evaluation

I. Introduction

Viscon is an additive for diesel fuel which is being proposed as a strategy for reducing PM and NOx emissions for diesel engines. The active component of Viscon is an ultra high molecular weight polyisobutylene (UHMWPIB) polymer. It is combined with CARB diesel at 1 part polymer to 99 parts diesel. Viscon is used at less than 5 ppm UHMWPIB to the end use CARB diesel. UHMWPIB is a non-toxic, colorless, tasteless, odorless food grade hydrocarbon polymer, which is insoluble in water. Lower molecular weight PIB is a component in PIB amine keep-clean additives for gasoline. UHMWPIB has been used as a method for controlling releases of diesel fuel, approved for use in California. The use of Viscon as an additive to CARB diesel creates no additional risks to the environmental or to human health when compared to unmodified CARB diesel. The use of Viscon as an additive to diesel fuel can result in a significant reduction in PM and NOx emissions from diesel engines with no significant risk to the air, water and soil environments.

Viscon should be considered by California regulatory authorities as posing no significant risk to human health or to the environment.

II. Executive Summary

II-A. Summary of regulatory approvals.

Viscon is exempt from the US EPA's requirement for registration of fuel additives under 49CFR Part 79 Subpart A Section 79.2 (e), since it is comprised of only hydrogen and carbon.

No other regulatory regimes under which Viscon may be required to be approved have been identified, either U.S. or international.

II-B. Background information on Viscon.

Viscon is an additive for diesel fuel. It is used at a dose level in diesel fuel of about 500 ppm. Viscon is comprised of 1 part UHMWPIB and 99 parts CARB diesel. UHMWPIB is the active component in Viscon. It has an average molecular weight of about 7 million Daltons. Its chemical formula is C_4H_8. UHMWPIB is a food grade material (see Attachment 1, Food-Contact Applications).

II-C. Manufacturing, Transportation and Storage of Fuel and Components

Viscon is manufactured in Bakersfield, California at Las Palmas Oil and Dehydration. The active component of Viscon, UHMWPIB (Attachment 2, BASF's Oppanol - Polyisobutylenes) is a tough rubber solid which is delivered to the site and stored in a clean dry enclosed room in 44 pound polyethylene bags.

The manufacturing process begins by granulating the UHMWPIB to a specific size. Refer to Attachment 3, Viscon Production Flow for a complete schematic of the production steps. CARB diesel fuel is used to dissolve the UHMWPIB. The CARB diesel fuel is pre-heated to 180-185° F using a low-emissions boiler and transferred to a specially designed insulated column holding 770 gallons of fuel. The granulated HHMWPIB is then combined with the diesel. The UHMWPIB is slowly added to the top of the column, dissolved and continually mixed for 12 hours. There is no reactive chemistry involved. The finished product is transferred via pipeline to bulk holding tanks for eventual transfer to shipment vessel(s). The type of shipment vessel varies depending on customer requirements. Tanker trucks, totes, and 55-gallon drums are typical containers that are transported to customers. All liquid production areas are diked in accordance with EPA/California regulations.

Viscon is added to diesel fuel at the customer's site using equipment customarily used in their business. It is stored on the customer's site in storage tanks customarily used for storage of diesel fuel additives and petroleum products. Attachment 4, Customer-Site Storage provides examples of storage containers. All precautions normally taken for storage of diesel fuel are followed for Viscon storage.

II-D. Historical Use of Viscon's Active Component

Lower molecular weight PIB is used in a large part of gasoline consumed in the United States. It is a component in one category of keep-clean additive, PIB amines, required by State and Federal regulations. Also refer to Attachment 2, BASF's Oppanol other uses of PIB.

II-E. Information Necessary for Risk Assessment

Viscon is 1 part UHMWPIB and 99 parts CARB diesel. The diesel fuel used in Viscon poses the same risk as diesel fuel used in other applications. UHMW PIB is a solid rubber before it is added to its diesel fuel carrier. UHMWPIB does not change the chemistry of CARB diesel and does not add to its toxicity. UHMWPIB is colorless, virtually tasteless and odor free. UHMWPIB is insoluble in water. UHMWPIB does change the physical properties of the CARB diesel in which it is blended. The Viscon additive is highly viscous. Refer to Attachment 5, Viscosity Measurements for Viscon viscosity test results. Viscon also has restricted mobility in soil and in water when compared to diesel fuel. A similar combination of UHMWPIB and hydrocarbon liquids was used as a method for controlling and collecting oil spills. UHMWPIB inhibits dispersion of the base petroleum liquid in water and can be used to immobilize a spill on land. The environmental product was called Elastol and was licensed (see Attachment 6, Issuance of License for Oil Spill Clean-Up Agent) by the State Water Resources Control Board for use on oil spills in California.

The amount of UHMWPIB added to the final diesel product, less than 5 ppm, has only a minor effect on the physical properties of diesel fuel at rest. However, it does have a significant effect on the physical properties of diesel under dynamic conditions. One well known example is the use of this polymer at similar concentrations as a drag reduction additive in pipelines. This phenomenon is viscoelasticity, an immediate and temporary increase in viscosity when the fluid is put under shear stress (see Attachment 7, Extensional Viscosity)

The anticipated use of Viscon in California is in CARB diesel. There would be no significant change in the physical, chemical or toxic properties of CARB diesel in handling, transport and storage caused by addition of less than 5 ppm of UHMWPIB with the exception of changes to CARB diesel's physical properties under conditions of shear stress.

III. Risk Assessment

III-A. CARB Diesel Containing 5 ppm Viscon

A risk assessment of CARB diesel treated with Viscon at the effective dose level, about 5 ppm UHMWPIB, would be the same as for CARB diesel without the additive, with the exception of risks associated with diesel exhaust emissions. The purpose for adding Viscon to CARB diesel is to reduce emissions of PM, NOx, HC, and CO. The results of tests conducted under CARB protocols to assess the potential benefit of Viscon as a strategy for reducing harmful exhaust emissions from diesel engines is attached. This testing includes data related to the effect of Viscon treatment on toxic emissions (see Attachment 8, CARB-Protocol Emissions Test Results).

A risk analysis of CARB diesel treated with Viscon for potential environmental and resource impacts that may result from likely release scenarios would be the same as a risk analysis of untreated CARB diesel. There are no additional risks created by addition of about 5 ppm of UHMWPIB to CARB diesel. UHMWPIB is a non toxic polymer which is insoluble in water. It is dissolved at 1 part UHMWPIB to 99 parts CARB diesel to produce Viscon. UHMWPIB is a pure hydrocarbon, food grade substance.

UHMWPIB does not change the chemical properties of CARB diesel nor does the concentration of UHMWPIB used in treating CARB diesel change CARB diesel's physical properties at rest. It does change the physical properties of CARB diesel under conditions of shear stress, causing an immediate and temporary increase in CARB diesel's viscosity. The increase in CARB diesel's viscosity could reduce vapor loss from a release under certain conditions and could restrict travel of the fuel in soil and dispersion in water. These conclusions are based upon work done with the same polymer as an environmental technology used to reduce the risk of spills of liquid hydrocarbons.

III-B. The Viscon Additive.

The Viscon fuel additive is comprised of 1 part UHWPIB and 99 parts CARB diesel. The risk of a potential environmental or resource impact resulting from a release of Viscon is significantly less than from a release of CARB diesel. Viscon is highly viscous.. The viscosity of Viscon increases further when put under conditions of shear stress. Penetration of Viscon in soil and transport in soil are minimal when compared to CARB diesel. Viscon does not disperse in water, and maintains its integrity on the surface of water.

UHMWPIB has been used as a method for reducing the hazard from releases of hydrocarbon liquids. The product was called Elastol Elastol was used as a fine powder which dissolved in a spill to form a substance similar to Viscon. Refer to Attachments 9, 10, & 11, Oil Spill Recovery Using Elastol, Reports1-3. A laboratory investigation of the properties of Elastol in solution was carried out at BASF (see Attachment 12, Toxicity and Soil Penetration). UHMWPIB was also used as a 1% solution in a hydrocarbon liquid to restrict the spread, dispersion and emulsion of heavy oil.

Toxicity tests on Elastol were carried out by U.S. Testing Labs in New Jersey (see Attachment 13, Oil Dispersant Toxicity Test). Abalone Larval Development Short Term Toxicity tests were carried out in California to support a request for a license to use Elastol in California. Data from the abalone test is missing from company files, however a memorandum explaining the results of the test is Attachment 14, Abalone Larval Development Test - Memorandum. The State Water Resources Control Board issued the license on May 1, 1992 (see Attachment 6, Issuance of License for Oil Spill Clean-Up Agent). The UHMWPIB used in the Elastol product is the same as the active component of Viscon.

III-C. Release Scenarios

III-C.1 CARB diesel treated with Viscon

The release scenarios for Viscon treated CARB diesel are the same as for CARB diesel. Viscon is added to CARB diesel at a fuel distributor's site or a user's site. Once added to CARB diesel the Viscon treated fuel follows the same pathway as the CARB diesel would normally follow. As noted above any release occurring during the storage, transportation and transfer of Viscon treated CARB diesel would have the same risk factors as for neat CARB diesel, except to the extent that added viscosity under conditions of shear stress may help mitigate the hazard from such a release.

III-C.2 Viscon Additive

Viscon is produced at GTAT California's facility in Bakersfield, California. The production facility has several dissolving units each with a capacity of 770 gallons. Dissolving units and storage tanks for Viscon are contained within diked areas in accordance with US EPA and California regulations for facilities storing quantities of diesel fuel. Any accident resulting in a tank rupture or valve failure would be limited to the diked area. Vapor release to the air would be somewhat less than from a release of an equal amount of CARB diesel. The addition of the UHMWPIB to diesel limits its ability to penetrate the ground and the walls of the dike. Recovery is enhanced by the viscoelastic properties of the liquid (see Attachment 12, Toxicity and Soil Penetration).

Viscon is transported to the customer via tanker trucks, totes, and 55-gallon drums. A release resulting from an accident during transportation would have limited mobility on the ground and could easily be controlled by standard spill containment equipment. Runoff of a spill of Viscon into an adjacent waterway would be inhibited by product viscosity, resulting in a significantly reduced hazard when compared to a spill of diesel fuel.

In the event that a Viscon release found its way into a creek or river the spill would have limited ability to spread on the surface and there would be no dispersion into the body of water. Standard oil spill booms could contain the spill and the effectiveness of recovery equipment would be significantly enhanced compared to its use with a diesel spill (see Attachments 9, 10, 11, Oil Spill Recovery Using Elastol, Reports1-3, and Attachment 12, Toxicity and Soil Penetration).

It is not anticipated that Viscon would be stored in underground storage tanks. However, if Viscon is stored underground and there is a breach in the tank due to a catastrophic event, or slow leakage or spillage around the fill port of the tank the spilled liquid would have minor mobility in the soil.

Potential air releases in manufacture of Viscon occur from the handling and storage of the CARB diesel which comprises 99% of the final product. The Viscon production facility is operated in accordance with all appropriate regulations governing the storage and handling of diesel fuel. The completed Viscon product has significantly less potential for release of vapor to the air than CARB diesel.

Air releases from Viscon during transfers and accidental releases would be reduced when compared to CARB diesel. (Attachment 9) In addition, any release in transfers or accidents is more easily contained and removed than would be the case of a similar size release of CARB diesel reducing the time the spill is open to the environment.

III-D. Exposure Pathways

III-D.1 CARB diesel treated with Viscon

The exposure pathways for CARB diesel treated with Viscon are the same as for CARB diesel, except to the extent that the addition of Viscon may reduce exposure as a result of increased viscosity under conditions of shear stress.

The polymer molecules in the Viscon treated CARB diesel are biodegradable like the fuel molecules. The pure hydrocarbon PIB molecules do not raise transformation issues when combined with CARB diesel. UHMWPIB is a non-toxic substance cleared for use in packaging exposed to food (see Attachment 1, Food-Contact Applications). Exposure to UHMWPIB does not raise chronic or acute exposure or other issues related to human exposure in any media (see Attachment 2, BASF's Oppanol - Polyisobutylenes).

III-D.2 Viscon Additive

The potential exposure pathways for Viscon in relation to both human and ecological receptors are reduced compared to those for CARB diesel. Viscon is used at a concentration of less than 500 ppm in CARB diesel. The volume of product which may be exposed to human or ecological receptors is 1/20th of 1% of CARB diesel volume, if it is assumed that all CARB diesel is treated with Viscon. The viscosity of Viscon is 57.97 Centipoise (cP) at 1,800 reciprocal seconds (D(1/s)) at 90° F compared to 2.33 Centipoise (cP) at 1,800 reciprocal seconds (D(1/s)) for CARB diesel. The higher viscosity of Viscon further limits the exposure pathways for human and ecological receptors when compared to neat CARB diesel because of reduced migration in soil, and reduced dispersion in water. Viscoelastic properties of Viscon, an immediate and temporary increase in viscosity under shear stress, further limit the spread of Viscon in an active water system such as a river or creek, where the action of the water causes the spill to consolidate and not break up and spread on the surface. The cohesiveness of Viscon also reduces potential pathways to human and ecological receptors because of the significantly increased capabilities of spill containment and recovery equipment to control and recover an accidental spill when compared to a spill of CARB diesel (see Attachment 9, Oil Spill Recovery Using Elastol, Reports1-3 and Attachment 12, Toxicity and Soil Penetration).

III-E. Risk Determination

III-E.1 Waste Management

A release of CARB diesel treated with Viscon would respond to standard petroleum cleanup strategies and technologies the same as untreated CARB diesel. A release of

CARB diesel treated with Viscon would be no harder or easier to cleanup than CARB diesel without Viscon.

The disposal of soils contaminated with CARB diesel treated with Viscon would be handled the same as soils contaminated with CARB diesel without Viscon.

The only potential waste associated with the production of Viscon is product which does not meet product specification. This waste would be 99% CARB diesel and 1% PIB and would be handled in the same manner as CARB diesel contaminated with pure hydrocarbon substance.

Discarded Viscon or CARB diesel treated with Viscon would be subject to the same disposal regulations as discarded CARB diesel.

III-E.2 Risk/Benefit Assessment

There is no significant risk to human health or to the environment caused by the production, transportation, handling, storage or use of Viscon as an additive to CARB diesel in addition to risk normally associated with the use of untreated CARB diesel. On the other hand, the use of Viscon as an additive to CARB diesel could significantly reduce the impact on human health and the environment associated with the combustion of CARB diesel in diesel engines due to demonstrated reductions in exhaust emissions of NOx, PM, CO and HC.

Attachment 1

Food-Contact Applications

BASF Corporation

BASF

October 27, 2000

GTA Technologies, Inc..
Attn. Jerry Trippe
7400 Gallerher Road
Gainesville, VA 20155

Fax: 703 753 9476

RE: Oppanol Approvals for Food Contact

Dear Jerry,

As per your request, please find attached the requested information on Oppanol in contact with food.

This is for informational purposes only. In case you intend to use a specific Oppanol grade in an application with food contact, I will ask Product Stewardship to issue a statement covering that particular grade.

If you have any questions or comments, please do not hesitate to call me at 973 426 2531.

Best regards,

Uli Eichenauer
Marketing Manager

Attachment

Food-Contact Applications

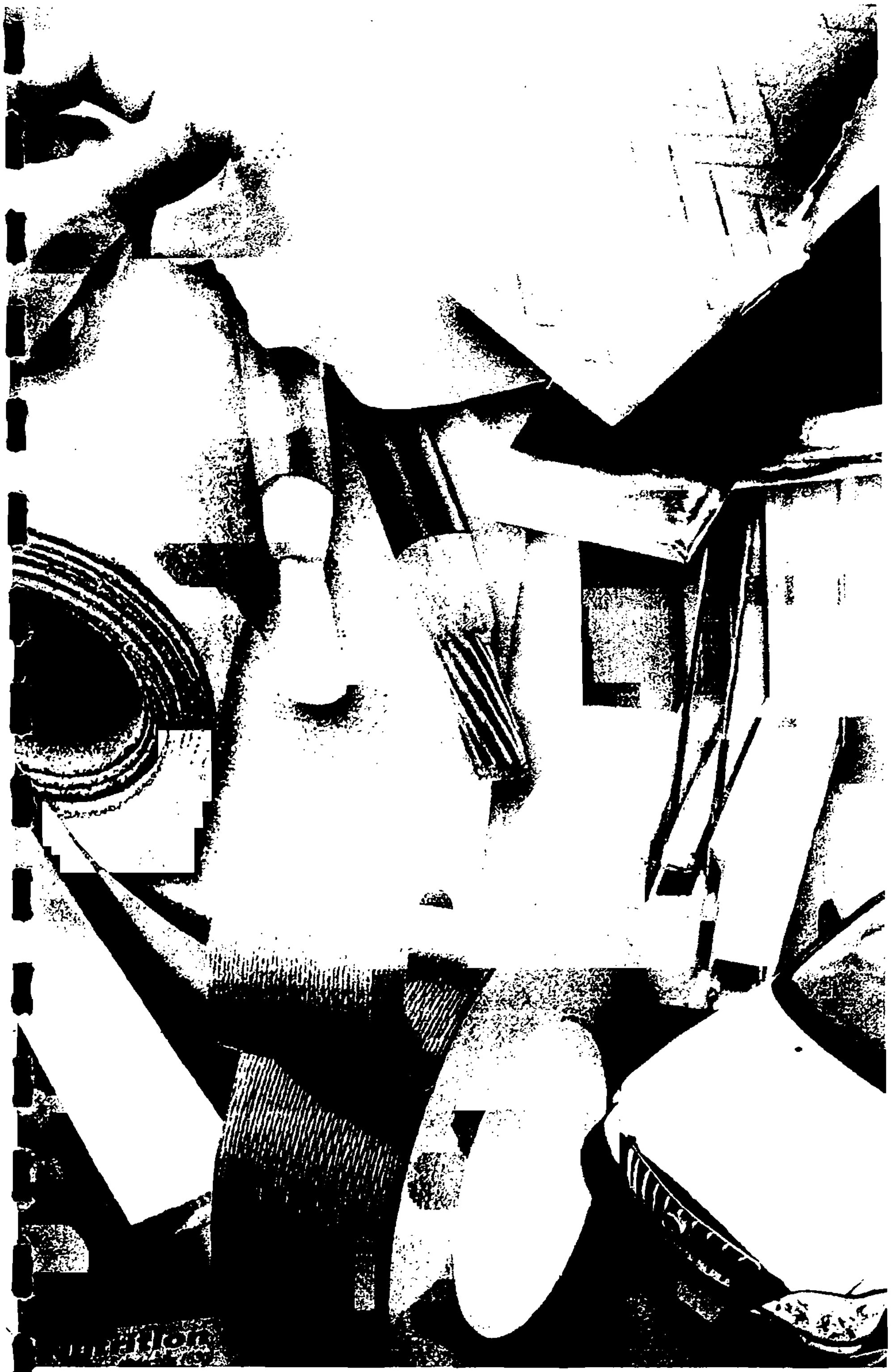
Oppanol fulfil the requirements of:

- US FDA 21 CFR 172.615 Chewing gum base
- American Food Chemical Codex of 1996 concerning chewing gum
- German legislation regarding chewing gum
- US FDA 21 CFR 175.105 Adhesives
- US FDA 21 CFR 175.125 Pressure-sensitives adhesives
- US FDA 21 CFR 175.300 Resinous and polym. Coatings
- US FDA 21 CFR 176.189 Component and paperboard in contact with dry food
- US FDA 21 CFR 177.1420 Polyisobutene polymers (Oppanol B 100 and higher molar mass products)
- US FDA 21 CFR 178.3570 Lubricants with incidental food contact
- US FDA 21 CFR 178.3910 Surface lubricant used in the manufacture of metallic articles
- German Health authorities recommendation on polyisobutene(Empfehlung XX, Polybuten, 167. Mitteilung Bundesgesundheitsblatt 27, 289, 1984)
- German regulation concerning use for toys or for consumer articles that come into contact with food (Lebensmittel-und Bedarfsgegenständegesetz, Paragraph 5, No.1 and No 5)

Attachment 2

BASF's Oppanol - Polyisobutylenes

BASF's OPPANOL®
POLYISOBUTYLENES



BASF INVENTED PIB. NOW WE'VE MADE IT BETTER.

EASY TO HANDLE PIB

HELPING MAKE PRODUCTS BETTER™

BASF

Contents

1. Portfolio

Oppanol® products are classified into two groups according to molecular weight:

MM-Oppanol:	
Medium molecular weight	(Mv 40,000 - 85,000)
HM-Oppanol:	
High molecular weight	(Mv 20,0000 - 4,000,000)

Products

MM-Oppanol:
B 10 SFN, B 12 SFN, B 13 SFN, B 15 SFN
HM-Oppanol:
B 30 SF, B 50, B 50 SF, B 80, B 100, B 150, B 200

2. Chemical Nature

The Oppanol types consist of polyisobutylenes with different molar masses. They are mainly used in the production of adhesives, sealants, lubricants, coatings and chewing gum.

3. General Information

3.1. Properties

Purity

Oppanol is pure polyisobutylene with an ash content of less than 100 ppm and a heavy metal content of less than 3 mg/kg (except for iron < 10 mg/kg).

Food-Contact Applications

The Oppanol polymers fulfill the requirements of German legislation regarding chewing gum and the regulations concerning chewing gum contained in the American Food Chemical Codex of 1996 and FDA Paragraph 21 CFR 172.615 "Chewing gum base".

In addition the use of Oppanol products is governed by the following FDA regulations:

21 CFR 175.105
Adhesives

21 CFR 175.125
Pressure-sensitive adhesives

21 CFR 175.300
Resinous and polymeric coatings

21 CFR 176.180
Components of paper and paperboard in contact with dry food

21 CFR 177.1420
Polyisobutylene polymers (Oppanol B 100 and products with a higher molar mass)

21 CFR 178.3570
Lubricants with incidental food contact

21 CFR 178.3910
Surface lubricants used in the manufacture of metallic articles

Appearance, Color, Odor

Oppanol is virtually colorless and very tacky. Its tack decreases substantially with increasing molar mass. Oppanol is virtually tasteless and odor-free.

Water Resistance

Oppanol is fully resistant to water, including boiling water. It is completely insoluble in water.

Permeability to Gases and Water Vapor

Oppanol has very low permeability to gases such as Argon, water or aqueous solutions. Oppanol is resistant to the following substances at room temperature:

- Diluted and concentrated acids (hydrochloric acid, sulfuric acid, phosphoric acid, chlorosulphonic acid, phenolsulphonic acid, formic acid, acetic acid)
- Diluted and concentrated ammonia
- Diluted and concentrated solutions of sodium hydroxide and potassium hydroxide
- Aqueous quicklime, aqueous hydrogen sulfite, copper sulfate solution, hydrogen peroxide, potassium permanganate solution, chromic acid, potassium dichromate solution

Oppanol has adequate resistance to:

- Concentrated nitric acid and mixed acid

Oppanol is not resistant to:

- Chlorine and bromine in liquid, aqueous or gaseous form

Solvent Resistance

Oppanol is insoluble in:

- Methanol, ethanol, ethylene glycol, glycerin
- Acetone, cyclohexanone
- Methyl acetate, ethyl acetate

Oppanol is solvated by:

- Ethyl ether
- Butyl acetate
- Oils and fats of animal and vegetable origin

Oppanol is soluble in:

- Paraffin, mineral oil (gasoline, diesel oil, lubricating oil, bitumen)
- Benzene, toluene, xylene, cyclohexane, poly-α-olefins, oil soluble synthetic esters
- Methylene chloride, tetra chloromethane, chlorobenzene
- Carbon disulfide

Resistance to Low Temperatures

Oppanol remains elastic at temperatures down to -50°C. It gradually becomes harder at lower temperatures and eventually becomes brittle.

Heat Resistance

- The mechanical properties of high molecular weight Oppanol remain virtually unchanged up to a temperature of about 100°C. It gradually becomes plastic at higher temperatures, and it starts to flow at 180 - 200°C (under nitrogen). The polymer starts to degrade rapidly at this temperature in the presence of air.
- Medium molecular weight Oppanol starts to flow at about 100°C. It starts to degrade at 160 - 180°C.

Resistance to Sunlight and Oxidation

Unstabilized Oppanol undergoes hardly any discoloration in diffuse light, and it does not undergo any other significant physical changes. It begins to degrade in direct sunlight, and especially when irradiated with UV light, which is indicated by a decrease in strength and elasticity and increased tackiness. The resistance of Oppanol to sunlight can be improved substantially by adding pigments and fillers such as carbon black or by adding antioxidants and UV stabilizers.

Affinity for Fillers

Oppanol has a high affinity for all types of fillers. There is no difficulty in preparing sheets consisting of 1 part of Oppanol and 10 parts of fillers such as china clay, chalk or talc, etc.

Compatibility with Rubber, Resins, Waxes, etc.

Oppanol can be mixed with rubber and rubber substitutes.

Dielectric Properties

Oppanol is a nonpolar, hydrocarbon polymer. It is an excellent insulator, and its dielectric properties are not affected by prolonged immersion in water.

Dimensional Stability

Oppanol displays cold flow, and undergoes permanent deformation under a permanent load.

Reactivity

Oppanol is an almost completely saturated paraffinic polymer, and therefore practically inert.

Cross-Linking

The methods that are usually used to cross-link saturated ethylene polymers, such as applying high-energy radiation or adding peroxide and allowing it to decompose, cause Oppanol to break down.

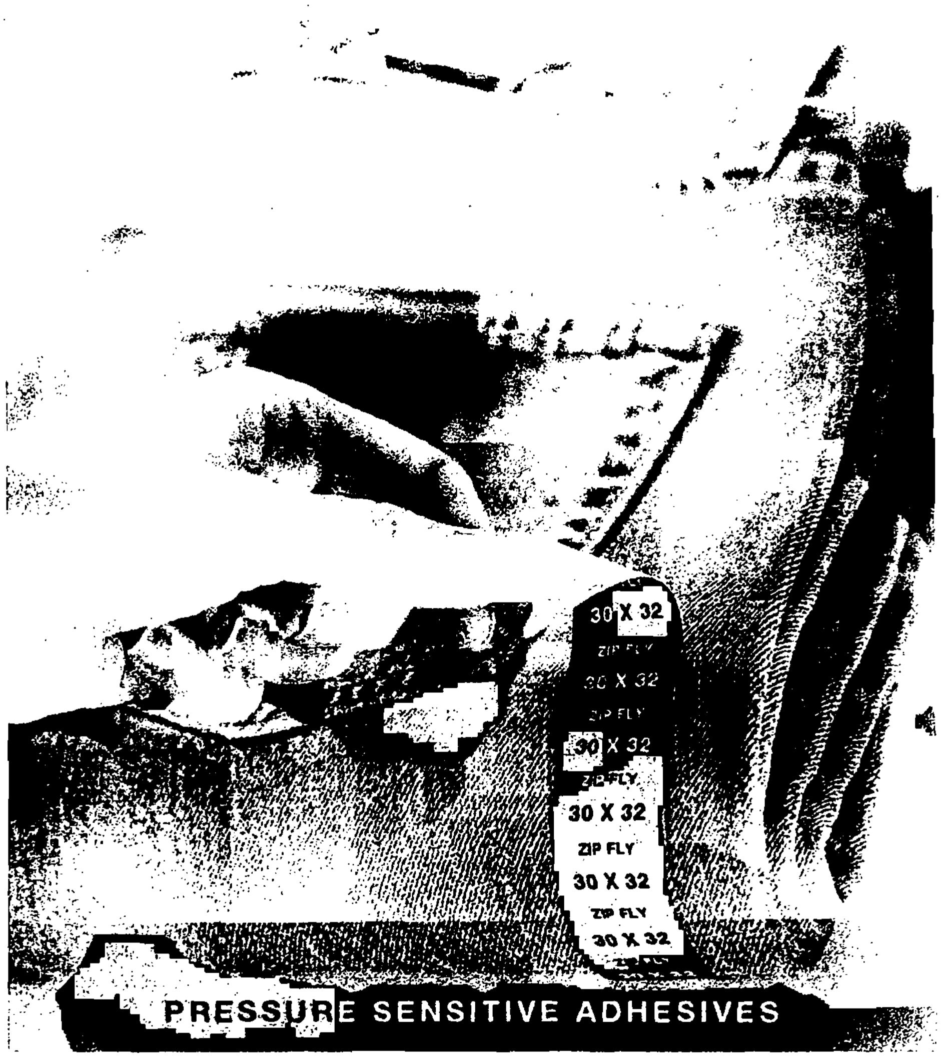
Because Oppanol is saturated, it cannot be vulcanized with sulfur. Peroxides need to be added to Oppanol before it can be vulcanized.

Typical properties

Density at 20°C	0.92	g/cm^{-3}
Glass transition temperature, T_g (DSC)	-62	°C
Specific heat, c	2.0	kJ*kg^{-1}K^{-1}
Thermal conductivity, λ	0.19	W*K^{-1}*m^{-1}
Refractive index, $n^{20}D$	1.51	
Dielectric constant, ε_r (50 Hz, 23°C)	2.2	
Dissipation factor, tan δ (50 Hz, 23°C)	<=5*10^{-4}	
Specific resistance	1,016	Ω*cm
Coefficient of permeability to water vapor	2.5*10^{-7}	g*m^{-1}*h^{-1}*mbar^{-1}

Note:

The details presented here on the properties and processing of Oppanol® and its applications are for information purposes only. They do not constitute a specification or a guarantee of specific properties.



3.2. Processing

Oppanol is usually packaged in 20 kg cardboard boxes, 20 kg bags, and 100 lbs drums.

Oppanol is a thermoplastic and can be processed with conventional machinery used in the rubber industry, such as kneaders, roll mills, calendars, single- and twin-screw extruders, and extrusion presses. Recently, press mixers have also been used.

3.3. Removing Packaging

Cardboard box (Fig. 1 - Fig. 4)

BASF recommends opening the box on both sides longitudinally by hand (Fig. 2), pulling out the flaps (Fig. 3), and folding down the side walls (Fig. 4).

Figure 1

Figure 2

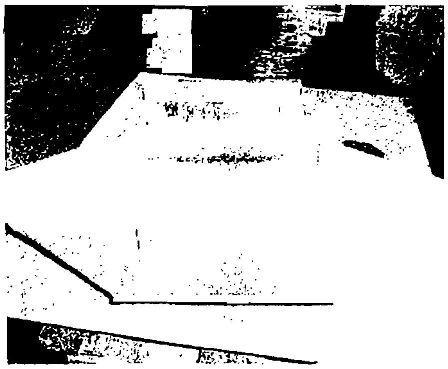


Figure 3

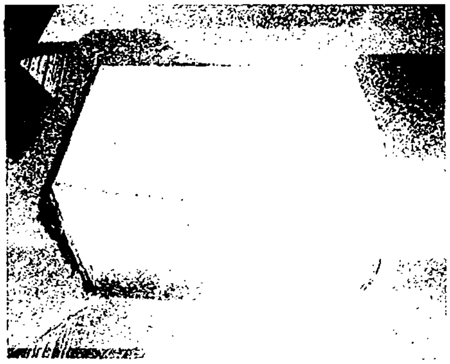


Figure 4

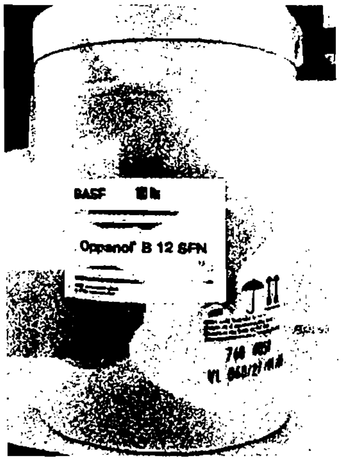


Figure 5

Drum (Fig. 5)

Remove lid from the top of the drum. Place drum upside down to remove the material.

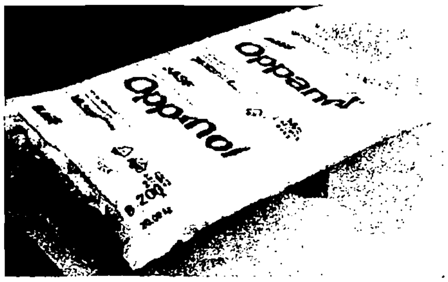


Figure 6

Figure 7

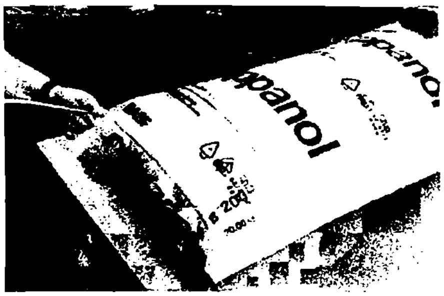


Figure 8

Plastic bag (Fig. 6 - Fig. 8)

BASF recommends cutting open the liner at the front and the sides (Fig. 7). If the bag sticks to the contents and is difficult to remove, then the bag can be inflated with compressed air (Fig. 8) before it is cut open.

3.4. Applications

Formulations that Contain Fillers

Building industry:
For sealing membranes used to seal buildings from standing water; roofing membranes with or without standing water, waterproofing for tunnels and cellars in combination with bitumen

Corrosion protection:
Linings for chemical reactors, other vessels, and underbody sealants for automobiles

Electrical industry:
Conductive films filled with graphite and magnetic films filled with barium ferrite

Electrical insulation:
Extremely high flashover voltage

Inorganic fillers:
Carbon black, graphite, chalk, shale, quartz, china clay and talc

Thermoplastic additives:
Thermoplastics such as EVA copolymers, PP, HDPE, LDPE and LLDPE act as plasticizers at temperatures above their melting point. They reduce shear, resulting in less mechanical degradation when Oppanol is processed. At temperatures below their melting point, these thermoplastics act as fillers at low deformation, resulting in a higher modulus of elasticity and a higher elongation at break.

Rubber Industry

Coating compounds:
Additive for compounds of natural and synthetic rubber

Regeneration:
Used in the regeneration of waste vulcanized rubber

Cable sheathing:
Good insulator with self sealing properties to prevent short circuits if sheathing is punctured

Ebonite compounds:
Increases the impact resistance of ebonite

Mixtures with Waxes

Mixtures of this type are mainly used to coat, impregnate and laminate paper, plastic film, and metal foil.
Advantages: High melt viscosity, low permeability to water vapor, very pliable film, better adhesion, improved sealability

Mixtures with Bitumen

Advantages: Increased melt viscosity, a more pliable bitumen film, improved resistance to changes in temperature (in bridge construction), higher weathering resistance, better adhesion, very high water resistance

Adhesives

Oppanol® is used on account of its resistance to aging and to attack by chemicals in pressure sensitive adhesives for technical and medical applications, such as surgical plasters, sealing tapes, insulating tapes, masking tapes and anticorrosion tapes.

Permanently Elastic Sealants

Permanently elastic sealants (mainly for double-glazed windows) can be manufactured by blending different Oppanol® types and using fillers such as chalk, zinc oxide, china clay or barites. Bitumen may also be included in the formulation.

Chewing Gum Base

Chewing gum base is manufactured by mixing Oppanol with chalk, corn oil, paraffin wax and other waxes and fats, etc. The chewing gum itself is made by adding icing sugar, dextrose, glycerin, citric acid and flavoring to the chewing gum base.

Mixtures with Mineral Oil and Lubricants

Oppanol can be used to increase the viscosity and adhesion of oils and chain lubricants, or as a thickener for lubricating grease, and a drag reducer in oil pipelines.


PROTECTIVE FILMS


CLING FILMS


HOT MELT ADHESIVES


MAGNETIC BINDERS

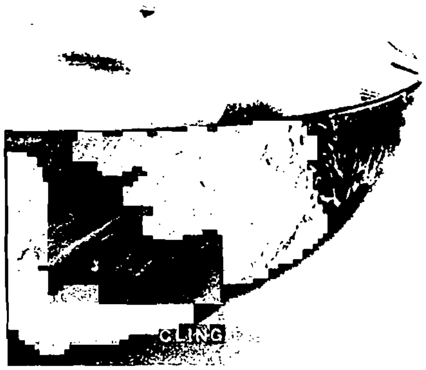
4. Other Possible Applications

- Oppanol®

- Disposal of solid and liquid waste
- Disposal of metal dust, asbestos dust, and toxic sludge
- Removing oil pollution from water
- Cleaning up oil slicks after tanker accidents
- Recycling plastic waste (in the automotive sector)
- Can be processed chemically into lubricant additives, copolymers, and sealants with enhanced adhesion

- Blends of Oppanol® and other polymers

- Sterile tubes for medical suction equipment
- Infusion tubes
- Seals for disposable syringes
- Medical metering equipment
- Automotive films
- Decorative films, including films laminated with textile fibers
- Household films
- Cling film for food packaging
- Peelable film for yogurt containers, etc.
- Cosmetic packaging
- Sealants for bottle caps
- Non-slip tablemats
- Protective panels for vacuum cleaners



Note:

The details presented here on the properties and processing of Oppanol and its applications are for information purposes only. They do not constitute a specification or a guarantee of specific properties.

5. Specifications, Technical Literature, Safety Data Sheets, and Product Range

The C of A lists Staudinger index (Jo) measured by a BASF method. Specifications, technical literature, and safety data sheets are available from your local BASF representatives.

Product range:

Oppanol	Molecular Weight		Consistency
	Mw (GPC)	Mv	
B 10 SFN	36,000	40,000	Soft, resinous
B 12 SFN	51,000	55,000	Soft, resinous
B 13 SFN	60,000	65,000	Soft, resinous
B 15 SFN	75,000	85,000	Soft, resinous
B 30 SF	200,000	200,000	Soft, resinous
B 50 / B 50 SF	340,000	400,000	Soft, resinous
B 80	750,000	800,000	Rubbery
B 100	1,100,000	1,110,000	Rubbery
B 150	2,500,000	2,600,000	Rubbery
B 200	4,100,000	4,000,000	Rubbery

6. Markings

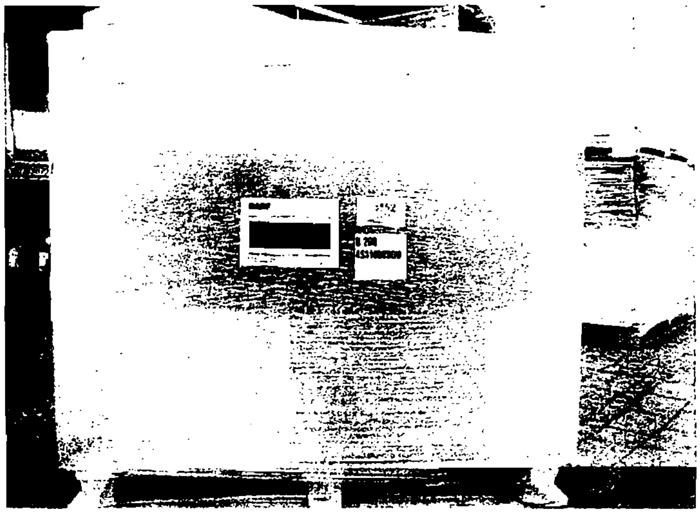
6.1. Oppanol® B 10 SFN, B 12 SFN, B 13 SFN, B 15 SFN, B 30 SF, B 50, B 50 SF

These products are packed in 20 kg (44 lb) corrugated cardboard boxes with an inner silicone release coating and in 100 lb paper/fiber drums lined with a silicone coated nylon liner.

The lid is labeled as follows:
BASF Oppanol B XX XXX 20 kg
BASF Aktiengesellschaft D-67056 Ludwigshafen
MADE IN GERMANY

The cardboard boxes are labeled on only one side of the box.

The symbols for "this side up" and "protect from moisture" also appear.

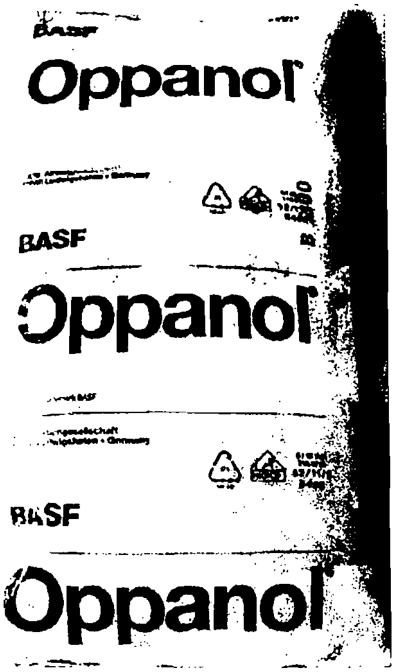


The pallet is covered with shrink wrap to protect it from moisture.

On one pallet there are 30 cardboard boxes or 9 drums.

A large, colored sticker is attached to one of the boxes on each pallet in order to draw attention to the designation of the product. Attached to the same box is a stamped label, which gives details of the total net weight of the pallet load and the number of the pallet. This serial number is important for tracing back the pallet and for processing shipment related requests.

6.2. Oppanol® B 80, B 100, B 150, B 200



These products are supplied in 20 kg LDPE bags.

Each bag is labeled as follows:

BASF Oppanol B XX XXX 20 kg
BASF Aktiengesellschaft D-67056 Ludwigshafen Germany

The bags are also labeled with the code number of the packaging and a recycling symbol.

The grade of product is printed on the label.

The bags are supplied on pallets in units of 30 (Oppanol B 150 / B 200) or 40 (Oppanol B 80 / B 100). A large corrugated cardboard cover is placed over the bags on the pallet in order to ensure that the stack remains stable when the bags at the bottom are deformed under the weight of the bags on top as the result of cold flow.

A large sticker is attached to the cardboard cover of each pallet in order to draw attention to the designation of the product. A label is also attached which gives details of the total net weight of the pallet load and the number of the pallet. This pallet number is important for tracing back for processing complaints.

The cardboard cover is then shrink wrapped to protect it from moisture.

7. Dispatch

When the product is ready to be shipped, labels are attached providing details of the internal work order number and customer specific information.

These labels appear on the outside of the shrink wrap.

8. Traceability

In case of questions about the shipped product, information can be retrieved from our system. It is important that all information printed on the packaging, on the pallet, and on paperwork associated with the shipment (including purchase order, internal work order numbers, etc.) should be kept for your records.

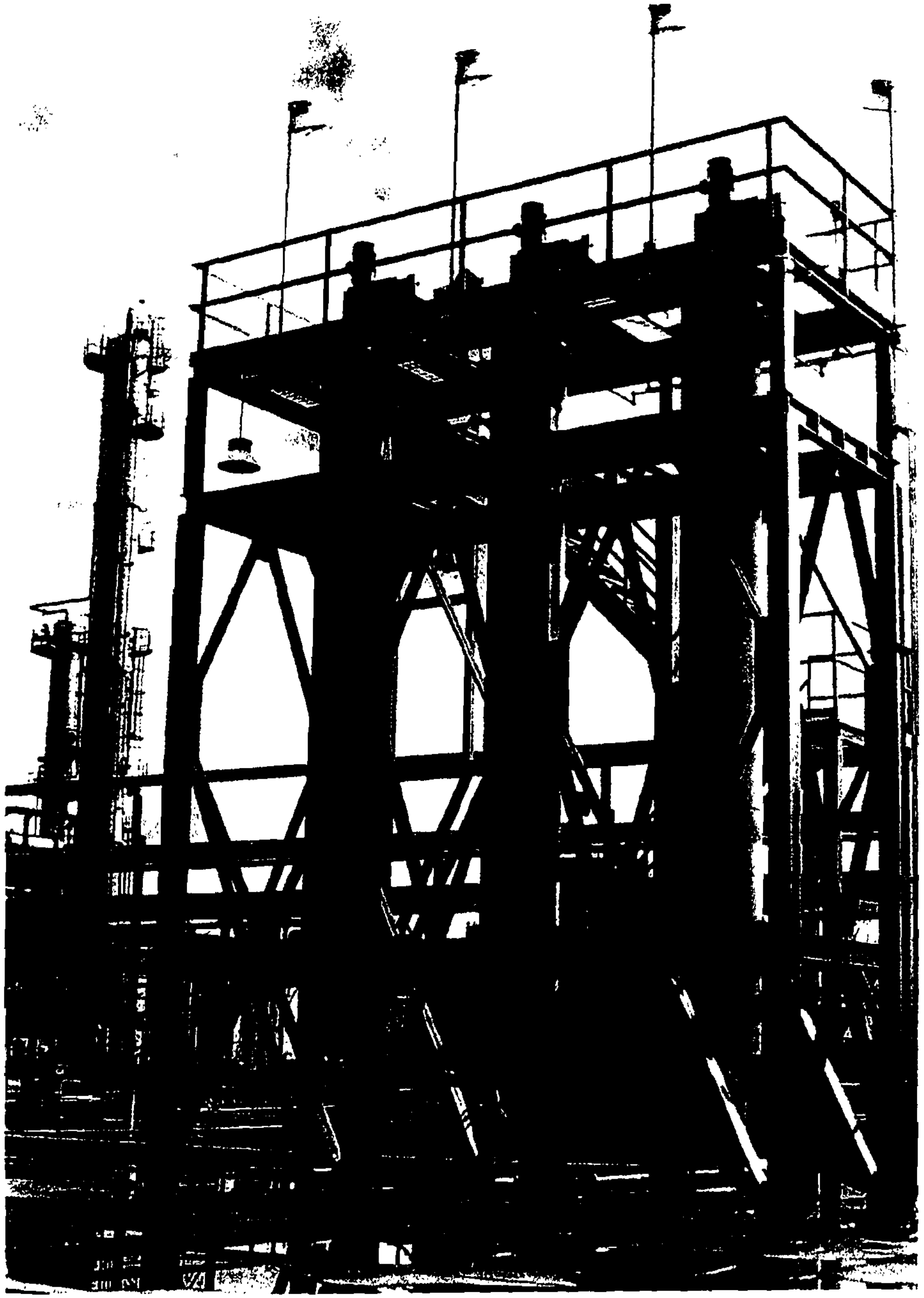
The pallet number helps us to identify the exact production time (within one hour) and therefore all of the quality information can be retrieved. Please, note that the pallet number is attached only once to the outside shrink wrap on the pallet.

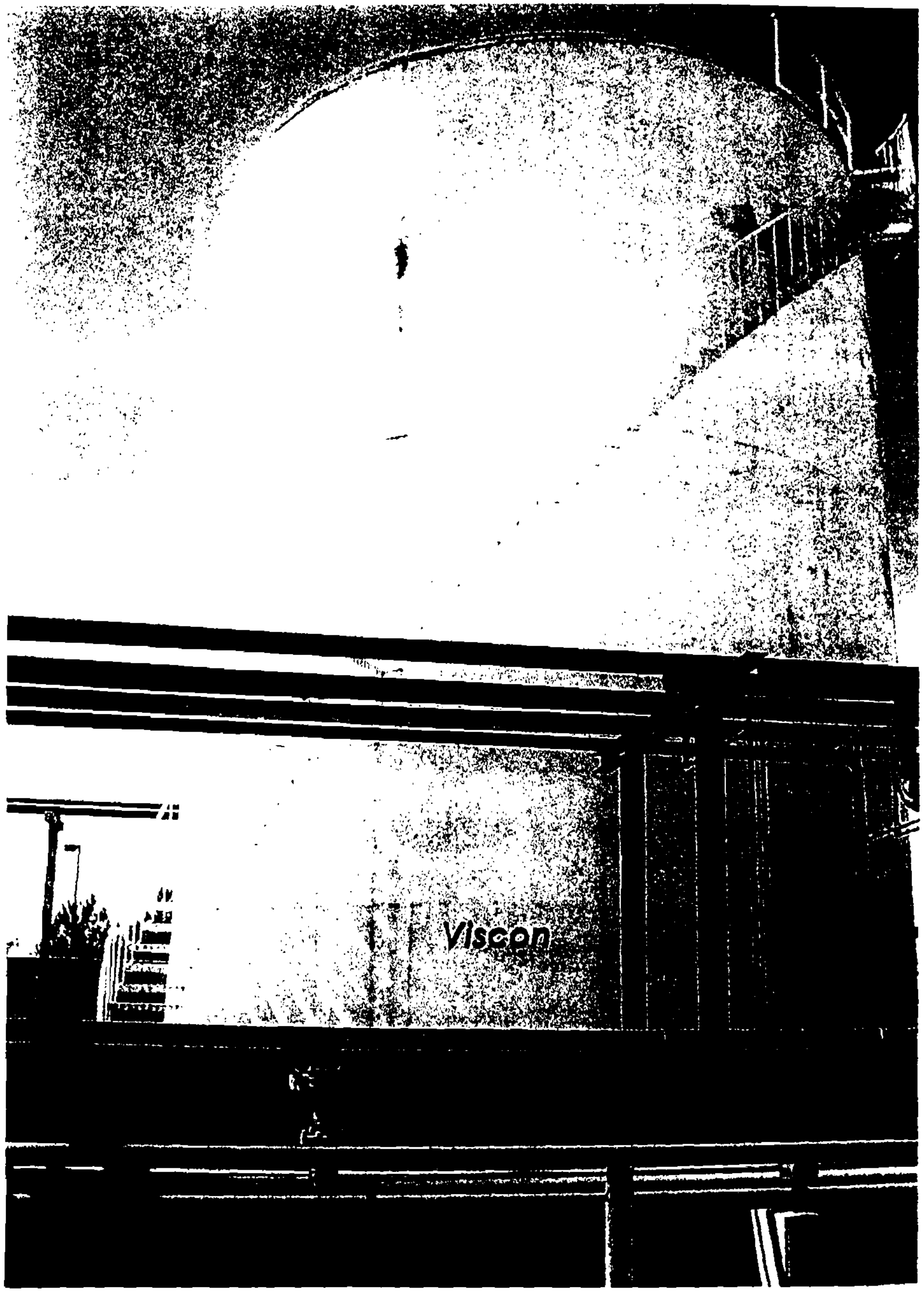
Note:

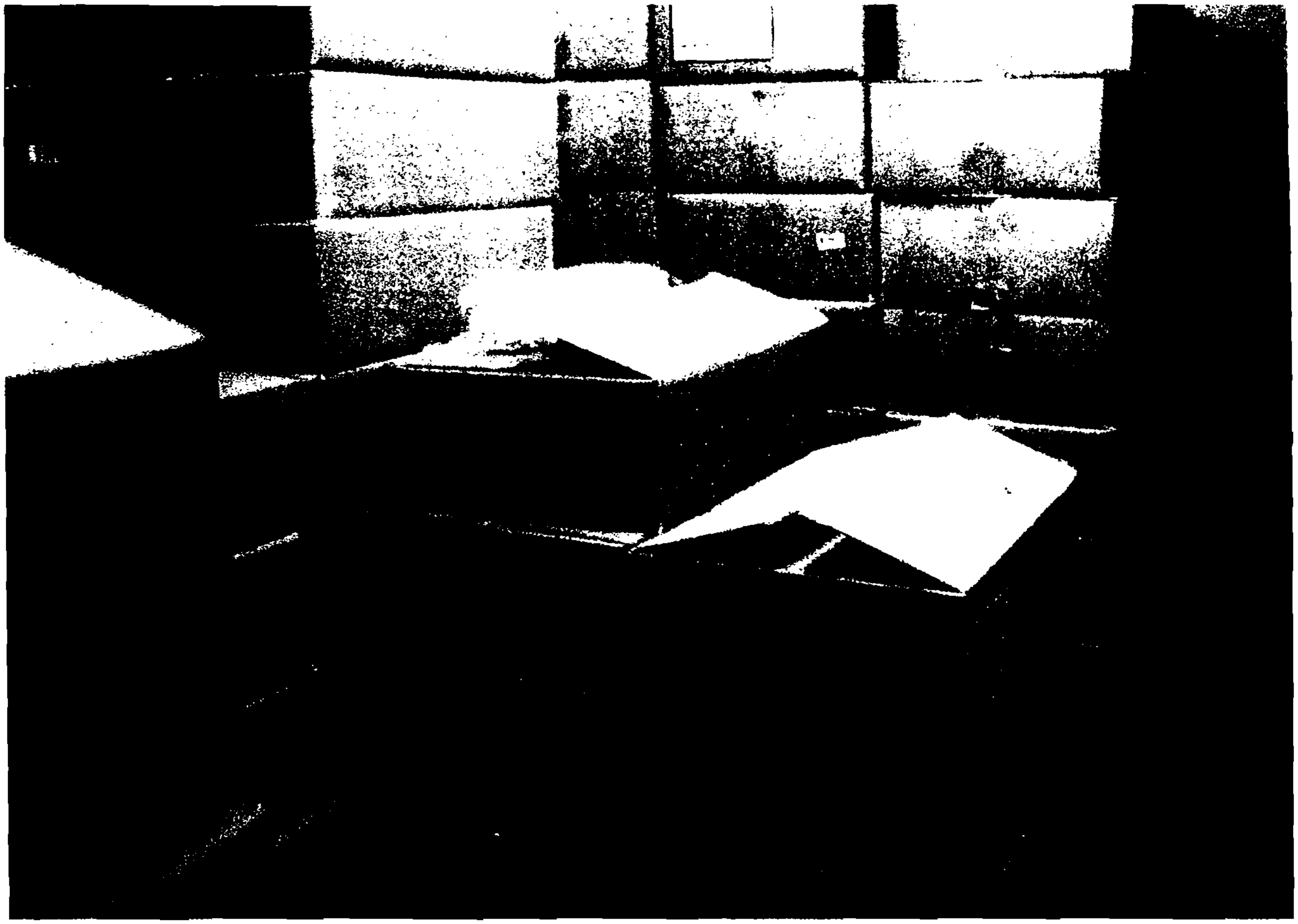
The details presented here on the properties and processing of Oppanol and its applications are for information purposes only. They do not constitute a specification or a guarantee of specific properties.

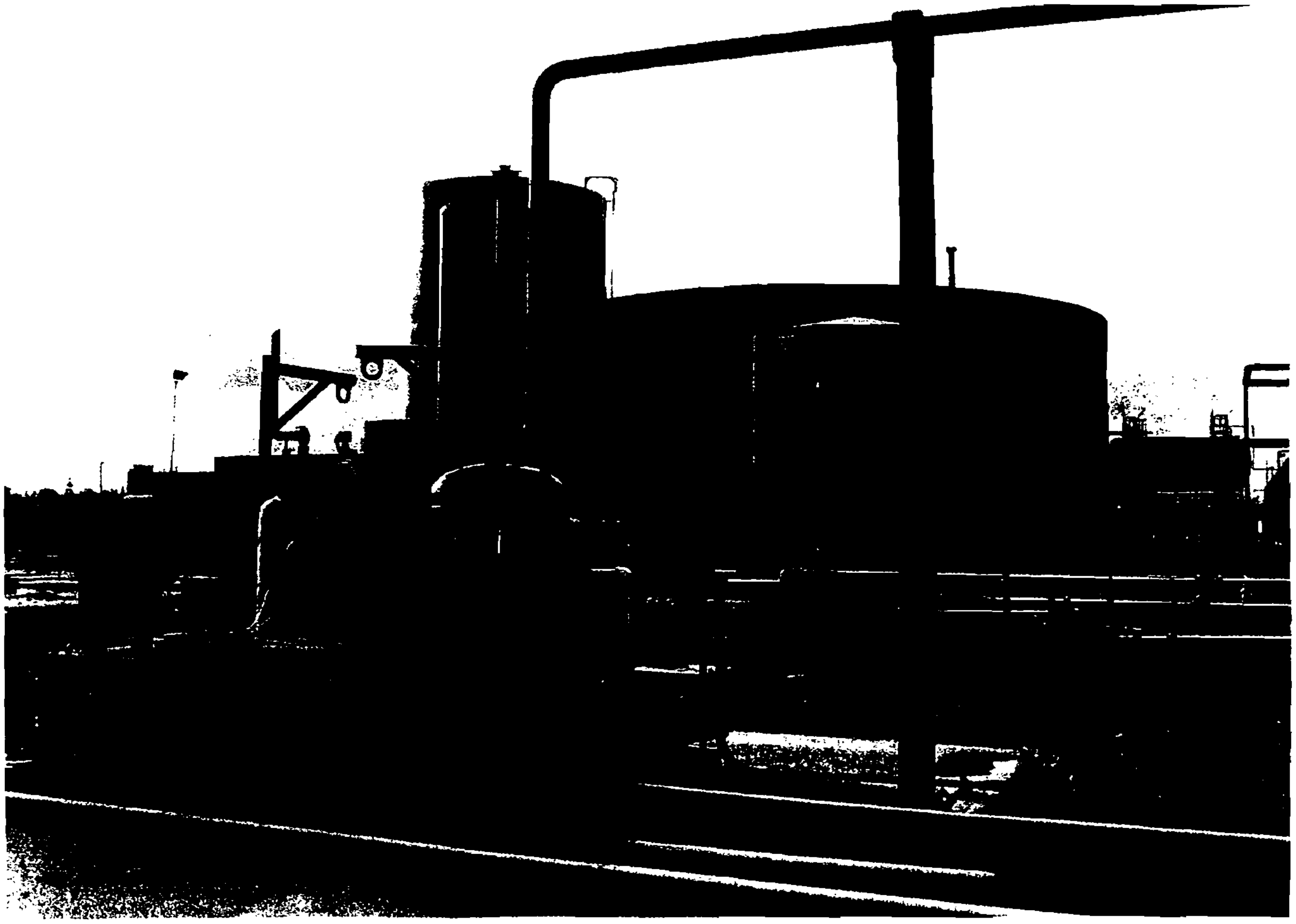
Attachment 3

Viscon Production Flow



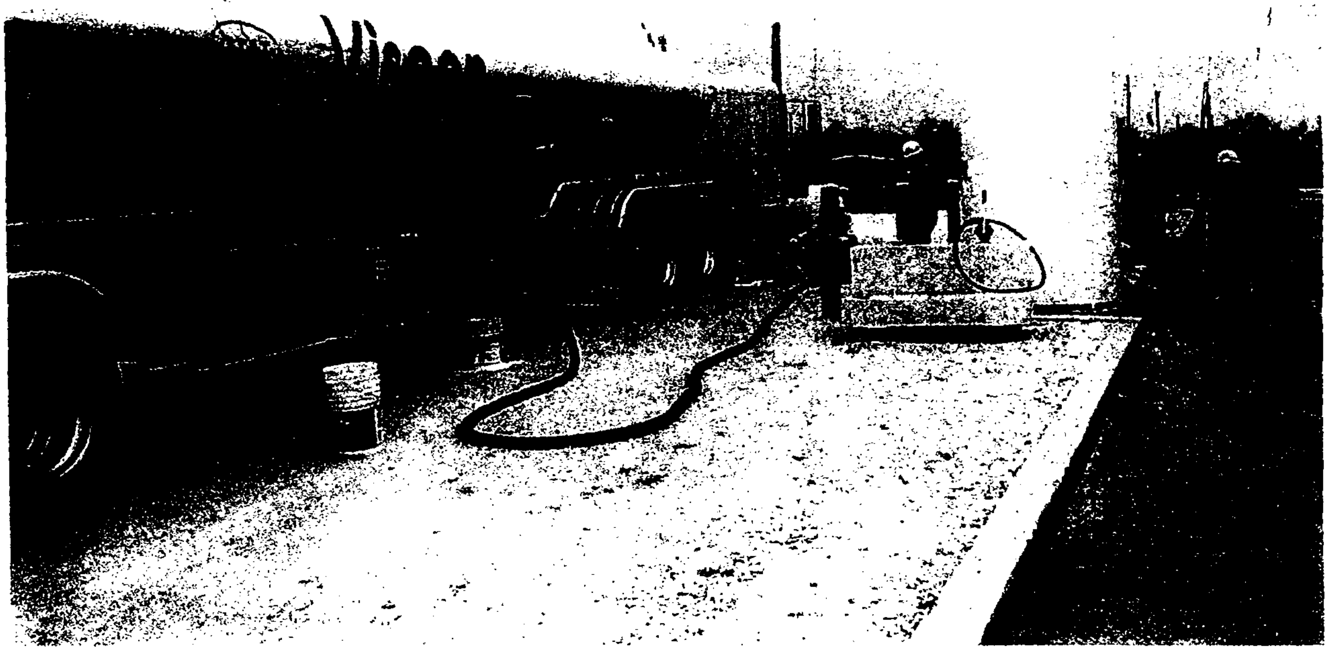

Viscon

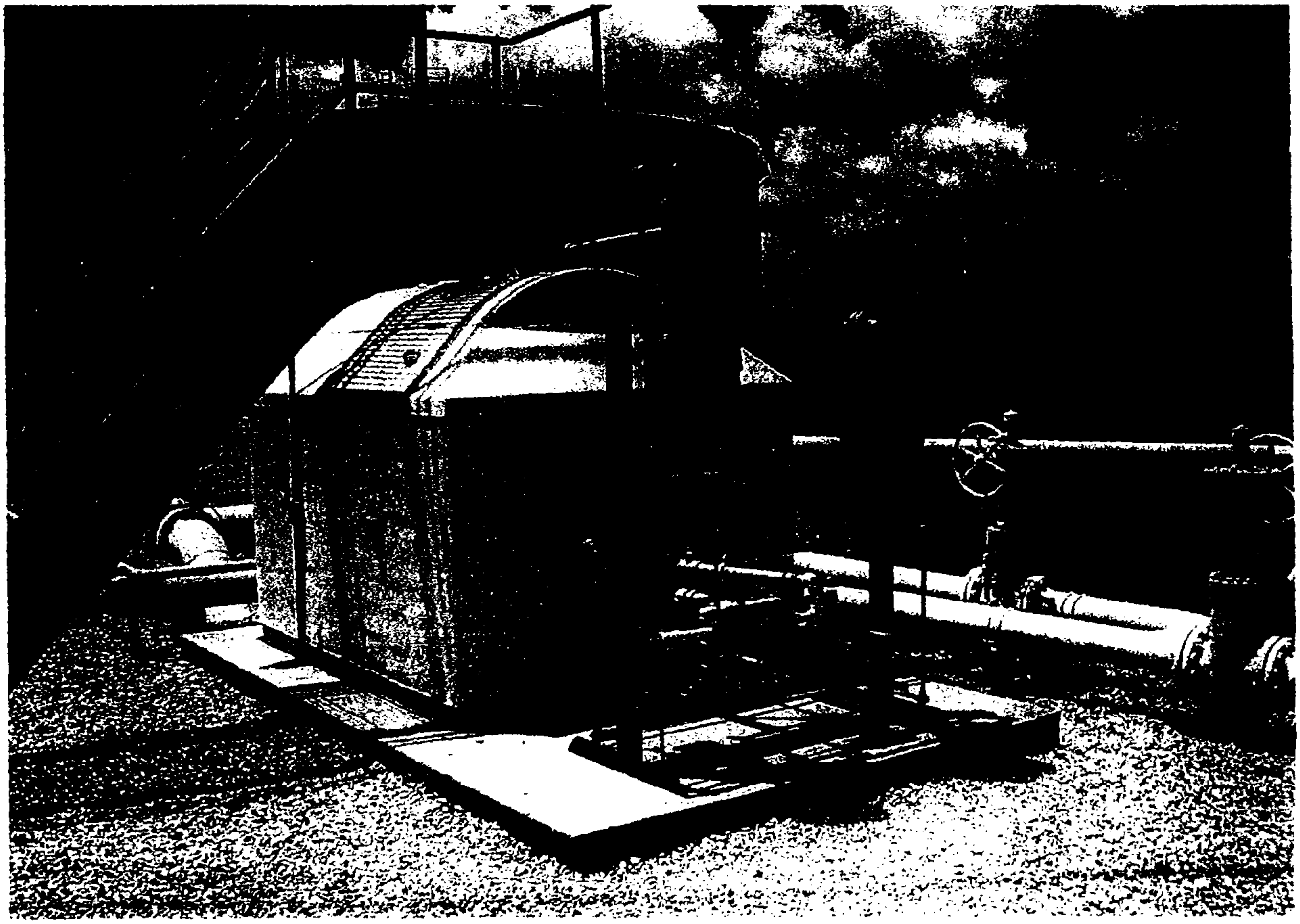




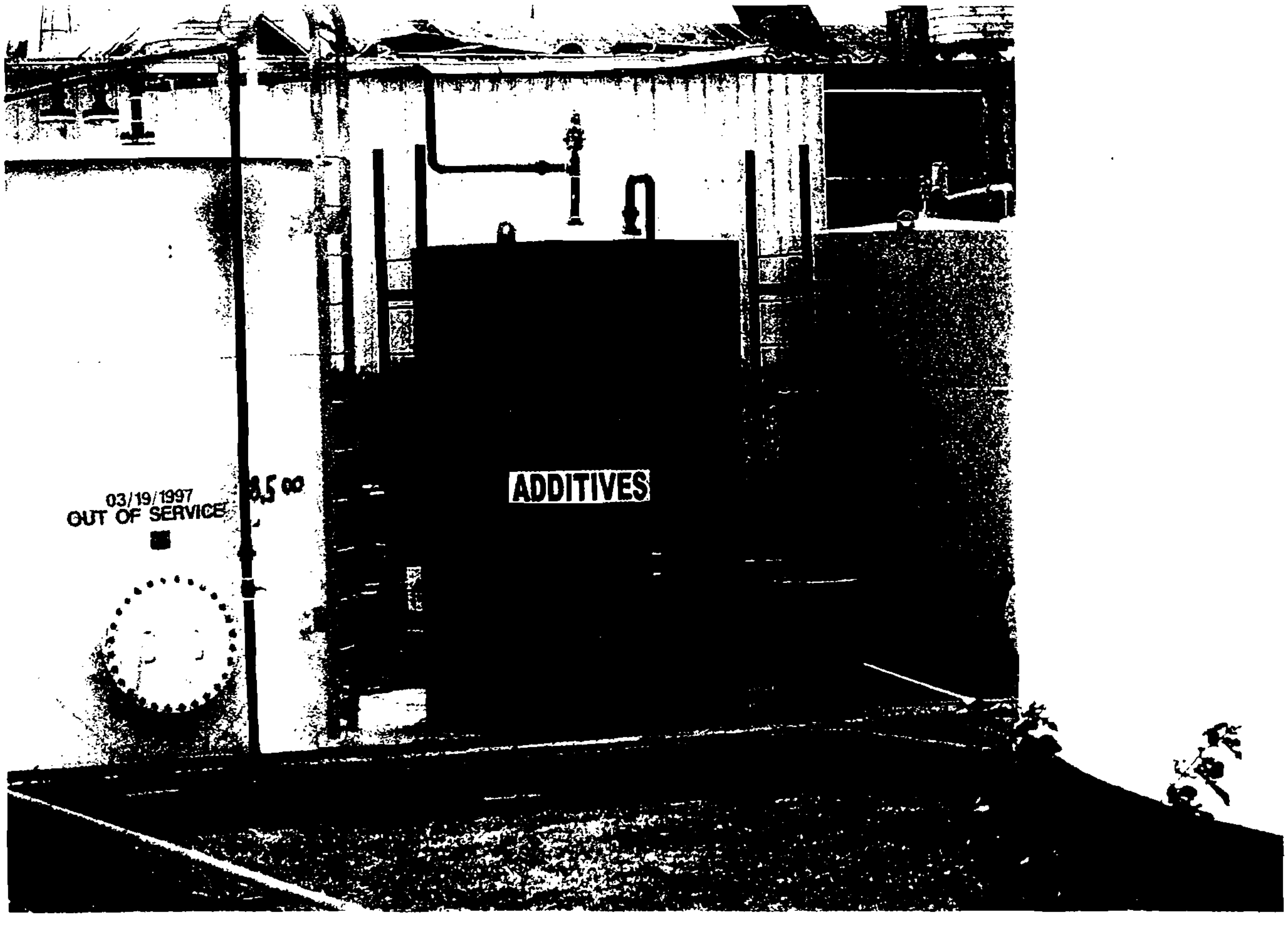
Attachment 4

Customer-Site Storage






Truck Centers
Sales-Parts-Service


03/19/1997
OUT OF SERVICE
8,500
ADDITIVES

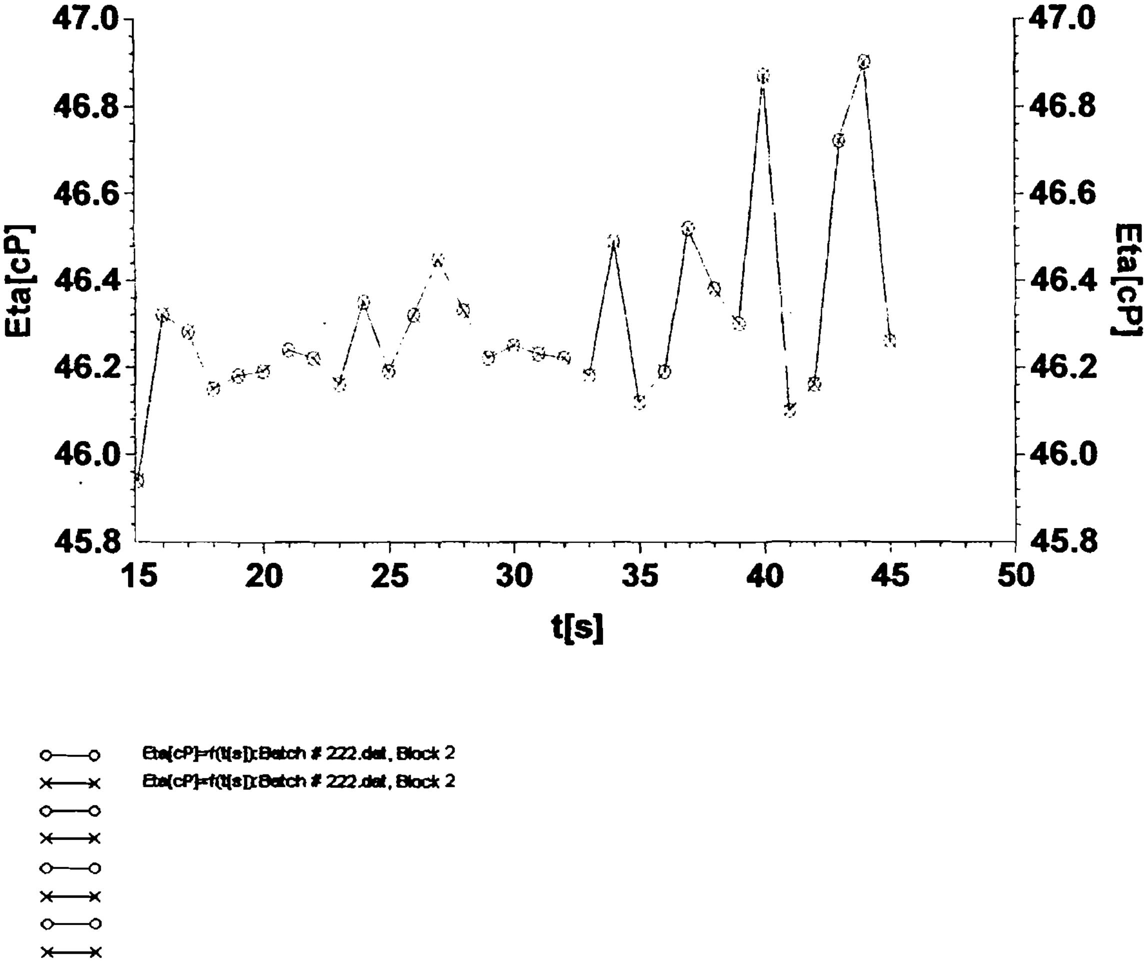
Attachment 5

Viscosity Measurements (Quality Control)

Data-report C:\RHEO28\DATA\Batch # 222.dat 09:03 03/01/07

Customer:	**Quality Control**
Measuring-Ident:	**Batch # 222**
Medium-Ident:	**Tower 3**
Operator:	Misty
Comment:	
	Batch was made 10.09.06
Program filename:	C:\RHEO28\PROG\Viscon Sequence.seq
Prog.mode:	sequence
Date:	06:58 10/10/06
Block termination:	Block end
Block 2 of 2:	
measuring-system:	CC48 DIN
Rheometer:	R/S+ Rheometer Ver.:9.00 from 15.02.05, Serialnumber: #303117

filters active
t[s]>=15
data-graph:



Data-grid: Batch # 222.dat Block:2
Datafilter is active!

MP#	t[s]	Eta[mPas]	D[1/s]	Tau[Pa]	T[°C]	M[%.]	n[rpm]	Step
15	15	45.94	250	11.484	32	60.44	48.62	1
16	16	46.32	250	11.581	32	60.95	48.62	1
17	17	46.28	250	11.569	32	60.89	48.62	1
18	18	46.15	250	11.538	32	60.72	48.62	1
19	19	46.18	250	11.545	32	60.76	48.62	1
20	20	46.19	250	11.547	32	60.77	48.62	1
21	21	46.24	250	11.56	32	60.84	48.62	1
22	22	46.22	250	11.556	32	60.82	48.62	1
23	23	46.16	250	11.539	32	60.73	48.62	1
24	24	46.35	250	11.587	32	60.98	48.62	1
25	25	46.19	250	11.548	32	60.78	48.62	1
26	26	46.32	250	11.581	32	60.95	48.62	1
27	27	46.45	250	11.613	32	61.12	48.62	1
28	28	46.33	250	11.583	32	60.97	48.62	1
29	29	46.22	250	11.554	32	60.81	48.62	1
30	30	46.25	250	11.563	32	60.86	48.62	1
31	31	46.23	250	11.557	32	60.83	48.62	1
32	32	46.22	250	11.555	32	60.82	48.62	1
33	33	46.18	250	11.546	32	60.77	48.62	1
34	34	46.49	250	11.623	32	61.17	48.62	1
35	35	46.12	250	11.531	32	60.69	48.62	1
36	36	46.19	250	11.547	32	60.77	48.62	1
37	37	46.52	250	11.629	32	61.21	48.62	1
38	38	46.38	250	11.594	32	61.02	48.62	1
39	39	46.3	250	11.576	32	60.93	48.62	1
40	40	46.87	250	11.718	32	61.67	48.62	1
41	41	46.1	250	11.525	32	60.66	48.62	1
42	42	46.16	250	11.539	32	60.73	48.62	1
43	43	46.72	250	11.679	32	61.47	48.62	1
44	44	46.9	250	11.726	32	61.72	48.62	1
45	45	46.26	250	11.564	32	60.86	48.62	1

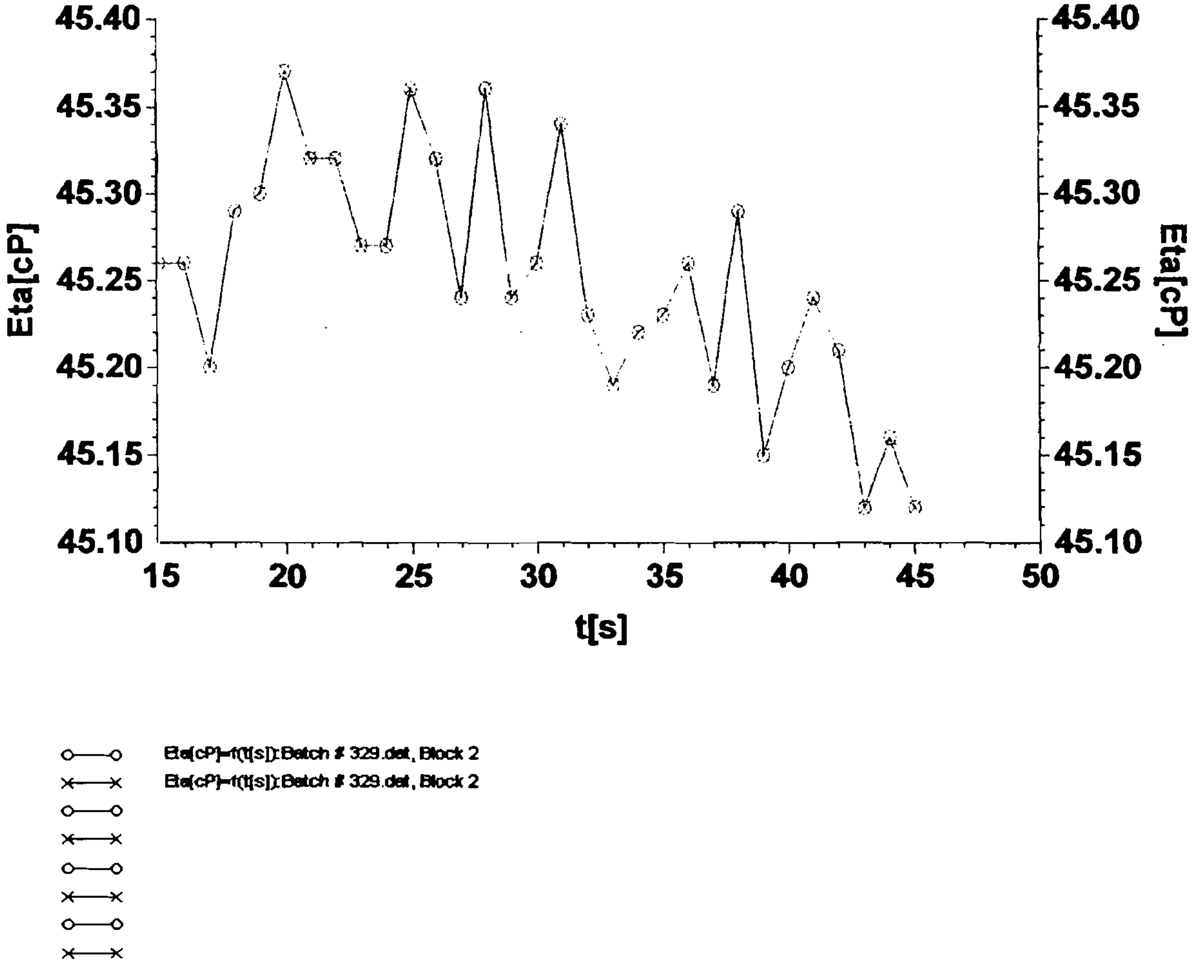
Analysis-results:
filter activated: t[s]>=15
step1: average/mean of Eta[Pas]=0.046, S=0.0002
End of report

Data-report: C:\RHEO28\DATA\Batch # 329.dat   08:51 03/01/07

Customer: **Quality Control**
Measuring-Ident: **Batch # 329**
Medium-Ident: **Tower 2**
Operator: Preston
Comment:
Batch was made 12.8.06

Program filename: C:\RHEO28\PROG\Viscon Sequence.seq
Prog.mode: sequence
Date: 06:44 11/12/06
Block termination: Block end
Block 2 of 2:
measuring-system: CC48 DIN
Rheometer: R/S+ Rheometer Ver.:9.00 from 15.02.05, Serialnumber: #303117

filters active
t[s]>=15
data-graph:



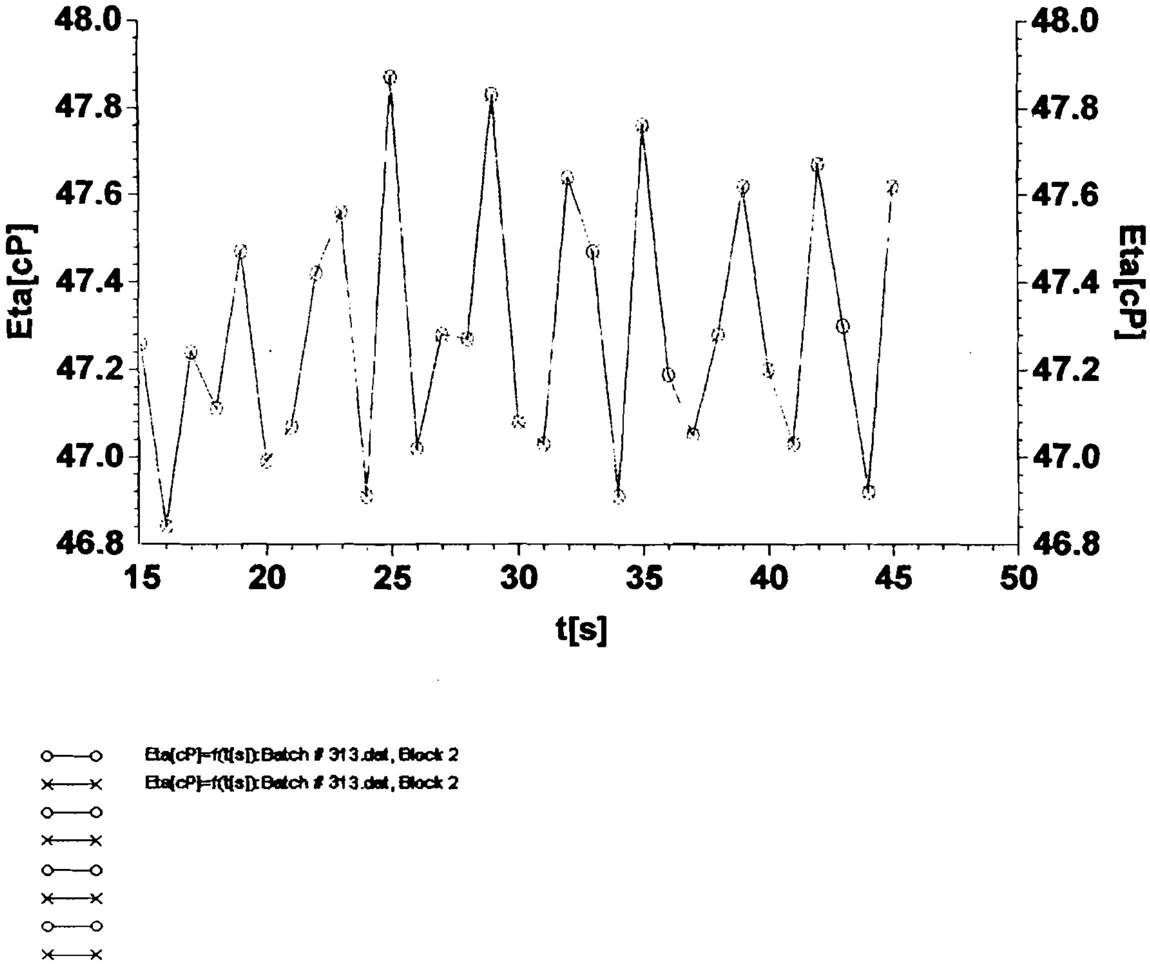
```
Data-grid: Batch # 329.dat Block:2
Datafilter is active!
MP#    t[s]    Eta[mPas] D[1/s]    Tau[Pa]    T[°C]    M[%.]    n[rpm]    Step
15     15      45.26     250       11.314     31.4     59.55    48.62     1
16     16      45.26     250       11.316     31.4     59.56    48.62     1
17     17      45.2      250       11.3       31.4     59.47    48.62     1
18     18      45.29     250       11.322     31.4     59.59    48.62     1
19     19      45.3      250       11.325     31.4     59.6     48.62     1
20     20      45.37     250       11.342     31.4     59.69    48.62     1
21     21      45.32     250       11.33      31.4     59.63    48.62     1
22     22      45.32     250       11.329     31.4     59.63    48.62     1
23     23      45.27     250       11.318     31.4     59.57    48.62     1
24     24      45.27     250       11.318     31.4     59.57    48.62     1
25     25      45.36     250       11.341     31.4     59.69    48.62     1
26     26      45.32     250       11.33      31.4     59.63    48.62     1
27     27      45.24     250       11.309     31.4     59.52    48.62     1
28     28      45.36     250       11.341     31.4     59.69    48.62     1
29     29      45.24     250       11.311     31.4     59.53    48.62     1
30     30      45.26     250       11.315     31.4     59.55    48.62     1
31     31      45.34     250       11.334     31.4     59.65    48.62     1
32     32      45.23     250       11.308     31.4     59.52    48.62     1
33     33      45.19     250       11.298     31.4     59.46    48.62     1
34     34      45.22     250       11.305     31.4     59.5     48.62     1
35     35      45.23     250       11.307     31.4     59.51    48.62     1
36     36      45.26     250       11.315     31.4     59.55    48.62     1
37     37      45.19     250       11.298     31.4     59.47    48.62     1
38     38      45.29     250       11.322     31.4     59.59    48.62     1
39     39      45.15     250       11.287     31.4     59.41    48.62     1
40     40      45.2      250       11.3       31.4     59.48    48.62     1
41     41      45.24     250       11.311     31.4     59.53    48.62     1
42     42      45.21     250       11.303     31.4     59.49    48.62     1
43     43      45.12     250       11.279     31.4     59.36    48.62     1
44     44      45.16     250       11.289     31.4     59.42    48.62     1
45     45      45.12     250       11.28      31.4     59.37    48.62     1

Analysis-results:
filter activated: t[s]>=15
step1: average/mean of Eta[Pas]=0.045, S=0.0001
End of report
```

Data-report: C:\RHEO28\DATA\Batch # 313.dat 08:50 03/01/07 page 1

Customer: **Quality Control**
Measuring-Ident: **Batch # 313**
Medium-Ident: **Tower 1**
Operator: Misty
Comment:
Batch was made 11.07.06

Program filename: C:\RHEO28\PROG\Viscon Sequence.seq
Prog.mode: sequence
Date: 06:02 08/11/06
Block termination: Block end
Block 2 of 2:
measuring-system: CC48 DIN
Rheometer: R/S+ Rheometer Ver.:9.00 from 15.02.05, Serialnumber: #303117

filters active
t[s]>=15
data-graph:



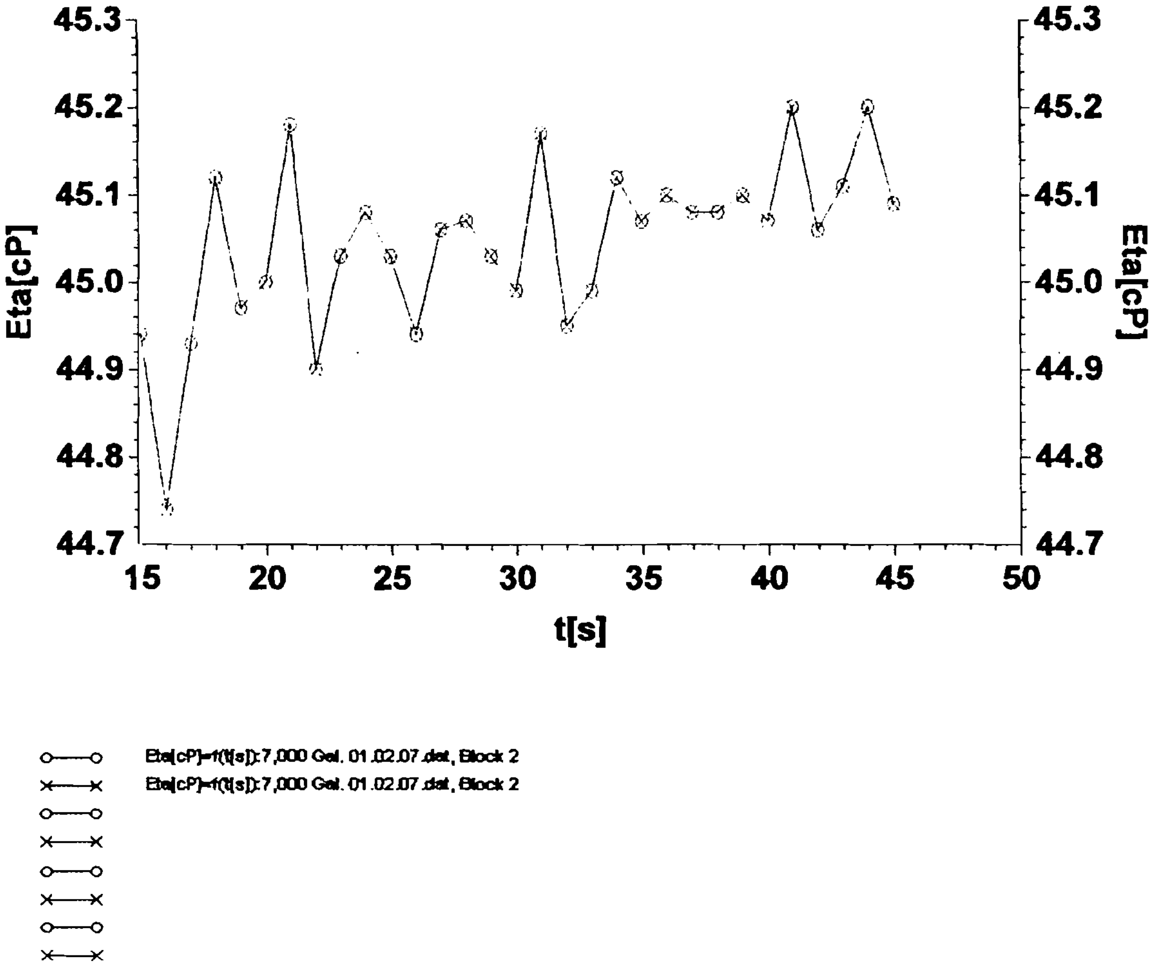
```
Data-grid: Batch # 313.dat Block:2
Datafilter is active!
MP#   t[s]   Eta[mPas] D[1/s]   Tau[Pa]   T[°C]   M[%.]   n[rpm]   Step
15    15     47.26     250      11.816    31.9    62.19   48.62    1
16    16     46.84     250      11.71     31.9    61.63   48.62    1
17    17     47.24     250      11.81     31.9    62.16   48.62    1
18    18     47.11     250      11.778    31.9    61.99   48.62    1
19    19     47.47     250      11.868    31.9    62.47   48.62    1
20    20     46.99     250      11.747    31.9    61.82   48.62    1
21    21     47.07     250      11.768    31.9    61.94   48.62    1
22    22     47.42     250      11.856    31.9    62.4    48.62    1
23    23     47.56     250      11.891    31.9    62.59   48.62    1
24    24     46.91     250      11.728    31.9    61.73   48.62    1
25    25     47.87     250      11.968    31.9    62.99   48.62    1
26    26     47.02     250      11.754    31.9    61.86   48.62    1
27    27     47.28     250      11.819    31.9    62.2    48.62    1
28    28     47.27     250      11.817    31.9    62.2    48.62    1
29    29     47.83     250      11.958    31.9    62.94   48.62    1
30    30     47.08     250      11.769    31.9    61.94   48.62    1
31    31     47.03     250      11.758    31.9    61.88   48.62    1
32    32     47.64     250      11.909    31.9    62.68   48.62    1
33    33     47.47     250      11.867    31.9    62.46   48.62    1
34    34     46.91     250      11.728    31.9    61.73   48.62    1
35    35     47.76     250      11.941    31.9    62.85   48.62    1
36    36     47.19     250      11.797    31.9    62.09   48.62    1
37    37     47.05     250      11.763    31.9    61.91   48.62    1
38    38     47.28     250      11.82     31.9    62.21   48.62    1
39    39     47.62     250      11.905    31.9    62.66   48.62    1
40    40     47.2      250      11.799    31.9    62.1    48.62    1
41    41     47.03     250      11.757    31.9    61.88   48.62    1
42    42     47.67     250      11.918    31.9    62.73   48.62    1
43    43     47.3      250      11.824    31.9    62.23   48.62    1
44    44     46.92     250      11.731    31.9    61.74   48.62    1
45    45     47.62     250      11.905    31.9    62.66   48.62    1

Analysis-results:
filter activated: t[s]>=15
step1: average/mean of Eta[Pas]=0.047, S=0.0003
End of report
```

Data-report: C:\RHEO28\DATA\7,000 Gal. 01.02.07.dat 08:49 03/01/07

Customer: **Quality Control**
Measuring-Ident: **7,000 Gallons**
Medium-Ident: **Tank 351**
Operator: Misty
Comment:
7,000 gallons going to Texas pulled from Tank 351 01.02.07

Program filename: C:\RHEO28\PROG\Viscon Sequence.seq
Prog.mode: sequence
Date: 12:23 02/01/07
Block termination: Block end
Block 2 of 2:
measuring-system: CC48 DIN
Rheometer: R/S+ Rheometer Ver.:9.00 from 15.02.05, Serialnumber: #303117

filters active
t[s]>=15
data-graph:

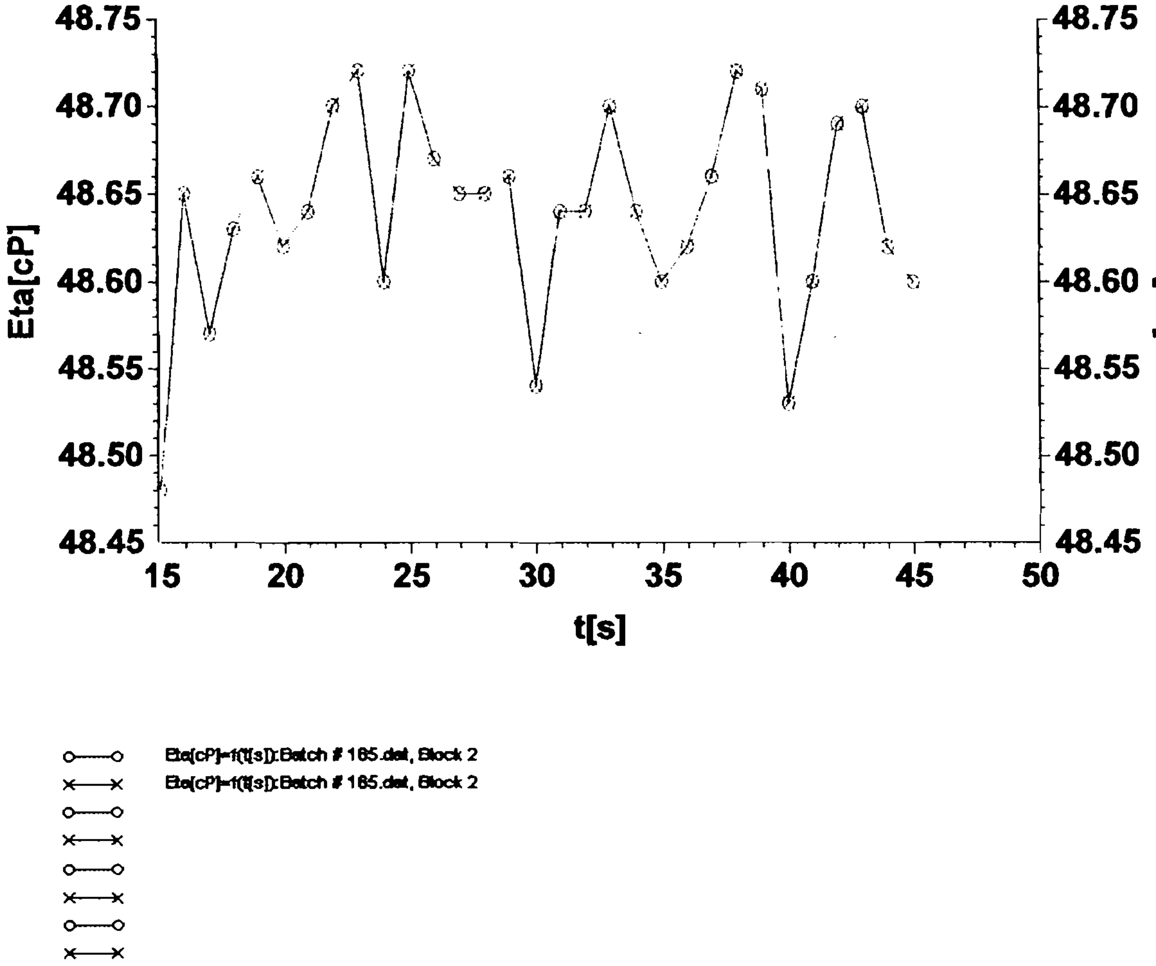


```
Data-grid: 7,000 Gal. 01.02.07.dat Block:2
Datafilter is active!
MP#    t[s]    Eta[mPas] D[1/s]   Tau[Pa]   T[°C]    M[%.]    n[rpm]    Step
15     15      44.94     250      11.234    32.2     59.13    48.62     1
16     16      44.74     250      11.186    32.2     58.88    48.62     1
17     17      44.93     250      11.232    32.2     59.12    48.62     1
18     18      45.12     250      11.281    32.2     59.38    48.62     1
19     19      44.97     250      11.243    32.2     59.18    48.62     1
20     20      45        250      11.25     32.2     59.21    48.62     1
21     21      45.18     250      11.294    32.2     59.44    48.62     1
22     22      44.9      250      11.225    32.2     59.08    48.62     1
23     23      45.03     250      11.257    32.2     59.25    48.62     1
24     24      45.08     250      11.269    32.2     59.31    48.62     1
25     25      45.03     250      11.258    32.2     59.26    48.62     1
26     26      44.94     250      11.234    32.2     59.13    48.62     1
27     27      45.06     250      11.265    32.2     59.29    48.62     1
28     28      45.07     250      11.267    32.2     59.3     48.62     1
29     29      45.03     250      11.257    32.2     59.25    48.62     1
30     30      44.99     250      11.247    32.2     59.2     48.62     1
31     31      45.17     250      11.293    32.2     59.44    48.62     1
32     32      44.95     250      11.237    32.2     59.14    48.62     1
33     33      44.99     250      11.248    32.2     59.2     48.62     1
34     34      45.12     250      11.279    32.2     59.36    48.62     1
35     35      45.07     250      11.268    32.2     59.3     48.62     1
36     36      45.1      250      11.274    32.2     59.34    48.62     1
37     37      45.08     250      11.269    32.2     59.31    48.62     1
38     38      45.08     250      11.271    32.2     59.32    48.62     1
39     39      45.1      250      11.275    32.2     59.34    48.62     1
40     40      45.07     250      11.268    32.2     59.31    48.62     1
41     41      45.2      250      11.299    32.2     59.47    48.62     1
42     42      45.06     250      11.265    32.2     59.29    48.62     1
43     43      45.11     250      11.277    32.2     59.36    48.62     1
44     44      45.2      250      11.301    32.2     59.48    48.62     1
45     45      45.09     250      11.272    32.2     59.32    48.62     1

Analysis-results:
filter activated: t[s]>=15
step1: average/mean of Eta[Pas]=0.045, S=0.0001
End of report
```

Data-report: C:\RHEO28\DATA\Batch # 165.dat 08:47 03/01/07

Customer:	**Qualtiy Control**
Measuring-Ident:	**Batch # 165**
Medium-Ident:	**Tower # 2**
Operator:	Preston
Comment:	
	Batch made 8.31.06
Program filename:	C:\RHEO28\PROG\Viscon Sequence.seq
Prog.mode:	sequence
Date:	10:27 06/09/06
Block termination:	Block end
Block 2 of 2:	
measuring-system:	CC48 DIN
Rheometer:	R/S+ Rheometer Ver.:9.00 from 15.02.05, Serialnumber: #303117

filters active
t[s]>=15
data-graph:



Data-grid: Batch # 165.dat Block:2
Datafilter is active!

MP#	t[s]	Eta[mPas]	D[1/s]	Tau[Pa]	T[°C]	M[%.]	n[rpm]	Step
15	15	48.48	250	12.12	31.8	63.79	48.62	1
16	16	48.65	250	12.163	31.8	64.01	48.62	1
17	17	48.57	250	12.142	31.8	63.91	48.62	1
18	18	48.63	250	12.158	31.8	63.99	48.62	1
19	19	48.66	250	12.166	31.8	64.03	48.62	1
20	20	48.62	250	12.155	31.8	63.97	48.62	1
21	21	48.64	250	12.161	31.8	64	48.62	1
22	22	48.7	250	12.174	31.8	64.08	48.62	1
23	23	48.72	250	12.181	31.8	64.11	48.62	1
24	24	48.6	250	12.15	31.8	63.95	48.62	1
25	25	48.72	250	12.179	31.8	64.1	48.62	1
26	26	48.67	250	12.168	31.8	64.04	48.62	1
27	27	48.65	250	12.163	31.8	64.02	48.62	1
28	28	48.65	250	12.162	31.8	64.01	48.62	1
29	29	48.66	250	12.166	31.8	64.03	48.62	1
30	30	48.54	250	12.134	31.8	63.86	48.62	1
31	31	48.64	250	12.159	31.8	64	48.62	1
32	32	48.64	250	12.161	31.8	64.01	48.62	1
33	33	48.7	250	12.175	31.8	64.08	48.62	1
34	34	48.64	250	12.159	31.8	63.99	48.62	1
35	35	48.6	250	12.149	31.8	63.94	48.62	1
36	36	48.62	250	12.154	31.8	63.97	48.62	1
37	37	48.66	250	12.166	31.8	64.03	48.62	1
38	38	48.72	250	12.18	31.8	64.1	48.62	1
39	39	48.71	250	12.178	31.8	64.1	48.62	1
40	40	48.53	250	12.132	31.8	63.85	48.62	1
41	41	48.6	250	12.15	31.8	63.95	48.62	1
42	42	48.69	250	12.172	31.8	64.06	48.62	1
43	43	48.7	250	12.174	31.8	64.07	48.62	1
44	44	48.62	250	12.154	31.8	63.97	48.62	1
45	45	48.6	250	12.149	31.8	63.94	48.62	1

Analysis-results:
filter activated: t[s]>=15
step1: average/mean of Eta[Pas]=0.049, S=0.0001
End of report

Attachment 6

Issuance of License for Oil Spill Clean-Up Agent

STATE OF CALIFORNIA

State Water Resources Control Board

LICENSE for Oil Spill Cleanup Agent

Issued to: GENERAL TECHNOLOGIES APPLICATIONS, INC.

PRODUCT NAME: *"ELASTOL"*

PRODUCT CLASSIFICATION: *COLLECTING AGENT*

DATE ISSUED: *MAY 1, 1992*

EXPIRATION DATE: *MAY 1, 1997*

The applicant having followed the procedure as outlined in Title 23, Chapter 3, Subchapter 10, of the California Administrative Code, and having submitted proper applications which was reviewed by interested agencies and is found in order for approval, this license is hereby issued.

Use of the product must be in strict compliance with Section 2332 of referenced Administrative Code.

The term of this license shall be for a period of five (5) years unless revoked prior to that date for good cause.

This license does not denote endorsement of the product by the State Water Resources Control Board or any other State agency.

Jesse M. Diaz
Chief, Division of Water Quality

Attachment 7

Extensional Viscosity

Extensional Viscosity and a Single Phenomenological Basis for the GTA Fuel Additive

1. Approach

We begin with the equations for Newtonian viscosity as a function of concentration and molecular weight. Then we look at the parameters influencing the extensional viscosity. Finally, we look at the parameters governing the evaporation of a liquid from the surface of an evaporating drop. The extensional viscosity relationship is then overlaid on the equation for evaporation of a liquid drop. Calculated values will be given in the next discussion paper.

2. Resting Viscosity of a Dilute Polymer Solution

The Newtonian (resting) viscosity of a very dilute polymer solution is close to that of the solvent. This is a consequence of the following two equations:

(I) $[\eta] = KM^{1/2}$ and

(II) $\eta_{sp} = [\eta]c + k'[\eta]^2c^2$

where $[\eta]$ is the intrinsic viscosity of the polymer - solvent system, M is molecular weight, and K is the constant of proportionality. Note that $[\eta]$ is weakly dependent on molecular weight, thus the specific viscosity of a given solution concentration is also little increased by M. This is especially the case when the polymer concentration, c, is also small as it is for fuel additive at 10 ppm, or 0.0010 grams per deciliter. c is 1×10^{-3} g/dl and c^2 is $1\times10^{-6} g^2/dl^2$. Thus the treated fuel is not very different from untreated fuel at rest. References for this are 1) Billmeyer and 2) Flory.

3. Extensional Viscosity

The ratio of viscosity of stretched, elongated of extended polymer solution to the viscosity of the unperturbed solution is given by

(III)

$$\eta/\eta_o = 3 + \dot{\varepsilon}c\eta_o K^2M^{(1+2\alpha)}/RT$$

The extensional viscosity, η, is strongly dependent on the molecular weight. The term $M^{(1+2\alpha)}$ becomes M^2 for the case of worst solvent for the polymer, and M^3 for the best possible solvent. Polyisobutylene and fuel are ideally compatible and the term more closely approaches M^3 than M^2. Despite the strong dependencies of η/η_o on the molecular weight, η/η_o approaches the low limiting value of 3 when c approaches 0. This is why the ratio can be "tuned" to a particular type of engine or burning condition, (further discussions will be postponed to the next section). The rate of strain, $\acute{\varepsilon}$ is a measure of elongation per unit length per second, or $\Delta L/L\Delta t$. This parameter changes when the solution is sheared, stretched, or deformed. Physically the large polymer chains are deformed from a random coil conformation to a stretched chain conformation. In the absence of the strain, the chains thermally relax to the random coils. Often the strain induces a stress which breaks some of the extended molecules in the middle (mid-point break theory). However, in undergoing a break, the fluid is also most rigid. In other words $\Delta L/L\Delta t$ was very large and η/η_o was also maximized. Regions where $\Delta L/L\Delta t$ are large include turbulent liquid flow regions (drag reduction effect), injection from a nozzle (cohesive effect), the interaction of a liquid stream or droplets with high velocity air. These conditions exist in most modern engines, especially when conditions are changing in the millisecond to microsecond domain. K in this equation is obtained in the laboratory by plotting the log of the intrinsic viscosity against the log of the molecular weight and taking the slope of the line. K is constant for a particular polymer solvent system. The K for polyisobutylene in Benzene is 1.07×10^{-3} at 297°K. T enters the expression for η/η_o in the term 1/RT where R is the gas constant. T has little effect on η/η_o since there is usually little displacement from 298 degrees (25°C). T could be 273 (0°C) or perhaps 325 degrees, but the effect on η/η_o is very small.

4. Effects on Fuel Properties

Under some conditions η/η_o can approach 10,000. When this is too large for an optimal effect on combustion or volumetric efficiency, or delayed vaporization, or suppression of vapor-like particles, the concentration can be decreased toward zero. This it is always possible to tune the fuel for 2 cycle spark ignition, 4 cycle spark ignition, compression ignition, turbine or other combustion scenarios. c can also be changed for different carburetor or fuel injection systems. High molecular weight is an advantage because it generates large η/η_o values at low concentrations where "at rest" fuel properties are virtually unaffected. There is no doubt that 5 to 10 ppm concentrations of 7.2×10^6 M PIB decreases energy loss in turbulently flowing fuels, resulting in flow rate increase of more than 20%. There is also no doubt that the formation of vapor-like particles is suppressed at low concentrations of high molecular weight PIB. These two effects are related to η/η_o.

However, η/η_o is also related to transient increases in the "solidity" and surface tension of particles produced by shear at surfaces or in turbulent air. The following relationships have been derived in "Physical Chemistry", by Moelwyn - Hughes p. 1213. The derivation will not be repeated here. Consider a sphere of isolated liquid in an inert atmosphere at constant temperature and pressure. Let the radius be larger than 10^{-6}cm. The number of molecules vaporizing from the surface of the sphere per second is given by

(IV) $dN/dt = 4\pi rDn^\circ$

r is the radius of the droplet and D is the diffusion coefficient of molecules within the droplet. n° is the saturation vapor pressure at the interface of the drop with the gaseous atmosphere. r_m is the molecular radius. The link between D and η is via the Stokes relationship or

(V) $D = RT/n_o 6\pi n r_m$

accumulating the constants and the radius of a molecule equation V becomes

$D = k/\eta$, or for extensional viscosity η

(VI) $D = k/\eta$

Substitution of VI into V we get

$$dN/dt = 4\pi rkn^\circ/\eta$$

Thus during periods close to those where $D\Delta L/L\Delta t$ is large, the rate of vaporization, dN/dt is very depressed. Simultaneously the droplet is very rigid and solid like, and the surface is equally tense or hardened. When η subsequently approaches $3\eta_o$ the rate of evaporation increases sharply. During the "hardened" phase both the surface tension and bulk viscosity of the droplet favor transport without coating or premature vaporization. This leads to improved performance in gasoline and diesel engines.

Another equation incorporates D and γ, or surface tension into the expression for the lifetime of a spherical droplet. This equation is,

(VII) $t = (r^2 n_L/2Dn^\circ)\ (1-4\gamma/n_L r k_c T)$

where n_L is the number of molecules per cm^3 in the liquid and r is the radius of the droplet.

again replacing D by k/η we get

$$\text{(VIII)} \qquad t = (r^2\eta n_L)/(2kn^\circ)(1-4\gamma/n_L r k_c T)$$

In equation (VIII) the surface tension approaches 0 when saturated vapor is present above the droplet interface and γ approaches 0. The droplet lifetime equation (VIII) then becomes proportional to η.

Relaxation of PIB and η

η becomes larger as $\dot{\varepsilon}$ increases. Similarly η decreases as $\dot{\varepsilon}$ approaches zero. When the stretching force is released the extensional or elongational viscosity decreases. The increase or decrease in η depends on the product of the strain $\dot{\varepsilon}$ and the reciprocal of the time it takes for the molecule to thermally relax to the unstretched conformation. The units of the stretching rate or elongation rate are reciprocal seconds and the units of polymer relaxation times are seconds. The product of the two factors is dimensionless. The following equation links η to $\dot{\varepsilon}$ and θ.

$$\eta = 3\eta_o + (3cRT/M)\Sigma_p \ (\theta_p 1((1-2\dot{\varepsilon}\theta_p)(1+\dot{\varepsilon}\theta_p))$$

θ_p is the relaxation time of the p th normal mode of chain response. Note that as $\dot{\varepsilon}\rightarrow 1/2\theta_1$ where θ, is the longest relaxation time, the $(1-2\dot{\varepsilon}\theta_1)$ term approaches zero. As the denominator approaches zero, η approaches infinite elongational viscosity. The relaxation time θ_1 is proportional to

$$[\eta]M\eta_o/RT$$

where $[\eta]$ is itself equal to KM^α and α is between 0.5 (θ solvent = poor solvent) and 1.0 (perfect solvent). Thus the relaxation time is proportional to $M^2\eta_o/RT$ in a good solvent. Relaxation time increases with M^2 and therefore a state of high η will exist longer than it would for the case of a lower molecular weight. The mist particles would retain a high η for a desirable period during engine operation. Since η approaches ∞ when $\dot{\varepsilon}$ approaches $1/2\theta$ a high molecular weight polymer in a good solvent will develop an extensional viscosity that approaches infinity at lower extension rates than a low molecular weight polymer in a poor solvent. The former is the case for the GTA fuel additive in gasoline and diesel fuels. Concentration then provides the final tuning for the desired η at a particular $\dot{\varepsilon}$.

Summary

1. The large η/η_o possible using low concentrations of $7.2\text{x}10^6$ M PIB in gasoline and diesel fuels influences pre-combustion events and thus affects combustion.

2. Through c, η/η_o can be tuned to improve the operation of several types of engines.

3. η/η_o changes are linearly dependent on concentration and $\Delta L/L\Delta t$ and this provides another dimension for engine tuning.

4. Through c, η/η_o can be tuned to:

    a) eliminate vapor-like burning
    b) promote diffusive burning (diesel)
    c) develop a uniform cloud mix for improved combustion (diesel)
    d) improve volumetric efficiency by slightly delaying vaporization (2-stroke and 4-stroke spark ignition engines)
    e) negate undesirable surface coating effects through momentary increases in surface and bulk rigidity
    f) promote diesel fuel jet penetration prior to ignition and diffusive burning
    g) decrease the extent of vapor explosion before TDC in a diesel
    h) prevent droplet agglomeration and surface wetting after TDC in a diesel.

Attachment 8

CARB-Protocol Emissions Test Results

Olson-EcoLogic
Engine Testing Laboratories, LLC

ISO 9001:2000 Registered

FINAL REPORT

Engine and Fuel Testing to Measure Exhaust Emissions from a Model 3306 Caterpillar Diesel Engine

When Operating Over the ISO 8178 8-Mode Off-Road
Emission Test Cycle and When Operating With
Viscon Treated Ultra Low Sulfur Diesel Fuel
Meeting California ULSD Specifications

Prepared for
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Viscon California
Formerly GTAT California
Bakersfield, CA

December 1, 2006
Revised August 8, 2007
Revised October 22, 2008

Prepared by
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Introduction and Background

This emission testing project is a follow-on project for Viscon California, formerly GTAT (Las Palmas Oil and Dehydration Company) using the same diesel engine that has already completed standard controlled substance emission testing in accordance with the CARB protocol entitled *Verification Procedure, Warranty and In-Use Strategies to Control Emissions from Diesel Engines as Described in the Final Regulation Order, Title 13, California Code of Regulations, Sections 2700 through 2710.*

Original emission testing and 1000 hours of durability operation with the same test engine was completed in 2004 with Viscon fuel treatment resulting in significant reductions of NOx and Particulates compared to original baseline emission measurements before fuel treatment with Viscon.

Subsequent to conclusion of the above testing project, CARB has specified that the Viscon treated diesel fuel must additionally be tested as an alternative fuel with detailed exhaust emission measurements of uncontrolled substances, including toxic hydrocarbons, PAH's and Carbonyls. This new emission report provides all of the CARB required data after operating the test engine and measuring emissions in exact accordance with CARB pre-approved testing and analysis protocols as described in this detailed report.

Since all of the previous emission and durability testing was conducted over two years ago the then available test fuel is no longer available. Accordingly, the same engine was operated and tested on commercially available ultra low sulfur diesel fuel that meets California ULSD specifications. Baseline emissions were again measured after 50 hours of stabilizing operation with the new ULSD test fuel. Subsequent stabilizing operation for 125 hours with the same fuel treated with Viscon was conducted and emissions were again measured for comparison to the new baseline data.

Test Engine

The test engine for this project was a Model 3306 six cylinder Caterpillar diesel engine rated at 265 HP. This is the same engine (without modification) used in the prior emission testing to measure changes in exhaust emissions with the Viscon polymer additive admixed to the baseline no. 2 diesel fuel. The previous engine testing is described in an ETS (Olson Engineering, Inc.) summary report dated August 19, 2003 providing the data comparisons before durability testing and a second summary report (Olson-EcoLogic) dated November 26, 2004 covering the emission/fuel economy measurements after 1000 hours of engine durability operation with the Viscon treated fuel. Both reports are available upon request.

Test Fuel

Previous testing with the specified test engine was done in 2003 and 2004 using commercially available no. 2 diesel fuel for the baseline and Viscon treated test fuel. This fuel met California fuel specifications that existed in the earlier time frame, but such fuel is no longer available in the California commercial market. Accordingly, all of the test work described in this report was done with one batch of commercially available no. 2 ultra low sulfur diesel fuel. This test fuel has a sulfur content of less than 15 ppm and other composition differences compared to the test fuel used in earlier years with this engine. Fuel specifications are provided in the Appendix.

Test Protocol

As in all previous testing with the specified test engine the official test protocol was the ISO 8178 8-mode steady-state test as required for certification of heavy-duty diesel engines in off-road applications. This operating test protocol involves the collection and analysis of emissions from a hot-start while operating the engine over 8-modes of warmed up operation at specific loads and speeds under stabilized conditions. The detailed testing cycle is as follows:

Mode No.	Weighting Factor, %	RPM	Torque, %
1	15	Rated	100
2	15	Rated	75
3	15	Rated	50
4	10	Rated	10
5	10	Max torque, rpm	100
6	10	Max torque	75
7	10	Max torque	50
8	15	Idle	0

The engine was operated and emissions were recorded every second of each mode for five minutes to stabilize emissions. The last two minutes of each mode were recorded second-by-second and averaged to provide the stabilized steady-state emission/fuel economy results.

All engine exhaust for all modes passed through the Horiba Olson-Ecologic dilution tunnel. The dilution tunnel was fixed to operate at a total constant flow of 70 cubic meters per minute, providing variable exhaust dilution for each mode as a function of actual exhaust flow rates. Primary air was measured through the initial critical flow venturi (dilution air) and the total temperature corrected volume (Vmix) of dilutant air plus exhaust was measured continuously at the second critical flow venturi. The calculated dilution ratio mode-by-mode is simply the temperature corrected composite total (Vmix) divided by the exhaust flow (Vmix – dilution air). The measured dilution ratio is expected to be essentially a constant for the same mode for all tests, but the actual dilution ratios were used as measured for each individual test to allow for test-to-test variance.

Gaseous emissions for each test mode were measured every tenth of a second for each five minutes of mode operation. Only the last two minutes of each mode were averaged to provide the stabilized diluted mode data. Dilute data from each mode was then multiplied by the specific mode dilution ratio to obtain the raw modal data and then multiplied by the appropriate mode weighting factor before adding all eight modes together. Finally, the total sum of the weighted modal data was divided by the weighted horsepower and by the test time to provide the weighted grams per bhp-hr for direct data comparisons to the official emission standards for controlled substances.

Particulate sampling involved initial calculation of exhaust mass flow per mode from an actual full 8-mode test. Secondary dilution ratios in the AVL Smart Sampler calculation were programmed for each mode and time of sampling was adjusted to properly compensate for specified modal weighting factors. Since the AVL PM Sampler draws its sample from the exhaust dilution tunnel for each mode the dilution ratio existing for each mode was included in the sample calculation to ultimately determine the total raw exhaust volume for proper calculation of the generated particulates in grams/bhp-hr. All particulate sampling resulted in the capture of measured and weighted particulates on a single filter media for each mode of each 8-mode test (eight complete particulate samples per test).

Exhaust sampling and subsequent gas chromatography analysis for uncontrolled toxic hydrocarbons (C2-C12) followed the detailed Standard Operating Procedure (S.O.P.) described in the Appendix. Modal sample collection was done for a total of 20 minutes. Modes 1, 2, 3 and 8 were collected for three minutes of the five minute mode, while modes 4, 5, 6 and 7 were collected for two minutes. Samples were drawn from each bag and analyzed by gas chromatography. The overall dilution ratio for the 8-modes (20 minutes of testing time) was used to correct and calculate the resulting G.C. data in grams/bhp-hr. $((\text{CONC}^{\text{ppb}}/10^{-9})(\text{Vmix,ft}^3)(\text{Density,g/ft}^3)/\text{Work,bhp-hr})$. Simultaneously samples were drawn and captured for PAH and Carbonyl analysis at an off-site location (Desert Research Institute) as described in the Appended S.O.P. for this procedure.

Tasks Descriptions

The specific tasks and order of operation were as follows:

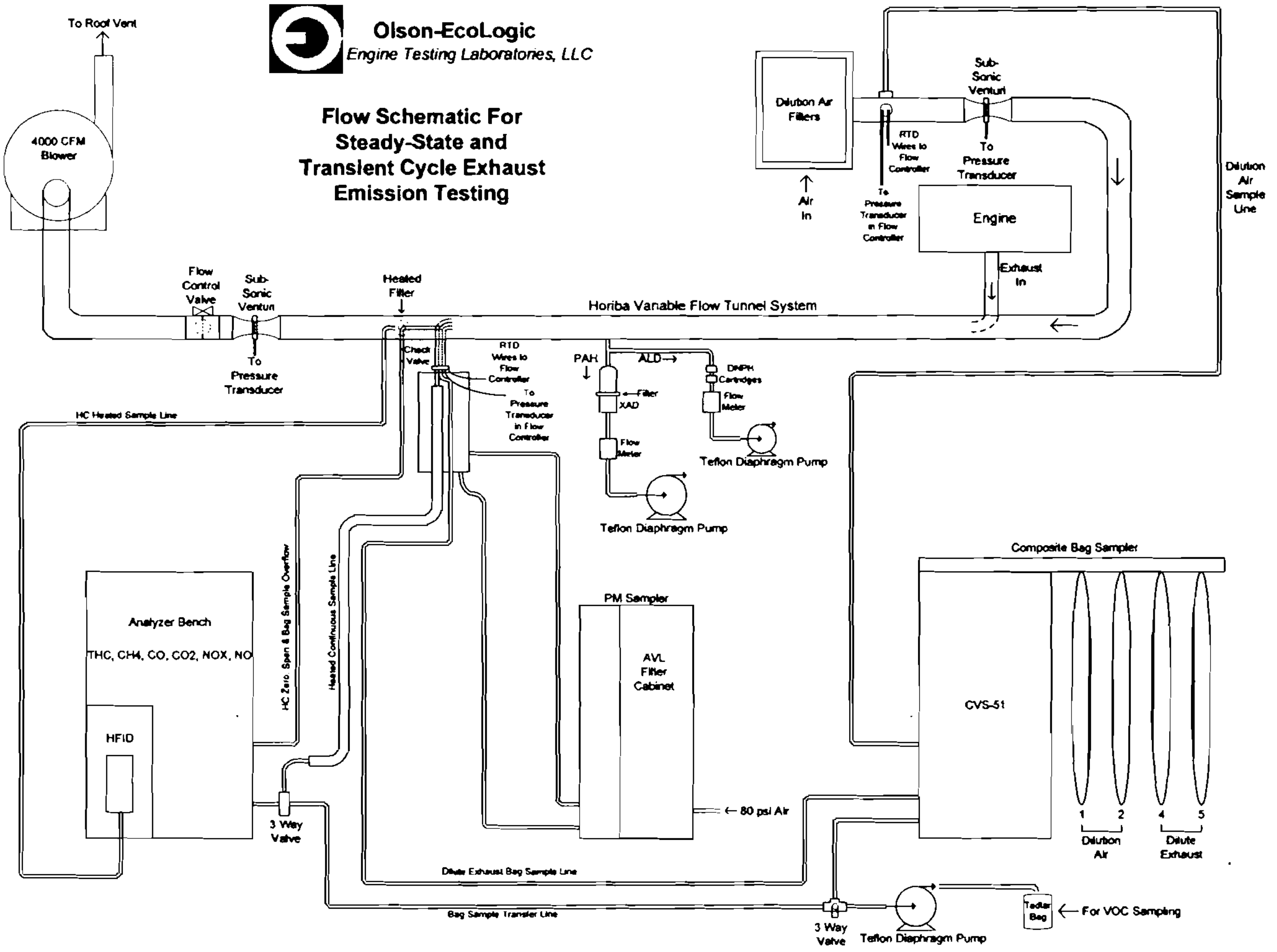
1. Modified engine/dyno coupling and adapted engine to dynamometer.
2. Instrumented and MAP engine, verified test cycle and all calibrations – initiated engine testing.
3. Operated engine over a representative load cycle for 50 hours on the ULSD test fuel.

4. Conducted nine standard ISO 8178 8-mode baseline emission tests for PM and gaseous emissions simultaneously capturing dilute exhaust gas samples from three of the tests for in house measurement of toxic hydrocarbons by gas chromatography and for off-site (Desert Research Institute) analysis of PAH's and Carbonyls.
5. Added the Viscon product to the baseline ULS diesel fuel in the client specified concentrations and operated engine over the same load schedule as used in Task no. 3 for 125 hours to stabilize emissions.
6. Conducted several unofficial ISO 8178 8-mode tests during emission stabilizing operation to assure effectiveness and stabilization of the Viscon product. No samples were captured for toxic hydrocarbons, PAH's or Carbonyls during this task.
7. Conducted nine ISO 8178 8-mode standard emission tests with the Viscon treated fuel, again capturing triplicate samples for toxic hydrocarbons, PAH's and Carbonyls exactly as in Task no. 4.
8. Conducted quality audit functions for all data, calculated and reported changes in all measured emission caused by the Viscon treated fuel compared to the baseline fuel at a 95% confidence level. Prepared final report.

Test Facility, Equipment and Capability

All testing discussed in this report was conducted at the Olson-EcoLogic heavy–duty engine test facility located in Fullerton, California. All initial engine operation and emission testing was conducted in the Olson-EcoLogic test cell 1. The test cell is equipped with a 450 horsepower full electric dynamometer, air conditioning and conventional sensors for continuous measurement of pressures, temperatures and air mass. State-of-the-art Horiba analyzers were used for dilute gas measurement of THC, CO, CO_2, NOx and NO. An AVL Smart Particulate Sampler was used to capture particulates and fuel consumption was measured gravimetrically. The test cell operation is controlled by a fully integrated Labview based custom software program.

Heated sample lines were used to transport the exhaust gases to HC, NOx and NO analyzers. Calibrations with certified gases were routed to the analysers through the same sample lines used to sample the exhaust gases. In all cases the requirements of CFR 40 were followed. The particulate filters were conditioned for temperature and humidity before and after accumulation of particulates. Air mass to the engine was measured by a temperature corrected Sierra Air mass sensor as a secondary backup calibrated by the dilution tunnel venturi measurements of diluent air and total Vmix. Engine intake air was controlled between 68 and 86 degrees F and fuel temperature was controlled to 100 degrees F +/- 10 degrees F as specified in CFR 40. A schematic of the complete exhaust gas sampling system is shown in the following figure.



The quality management system of Olson-EcoLogic is ISO 9001:2000 registered. The Company is officially recognized by EPA and CARB as a capable emission test facility for the protocols used in this project. All test activity was under the direction and responsibility of Donel R. Olson. Mr. Olson is a registered professional mechanical engineer with 50 years of experience in the measurement and analysis of engine emissions. Over twenty engine emission test laboratories in the United States and Germany have been under his ownership and direction during the past 35 years. Details of the Olson-EcoLogic emission test facility capability can be viewed and obtained on the Olson-EcoLogic website (www.ecologiclabs.com).

Other

Olson-EcoLogic Engine Testing Laboratories, LLC was acting as an independent contractor and not as agents or employees of the client in the conduct of work related to this project.

The Company does not guarantee the results of any test protocol, however, if repeat tests are not within acceptable variances Olson-EcoLogic on their own decision repeats the tests at no additional cost to the client.

Test Results

All of the exhaust emission tests reported here are listed chronologically in Table 1.

After several preliminary tests to verify the engine emissions stability, "official" testing starting with test no. 8MLP14 using the reference fuel and finished with the ninth test, no. 8MLP22. This set of tests and the following sets are listed in Table1.

Viscon additive at the normal concentration of 1oz per 20 gallons was admixed in the same fuel used to measure baseline emissions and several additional (unofficial) 8-mode tests were conducted during a 125 hour period of typical engine operation. This was intended to provide stability of exhaust emissions with the Viscon treated reference fuel.

Beginning with Viscon treated test no. 8MLP35, nine official tests were completed to compare to the reference fuel baseline data.

The third test series, starting with test no. 8MLP46, was a set of three heavy dosage tests with Viscon additive admixed to the reference fuel at ten times the normal dosage (10oz. per 20 gallons).

The fourth and final set of five tests, with reference fuel only (no Viscon) started with test no. 8MLP49, immediately after the data set with 10 times dosage of Viscon. Other than engine warm-up and fuel flushing, there was no significant engine operation prior to start of this data set. The purpose was to see any residual effect of the Viscon additive.

Concurrently with the above tests, as shown in Tables 2 and 3, data were collected for toxic compounds analysis including VOC's, PAH's and Carbonyls. Triplicate sets of data were obtained with the baseline reference fuel (test nos. 17, 18, and 19) and for comparison, triplicate sets of data were obtained for the Viscon treated reference fuel (test nos. 39, 40, and 41). In addition, VOC analyses (only) were conducted for test nos. 46 and 47, which were tests conducted with 10 times the normal Viscon dosage.

Table 2 provides the results of all VOC, PAH and Carbonyl data for the triplicate baseline sets compared to the triplicate sets of data obtained with the Viscon treated reference fuel.

Table 3 only provides the VOC data for duplicates of the Viscon heavy dosage tests (test nos. 46 and 47). No analysis of these data have been made for PAH and Carbonyl results.

Discussion of Results

The measured effect of the Viscon additive on all controlled emissions can be seen in Tables 1 and 1A.

The product as demonstrated for the Caterpillar Model 3306 engine under steady-state operating conditions will reduce exhaust particulates to satisfy level 1 CARB criteria (25-50%). This result is consistent with earlier data accumulated on the same engine.

Additional data collection required by CARB involved two major expansions of the project.

> 1) Exhaust particulates were sampled for each mode of the 8-mode test protocol instead of composite sample collection of all 8 modes on one filter media and
>
> 2) Integrated samples over the 8-modes of testing were collected and analyzed for toxic hydrocarbons (VOC's), PAH's and Aldehydes . These specific testing protocols are described in the appendix.

Particulate Sampling and Analysis

The PM sampling for each mode resulted in measurement of PM for eight specific conditions for each 8-mode test. To be consistent with the ISO 8-mode test protocol, the specific sampling for each mode was weighted by dilution ratio selection and time of sampling capture to match the ISO specific weighting factors. Accordingly, modes 1, 2, 3 and 8 were weighted 15% each and modes 4, 5, 6 and 7 were weighted 10% each to total 100% for all eight modes.

The analysis of the PM data was accomplished by weighing the captured PM for each mode and dividing that weight by sampling time and the horsepower generated during the mode to provide the weighted PM result in grams/hp-hr. For the idle mode, (mode 8) this calculation was not possible because hp at idle is zero. Therefore, the idle PM data is reported in grams/hour only. However, the idle PM weight does go into the calculation of total weighted grams/bhp-hr. The PM values from all 7 of the other operating modes have been summed and tabulated in Tables 1 and 1A to show the total PM generated in grams/bhp-hr.

The PM measurements illustrate some very interesting reductions in PM caused by the Viscon additive. At the rated speed of 2200 RPM and the intermediate speed of 1400 RPM there is a clear relationship with load as shown below:

Percent PM Reduction caused by Viscon		
Engine Load	**2200 RPM**	**1400 RPM**
100%	15.3%	4.5%
75%	29.6%	17.3%
50%	28.0%	31.8%
10%	35.6%	- -

Simultaneously idle PM (mode 8) was reduced 56% with the Viscon additive. This discovery can have specific importance in vehicle and engine operations that involve a significant amount of idling operation such as school busses, delivery vehicles, etc. In addition to the PM reduction, idle NOx emissions were also reduced over 10% as can be seen in Table 1.

The VOC, PAH and Carbonyl comparisons shown in Tables 2 and 3 for the same tests are somewhat of a mixed bag. For example, 1,3-butadiene is beyond the measurable data in the exhaust by the Viscon additive. As expected by the technical theory, the PAH's also show significant reductions with the Viscon fuel treatment. However, some increases were demonstrated for some VOC's and some Carbonyls, which may also be expected.

Table 1

Viscon California Data Summary Table

Caterpillar 3306 Diesel Engine

Testing Conducted by Olson-Ecologic Engine Testing Laboratories

Testing Conducted October 2006

				GRAMS PER BHP-HR							GRAMS PER BHP-HR							WTD AVG	GRAMS/HR	GRAMS/HR
FUEL	TEST NO.	Absolute Humidity	WGT. AVG BHP-HR	HC	CO	NOx	NO	FUEL	CO2	NMHC	PM Mode 1	PM Mode 2	PM Mode 3	PM Mode 4	PM Mode 5	PM Mode 6	PM Mode 7	Total PM	Idle PM (Mode 8)	Mode 8 NOx
ULSD	8MLP14	58.2 - 60.1	135.15	1.33	1.68	5.80	5.26	179.42	564.32	0.96	0.129	0.183	0.232	3.094	0.342	0.237	0.234	0.289	20.54	27.31
ULSD	8MLP15	50.8 - 56.1	136.21	1.41	1.72	5.88	5.20	178.66	561.61	0.70	0.122	0.145	0.251	2.106	0.373	0.261	0.248	0.250	2.06	28.49
ULSD	8MLP16	48.1 - 51.0	136.64	1.41	1.69	5.90	5.12	179.05	562.91	0.72	0.108	0.127	0.251	2.209	0.355	0.261	0.241	0.240	2.06	17.11
ULSD	8MLP17	54.7 - 58.4	136.55	1.34	1.71	5.26	4.82	178.53	561.42	0.48	0.122	0.143	0.263	2.221	0.427	0.318	0.292	0.284	14.39	18.36
ULSD	8MLP18	57.5 - 59.1	136.93	1.38	1.70	5.75	5.11	178.67	561.75	0.72	0.121	0.145	0.254	2.430	0.392	0.281	0.314	0.297	30.85	25.37
ULSD	8MLP19	52.7 - 55.3	136.62	1.40	1.71	5.76	5.05	178.71	561.78	0.72	0.127	0.135	0.207	2.211	0.410	0.265	0.226	0.276	26.72	23.95
ULSD	8MLP20	51.4 - 53.3	136.77	1.38	1.63	5.85	5.11	178.17	560.36	0.71	0.118	0.153	0.241	2.322	0.352	0.236	0.241	0.273	26.70	17.85
ULSD	8MLP21	55.8 - 58.4	135.71	1.36	1.73	5.93	5.27	177.44	557.85	0.71	0.112	0.141	0.228	2.108	0.348	0.241	0.243	0.248	12.34	27.76
ULSD	8MLP22	60.9 - 64.5	136.68	1.42	1.68	5.98	5.36	177.92	559.30	0.79	0.102	0.161	0.210	1.917	0.312	0.208	0.124	0.231	18.51	26.47
AVERAGES (BASELINE)			**136.362**	**1.379**	**1.695**	**5.790**	**5.144**	**178.507**	**561.255**	**0.722**	**0.118**	**0.148**	**0.237**	**2.291**	**0.368**	**0.256**	**0.240**	**0.265**	**17.128**	**23.630**
Viscon	8MLP35	33.9 - 36.7	134.86	1.52	1.81	5.79	4.94	176.69	554.88	0.74	0.111	0.097	0.141	1.444	0.332	0.179	0.146	0.190	6.16	18.35
Viscon	8MLP36	37.3 - 41.9	136.04	1.53	1.82	5.87	5.00	176.64	554.67	0.73	0.087	0.087	0.141	1.404	0.320	0.163	0.131	0.170	2.06	17.74
Viscon	8MLP37	34.0 - 36.6	136.67	1.51	1.87	6.05	5.14	177.54	557.48	0.74	0.090	0.107	0.188	1.478	0.366	0.241	0.139	0.200	2.06	19.91
Viscon	8MLP38	32.5 - 35.3	137.01	1.52	1.86	6.27	5.19	176.43	553.96	0.77	0.100	0.100	0.178	1.625	0.352	0.224	0.124	0.197	2.05	16.07
Viscon	8MLP39	31.0 - 41.9	136.03	1.53	1.82	6.05	5.09	178.53	560.65	0.74	0.103	0.115	0.182	1.247	0.328	0.200	0.168	0.208	16.45	23.96
Viscon	8MLP40	34.5 - 43.2	136.77	1.47	1.84	6.20	5.09	177.76	558.39	0.72	0.097	0.102	0.175	1.439	0.382	0.228	0.182	0.211	10.26	27.18
Viscon	8MLP41	46.7 - 50.2	136.77	1.46	1.87	5.86	5.02	176.97	555.84	0.72	0.109	0.120	0.204	1.805	0.389	0.257	0.256	0.246	16.43	18.48
Viscon	8MLP42	47.7 - 53.3	136.92	1.47	1.81	6.17	5.22	177.19	556.60	0.71	0.096	0.094	0.163	1.513	0.391	0.224	0.183	0.210	10.28	17.51
Viscon	8MLP43	56.2 - 58.9	135.92	1.53	1.74	6.06	5.07	176.20	553.38	0.76	0.106	0.117	0.166	1.330	0.301	0.192	0.146	0.188	2.06	31.18
AVERAGES (WITH VISCON)			**136.332**	**1.504**	**1.827**	**6.036**	**5.084**	**177.106**	**556.206**	**0.737**	**0.100**	**0.105**	**0.171**	**1.476**	**0.351**	**0.212**	**0.164**	**0.202**	**7.534**	**21.153**
[redacted]																				
10X Viscon	8MLP46	61.4 - 83.2	136.95	1.49	1.77	6.01	5.00	176.22	553.50	0.71	0.104	0.122	0.181	1.656	0.373	0.269	0.197	0.236	18.48	22.64
10X Viscon	8MLP47	57.4 - 61.6	137.03	1.48	1.77	8.09	5.12	175.98	552.82	0.72	0.093	0.127	0.213	1.809	0.349	0.281	0.168	0.232	14.39	26.29
10X Viscon	8MLP48	56.2 - 59.7	136.88	1.46	1.77	8.06	5.09	175.93	552.67	0.73	0.102	0.122	0.169	1.331	0.350	0.294	0.219	0.235	24.68	25.89
AVERAGES (WITH 10X VISCON)			**136.953**	**1.471**	**1.789**	**6.053**	**5.070**	**176.043**	**552.997**	**0.720**	**0.099**	**0.124**	**0.188**	**1.599**	**0.357**	**0.281**	**0.195**	**0.234**	**19.183**	**24.940**
ULSD	8MLP49	54.4 - 60.1	136.99	1.44	1.66	6.06	5.09	176.99	556.30	0.75	0.084	0.124	0.150	1.364	0.345	0.216	0.139	0.210	22.61	40.75
ULSD	8MLP50	60.8 - 66.4	136.49	1.49	1.72	6.03	5.04	176.64	554.95	0.68	0.124	0.183	0.232	3.098	0.343	0.237	0.234	0.289	20.54	25.22
ULSD	8MLP51	63.1 - 64.6	136.33	1.50	1.76	6.12	5.01	176.32	553.80	0.68	0.108	0.140	0.235	2.029	0.392	0.306	0.226	0.279	30.83	32.35
ULSD	8MLP52	63.5 - 64.9	135.64	1.47	1.78	5.65	4.95	177.10	556.37	0.64	0.109	0.117	0.222	2.138	0.402	0.294	0.438	0.282	22.61	19.81
ULSD	8MLP53	59.3 - 64.5	136.11	1.48	1.82	8.04	5.01	177.42	557.28	0.68	0.111	0.137	0.194	2.067	0.402	0.310	0.255	0.278	30.82	32.71
AVERAGES (BL AFTER VISCON)			**136.312**	**1.478**	**1.748**	**5.980**	**5.020**	**176.894**	**555.740**	**0.686**	**0.107**	**0.140**	**0.207**	**2.139**	**0.376**	**0.272**	**0.258**	**0.288**	**25.483**	**30.168**

Table 2 (cont.)

	ULSF				*ULSF w/ Viscon*				
	8MLP17	*8MLP18*	*8MLP19*	***Average***	*8MLP39*	*8MLP40*	*8MLP41*	***Average***	***Change***
Carbonyls	(Analyzed via High Performance Liquid Chromatography by Desert Research Institute)								
formaldehyde	0.027876	0.026773	0.027121	**0.027257**	0.035915	0.032348	0.032137	**0.033467**	**23%**
acetaldehyde	0.007410	0.007211	0.007535	**0.007385**	0.009786	0.009169	0.008887	**0.009281**	**26%**
acetone	0.002020	0.001754	0.001827	**0.001867**	0.002895	0.002536	0.002490	**0.002640**	**41%**
acrolein	0.000813	0.001405	0.000857	**0.001025**	0.002133	0.001474	0.001846	**0.001817**	**77%**
propionaldehyde	0.001346	0.001304	0.001346	**0.001332**	0.001651	0.001444	0.001443	**0.001512**	**14%**
crotonaldehyde	0.000904	0.001060	0.001027	**0.000997**	0.001260	0.001122	0.001175	**0.001186**	**19%**
methyl ethyl ketone	0.000527	0.000410	0.000448	**0.000462**	0.000484	0.000437	0.000518	**0.000480**	**4%**
methacrolein	0.000474	0.000491	0.000377	**0.000447**	0.000635	0.000500	0.000552	**0.000562**	**26%**
butyraldehyde	0.004892	0.004370	0.005015	**0.004759**	0.004111	0.003893	0.004090	**0.004031**	**-15%**
benzaldehyde	0.000631	0.000617	0.000652	**0.000633**	0.001054	0.000536	0.000583	**0.000724**	**14%**
glyoxal	0.000404	0.000134	0.000429	**0.000322**	0.000644	0.000631	0.000731	**0.000669**	**108%**
valeraldehyde	0.000770	0.000515	0.000567	**0.000617**	0.000590	0.000424	0.000475	**0.000497**	**-20%**
m-tolualdehyde	0.000012	0.000025	0.000012	**0.000016**	0.000126	0.000101	0.000101	**0.000110**	**570%**
hexanaldehyde	0.000350	0.000292	0.000305	**0.000316**	0.000453	0.000382	0.000270	**0.000368**	**17%**

Table 3

Percent change of various emissions comparing ULSF to ULSF w/ 10x Viscon - Caterpillar 3306 Diesel Engine (Units in g/bhp-hr)

Testing Conducted by Olson-Ecologic Engine Testing Laboratories for Viscon California October 2006

	ULSF				*ULSF w/ 10x Viscon*			
	8MLP17	*8MLP18*	*8MLP19*	***Average***	*8MLP46*	*8MLP47*	***Average***	***Change***
VOC's	(Analyzed via Gas Chromatography by Olson-EcoLogic Engine Testing Laboratories)							
1,3-butadiene	0.000245	0.000212	0.000300	**0.000252**	<RL	<RL	**<RL**	**-100%**
benzene	0.008692	0.008825	0.009560	**0.009026**	0.011786	0.010998	**0.011392**	**26%**
toluene	0.004514	0.004058	0.004111	**0.004228**	0.005157	0.005194	**0.005176**	**22%**
ethylbenzene	0.002038	0.001774	0.001621	**0.001811**	0.001969	0.001515	**0.001742**	**-4%**
m&p-xylene	0.004081	0.003440	0.004175	**0.003898**	0.002573	0.002435	**0.002504**	**-36%**
o-xylene	0.002292	0.002320	0.002320	**0.002311**	0.001691	0.001706	**0.001699**	**-26%**

APPENDIX

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OLSON-ECOLOGIC ENGINE TESTING LABORATORY
GTAT ISO-8178 8-MODE TESTING OF VISCON POLYMER
8MLP14 (MULTI-FILTER)
BASELINE

Mode	EngSpd RPM	DynTrq lb-ft	EngPwr Hp	CO2 %	CO ppm	NOx ppm	NO ppm	HC FID ppm	FUEL RT GM/MIN	AirMas scfm	EngExh deg/F	ABSHUM GR/LB	Air In degF	Baro P InHga	f/aCAL FACTOR	KNOx PPM	FuelIn degF	KNO PPM	Methane ppm	NMHC ppm	Humidy %	Oil P psig	nH/nC RATIO
1	2200.1	581.8	243.7	5.65	158.41	636.55	572.96	338.4	726	493.8	880.7	59.7	74.7	30.00	0.027	612.27	99.9	551.1	70.9	267.5	46.9	57.6	1.8
2	2200.0	469.9	196.8	5.44	102.83	577.94	531.78	413.0	583.5	428.1	828.9	60.1	76.2	30.00	0.026	556.37	101.9	511.9	86.5	326.5	44.9	53.6	1.8
3	2200.0	314.9	131.9	4.91	112.43	460.59	417.22	532.7	411.5	348.2	731.5	59.3	76.5	30.00	0.023	442.54	103.2	400.9	111.5	421.2	43.9	53.1	1.8
4	2199.9	62.1	26.0	3.05	231.83	175.33	136.49	779.8	171.5	258.3	503.0	58.2	76.3	30.00	0.015	167.99	105.3	130.8	165.2	614.7	43.4	53.7	1.8
5	1399.8	790.4	210.7	7.53	890.10	759.78	694.32	199.0	568.5	273.4	1011.0	58.2	75.9	30.00	0.035	727.98	99.4	665.3	123.4	75.6	43.9	36.4	1.8
6	1399.9	578.1	154.1	7.37	636.14	756.13	699.55	316.8	414	218.1	944.1	58.6	76.4	30.00	0.035	725.17	98.6	670.9	187.5	149.3	43.6	37.2	1.8
7	1400.0	382.3	101.9	6.60	254.49	652.23	609.87	480.1	279.5	176.8	793.3	58.4	76.4	30.00	0.031	625.18	97.5	584.6	220.9	259.1	43.3	40.1	1.8
8	604.6	0.9	0.1	4.18	264.72	350.15	279.21	1051.4	17.5	54.4	341.6	59.4	76.6	30.00	0.020	336.52	91.8	268.4	837.8	213.5	43.9	20.3	1.8

WT. FAC %	Mode No	HC	CO	KNOX	KNO	FUEL	EXHAUST	CO2	NMHC	NO2/NOX RATIO
		GRAMS/HOUR								
15.00	1	260.65	245.26	1557.35	1392.2983	43560	1698575	137464.8	206.3	0.10
15.00	2	265.31	132.77	1180.21	1082.5905	35010	1413978	110407.9	210.1	0.08
15.00	3	266.64	113.11	731.43	664.18616	24690	1098339	77580.8	211.3	0.09
10.00	4	256.87	153.50	182.73	145.04685	10290	709466	31705.8	203.5	0.22
10.00	5	89.57	805.45	1082.24	984.22309	34110	1008990	107040.8	34.1	0.09
10.00	6	106.20	428.64	802.74	741.70849	24840	750301	76069.3	50.2	0.07
10.00	7	121.57	129.55	522.84	490.35303	16770	562978	52799.8	65.8	0.06
15.00	8	25.83	13.07	27.31	22.310359	1050	53735	3240.5	5.4	0.20

WTD AVG BHP = 135.15   KW = 100.78

	HC	CO	KNOX	KNO	FUEL	EXHAUST	CO2	NMHC
WTD AVG GM/H =	180.19	227.35	783.50	710	24248	942568	76266	130.32
AVG GM/BHPH =	**1.33**	**1.68**	**5.80**	**5.26**	**179.42**		**564.32**	**0.96**
AVG GM/KWH =	1.79	2.26	7.77	7.05	240.60		756.76	1.29

WT AVG NO2/NOX RATIO = 0.116224791

W.F.	0.15	0.15	0.15	0.10	0.10	0.10	0.10	0.15
MODE =	1	2	3	4	5	6	7	8
PARTIC. WT, MG =	1.22	1.11	0.74	0.84	1.47	0.58	0.32	0.10
Exh.Probe Mass Flow Rate (g/Sec.)=	1.087	0.868	0.682	0.441	0.859	0.671	0.567	0.137
Sample Time (Sec.)=	180.0	180.0	180.0	120.0	120.0	120.0	120.0	180.0
Dil.Exh.Sample Mass-Part.Filter (kg) =	0.20	0.16	0.12	0.05	0.10	0.08	0.07	0.02
Dil.Tunnel Tot Flow Temp.Corr. (scmm)=	65.08	65.27	65.33	65.34	65.21	65.22	65.24	65.28
Dil.Tunnel Tot Mass Flow (kg/Hr.)=	5048.84	5063.39	5068.55	5068.82	5059.23	5059.70	5061.06	5064.61
Partic.Mass Flow Rate (g/Hr.)=	31.48	35.97	30.55	80.46	72.15	36.45	23.80	20.54
GM/BHPH=	0.129	0.183	0.232	3.094	0.342	0.237	0.234	
WTD AVG GM/H =	39.07							
WEIGHTED AVG GM/BHPH =	**0.289**							
WTD AVG GM/KWH =	0.388							

OLSON-ECOLOGIC ENGINE TESTING LABORATORY
GTAT ISO-8178 8-MODE TESTING OF VISCON POLYMER
8MLP15 (MULTI-FILTER)
BASELINE

Mode	EngSpd RPM	DynTrq lb-ft	EngPwr Hp	CO2 %	CO ppm	NOx ppm	NO ppm	HC FID ppm	FUEL RT GM/MIN	AirMas scfm	EngExh deg/F	ABSHUM GR/LB	Air In degF	Baro P InHga	f/aCAL FACTOR	KNOx PPM	FuelIn degF	KNO PPM	Methane ppm	NMHC ppm	Humidy %	Oil P psig	nH/nC RATIO
1	2200.0	601.1	251.8	5.86	177.70	669.80	585.77	431.77	738	498.1	905.6	55.6	78.5	30.00	0.028	637.62	97.8	557.8	236.3	195.5	38.6	52.5	1.8
2	2199.9	468.8	196.4	5.48	102.07	603.90	541.07	440.17	579.5	423.3	838.1	56.1	79.2	30.00	0.026	575.59	99.2	515.7	194.2	246.0	38.0	52.7	1.8
3	2199.9	314.4	131.7	4.93	118.81	477.06	424.57	554.00	412.5	347.0	740.7	56.1	79.5	30.00	0.023	454.72	101.9	404.7	204.2	349.8	37.6	51.1	1.8
4	2200.0	61.9	25.9	3.06	238.17	182.76	139.45	814.03	172	258.0	510.7	55.3	79.0	30.00	0.015	173.86	101.7	132.7	303.9	510.1	37.7	52.9	1.8
5	1400.0	790.0	210.5	7.55	899.37	792.09	702.06	186.32	568	272.9	1028.5	54.6	79.1	30.00	0.035	752.19	97.8	666.7	184.2	4.2	37.1	36.2	1.8
6	1399.9	578.2	154.1	7.36	643.55	779.49	704.54	308.17	414.5	220.3	954.0	52.2	78.2	30.00	0.034	735.86	99.5	665.1	237.2	71.0	36.6	37.6	1.8
7	1400.2	382.2	101.9	6.66	258.38	882.16	626.74	440.37	281.25	178.2	801.0	51.3	77.7	30.00	0.031	642.49	99.0	590.3	267.4	172.9	36.6	40.1	1.8
8	592.5	-1.4	0.1	3.73	295.83	348.30	268.87	853.89	18.75	52.8	285.8	50.8	78.0	30.00	0.018	327.64	91.4	252.9	831.5	22.4	35.8	21.5	1.8

		GRAMS/HOUR								
WT. FAC %	Mode No	HC	CO	KNOX	KNO	FUEL	EXHAUST	CO2	NMHC	NO2/NOX RATIO
15.00	1	325.74	269.48	1588.52	1382.0788	44280	1665625	139513.28	148.1	0.13
15.00	2	278.67	129.89	1203.34	1075.4394	34770	1393244	109606.15	156.3	0.10
15.00	3	276.46	119.18	749.33	868.78109	24750	1092833	77731.28	175.3	0.11
10.00	4	267.96	157.59	188.99	147.19242	10320	708739	31759.86	169.5	0.24
10.00	5	84.51	811.28	1114.71	983.13518	34080	1005486	106952.12	1.9	0.11
10.00	6	103.59	434.81	816.80	737.20553	24870	751621	78163.35	23.9	0.10
10.00	7	111.37	131.34	536.55	494.12535	16875	561913	53183.50	43.9	0.08
15.00	8	22.48	15.66	28.49	22.479948	1005	57031	3103.81	0.6	0.23

WTD AVG BHP = 136.25 KW = 101.60

	HC	CO	KNOX	KNO	FUEL	EXHAUST	CO2	NMHC
WTD AVG GM/H =	192.25	233.63	801.16	708	24335	934086	76497	95.96
AVG GM/BHPH =	**1.41**	**1.71**	**5.88**	**5.20**	**178.61**		**561.45**	**0.70**
AVG GM/KWH =	1.89	2.30	7 89	6.97	239.52		752.92	0.94

WT AVG NO2/NOX RATIO = 0.137938873

W.F.	0.15	0.15	0.15	0.10	0.10	0.10	0 10	0.15
MODE =	1	2	3	4	5	6	7	8
PARTIC. WT, MG =	1.19	0.88	0.80	0.57	1.60	0.64	0.34	0.01
Exh.Probe Mass Flow Rate (g/Sec.)=	1.087	0.868	0.682	0.441	0.859	0.671	0.567	0.137
Sample Time (Sec.)=	180	180	180	120	120	120	120	180
Dil.Exh.Sample Mass-Part.Filter (kg) =	0.20	0.16	0.1228	0.05	0.10	0.08	0.07	0.02
Dil.Tunnel Tot Flow Temp.Corr. (scmm)=	65.14	65.28	65.35	65.37	65.20	65.23	65.21	65.33
Dil.Tunnel Tot Mass Flow (kg/Hr.)=	5053.70	5064.15	5069.57	5071.34	5057.89	5060.49	5058.80	5068.23
Partic.Mass Flow Rate (g/Hr.)=	30.74	28.52	33.04	54.62	78.51	40.22	25.28	2.06
GM/BHPH=	0.122	0.145	0.251	2.106	0.373	0.261	0.248	

WTD AVG GM/H = 34.02

WEIGHTED AVG GM/BHPH = 0.250

AVG GM/KWH = 0.335

OLSON-ECOLOGIC ENGINE TESTING LABORATORY
GTAT ISO-8178 8-MODE TESTING OF VISCON POLYMER
8MLP16 (MULTI-FILTER)
BASELINE

Mode	EngSpd RPM	DynTrq lb-ft	EngPwr Hp	CO2 %	CO ppm	NOx ppm	NO ppm	HC FID ppm	FUEL RT GM/MIN	AirMas scfm	EngExh deg/F	ABSHUM GR/LB	Air In degF	Baro P InHga	f/aCAL FACTOR	KNOx PPM	FuelIn degF	KNO PPM	Methane ppm	NMHC ppm	Humidy %	Oil P psig
1	2200.0	808.1	254.7	5.72	175.70	673.44	573.68	415.46	745.5	505.1	905.4	48.9	75.7	30.00	0.027	630.57	101.1	537.1	221.7	193.7	37.2	52.7
2	2200.0	468.5	196.3	5.39	102.82	606.15	531.46	453.87	582.5	428.8	840.2	48.7	78.8	30.00	0.025	567.30	103.4	497.4	193.4	260.5	36.0	49.5
3	2200.0	314.8	131.9	4.90	110.54	484.04	423.18	543.09	416	351.6	742.1	48.4	78.9	30.00	0.023	452.73	103.4	395.8	198.8	344.5	35.4	50.3
4	2200.0	62.1	26.0	3.09	228.24	184.87	141.20	791.01	173	259.8	514.1	48.1	78.6	30.00	0.015	172.79	103.2	132.0	296.7	492.3	35.5	52.9
5	1399.9	788.9	210.3	7.56	692.08	798.32	701.96	193.65	568	271.1	1028.3	48.4	78.7	30.00	0.035	746.70	100.4	856.6	189.9	3.9	35.7	36.0
6	1399.8	576.5	154.2	7.44	633.20	794.90	708.55	313.37	415.5	219.0	959.9	48.8	77.6	30.00	0.035	744.18	102.2	663.3	244.8	68.5	34.9	37.2
7	1399.9	382.0	101.9	6.76	260.09	689.37	625.21	468.30	280.75	177.1	805.6	49.0	78.0	30.00	0.032	645.66	101.7	585.6	277.8	190.5	34.5	39.1
8	587.4	-1.3	0.0	6.22	300.93	354.49	279.94	828.76	16.25	52.7	299.0	51.0	78.4	30.00	0.029	333.64	93.9	263.5	819.9	8.9	35.5	20.3

WT. FAC %	Mode No	GRAMS/HOUR HC	CO	KNOX	KNO	FUEL	EXHAUST	CO2	NMHC	NO2/NOX RATIO
15.00	1	324.01	275.44	1623.97	1375.5022	44730	1718239	140941.9	151.7	0.15
15.00	2	293.81	133.89	1211.87	1060.05	34950	1421003	110126.0	169.1	0.12
15.00	3	275.42	112.88	758.17	664.5374	24960	1109042	78413.3	175.4	0.13
10.00	4	259.02	150.23	186.84	145.51735	10380	704589	31990.6	182.7	0.24
10.00	5	88.88	803.62	1105.07	968.99423	34080	1003352	106956.7	1.8	0.12
10.00	6	104.57	424.70	819.99	729.91488	24930	746258	76367.2	22.9	0.11
10.00	7	116.33	129.87	529.65	461.66002	18845	552294	53054.8	47.5	0.09
15.00	8	12.87	9.39	17.11	13.683968	975	34356	3048.5	0.1	0.21

WTD AVG BHP = . 136.67 KW = 101.92

	HC	CO	KNOX	KNO	FUEL	EXHAUST	CO2	NMHC
WTD AVG GM/H =	192.57	230.52	805.62	699	24466	943045	76916	97.94
AVG GM/BHPH =	**1.41**	**1.69**	**5.90**	**5.12**	**179.01**		**562.78**	**0.72**
AVG GM/KWH =	1.89	2.26	7.91	6.66	240.06		754.71	0.96

WT AVG NO2/NOX RATIO = 0.146974817

W.F.	0.15	0.15	0.15	0.10	0.10	0.10	0.10	0.15
MODE =	1	2	3	4	5	6	7	8
PARTIC. WT, MG =	1.07	0.77	0.60	0.60	1.52	0.64	0.33	0.01
Exh.Probe Mass Flow Rate (g/Sec.)=	1.087	0.868	0.682	0.441	0.859	0.671	0.567	0.137
Sample Time (Sec.)=	180	180	180	120	120	120	120	180
I.Exh.Sample Mass-Part.Filter (kg) =	0.20	0.16	0.1228	0.05	0.10	0.08	0.07	0.02
unnel Tot Flow Temp.Corr. (scmm)=	65.03	65.23	65.35	65.37	65.20	65.24	65.23	65.38
Dil.Tunnel Tot Mass Flow (kg/Hr.)=	5045.10	5060.48	5069.88	5071.17	5056.19	5061.01	5060.81	5072.11
Partic.Mass Flow Rate (g/Hr.)=	27.59	24.94	33.04	57.50	74.59	40.23	24.55	2.06
GM/BHPH=	0.108	0.127	0.251	2.209	0.355	0.261	0.241	

WTD AVG GM/H = 32.829

WEIGHTED AVG GM/BHPH = 0.240

WTD AVG GM/KWH = 0.322

OLSON-ECOLOGIC ENGINE TESTING LABORATORY
GTAT ISO-8178 8-MODE TESTING OF VISCON POLYMER
8MLP17 (MULTI-FILTER)
BASELINE

Mode	EngSpd RPM	DynTrq lb-ft	EngPwr Hp	CO2 %	CO ppm	NOx ppm	NO ppm	HC FID ppm	FUEL RT GM/MIN	AirMas scfm	EngExh deg/F	ABSHUM GR/LB	Air In degF	Baro P InHga	f/aCAL FACTOR	KNOx PPM	FuelIn degF	KNO PPM	Methane ppm	NMHC ppm	Humidy %	Oil P psig	nH/nC RATIO
1	2200.0	604.9	253.4	5.80	183.08	610.16	557.56	406.71	741	500.4	911.3	54.7	78.6	30.00	0.027	579 54	103.4	529 58	322.98	83.72	37.74	49 66	1.8
2	2200 0	469.6	196.7	5.49	109.75	550 34	513.57	442.73	583.5	426.0	650.1	56.0	79.8	30.00	0.026	524.46	106 0	489.41	282.88	159.85	37.26	48.55	1.8
3	2200 0	314.7	131.8	4 98	118.82	424.16	389 13	537.02	413.5	346.9	747.7	56.7	79.8	30 00	0.024	404.86	107.3	371.42	279.48	257.54	37 59	50.18	1.8
4	2200.0	61 8	25 9	3 16	228.07	161.15	112.34	792.96	170	258.2	516.7	56.7	79.7	30 00	0.015	153.85	107.7	107.24	415.55	377.42	37.78	52.67	1.8
5	1399.9	789.6	210.4	7.74	912.76	708.90	665.50	169.01	568 5	272.9	1033.4	56 9	79.5	30.00	0.036	677.05	104.8	635.60	169.01	95.85	36.18	36 02	1.8
6	1400.0	578.6	154.2	7.58	657.07	889.29	650.04	291.77	413 5	218.6	962.0	57.2	79.7	30.00	0.035	658.80	104.8	621.29	291.77	53.88	36 16	37.19	1.8
7	1400.0	382.2	101.9	6.86	262.26	594.44	536.12	434.65	279.5	177.2	806.2	57.4	79.7	30.00	0.032	568.36	104.9	512.60	388.81	45.84	38.19	40.04	1.8
8	590.5	0 7	0.0	5 12	287.57	307.97	290.65	706.42	16.25	54.3	338.1	58.4	79.8	30.00	0.024	295.19	98.8	278.60	706.42	535.76	38.70	20.11	1.8

WT. FAC %	Mode No	HC	CO	KNOX	KNO	FUEL	EXHAUST	CO2	NMHC	NO2/NOX RATIO
		GRAMS/HOUR								
15.00	1	311.05	281.45	1463.68	1329.9143	44460	1687536	140113.88	64.4	0.09
15.00	2	281.88	140.45	1102.66	1026.3731	35010	1401200	110343.47	102.3	0.07
15.00	3	266.25	118.21	662.83	609.5737	24810	1086266	77956.07	128.4	0.08
10.00	4	249.76	144.39	160.02	113.71427	10200	678946	31456.06	120.4	0.30
10 00	5	74.02	803.57	979.25	914.64182	34110	983296	107092.87	42.0	0.06
10.00	6	95.12	430.57	709.23	667.78798	24810	730829	78005.74	17.6	0.06
10 00	7	105.97	128.53	457.60	413.62956	16770	543164	52850.70	11.2	0.10
15.00	8	13.31	10.89	18.36	17.563971	975	41333	3044.77	10.1	0 06

WTD AVG BHP = 136.53 KW = 101.81

	HC	CO	KNOX	KNO	FUEL	EXHAUST	CO2	NMHC
WTD AVG GM/H =	183.36	233.36	717.74	658	24377	926074	76659	64.91
AVG GM/BHPH =	**1.34**	**1.71**	**5.26**	**4.82**	**178.54**		**561.47**	**0.48**
AVG GM/KWH =	1 80	2.29	7.05	6.47	239.43		752 94	0.64

WT AVG NO2/NOX RATIO = 64.90954311

W F.	0.15	0.15	0.15	0.10	0.10	0.10	0.10	0.15
MODE =	1	2	3	4	5	6	7	8
PARTIC. WT, MG =	1.20	0.87	0.84	0.60	1.83	0.78	0.40	0.07
Exh.Probe Mass Flow Rate (g/Sec.)=	1.087	0.868	0.682	0.441	0.859	0.671	0.567	0.137
Sample Time (Sec.)=	180	180	180	120	120	120	120	180
Dil.Exh.Sample Mass-Part.Filter (kg) =	0.196	0.156	0.123	0.053	0.103	0.081	0.068	0.025
Dil Tunnel Tot Flow Temp.Corr. (scmm)=	65.04	65.31	65.31	65.37	65.20	65.24	65.24	65.34
Dil Tunnel Tot Mass Flow (kg/Hr.)=	5045.96	5066.95	5067.04	5071.25	5058.16	5061.63	5061.23	5068.85
Partic.Mass Flow Rate (g/Hr.)=	30.9473	28.2146	34.6718	57.4971	89.7985	49.0322	29.7544	14.3884
GM/BHPH=	0.122	0.143	0.263	2.221	0.427	0.318	0.292	

WTD AVG GM/H = 38.842

WEIGHTED AVG GM/BHPH = 0.284

WTD AVG GM/KWH = 0.381

Approved ________

OLSON-ECOLOGIC ENGINE TESTING LABORATORY
GTAT ISO-8178 8-MODE TESTING OF VISCON POLYMER
8MLP18 (MULTI-FILTER)
BASELINE

Mode	EngSpd RPM	DynTrq lb-ft	EngPwr Hp	CO2 %	CO ppm	NOx ppm	NO ppm	HC FID ppm	FUEL RT GM/MIN	AirMas scfm	EngExh deg/F	ABSHUM GR/LB	Air In degF	Baro P InHga	f/aCAL FACTOR	KNOx PPM	FuelIn degF	KNO PPM	Methane ppm	NMHC ppm	Humidy %	Oil P psig	nH/nC RATIO
1	2199.9	610.9	255.9	5.72	174.36	633.06	543.52	396.6	749	505.4	901.7	58.5	77.0	30.00	0.027	606.97	101.3	521.1	206.8	189.8	42.6	54.3	1.8
2	2200.0	469.2	196.6	5.40	103.52	580.13	519.98	439.5	581.5	428.2	842.6	59.3	78.1	30.00	0.025	557.38	104.1	499.6	184.1	255.4	41.6	50.3	1.8
3	2200.0	315.2	132.0	4.88	115.01	461.90	412.62	535.8	413.5	350.0	744.8	59.1	78.4	30.00	0.023	443.61	105.2	396.5	181.8	353.9	41.1	50.6	1.8
4	2200.0	62.2	26.0	3.03	230.02	170.75	135.06	767.2	171.5	259.0	510.9	58.4	78.0	30.00	0.015	163.69	105.2	129.5	277.2	490.0	41.2	52.6	1.8
5	1400.1	789.1	210.3	7.53	891.31	766.79	694.80	193.2	568	273.0	1028.7	58.0	77.7	30.00	0.035	736.33	104.7	665.5	189.8	3.4	41.2	38.1	1.8
6	1400.0	578.5	154.2	7.35	639.39	749.96	696.71	313.7	415	219.2	957.0	56.0	77.9	30.00	0.034	718.15	106.6	667.2	243.9	69.8	41.0	37.2	1.8
7	1399.8	382.2	101.6	6.58	250.66	639.72	616.59	458.7	261	178.2	602.8	57.5	77.8	30.00	0.031	611.92	104.0	589.8	268.2	190.5	40.8	40.1	1.8
8	581.3	0.8	0.1	4.39	284.86	345.90	284.87	874.1	17.25	53.0	385.7	58.4	78.1	30.00	0.021	331.57	99.5	273.1	842.9	31.2	41.0	18.7	1.8

WT. FAC %	Mode No	HC	CO	KNOX	KNO	FUEL	EXHAUST	CO2	NMHC	NO2/NOX RATIO
		GRAMS/HOUR								
15.00	1	311.04	274.83	1571.80	1341.304	44940	1729985	141652.39	149.4	0.14
15.00	2	263.38	134.17	1166.82	1061.0038	34890	1418609	109966.59	165.3	0.10
15.00	3	270.72	116.81	740.17	683.16177	24810	1106512	77944.16	179.5	0.11
10.00	4	254.46	153.36	179.30	144.57814	10290	714316	31713.55	164.0	0.21
10.00	5	86.93	806.11	1094.05	983.9268	34080	1008399	106952.62	1.5	0.10
10.00	6	105.75	433.30	799.54	741.75855	24900	754388	78254.40	23.6	0.07
10.00	7	117.13	128.66	516.02	498.68402	16860	567536	53101.75	48.9	0.04
15.00	8	20.25	13.27	25.37	21.298028	1035	50540	3210.11	0.7	0.18

WTD AVG BHP = 136.93 KW = 102.11

	HC	CO	KNOX	KNO	FUEL	EXHAUST	CO2	NMHC
WTD AVG GM/H =	169.24	233.00	787.51	700	24484	950311	76918	98.03
AVG GM/BHPH =	**1.38**	**1.70**	**5.75**	**5.11**	**178.67**		**561.75**	**0.72**
AVG GM/KWH =	1.85	2.26	7.71	6.85	239.60		753.32	0.96

WT AVG NO2/NOX RATIO = 0.120413745

W.F.	0.15	0.15	0.15	0.10	0.10	0.10	0.10	0.15
MODE =	1	2	3	4	5	6	7	8
PARTIC. WT, MG =	1.20	0.88	0.81	0.66	1.68	0.69	0.43	0.15
:xh.Probe Mass Flow Rate (g/Sec.)=	1.087	0.868	0.682	0.441	0.859	0.671	0.567	0.137
Sample Time (Sec.)=	180	180	180	120	120	120	120	180
.Exh.Sample Mass-Part.Filter (kg) =	0.20	0.16	0.1228	0.05	0.10	0.08	0.07	0.02
unnel Tot Flow Temp.Corr. (scmm)=	65.02	65.16	65.38	65.37	65.18	65.23	65.24	65.37
Dil.Tunnel Tot Mass Flow (kg/Hr.)=	5044.29	5054.77	5072.144	5071.70	5056.48	5060.61	5061.27	5071.44
Partic.Mass Flow Rate (g/Hr.)=	30.937	28.470	33.467	63.253	82.411	43.366	31.986	30.848
GM/BHPH=	0.121	0.145	0.254	2.430	0.392	0.281	0.314	

WTD AVG GM/H = 40.660

WEIGHTED AVG GM/BHPH = 0.297

WTD AVG GM/KWH = 0.398

OLSON-ECOLOGIC ENGINE TESTING LABORATORY
GTAT ISO-8178 8-Mode Testing of Viscon Polymer
8MLP19 (MULTI-FILTER)
BASELINE

Mode	EngSpd RPM	DynTrq lb-ft	EngPwr Hp	CO2 %	CO ppm	NOx ppm	NO ppm	HC FID ppm	FUEL RT GM/MIN	AirMas scfm	EngExh deg/F	ABSHUM GR/LB	Air In degF	Baro P InHga	f/aCAL FACTOR	KNOx PPM	FuelIn degF	KNO PPM	Methane ppm	NMHC ppm	Humidy %	Oil P psig
1	2199.9	805.0	253.4	5.80	176.97	658.26	560.53	418.73	744.5	503.9	906.3	55.3	75.6	30.00	0.027	626.26	103.7	533.3	220.7	198.00	42.3	54.1
2	2200.0	469.6	196.8	5.50	110.60	590.32	531.19	463.90	583	430.2	841.6	54.4	76.8	30.00	0.026	560.31	106.4	504.2	194.9	289.02	39.9	49.7
3	2200.0	314.9	131.9	4.99	120.31	469.58	418.63	550.41	414.5	349.9	743.4	54.0	77.2	30.00	0.024	445.22	106.9	396.9	190.3	360.07	39.0	50.2
4	2200.0	82.1	26.0	3.19	238.73	180.74	140.12	811.99	172	259.9	514.2	53.7	77.1	30.00	0.018	171.24	106.0	132.8	294.4	517.59	38.9	52.8
5	1400.0	790.7	210.8	7.66	897.33	794.08	699.43	197.02	569	272.8	1026.9	53.2	78.8	30.00	0.036	751.43	101.8	661.9	193.0	3.99	39.0	35.8
6	1400.0	578.2	154.2	7.51	870.35	783.60	701.87	314.17	413	219.5	957.8	52.8	77.1	30.00	0.035	740.80	102.4	663.4	254.1	60.04	38.3	36.7
7	1400.0	382.4	101.9	6.80	261.22	679.78	615.36	445.34	276.5	176.8	804.7	52.7	77.3	30.00	0.032	642.48	102.3	581.6	277.7	167.60	38.1	39.7
8	586.2	0.8	0.1	4.81	338.67	367.30	304.00	949.07	17	53.1	383.4	54.4	77.9	30.00	0.023	348.67	99.3	288.6	835.4	113.85	38.6	18.8

WT. FAC %	Mode No	GRAMS/HOUR HC	CO	KNOX	KNO	FUEL	EXHAUST	CO2	NMHC	NO2/NOX RATIO
15.00	1	321.53	273.15	1567.99	1344.751	44670	1694480	140762.36	152.6	0.15
15.00	2	294.46	141.11	1174.46	1054.556	34980	1396737	110207.19	171.4	0.10
15.00	3	272.60	119.77	728.16	650.8972	24870	1064892	78124.55	179.0	0.11
10.00	4	256.11	151.36	178.36	141.0157	10320	679805	31807.06	164.7	0.22
10.00	5	87.28	798.97	1099.18	963.5473	34140	993294	107153.75	1.8	0.12
10.00	6	103.09	442.14	802.73	717.8688	24780	734755	77866.88	19.8	0.10
10.00	7	108.37	127.77	516.30	468.5155	16590	541494	52271.27	41.0	0.09
15.00	8	19.74	14.16	23.95	20.2007	1020	45588	3162.58	2.4	0.17

WTD AVG BHP = **136.62** **KW =** **101.87**

	HC	CO	KNOX	KNO	FUEL	EXHAUST	CO2	NMHC
WTD AVG GM/H =	191.74	234.25	786.84	690	24414	928189	76748	98.53
AVG GM/BHPH =	**1.40**	**1.71**	**5.76**	**5.05**	**178.71**		**561.78**	**0.72**
AVG GM/KWH =	1.88	2.30	7.72	6.77	239.65		753.36	0.97

WT AVG NO2/NOX RATIO = 0.133748634

W.F.	0.15	0.15	0.15	0.10	0.10	0.10	0.10	0.15
MODE =	1	2	3	4	5	6	7	8
PARTIC. WT, MG =	1.25	0.82	0.66	0.60	1.76	0.65	0.31	0.13
:xh.Probe Mass Flow Rate (g/Sec.)=	1.087	0.868	0.682	0.441	0.859	0.671	0.567	0.137
Sample Time (Sec.)=	180	180	180	120	120	120	120	180
l.Exh.Sample Mass-Part.Filter (kg) =	0.20	0.16	0.12	0.05	0.10	0.08	0.07	0.02
unnel Tot Flow Temp.Corr. (scmm)=	65.11	65.28	65.34	65.37	65.20	65.23	65.26	65.34
Dil.Tunnel Tot Mass Flow (kg/Hr.)=	5051.29	5064.62	5069.43	5071.71	5058.45	5060.83	5063.23	5069.15
Partic.Mass Flow Rate (g/Hr.)=	32.271	26.581	27.255	57.502	86.368	40.654	23.069	26.723
GM/BHPH=	0.127	0.135	0.207	2.211	0.410	0.265	0.226	

WTD AVG GM/H = 37.704

WEIGHTED AVG GM/BHPH = 0.276

WTD AVG GM/KWH = 0.370

OLSON-ECOLOGIC ENGINE TESTING LABORATORY
GTAT ISO-8178 8-MODE TESTING OF VISCON POLYMER
8MLP20 (MULTI-FILTER)
BASELINE

Mode	EngSpd RPM	DynTrq lb-ft	EngPwr Hp	CO2 %	CO ppm	NOx ppm	NO ppm	HC FID ppm	FUEL RT GM/MIN	AirMas scfm	EngExh degF	ABSHUM GR/LB	Air In degF	Baro P InHga	f/aCAL FACTOR	KNOx PPM	FuelIn degF	KNO PPM	Methane ppm	NMHC ppm	Humidy %	Oil P psig
1	2200.0	607.7	254.6	5.80	170.27	674.00	581.66	399.96	744.5	504.8	906.8	52.1	73.8	30.00	0.027	636.12	101.5	549.0	208.5	191.4	42.3	52.4
2	2200.0	469.8	196.8	5.45	105.04	601.26	534.63	440.22	581.5	430.8	838.1	51.8	74.5	30.00	0.026	567.07	103.9	504.2	179.1	261.1	41.0	49.9
3	2200.1	314.9	132.0	4.93	119.05	480.74	422.35	534.65	413.5	352.0	741.3	51.4	74.8	30.00	0.023	452.94	105.4	397.9	182.9	351.8	40.3	50.2
4	2200.0	62.1	26.0	3.17	234.83	185.73	142.53	781.19	172	259.5	511.5	51.5	74.6	30.00	0.015	175.04	104.9	134.3	281.4	499.7	40.7	53.1
5	1400.0	789.4	210.4	7.59	867.19	800.42	701.27	198.73	565	273.9	1020.2	51.5	74.2	30.00	0.036	754.35	100.0	660.9	194.9	3.8	41.2	36.1
6	1399.9	578.7	154.2	7.47	599.19	798.58	708.81	305.83	412	216.9	953.8	51.4	74.5	30.00	0.035	752.33	101.2	667.8	247.2	58.7	40.7	37.2
7	1399.9	382.2	101.9	6.71	240.74	686.22	618.37	449.19	278	175.8	799.9	51.4	74.6	30.00	0.031	646.50	100.5	582.6	268.9	180.3	40.6	39.7
8	592.3	0.9	0.1	5.99	292.71	343.90	268.33	830.5	16.75	53.8	376.8	53.3	75.2	30.00	0.028	325.52	98.1	254.0	749.0187	81.4	41.2	19.2

		GRAMS/HOUR								
WT. FAC %	Mode No	HC	CO	KNOX	KNO	FUEL	EXHAUST	CO2	NMHC	NO2/NOX RATIO
15.00	1	307.59	263.21	1615.48	1365.9814	44670	1696251	140822.01	147.7	0.14
15.00	2	281.24	134.89	1196.35	1061.047	34890	1404736	109972.20	167.4	0.11
15.00	3	267.70	119.82	748.90	659.5425	24810	1095767	77948.96	176.8	0.12
10.00	4	246.77	150.31	184.07	143.93756	10320	685974	31831.90	160.5	0.23
10.00	5	68.23	773.85	1105.90	964.32358	33900	994629	106426.17	1.7	0.12
10.00	6	100.82	397.05	819.02	725.94047	24720	737748	77753.88	19.4	0.11
10.00	7	111.39	120.00	529.43	478.28989	16680	551283	52560.46	44.9	0.10
15.00	8	13.79	9.77	17.85	14.115439	1005	36735	3140.52	1.4	0.22

WTD AVG BHP = 136.77 KW = 101.99

	HC	CO	KNOX	KNO	FUEL	EXHAUST	CO2	NMHC
WTD AVG GM/H =	185.47	223.27	800.63	699	24368	931987	76640	96.64
AVG GM/BHPH =	**1.36**	**1.63**	**5.85**	**5.11**	**178.17**		**560.36**	**0.71**
AVG GM/KWH =	1.82	2.19	7.85	6.86	238.93		751.45	0.95

WT AVG NO2/NOX RATIO = 0.145129416

W.F.	0.15	0.15	0.15	0.10	0.10	0.10	0.10	0.15
MODE =	1	2	3	4	5	6	7	8
PARTIC. WT, MG =	1.16	0.93	0.77	0.63	1.51	0.58	0.33	0.13
Exh.Probe Mass Flow Rate (g/Sec.)=	1.087	0.868	0.682	0.441	0.659	0.671	0.567	0.137
Sample Time (Sec.)=	180	180	160	120	120	120	120	180
Dil.Exh.Sample Mass-Part.Filter (kg) =	0.20	0.16	0.1228	0.05	0.10	0.08	0.07	0.02
Dil.Tunnel Tot Flow Temp.Corr. (scmm)=	65.09	65.30	65.36	65.36	65.21	65.25	65.25	65.29
Dil.Tunnel Tot Mass Flow (kg/Hr.)=	5049.5	5066.3	5070.8	5070.7	5058.7	5062.4	5062.2	5065.2
Partic.Mass Flow Rate (g/Hr.)=	29.937	30.156	31.806	60.366	74.103	36.466	24.552	26.702
GM/BHPH=	0.118	0.153	0.241	2.322	0.352	0.236	0.241	

WTD AVG GM/H = 37.339

WEIGHTED AVG GM/BHPH = 0.273

WTD AVG GM/KWH = 0.366

OLSON-ECOLOGIC ENGINE TESTING LABORATORY
GTAT ISO-8178 8-MODE TESTING OF VISCON POLYMER
8MLP21 (MULTI-FILTER)
BASELINE

Mode	EngSpd RPM	DynTrq lb-ft	EngPwr Hp	CO2 %	CO ppm	NOx ppm	NO ppm	HC FID ppm	FUEL RT GM/MIN	AirMas scfm	EngExh deg/F	ABSHUM GR/LB	Air In degF	Baro P InHga	f/aCAL FACTOR	KNOx PPM	FuelIn degF	KNO PPM	Methane ppm	NMHC ppm	Humidy %	Oil P psig	nH/nC RATIO
1	2200.0	614.0	257.2	5.85	184.35	668.84	589.93	396.29	746.5	499.2	914.2	56.6	80.8	29.90	0.028	638.27	97.1	563.0	214.0	182.3	36.2	56.2	1.8
2	2200.0	446.6	187.9	5.43	99.23	590.43	533.76	412.90	554.5	406.1	838.1	56.0	81.9	29.90	0.026	562.60	100.1	508.6	165.4	247.5	34.8	53.8	1.8
3	2200.0	314.6	131.9	4.85	113.98	469.25	418.51	540.52	410.5	343.7	746.5	55.8	81.5	29.90	0.023	446.99	101.8	398.7	178.0	364.5	35.0	51.2	1.8
4	2200.0	61.9	25.9	2.88	224.34	169.67	130.24	787.91	168	256.3	513.3	57.3	80.0	29.90	0.014	162.20	102.5	124.5	270.9	517.0	37.7	53.4	1.8
5	1400.0	789.6	210.4	7.35	886.26	790.87	708.99	176.90	567	270.8	1030.8	58.4	79.2	29.90	0.034	758.10	103.8	679.6	175.7	1.2	39.4	35.9	1.8
6	1400.0	576.2	154.0	7.06	631.99	786.63	715.10	297.50	412	217.8	961.6	57.5	79.2	29.90	0.033	752.48	103.4	684.1	234.2	83.3	36.9	38.8	1.8
7	1400.0	378.5	101.0	8.13	246.51	685.87	606.65	450.31	275	175.1	804.5	56.9	78.9	29.90	0.029	635.68	100.7	579.3	254.9	195.4	36.8	40.0	1.8
8	575.7	1.1	0.1	3.31	217.49	309.57	247.92	799.42	16	52.5	392.7	57.8	78.8	29.90	0.016	296.33	94.0	237.3	752.5	46.9	39.5	18.3	1.8

WT. FAC %	Mode No	GRAMS/HOUR HC	CO	KNOX	KNO	FUEL	EXHAUST	CO2	NMHC	NO2/NOX RATIO
15.00	1	302.67	283.01	1609.78	1411.4676	44790	1686441	141188.45	139.7	0.12
15.00	2	252.60	122.03	1138.60	1024.8661	33270	1345745	104925.58	151.9	0.10
15.00	3	272.90	115.67	745.25	666.42384	24630	1104660	77366.01	184.7	0.11
10.00	4	268.40	153.61	182.48	143.01999	10080	732524	31000.66	177.7	0.23
10.00	5	61.40	819.73	1151.96	1027.3166	34020	1029734	106757.87	0.8	0.10
10.00	6	103.61	442.42	865.41	785.46522	24720	777313	77873.79	22.1	0.09
10.00	7	120.74	132.85	562.82	514.36763	16500	593483	51937.73	52.6	0.09
15.00	8	22.66	12.40	27.76	22.753645	960	61326	2965.05	1.4	0.20

WTD AVG BHP = 135.71 KW = 101.20

	HC	CO	KNOX	KNO	FUEL	EXHAUST	CO2	NMHC
WTD AVG GM/H =	185.04	234.83	804.17	716	24080	943061	75704	96.95
AVG GM/BHPH =	**1.36**	**1.73**	**5.93**	**5.27**	**177.44**		**557.85**	**0.71**
AVG GM/KWH =	1.83	2.32	7.95	7.07	237.95		748.09	0.96

WT AVG NO2/NOX RATIO = 0.129745756

W.F.	0.15	0.15	0.15	0.10	0.10	0.10	0.10	0.15
MODE =	1	2	3	4	5	6	7	8
PARTIC. WT, MG =	1.12	0.82	0.73	0.57	1.49	0.59	0.33	0.06
Exh.Probe Mass Flow Rate (g/Sec.)=	1.087	0.868	0.682	0.441	0.859	0.671	0.567	0.137
Sample Time (Sec.)=	180	180	180	120	120	120	120	180
Dil.Exh.Sample Mass-Part.Filter (kg) =	0.20	0.16	0.1228	0.05	0.10	0.08	0.07	0.02
Dil.Tunnel Tot Flow Temp.Corr. (scmm)=	85.10	65.29	65.32	65.37	65.23	65.22	65.26	65.35
Dil.Tunnel Tot Mass Flow (kg/Hr.)=	5050.1	5064.8	5067.4	5071.6	5060.2	5060.1	5062.9	5069.8
Partic.Mass Flow Rate (g/Hr.)=	28.908	28.582	30.134	54.626	73.144	37.078	24.555	12.335
GM/BHPH=	0.112	0.141	0.228	2.108	0.348	0.241	0.243	

WTD AVG GM/H = 33.634

WEIGHTED AVG GM/BHPH = 0.248

WTD AVG GM/KWH = 0.332

OLSON-ECOLOGIC ENGINE TESTING LABORATORY
GTAT ISO-8178 8-MODE TESTING OF VISCON POLYMER
8MLP22 (MULTI-FILTER)
BASELINE

Mode	EngSpd RPM	DynTrq lb-ft	EngPwr Hp	CO2 %	CO ppm	NOx ppm	NO ppm	HC FID ppm	FUEL RT GM/MIN	AirMas scfm	EngExh degF	ABSHUM GR/LB	Air In degF	Baro P InHga	f/aCAL FACTOR	KNOx PPM	FuelIn degF	KNO PPM	Methane ppm	NMHC ppm	Humidy %	Oil P psig	nH/nC RATIO
1	2200.0	613.4	256.9	5.83	175.86	671.79	590.74	410.45	749.5	507.9	906.9	64.5	74.8	29.90	0.027	653.98	98.0	575.1	202.4	208.0	50.3	58.8	1.8
2	2199.9	462.9	193.9	5.45	103.69	606.71	551.32	447.68	577.5	423.0	842.8	61.6	75.9	29.90	0.026	586.22	100.2	532.7	189.1	278.6	46.2	55.9	1.8
3	2199.9	314.9	131.9	4.88	114.78	469.83	423.19	552.60	412	348.1	740.5	61.5	76.4	29.90	0.023	453.93	101.1	408.9	172.1	380.5	45.8	53.4	1.8
4	2200.0	62.0	26.0	2.98	233.05	168.73	131.48	808.75	169	260.3	510.7	62.0	75.9	29.90	0.015	163.21	101.3	127.2	265.2	543.8	46.8	53.2	1.8
5	1399.9	790.1	210.6	7.49	692.77	763.54	714.10	197.22	564	272.4	1023.8	61.4	75.6	29.90	0.035	756.85	102.6	889.8	179.2	18.1	46.7	37.1	1.8
6	1399.9	577.9	154.0	7.29	609.76	766.65	706.80	316.95	410.5	219.0	955.2	80.9	76.0	29.90	0.034	739.52	102.7	681.8	231.1	85.8	45.7	37.8	1.8
7	1399.9	382.2	101.8	6.45	232.93	655.31	611.93	477.10	277	178.5	800.6	81.0	75.9	29.90	0.030	632.26	100.8	590.4	249.7	227.4	45.8	40.5	1.8
8	567.4	1.3	0.1	3.91	303.17	344.97	298.71	990.20	16	51.9	392.0	62.7	76.2	29.90	0.019	334.25	93.8	289.4	959.0	31.2	46.7	17.9	1.8

WT. FAC %	Mode No	GRAMS/HOUR HC	CO	KNOX	KNO	FUEL	EXHAUST	CO2	NMHC	NO2/NOX RATIO
15.00	1	316.00	272.15	1662.68	1453.7156	44970	1792279	141736.45	160.7	0.12
15.00	2	283.98	132.21	1227.95	1113.2275	34650	1467868	109203.73	177.3	0.09
15.00	3	278.61	116.32	755.75	682.6725	24720	1160838	77633.47	192.5	0.10
10.00	4	267.76	155.09	178.44	141.96456	10140	750081	31191.37	181.5	0.22
10.00	5	88.57	805.92	1122.43	1018.043	33840	1057411	106183.69	8.1	0.09
10.00	6	106.59	412.18	821.28	756.2068	24630	790070	77425.37	28.9	0.08
10.00	7	122.63	120.34	536.86	502.66377	16820	599557	52333.40	58.7	0.07
15.00	8	23.75	14.62	26.47	23.489638	960	54804	2958.19	0.8	0.13

WTD AVG BHP = 136.68 KW = 101.92

	HC	CO	KNOX	KNO	FUEL	EXHAUST	CO2	NMHC
WTD AVG GM/H =	193.91	229.65	816.81	733	24318	991080	76443	107 41
AVG GM/BHPH =	**1.42**	**1.68**	**5.98**	**5.36**	**177.92**		**559.30**	**0.79**
AVG GM/KWH =	1.90	2.25	8.01	7.19	238 60		750.03	1.05

WT AVG NO2/NOX RATIO = 0.112176474

W.F.	0.15	0.15	0.15	0.10	0.10	0.10	0.10	0.15
MODE =	1	2	3	4	5	6	7	8
PARTIC. WT, MG =	1.02	0.96	0.67	0.52	1.34	0.51	0.17	0.09
:xh.Probe Mass Flow Rate (g/Sec.)=	1.087	0.868	0.682	0.441	0.859	0.671	0.567	0.137
Sample Time (Sec.)=	180	180	180	120	120	120	120	180
.Exh.Sample Mass-Part.Filter (kg) =	0.20	0.16	0.12	0.05	0.10	0.08	0.07	0.02
unnel Tot Flow Temp.Corr. (scmm)=	65.10	65.37	65.33	65.37	65.18	65.23	65.24	65.36
Dil Tunnel Tot Mass Flow (kg/Hr.)=	5050.7	5071.2	5068.7	5071.4	5056.8	5060.6	5061.6	5070.9
Partic.Mass Flow Rate (g/Hr.)=	26.330	31.159	27.664	49.832	65.737	32.053	12.647	18.507
GM/BHPH=	0.102	0.161	0.210	1.917	0.312	0.208	0.124	

WTD AVG GM/H = 31.576

WEIGHTED AVG GM/BHPH = 0.231

WTD AVG GM/KWH = 0.310

OLSON-ECOLOGIC ENGINE TESTING LABORATORY
GTAT ISO-8178 8-MODE TESTING OF VISCON POLYMER
8MLP35 (MULTI-FILTER)
w/Viscon

Mode	EngSpd RPM	DynTrq lb-ft	EngPwr Hp	CO2 %	CO ppm	NOx ppm	NO ppm	HC FID ppm	FUEL RT GM/MIN	AirMas scfm	EngExh deg/F	ABSHUM GR/LB	Air In degF	Baro P InHga	f/aCAL FACTOR	KNOx PPM	FuelIn degF	KNO PPM	Methane ppm	NMHC ppm	Humidy %	Oil P psig	nH/nC RATIO
1	2200.0	577.4	241.9	5.84	201.33	720.69	599.91	486.14	703	470.1	910.8	33.9	79.9	30.10	0.0275077	651.12	97.2	542.0	257.6	228.5	22.7	49.3	1.8
2	2200.0	470.1	196.9	5.62	124.68	661.20	565.74	515.32	576.5	406.7	863.8	35.7	81.6	30.10	0.0264724	599.94	98.9	513.3	238.2	277.1	22.6	49.7	1.8
3	2200.0	315.3	132.1	5.05	134.82	515.14	445.53	613.67	406	333.2	761.2	35.9	81.4	30.10	0.0239173	467.59	100.1	404.4	226.9	386.8	22.8	51.3	1.8
4	2199.9	61.9	25.9	3.14	256.17	179.66	138.93	851.37	165.5	254.1	517.7	35.7	80.8	30.10	0.0153007	163.01	100.1	126.0	341.8	509.8	23.1	53.0	1.8
5	1400.0	788.7	210.2	7.67	912.62	809.01	691.29	184.23	568.5	262.6	1054.6	35.3	80.6	30.10	0.0358942	733.35	97.7	626.6	184.2	0.0	23.0	36.4	1.8
6	1400 0	578.3	154.1	7.49	694.23	803.87	705.26	337.22	411	208.8	982.2	35.9	81.6	30.10	0.0350741	729.71	99.5	640.2	303.7	33.5	22.7	38.9	1.8
7	1400.0	382.1	101.9	6.69	257.33	686.30	615.93	502.25	275.5	171.7	819.0	36.7	82.6	30.10	0.0313588	624.10	99.0	560.1	320.2	182.1	22.4	41.1	1.8
8	576.0	1.3	0 1	4.51	358.00	307.22	251.31	944.13	15.25	51.9	397.3	36.7	82.4	30.10	0.0217134	279.36	92.3	226.5	944.1	0.0	22.5	17.6	1.8

WT FAC %	Mode No	GRAMS/HOUR HC	CO	KNOX	KNO	FUEL	EXHAUST	CO2	NMHC	NO2/NOX RATIO
15.00	1	349.66	291.07	1546.53	1282.6533	42180	1582999	132718.44	165.09	0.17
15.00	2	316.15	153.76	1215.44	1038.8483	34590	1347904	108877.27	170.70	0.14
15.00	3	294.23	129.93	740.34	642.89433	24360	1048089	76416.70	186.28	0.14
10.00	4	262.39	158.69	165.90	131.0522	9930	662232	30534.15	158.73	0.23
10.00	5	81.47	811.21	1070.91	910.58821	34110	989198	107057 35	0.00	0.15
10.00	6	110.42	456.93	789 05	691 58312	24660	731350	77436.48	11 01	0.12
10 00	7	123.73	127.42	507 71	457 18931	16530	546415	52032.30	45.06	0.10
15.00	8	18.78	14 32	18.35	15.319233	915	43275	2831.09	0.00	0.18

WTD AVG BHP = 134.86 KW = 100.57

	HC	CO	KNOX	KNO	FUEL	EXHAUST	CO2	NMHC
WTD AVG GM/H =	204 63	243.79	781.45	666	23830	896260	74833	99 79
AVG GM/BHPH =	**1.52**	**1.81**	**5.79**	**4.94**	**176.69**		**554.88**	**0.74**
AVG GM/KWH =	2.03	2.42	7 77	6 62	236.95		744 10	0 99

WT AVG NO2/NOX RATIO = 0.154101594

W.F.	0.15	0.15	0.15	0.10	0.10	0.10	0.10	0.15
MODE =	1	2	3	4	5	6	7	8
PARTIC. WT, MG =	1.04	0.59	0.45	0.39	1.42	0.44	0.20	0.03
Exh.Probe Mass Flow Rate (g/Sec.)=	1.087	0.868	0.682	0.441	0.859	0.671	0.567	0.137
Sample Time (Sec.)=	180	180	180	120	120	120	120	180
Dil.Exh.Sample Mass-Part.Filter (kg) =	0.20	0.16	0.1228	0.05	0.10	0.06	0.07	0.02
Tunnel Tot Flow Temp.Corr. (scmm)=	65.05	65.29	65.36	65.40	65.23	85.24	65.22	65.32
Dil.Tunnel Tot Mass Flow (kg/Hr.)=	5046.71	5064.89	5070.94	5073.57	5060.16	5061.52	5059.88	5067.54
Partic.Mass Flow Rate (g/Hr.)=	26.825	19.126	18.588	37.390	69.707	27.659	14.873	6.165
GM/BHPH=	0.111	0.097	0.141	1.444	0.332	0.179	0.146	

WTD AVG GM/H = 25.569

WEIGHTED AVG GM/BHPH = 0.190

WTD AVG GM/KWH = 0.254

OLSON-ECOLOGIC ENGINE TESTING LABORATORY
GTAT ISO-8178 8-MODE TESTING OF VISCON POLYMER
8MLP36 (MULTI-FILTER)
w/Viscon

Mode	EngSpd RPM	DynTrq lb-ft	EngPwr Hp	CO2 %	CO ppm	NOx ppm	NO ppm	HC FID ppm	FUEL RT GM/MIN	AirMas scfm	EngExh deg/F	ABSHUM GR/LB	Air In degF	Baro P InHga	f/aCAL FACTOR	KNOx PPM	FuelIn degF	KNO PPM	Methane ppm	NMHC ppm	Humidy %	Oil P psig	nH/nC RATIO
1	2200.0	596.1	249.7	5.82	222.35	716.22	590.06	458.65	726	479.6	920.9	37.3	79.6	30.10	0.027	652.26	100.7	537.4	244.8	213.9	25.1	51.382828	1.8
2	2200.0	470.3	197.0	5.49	117.80	648.66	551.86	503.34	577.5	406.9	863.0	41.9	81.6	30.10	0.026	597.24	102.7	508.0	237.8	265.5	26.4	50.175089	1.8
3	2200.0	315.0	132.0	4.98	127.93	505.38	435.75	814.29	407	339.0	759.7	41.9	80.3	30.10	0.024	465.37	102.9	401.2	233.7	380.6	27.6	51.410597	1.8
4	2200.0	61.9	25.9	3.14	251.14	178.33	136.11	876.48	164	255.5	516.0	40.6	77.0	30.10	0.015	163.70	102.5	124.9	348.8	527.7	29.8	53.166862	1.8
5	1400.0	769.1	210.3	7.63	914.45	812.16	704.56	201.83	566	266.2	1048.3	41.4	75.9	30.10	0.036	746.86	99.8	647.9	201.8	0.0	31.4	36.870917	1.8
6	1400.0	578.2	154.1	7.43	676.36	802.84	711.33	357.03	410.5	214.1	976.2	41.5	76.1	30.10	0.035	738.53	100.7	654.3	310.5	46.5	31.4	39.052405	1.8
7	1400.0	382.2	101.9	6.68	251.37	683.22	618.13	516.76	275.5	172.9	814.0	41.1	76.1	30.10	0.031	627.86	99.5	568.0	330.1	186.6	31.1	41.102698	1.8
8	583.0	1.4	0.2	4.51	353.68	269.30	235.47	976.85	15.5	53.8	369.5	41.5	76.3	30.10	0.022	266.11	92.0	216.6	976.9	0.0	31.1	18.148681	1.8

WT. FAC %	Mode No	GRAMS/HOUR HC	CO	KNOX	KNO	FUEL	EXHAUST	CO2	NMHC	NO2/NOX RATIO
15.00	1	342.21	333.47	1607.10	1318.0149	43560	1642557	137068.60	160.2	0.18
15.00	2	316.52	148.90	1240.24	1053.4205	34650	1381289	109074.72	167.7	0.15
15.00	3	299.24	125.26	748.61	648.11533	24420	1065102	76599.23	186.3	0.14
10.00	4	266.97	153.76	164.65	128.48007	9840	654976	30240.90	162.5	0.24
10.00	5	89.26	812.87	1090.70	941.76657	33960	989745	106552.61	0.0	0.13
10.00	6	117.60	449.11	803.27	711.2036	24630	735855	77332.60	15.4	0.11
10.00	7	127.52	124.69	511.86	464.57715	16530	547832	52024.61	46.3	0.10
15.00	8	19 73	14.36	17.74	14.748124	930	43957	2875.80	0.0	0.19

WTD AVG BHP = 136.04 KW = 101.45

	HC	CO	KNOX	KNO	FUEL	EXHAUST	CO2	NMHC
WTD AVG GM/H =	206 79	247.34	799.08	680	24030	912754	75458	99.54
AVG GM/BHPH =	**1.52**	**1.82**	**5.67**	**5.00**	**176.64**		**554.67**	**0.73**
AVG GM/KWH =	2.04	2.44	7.86	6.70	236.87		743.82	0.98

WT AVG NO2/NOX RATIO = 0.155277756

W.F.	0.15	0.15	0.15	0.10	0.10	0.10	0.10	0.15
MODE =	1	2	3	4	5	6	7	8
PARTIC. WT, MG =	0.64	0.53	0.45	0.38	1.37	0.40	0.18	0.01
Exh.Probe Mass Flow Rate (g/Sec.)=	1.087	0.868	0.682	0.441	0.859	0.671	0.567	0.137
Sample Time (Sec.)=	180	180	180	120	120	120	120	180
Dil.Exh.Sample Mass-Part.Filter (kg) =	0.20	0.16	0.1228	0.05	0.10	0.08	0.07	0.02
Dil.Tunnel Tot Flow Temp.Corr. (scmm)=	65.06	65.30	65.42	65.38	65.20	65.22	65.27	65.33
Dil.Tunnel Tot Mass Flow (kg/Hr.)=	5047.24	5066.24	5075.64	5072.22	5058.56	5059.88	5063.42	5068.18
Partic.Mass Flow Rate (g/Hr.)=	21.669	17.186	18.606	36.422	67.231	25.136	13.395	2 055
GM/BHPH=	0.087	0.087	0.141	1.404	0.320	0.163	0.131	

WTD AVG GM/H = 23.146

WEIGHTED AVG GM/BHPH = 0.170

WTD AVG GM/KWH = 0.228

OLSON-ECOLOGIC ENGINE TESTING LABORATORY
GTAT ISO-8178 8-MODE TESTING OF VISCON POLYMER
8MLP37 (MULTI-FILTER)
w/Viscon

Mode	EngSpd RPM	DynTrq lb-ft	EngPwr Hp	CO2 %	CO ppm	NOx ppm	NO ppm	HC FID ppm	FUEL RT GM/MIN	AirMas scfm	EngExh deg/F	ABSHUM GR/LB	Air In degF	Baro P InHga	f/aCAL FACTOR	KNOx PPM	FuelIn degF	KNO PPM	Methane ppm	NMHC ppm	Humidy %	Oil P psig	nH/nC RATIO	Exh. P psig
1	2200 0	606 6	254.1	5.82	219.44	735 47	608.13	440.35	744.5	482.7	923.3	36.6	77.2	30.10	0.027	668.74	96.6	553.0	240.0	200.3	26.7	53.1	1.8	0
2	2200 0	469 9	196 8	5.49	121.71	674 84	572.11	488.09	578	405.8	863.3	36.6	79.7	30.10	0.026	613.66	99.1	520.2	223.8	264 3	24.6	51.0	1.8	0
3	2200 0	314 8	131 9	4.93	132.16	516 12	449 27	607.41	406.5	334.1	760 7	36.6	80 6	30 10	0.023	469.24	99.6	408.5	226.1	381.3	23.9	51.1	1.8	0
4	2200.0	61 9	25 9	3.06	256 47	185.14	139 11	868.51	166.5	250 3	516 0	36.2	80.5	30.10	0.015	168.16	100.0	126.4	343.4	525.1	23.7	52 7	1.8	0
5	1400.0	789 5	210.4	7.56	900 41	824 72	710.87	228.23	568.5	261 3	1056 5	36 3	80 7	30.10	0.035	749.31	97.6	645.9	192.6	35 7	23.6	36 4	1.8	0
6	1400.1	578.1	154.1	7.43	722 96	834.44	731.05	348.52	413.5	210.7	982 8	34.8	80 9	30.10	0.035	755.47	98.4	661.9	307.3	41.2	22.5	38.9	1.8	0
7	1400.0	382.0	101.8	6.66	272.33	714.93	653.33	505.30	275.5	172 2	818 7	34.0	80.1	30.10	0.031	845.99	98.1	590.3	329.8	175.5	22.5	41.1	1.8	0
8	583 7	1 3	0 1	4.34	435 78	314 61	259.64	1122.590008	15 75	52 8	387.7	34.4	79.5	30 10	0 021	284.55	91.2	235.0	1045.3	77.3	23.2	17 7	1.8	0

WT. FAC	Mode	GRAMS/HOUR								NO2/NOX
%	No	HC	CO	KNOX	KNO	FUEL	EXHAUST	CO2	NMHC	RATIO
15.00	1	337.12	337.68	1690.66	1390.7494	44870	1736437	140811.74	154 0	0.17
15.00	2	307.14	153.94	1275.15	1079.2746	34680	1423277	109191.96	167.0	0.15
15.00	3	299.93	131 17	765.16	668.71307	24510	1111259	76874.27	189.2	0.13
10.00	4	275.46	163.50	176.12	135.32772	9990	701778	30676.32	168.4	0.25
10.00	5	102.27	810.99	1106.77	951.48078	34110	1031981	106992.00	16.0	0.14
10.00	6	115.68	482.34	828.05	724.83233	24810	762078	77859.47	13.7	0.12
10.00	7	124.96	135.38	527.55	483.74381	16530	563588	52015.91	43.6	0.09
15.00	8	23.79	18.56	19.91	16.862798	945	47421	2904.10	1.7	0.17

WTD AVG BHP = 136.67 KW = 101.92

	HC	CO	KNOX	KNO	FUEL	EXHAUST	CO2	NMHC
WTD AVG GM/H =	207.03	255.42	826.68	703	24265	953702	76192	100.94
AVG GM/BHPH =	**1.51**	**1.87**	**6.05**	**5.14**	**177.54**		**567.48**	**0.74**
AVG GM/KWH =	2.03	2 51	8.11	6.90	238.09		747.60	0.99

WT AVG NO2/NOX RATIO = 0.154022224

W.F.	0.15	0.15	0.15	0.10	0.10	0.10	0.10	0.15
MODE =	1	2	3	4	5	6	7	8
PARTIC. WT, MG =	0.89	0.65	0.60	0.40	1.57	0.59	0.19	0.01
Exh.Probe Mass Flow Rate (g/Sec.)=	1.087	0.868	0.682	0.441	0.859	0.671	0.567	0.137
Sample Time (Sec.)=	180	180	180	120	120	120	120	180
Dil.Exh.Sample Mass-Part.Filter (kg) =	0.20	0.16	0.1228	0.05	0.10	0.08	0.07	0.02
Dil.Tunnel Tot Flow Temp.Corr. (scmm)=	65 06	65.32	65.35	65.36	65.18	65.23	65.24	65.34
Dil.Tunnel Tot Mass Flow (kg/Hr.)=	5047.19	5067.19	5069.71	5070.63	5056.95	5060.45	5061.65	5069.22
Partic Mass Flow Rate (g/Hr.)=	22.958	21.081	24.779	38.327	77.022	37.080	14.135	2.056
GM/BHPH=	0.090	0.107	0.188	1.478	0.366	0.241	0 139	

WTD AVG GM/H = 27.287

WEIGHTED AVG GM/BHPH = 0.200

WTD AVG GM/KWH = 0.268

OLSON-ECOLOGIC ENGINE TESTING LABORATORY
GTAT ISO-8178 8-MODE TESTING OF VISCON POLYMER
8MLP38 (MULTI-FILTER)
w/Viscon

Mode	EngSpd RPM	DynTrq lb-ft	EngPwr Hp	CO2 %	CO ppm	NOx ppm	NO ppm	HC FID ppm	FUEL RT GM/MIN	AirMas scfm	EngExh deg/F	ABSHUM GR/LB	Air In degF	Baro P InHga	f/aCAL FACTOR	KNOx PPM	FuelIn degF	KNO PPM	Methane ppm	NMHC ppm	Humidy %	Oil P psig
1	2200.0	811.9	256.3	5.69	221.28	757.40	612.52	424.0	743	485.5	928.0	33.8	77.1	30.10	0.0268095	684.08	95.9	553.2	228.0	196.0	24.7	54.3
2	2200.0	469.7	196.8	5.35	118.28	689.46	573.16	491.8	574.5	405.6	862.5	33.9	79.6	30.10	0.025228	622.85	98.8	517.8	211.2	280.6	22.8	51.2
3	2200.0	314.9	131.9	4.83	128.75	540.81	451.87	604.4	408	330.6	758.2	33.4	80.0	30.10	0.0229023	488.08	99.5	407.8	211.2	393.2	22.2	51.5
4	2200.0	62.0	25.9	3.01	255.44	193.73	141.56	869.4	166	250.8	516.6	32.7	79.0	30.10	0.0147	174.55	99.4	127.5	331.4	538.0	22.5	53.4
5	1400.0	789.4	210.4	7.48	912.41	858.07	718.46	223.2	565.5	264.4	1048.5	32.5	78.9	30.10	0.0350607	772.77	96.8	647.0	199.9	23.3	22.4	36.9
6	1400.0	578.0	154.1	7.33	695.48	846.93	723.32	351.1	410	211.2	977.4	33.0	79.4	30.10	0.0343642	763.57	98.8	652.1	297.9	53.2	22.4	39.1
7	1400.0	382.2	101.9	6.58	256.96	738.88	646.84	510.1	275.5	172.5	815.0	33.6	79.2	30.10	0.0308787	667.10	97.9	583.8	321.4	188.7	23.0	41.4
8	592.2	1.4	0.2	5.94	361.02	342.87	265.73	1130.2	15.75	53.8	386.4	35.3	79.0	30.10	0.0282793	310.76	91.3	240.8	1041.7	88.5	24.2	18.2

WT. FAC %	Mode No	HC	CO	KNOX	KNO	FUEL	EXHAUST	CO2	NMHC	NO2/NOX RATIO
		GRAMS/HOUR								
15.00	1	330.94	347.14	1763.03	1417.9437	44580	1715444	140329.90	153.6	0.19
15.00	2	315.88	152.70	1321.02	1096.5218	34470	1407420	108497.76	180.9	0.17
15.00	3	304.41	128.32	811.79	681.01062	24480	1098474	76769.10	198.9	0.16
10.00	4	279.69	185.30	185.58	138.72984	9960	690679	30563.98	175.1	0.27
10.00	5	100.59	826.36	1149.82	958.41777	33930	1006180	106400.13	10.5	0.16
10.00	6	117.14	466.41	841.27	717.92063	24600	743837	77211.33	17.8	0.15
10.00	7	127.68	129.28	551.39	484.26495	18530	554420	52016.91	47.5	0.12
15.00	8	17.69	11.36	16.07	12.882996	945	34530	2934.68	1.4	0.22

WTD AVG BHP = 137.01 KW = 102.17

	HC	CO	KNOX	KNO	FUEL	EXHAUST	CO2	NMHC
WTD AVG GM/H =	207.87	254.66	859.59	711	24173	937892	75899	105.31
AVG GM/BHPH =	**1.52**	**1.86**	**6.27**	**5.19**	**176.43**		**553.96**	**0.77**
AVG GM/KWH =	2.03	2.49	8.41	6.96	236.60		742.87	1.03

WT AVG NO2/NOX RATIO = 0.16269108

W.F.	0.15	0.15	0.15	0.1	0.1	0.1	0.1	0.15
MODE =	1	2	3	4	5	6	7	8
PARTIC. WT, MG =	0.99	0.61	0.57	0.44	1.51	0.55	0.17	0.01
Exh.Probe Mass Flow Rate (g/Sec.)=	1.087	0.868	0.682	0.441	0.859	0.671	0.567	0.137
Sample Time (Sec.)=	180	180	180	120	120	120	120	180
Dil.Exh.Sample Mass-Part.Filter (kg) =	0.20	0.16	0.1228	0.05	0.10	0.08	0.07	0.02
Dil.Tunnel Tot Flow Temp.Corr. (scmm)=	65.08	65.28	65.32	65.39	65.21	65.20	65.25	65.33
Dil.Tunnel Tot Mass Flow (kg/Hr.)=	5048.64	5064.47	5067.82	5072.82	5058.93	5058.49	5062.38	5068.34
Partic.Mass Flow Rate (g/Hr.)=	25.55	19.77	23.53	42.18	74.11	34.55	12.65	2.06
GM/BHPH=	0.100	0.100	0.178	1.625	0.352	0.224	0.124	

WTD AVG GM/H = 26.984

WEIGHTED AVG GM/BHPH = 0.197

WTD AVG GM/KWH = 0.264

OLSON-ECOLOGIC ENGINE TESTING LABORATORY
GTAT ISO-8178 8-Mode Testing of Viscon Polymer
8MLP39 (MULTI-FILTER)
w/Viscon

Mode	EngSpd RPM	DynTrq lb-ft	EngPwr Hp	CO2 %	CO ppm	NOx ppm	NO ppm	HC FID ppm	FUEL RT GM/MIN	AirMas scfm	EngExh deg/F	ABSHUM GR/LB	Air In degF	Baro P InHga	f/aCAL FACTOR	KNOx PPM	FuelIn degF	KNO PPM	Methane ppm	NMHC ppm	Humidy %	Oil P psig
1	2200.0	595.7	249.5	5.81	214.72	737.61	601.25	443.98	737.5	477.1	923.8	31.0	80.1	30.10	0.0273528	662.09	90.8	539.5	257.4	186.82	20.8	48.8
2	2200.0	470.0	196.9	5.42	117.35	662.15	558.42	484.10	579.5	404.1	860.0	31.9	81.0	30.10	0.0255267	595.39	91.6	502.1	223.7	260.36	20.6	49.0
3	2200.1	314.9	131.9	4.80	121.93	509.20	436.76	593.14	411.5	335.1	755.5	34.5	79.9	30.10	0.0227886	460.65	97.4	395.1	219.7	373.39	23.0	50.4
4	2200.0	62.3	26.1	2.97	242.14	183.55	140.60	846.78	170.5	252.4	515.5	37.7	78.4	30.10	0.0145118	167.33	98.3	128.2	330.4	516.41	26.4	53.4
5	1400.0	790.0	210.6	7.47	904.79	813.02	691.21	231.1	569.5	262.6	1046.3	39.3	77.5	30.10	0.0350455	743.91	95.9	632.5	198.1	33.03	28.3	36.8
6	1400.0	577.7	154.0	7.23	626.87	603.55	700.81	348.74	412.25	211.3	973.2	39.1	77.9	30.10	0.0338996	734.87	97.4	640.9	309.7	39.03	27.8	39.2
7	1400.0	362.2	101.9	6.49	244.77	686.77	617.26	507.57	277.5	171.2	813.6	40.2	77.6	30.10	0.0304518	629.83	96.8	566.1	324.1	183.51	28.7	41.3
8	573.9	0.0	0.0	4.05	346.51	325.72	271.47	1063.7	16.75	51.3	391.6	41.9	78.2	30.10	0.0196272	299.91	91.9	250.0	1019.4	44.28	29.5	17.7

				GRAMS/HOUR						
WT. FAC %	Mode No	HC	CO	KNOX	KNO	FUEL	EXHAUST	CO2	NMHC	NO2/NOX RATIO
15.00	1	338.94	327.54	1659.25	1345.417	44250	1669185	139291.17	142.3	0.19
15.00	2	309.87	150.99	1256.49	1059.487	34770	1403076	109474.47	167.3	0.16
15.00	3	302.84	125.13	776.66	668.6548	24690	1113460	77447.62	191.5	0.14
10.00	4	283.68	163.05	185.12	144.9663	10230	718974	31415.09	174.9	0.23
10.00	5	104.91	825.51	1115.06	943.7639	34170	1014657	107151.88	15.0	0.15
10.00	6	118.64	426.67	825.57	719.3891	24735	758460	77695.69	13.3	0.13
10.00	7	129.81	125.63	531.93	479.7752	16650	566558	52397.61	47.2	0.10
15.00	8	25.74	16.65	23.96	20.48572	1005	52516	3091.65	1.1	0.17

WTD AVG BHP = **136.01** **KW =** **101.42**

	HC	CO	KNOX	KNO	FUEL	EXHAUST	CO2	NMHC
WTD AVG GM/H =	210.01	247.38	823.52	693	24288	941598	76262	100.37
AVG GM/BHPH =	**1.54**	**1.82**	**6.05**	**5.09**	**178.56**		**560.71**	**0.74**
AVG GM/KWH =	2.07	2.44	8.12	6.83	239.45		751.92	0.99

WT AVG NO2/NOX RATIO = 0.15687757

W.F.	0.15	0.15	0.15	0.1	0.1	0.1	0.1	0.15
MODE =	1	2	3	4	5	6	7	8
PARTIC. WT, MG =	1.00	0.70	0.58	0.34	1.41	0.49	0.23	0.08
Exh.Probe Mass Flow Rate (g/Sec.)=	1.067	0.868	0.682	0.441	0.859	0.671	0.567	0.137
Sample Time (Sec.)=	180	180	180	120	120	120	120	180
Dil.Exh.Sample Mass-Part.Filter (kg) =	0.20	0.16	0.1228	0.05	0.10	0.08	0.07	0.02
Dil.Tunnel Tot Flow Temp.Corr. (scmm)=	65.06	65.32	65.35	65.36	65.18	65.23	65.24	65.34
Dil.Tunnel Tot Mass Flow (kg/Hr.)=	5047.19	5067.19	5069.71	5070.63	5056.95	5060.45	5061.65	5069.22
Partic.Mass Flow Rate (g/Hr.)=	25.80	22.70	23.95	32.58	69.17	30.80	17.11	16.45
GM/BHPH=	0.103	0.115	0.182	1.247	0.326	0.200	0.168	

WTD AVG GM/H = 26.300

WEIGHTED AVG GM/BHPH = 0.208

WTD AVG GM/KWH = 0.279

OLSON-ECOLOGIC ENGINE TESTING LABORATORY
GTAT ISO-8178 8-MODE TESTING OF VISCON POLYMER
8MLP40 (MULTI-FILTER)
w/Viscon

Mode	EngSpd RPM	DynTrq lb-ft	EngPwr Hp	CO2 %	CO ppm	NOx ppm	NO ppm	HC FID ppm	FUEL RT GM/MIN	AirMas scfm	EngExh deg/F	ABSHUM GR/LB	Air In degF	Baro P InHga	f/aCAL FACTOR	KNOx PPM	Fuelin degF	KNO PPM	Methane ppm	NMHC ppm	Humidy %	Oil P psig
1	2200.0	607.4	254.4	5.84	225.46	760.02	602.48	410.37	743	476.6	931.8	34.5	83.6	30.00	0.027	687.68	91.1	545.1	233.6	176.6	20.4	54.1
2	2200.0	470.0	196.9	5.50	114.22	668.85	569.13	482.18	577.5	399.9	867.1	35.2	85.4	30.00	0.026	624.11	92.9	515.6	211.1	271.1	19.6	51.4
3	2200.1	314.7	132.0	4.96	120.36	544.18	456.95	599.99	409	327.9	761.8	34.6	85.9	30.00	0.023	492.46	95.0	413.5	212.6	367.4	18.9	52.1
4	2199.9	62.0	26.0	3.05	236.27	193.28	145.54	851.69	168	248.6	516.8	36.3	86.1	30.00	0.015	175.61	96.5	132.2	332.4	519.3	19.7	53.4
5	1400.0	790.1	210.6	7.72	912.56	849.15	704.87	204.16	573	258.8	1057.7	36.5	85.6	30.00	0.036	771.95	92.8	640.6	161.4	22.8	20.2	37.1
6	1400.0	577.7	154.0	7.52	729.67	847.76	719.55	344.05	413.5	208.4	985.1	37.3	86.4	30.00	0.035	772.16	94.6	655.4	305.5	38.6	20.1	39.0
7	1400.0	382.5	102.0	6.58	253.90	720.46	631.20	486.79	279	167.5	822.6	37.9	85.4	30.00	0.031	657.03	97.8	575.6	308.4	178.4	21.1	41.3
8	574.9	1.3	0.1	3.20	297.63	301.15	248.11	935.45	16.25	51.2	386.8	43.2	84.6	30.00	0.016	278.17	93.3	229.2	914.3	21.2	24.4	17.7

		GRAMS/HOUR								
WT. FAC %	Mode No	HC	CO	KNOX	KNO	FUEL	EXHAUST	CO2	NMHC	NO2/NOX RATIO
15.00	1	312.11	344.66	1727.12	1361.4565	44580	1674114	140393.25	135.0	0.21
15.00	2	302.66	144.11	1293.63	1067.2833	34650	1377611	109126.03	170.8	0.17
15.00	3	295.11	116.99	799.87	674.21366	24540	1074144	77004.13	191.3	0.16
10.00	4	273.84	152.69	186.45	143.5034	10080	690391	30984.94	168.7	0.25
10.00	5	90.35	811.77	1128.13	931.79953	34380	990654	107887.97	10.1	0.17
10.00	6	112.82	481.08	836.14	709.04162	24810	732737	77870.48	12.7	0.15
10.00	7	123.53	129.50	550.57	483.67072	16740	562391	52698.21	45.5	0.12
15.00	8	27.68	17.70	27.18	23.026856	975	63670	2986.70	0.6	0.18

WTD AVG BHP = 136.77 KW = 101.99

	HC	CO	KNOX	KNO	FUEL	EXHAUST	CO2	NMHC
WTD AVG GM/H =	200.69	251.32	847.30	696	24313	926068	76371	98.37
AVG GM/BHPH =	**1.47**	**1.84**	**6.20**	**5.09**	**177.76**		**558.39**	**0.72**
AVG GM/KWH =	1.97	2.46	8.31	6.82	238.39		748.61	0.96

WT AVG NO2/NOX RATIO = 0.17681689

W.F.	0.15	0.15	0.15	0.10	0.10	0.10	0.10	0.15
MODE =	1	2	3	4	5	6	7	8
PARTIC. WT, MG =	0.96	0.62	0.56	0.39	1.64	0.56	0.25	0.05
Exh.Probe Mass Flow Rate (g/Sec.)=	1.087	0.868	0.682	0.441	0.859	0.671	0.567	0.137
Sample Time (Sec.)=	180	180	180	120	120	120	120	180
Dil.Exh.Sample Mass-Part.Filter (kg) =	0.20	0.16	0.1228	0.05	0.10	0.08	0.07	0.02
Dil.Tunnel Tot Flow Temp.Corr. (scmm)=	65.12	65.32	65.39	65.40	65.18	65.20	65.21	65.25
Dil.Tunnel Tot Mass Flow (kg/Hr.)=	5051.82	5067.49	5072.70	5073.77	5056.37	5058.28	5059.05	5062.46
Partic.Mass Flow Rate (g/Hr.)=	24.79	20.11	23.14	37.39	80.45	35.18	18.59	10.26
GM/BHPH=	0.097	0.102	0.175	1.439	0.382	0.228	0.182	

WTD AVG GM/H = 28.906

WEIGHTED AVG GM/BHPH = 0.211

WTD AVG GM/KWH = 0.283

OLSON-ECOLOGIC ENGINE TESTING LABORATORY
GTAT ISO-8178 8-MODE TESTING OF VISCON POLYMER
8MLP41 (MULTI-FILTER)
w/Viscon

Mode	EngSpd RPM	DynTrq lb-ft	EngPwr Hp	CO2 %	CO ppm	NOx ppm	NO ppm	HC FID ppm	FUEL RT GM/MIN	AirMas scfm	EngExh deg/F	ABSHUM GR/LB	Air In degF	Baro P InHga	f/aCAL FACTOR	KNOx PPM	FuelIn degF	KNO PPM	Methane ppm	NMHC ppm	Humidity %	Oil P psig
1	2200.0	607.6	254.6	5.91	231.06	693.13	570.90	409.77	741	479.2	936.3	48.1	82.2	30.00	0.028	647.85	92.8	533.6	234.5	175.3	29.6	54.4
2	2200.0	470.0	196.9	5.49	116.52	636.88	542.49	485.29	575.5	401.2	867.4	47.1	62.7	30.00	0.026	593.88	93.7	505.9	213.2	272.1	28.6	51.6
3	2200.1	315.0	132.0	4.88	121.39	493.36	432.01	584.58	407.5	328.3	761.3	46.8	82.6	30.00	0.023	459.69	93.5	402.5	204.3	380.3	28.4	51.9
4	2200.0	62 1	26.0	2.92	236.92	165.81	129.00	829.31	167	249.3	514.4	47.0	82.1	30.00	0.014	154.55	92.1	120.2	314.8	514.5	29.0	53.7
5	1400.0	789.6	210.5	7.45	912.02	776.59	683.00	205.45	567.5	260.2	1054.4	46.7	81.4	30.00	0.035	723.39	91.7	636.2	177.5	27.9	29.5	37.8
6	1400.0	576.0	154.1	7.22	713.13	768.04	691.31	321.69	413	208.9	980.2	47.2	81.7	30.00	0.034	716.25	92.5	644.7	276.3	43.3	29.5	39.9
7	1400.0	381.9	101.6	6.36	255.57	671.03	613.28	478.64	276.5	170.1	814.8	48.0	81.6	30.00	0.030	627.08	91.6	573.1	298.3	180.4	30.2	41.8
8	579.0	1.4	0.2	3.98	297.89	252.93	198.08	941.31	16	52.3	381.9	50.2	81.8	30.00	0.019	237.62	90.2	186.1	915.1	26.2	31.3	17.7

		GRAMS/HOUR								
WT FAC %	Mode No	HC	CO	KNOX	KNO	FUEL	EXHAUST	CO2	NMHC	NO2/NOX RATIO
15.00	1	307 65	348.70	1606.21	1315.6659	44460	1656611	140018 96	132.1	0.18
15.00	2	304.26	146.85	1229.65	1045.7178	34530	1378248	108734.57	171.3	0.15
15.00	3	291.13	121.51	756 00	664.36165	24450	1088690	76726.23	190.2	0.12
10.00	4	276.91	159.01	170.41	135.5431	10020	717189	30774.32	173.6	0.22
10.00	5	93.26	632.16	1084 38	949.14714	34050	1015489	106796.17	12.7	0.12
10.00	6	109.65	488 59	806.20	724.76773	24780	760741	77773.18	14.8	0.10
10.00	7	124.35	133.46	537.97	493.21993	16590	575509	52211.88	47.1	0.09
15.00	8	22.17	14 10	18.48	14.808985	960	51135	2963.97	0.6	0.22

WTD AVG BHP = 136.77 KW = 101.99

	HC	CO	KNOX	KNO	FUEL	EXHAUST	CO2	NMHC
WTD AVG GM/H =	199.20	256.00	801 45	686	24204	933095	76022	98.95
AVG GM/BHPH =	**1.46**	**1.87**	**5.86**	**5.02**	**176.97**		**555.84**	**0.72**
AVG GM/KWH =	1.95	2.51	7.86	6.73	237.32		745.40	0.97

WT AVG NO2/NOX RATIO = 0.152715249

W.F.	0.15	0.15	0.15	0.10	0.10	0.10	0.10	0.15
MODE =	1	2	3	4	5	6	7	8
PARTIC. WT, MG =	1.07	0.73	0.65	0.49	1.67	0.63	0.35	0.08
Exh.Probe Mass Flow Rate (g/Sec.)=	1.087	0.868	0.682	0.441	0.859	0.671	0.567	0.137
Sample Time (Sec.)=	180	180	180	120	120	120	120	180
Dil.Exh.Sample Mass-Part.Filter (kg) =	0.20	0.16	0.1228	0.05	0.10	0.08	0.07	0.02
Dil.Tunnel Tot Flow Temp.Corr. (scmm)=	65.16	65.28	65.42	65.36	65.20	85.21	65.22	65.29
Dil Tunnel Tot Mass Flow (kg/Hr.)=	5055.21	5064.57	5074.99	5071 01	5058.59	5058.86	5060.07	5065.15
Partic.Mass Flow Rate (g/Hr.)=	27.645	23.663	26.871	46.954	81.954	39.581	26.029	16.432
GM/BHPH=	0.109	0.120	0.204	1.805	0.389	0.257	0.256	

WTD AVG GM/H = 33.644

WEIGHTED AVG GM/BHPH = 0.246

WTD AVG GM/KWH = 0.330

OLSON-ECOLOGIC ENGINE TESTING LABORATORY
GTAT ISO-8178 8-MODE TESTING OF VISCON POLYMER
8MLP42 (MULTI-FILTER)
w/Viscon

Mode	EngSpd RPM	DynTrq lb-ft	EngPwr Hp	CO2 %	CO ppm	NOx ppm	NO ppm	HC FID ppm	FUEL RT GM/MIN	AirMas scfm	EngExh deg/F	ABSHUM GR/LB	Air In degF	Baro P InHga	f/aCAL FACTOR	KNOx PPM	FuelIn degF	KNO PPM	Methane ppm	NMHC ppm	Humidy %	Oil P psig
1	2200.0	610.3	255.7	5.75	211.29	723.57	594.72	409.48	742.5	466.6	925.1	53.3	77.0	30.00	0.027	684.86	93.5	562.9	236.7	172.7	38.6	54.5
2	2200.0	469.7	196.7	5.35	107.04	650.78	554.14	475.06	576	407.7	659.5	52.7	76.0	30.00	0.025	615.13	97.6	523.8	212.6	262.5	37.2	52.3
3	2200.0	315.0	131.9	4.79	116.47	498.97	429.42	567.62	413	332.7	752.2	52.4	76.2	30.00	0.023	471.27	92.0	405.6	206.2	361.4	36.7	52.5
4	2200.0	61.9	26.0	2.91	235.14	172.45	128.48	612.83	165.5	251.1	508.9	52.6	77.8	30.00	0.014	162.97	91.9	121.4	320.8	492.0	37.3	54.1
5	1400.0	790.1	210.6	7.43	895.13	785.19	677.61	221.74	569	262.9	1046.6	49.1	76.4	30.00	0.035	735.65	91.1	634.9	186.3	35.4	34.2	38.1
6	1400.0	577.9	154.0	7.27	690.63	783.11	686.28	331.51	412.5	209.5	974.7	48.0	79.1	30.00	0.034	731.86	92.6	641.2	295.2	36.3	32.6	40.0
7	1400.0	382.1	101.8	6.49	249.05	683.93	614.23	476.18	275.5	170.0	810.5	47.7	79.3	30.00	0.030	638.62	91.4	573.5	317.1	159.1	32.2	42.1
8	581.5	1.5	0.2	4.75	326.69	290.24	223.25	1047.01	15.75	52.0	377.9	49.4	79.8	30.00	0.023	272.11	90.3	209.3	962.3	64.7	32.9	17.8

WT. FAC	Mode	GRAMS/HOUR								NO2/NOX
%	No	HC	CO	KNOX	KNO	FUEL	EXHAUST	CO2	NMHC	RATIO
15.00	1	318.42	328.16	1747.59	1428.206	44550	1703918	140310.03	134.0	0.18
15.00	2	306.13	138.64	1308.97	1112.515	34560	1415760	108837.16	169.8	0.15
15.00	3	291.59	122.33	799.45	690.21602	24780	1123010	77774.07	186.4	0.14
10.00	4	270.01	157.00	178.76	136.10434	9930	714005	30512.74	165.2	0.25
10.00	5	101.22	621.34	1108.94	952.61513	34140	1021428	107074.55	18.2	0.14
10.00	6	112.16	469.79	817.41	715.55558	24750	755461	77699.31	12.3	0.12
10.00	7	120.89	127.09	535.40	462.31265	16530	563006	52041.79	40.6	0.10
15.00	8	20.40	12.87	17.51	13.755073	945	42620	2923.77	1.7	0.23

WTD AVG BHP = 136.92 KW = 102.10

	HC	CO	KNOX	KNO	FUEL	EXHAUST	CO2	NMHC
WTD AVG GM/H =	200.61	247.83	845.08	715	24260	948186	76210	97.22
AVG GM/BHPH =	**1.47**	**1.81**	**6.17**	**5.22**	**177.19**		**556.60**	**0.71**
AVG GM/KWH =	1.96	2.43	8.28	7.01	237.61		746.41	0.95

WT AVG NO2/NOX RATIO = 0.166268274

W.F.	0.15	0.15	0.15	0.10	0.10	0.10	0.10	0.15
MODE =	1	2	3	4	5	6	7	8
PARTIC. WT, MG =	0.95	0.57	0.52	0.41	1.68	0.55	0.25	0.05
Exh.Probe Mass Flow Rate (g/Sec.)=	1.087	0.868	0.682	0.441	0.859	0.671	0.567	0.137
Sample Time (Sec.)=	180	180	180	120	120	120	120	180
Dil.Exh.Sample Mass-Part.Filter (kg) =	0.20	0.16	0.12	0.05	0.10	0.08	0.07	0.02
Dil.Tunnel Tot Flow Temp.Corr. (scmm)=	65.08	65.32	65.32	65.34	65.21	65.22	65.23	65.33
Dil.Tunnel Tot Mass Flow (kg/Hr.)=	5049.03	5067.14	5067.73	5069.02	5058.80	5059.85	5060.89	5068.66
Partic.Mass Flow Rate (g/Hr.)=	24.515	18.486	21.466	39.272	82.448	34.562	18.595	10.277
GM/BHPH=	0.096	0.094	0.163	1.513	0.391	0.224	0.183	

WTD AVG GM/H = 28.699

WEIGHTED AVG GM/BHPH = 0.210

WTD AVG GM/KWH = 0.281

OLSON-ECOLOGIC ENGINE TESTING LABORATORY
GTAT ISO-8178 8-MODE TESTING OF VISCON POLYMER
8MLP43 (MULTI-FILTER)
w/Viscon

Mode	EngSpd RPM	DynTrq lb-ft	EngPwr Hp	CO2 %	CO ppm	NOx ppm	NO ppm	HC FID ppm	FUEL RT GM/MIN	AirMas scfm	EngExh deg/F	ABSHUM GR/LB	Air In degF	Baro P InHga	f/aCAL FACTOR	KNOx PPM	FuelIn degF	KNO PPM	Methane ppm	NMHC ppm	Humidy %	Oil P psig
1	2200.0	594.1	248.9	5.73	198.11	703.75	575.50	460.29	725	484.3	910.2	56.2	71.6	30.00	0.027	670.88	92.8	548.8	238.3	224.0	49.1	50.2
2	2200.0	470.0	196.9	5.36	106.70	822.13	527.93	475.42	573	414.7	849.2	57.2	72.7	30.00	0.025	594.60	94.5	504.8	206.6	268.9	48.1	49.6
3	2200.0	315.0	132.0	4.76	121.11	479.29	404.02	573.60	405.5	338.0	746.3	56.3	72.4	30.00	0.023	457.11	95.3	385.3	204.8	368.8	47.9	50.9
4	2200.0	62.0	25.9	2.89	233.85	171.17	125.13	816.62	165.5	256.8	507.1	56.8	72.0	30.00	0.014	163.45	95.5	119.5	318.3	498.3	48.9	54.4
5	1400.0	790.1	210.6	7.35	880.13	781.02	659.60	208.93	564	266.0	1032.0	56.8	71.7	30.00	0.034	745.85	92.6	829.7	198.2	8.8	49.3	38.7
6	1399.8	577.7	154.0	7.06	592.55	752.44	646.28	349.61	409	215.7	959.6	56.3	72.1	30.00	0.033	717.53	93.7	616.3	291.3	56.3	48.3	40.4
7	1400.0	381.8	101.8	6.24	233.91	634.53	558.67	482.44	274.5	175.3	802.3	56.7	72.0	30.00	0.029	805.75	92.3	533.3	300.1	182.4	48.8	42.4
8	576.6	1.4	0.2	2.62	291.02	287.73	208.99	907.12	15.5	53.3	378.9	58.9	72.3	30.00	0.013	276.14	87.4	200.6	863.5	43.7	50.2	18.5

WT. FAC %	Mode No	GRAMS/HOUR HC	CO	KNOX	KNO	FUEL	EXHAUST	CO2	NMHC	NO2/NOX RATIO
15.00	1	348.51	296.46	1677.37	1365.4531	43500	1747465	136912.71	170.3	0.18
15.00	2	303.82	137.06	1254.80	1062.8951	34380	1471768	108273.90	172.5	0.15
15.00	3	289.83	123.01	762.73	645.17475	24330	1156901	76345.95	187.1	0.16
10.00	4	273.29	157.31	180.63	134.98705	9930	753696	30501.90	168.6	0.27
10.00	5	94.60	608.79	1125.72	946.18603	33840	1070618	106160.12	4.0	0.16
10.00	6	120.95	412.04	819.70	703.47755	24540	807700	77093.75	20.3	0.14
10.00	7	126.96	123.73	526.42	465.01948	16470	610361	51836.89	46.2	0.12
15.00	8	31.01	20.00	31.18	23.40723	930	76965	2831.28	1.5	0.27

WTD AVG BHP = 135.92 KW = 101.35

	HC	CO	KNOX	KNO	FUEL	EXHAUST	CO2	NMHC
WTD AVG GM/H =	207.56	236.97	824.16	690	23949	992225	75214	103.82
AVG GM/BHPH =	**1.53**	**1.74**	**6.06**	**5.07**	**176.20**		**553.38**	**0.76**
AVG GM/KWH =	2.05	2.34	8.13	6.80	236.29		742.09	1.02

WT AVG NO2/NOX RATIO = 0.183157386

W.F.	0.15	0.15	0.15	0.10	0.10	0.10	0.10	0.15
MODE =	1	2	3	4	5	6	7	8
PARTIC. WT, MG =	1.02	0.71	0.53	0.36	1.29	0.47	0.20	0.01
Exh.Probe Mass Flow Rate (g/Sec.)=	1.087	0.868	0.682	0.441	0.859	0.671	0.567	0.137
Sample Time (Sec.)=	180	180	180	120	120	120	120	180
Dil.Exh.Sample Mass-Part.Filter (kg) =	0.20	0.16	0.12	0.05	0.10	0.08	0.07	0.02
Dil.Tunnel Tot Flow Temp.Corr. (scmm)=	65.10	65.35	65.36	65.37	65.20	65.24	65.23	65.35
Dil.Tunnel Tot Mass Flow (kg/Hr.)=	5050.6	5069.6	5070.6	5071.6	5057.9	5061.5	5060.7	5069.8
Partic.Mass Flow Rate (g/Hr.)=	26.329	23.038	21.892	34.501	63.297	29.544	14.876	2.056
GM/BHPH=	0.106	0.117	0.166	1.330	0.301	0.192	0.146	

WTD AVG GM/H = 25.219

WEIGHTED AVG GM/BHPH = 0.186

WTD AVG GM/KWH = 0.249

OLSON-ECOLOGIC ENGINE TESTING LABORATORY
GTAT ISO-8178 8-MODE TESTING OF VISCON POLYMER
8MLP46 (MULTI-FILTER)
W/ 10x VISCON

Mode	EngSpd RPM	DynTrq lb-ft	EngPwr Hp	CO2 %	CO ppm	NOx ppm	NO ppm	HC FID ppm	FUEL RT GM/MIN	AirMas scfm	EngExh deg/F	ABSHUM GR/LB	Air In degF	Baro P InHga	f/aCAL FACTOR	KNOx PPM	FuelIn degF	KNO PPM	Methane ppm	NMHC ppm	Humidy %	Oil P psig
1	2200.0	610.6	255.8	5.76	206.77	686.17	549.34	414.40	741	486.6	920.1	61.4	74.5	30.00	0.027	662.66	92.8	530.5	241.7	172.6	48.4	54.8
2	2200.0	469.9	196.8	5.35	103.77	612.39	512.46	469.11	576	408.6	858.3	61.2	76.2	30.00	0.025	591.20	98.2	494.7	214.1	255.0	45.8	51.8
3	2200.0	315.1	132.0	4.76	111.59	471.03	399.41	573.36	406	334.8	755.4	63.2	76.8	30.00	0.023	457.02	98.9	387.5	211.0	362.4	48.3	52.3
4	2200.0	62.1	26.0	2.61	229.26	152.71	118.75	827.89	186	254.2	514.3	63.2	76.5	30.00	0.014	148.16	98.7	115.2	334.7	493.0	46.8	53.6
5	1400.0	789.4	210.4	7.30	908.06	752.37	635.26	224.25	564	263.6	1044.8	62.2	75.9	30.00	0.034	728.16	96.1	814.8	187.8	36.4	46.9	37.7
6	1400.0	577.8	154.0	7.06	621.09	745.18	643.41	336.73	409.5	212.1	972.2	62.0	76.5	30.00	0.033	720.86	97.5	822.4	297.1	39.6	45.9	39.2
7	1400.0	381.9	101.8	6.19	225.94	636.25	562.93	490.91	274.5	172.8	811.7	62.3	76.6	30.00	0.029	615.97	96.8	545.0	318.2	172.7	48.0	41.6
8	580.8	1.6	0.2	3.60	237.24	276.80	217.96	1090.2	15.75	52.9	395.3	83.2	76.8	30.00	0.018	268.57	90.3	211.5	997.3	92.9	46.3	18.0

GRAMS/HOUR

WT. FAC %	Mode No	HC	CO	KNOX	KNO	FUEL	EXHAUST	CO2	NMHC	NO2/NOX RATIO
15.00	1	319.19	320.13	1885.49	1341.8456	44460	1700422	140027.42	133.5	0.20
15.00	2	302.01	134.28	1256.86	1049.6945	34560	1416160	108857.03	164.8	0.16
15.00	3	291.54	114.05	767.40	852.9657	24360	1112947	76450.13	185.1	0.15
10.00	4	284.54	158.42	168.20	133.82301	9960	739386	30560.14	171.4	0.22
10.00	5	103.14	839.51	1105.96	929.55528	33840	1029917	106084.89	16.8	0.16
10.00	6	116.80	432.30	824.29	710.99189	24570	773274	77171.14	13.8	0.14
10.00	7	130.09	120.35	539.04	478.57959	16470	567333	51832.31	46.0	0.12
15.00	8	27.83	12.17	22.64	18.354422	945	55420	2901.40	2.4	0.21

WTD AVG BHP = 136.95 KW = 102.12

	HC	CO	KNOX	KNO	FUEL	EXHAUST	CO2	NMHC
WTD AVG GM/H =	204.52	242.15	823.61	685	24133	955733	75800	97.88
AVG GM/BHPH =	**1.49**	**1.77**	**6.01**	**5.00**	**176.22**		**553.50**	**0.71**
AVG GM/KWH =	2.00	2.37	8.06	6.70	236.31		742.25	0.96

WT AVG NO2/NOX RATIO = 0.172085804

W.F.	0.15	0.15	0.15	0.10	0.10	0.10	0.10	0.15
MODE =	1	2	3	4	5	6	7	8
PARTIC. WT, MG =	1.03	0.74	0.58	0.45	1.60	0.66	0.27	0.09
Exh.Probe Mass Flow Rate (g/Sec.)=	1.09	0.87	0.6820	0.44	0.86	0.87	0.57	0.14
Sample Time (Sec.)=	180	180	180	120	120	120	120	180
Dil.Exh.Sample Mass-Part.Filter (kg) =	0.20	0.16	0.1228	0.05	0.10	0.08	0.07	0.02
Dil.Tunnel Tot Flow Temp.Corr. (scmm)=	85.08	65.27	65.33	85.34	85.21	85.22	85.24	65.28
Dil.Tunnel Tot Mass Flow (kg/Hr.)=	5048.84	5063.39	5068.55	5068.82	5059.23	5059.70	5061.06	5064.61
Partic.Mass Flow Rate (g/Hr.)=	26.578	23.982	23.947	43.102	78.529	41.473	20.084	18.484
GM/BHPH=	0.104	0.122	0.181	1.656	0.373	0.269	0.197	

WTD AVG GM/H = 32.267

WEIGHTED AVG GM/BHPH = 0.236

WTD AVG GM/KWH = 0.316

OLSON-ECOLOGIC ENGINE TESTING LABORATORY
GTAT ISO-8178 8-MODE TESTING OF VISCON POLYMER
8MLP47 (MULTI-FILTER)
W/10x VISCON

Mode	EngSpd RPM	DynTrq lb-ft	EngPwr Hp	CO2 %	CO ppm	NOx ppm	NO ppm	HC FID ppm	FUEL RT GM/MIN	AirMas scfm	EngExh deg/F	ABSHUM GR/LB	Air In degF	Baro P InHga	f/aCAL FACTOR	KNOx PPM	FuelIn degF	KNO PPM	Methane ppm	NMHC ppm	Humidy %	Oil P psig
1	2200.1	811.8	256.3	5.88	203.96	692.53	564.28	410.91	739.5	489.7	919.1	61.6	75.1	30.00	0.027	669.23	94.2	545.30043	225.8	185.07	47.8	54.3
2	2200.0	469.8	196.8	5.29	103.56	619.97	526.51	456.83	573	409.1	853.1	59.5	76.2	30.00	0.025	596.00	96.6	506.15578	198.0	258.88	44.5	51.4
3	2200.0	314.8	131.9	4.70	112.92	472.26	404.11	552.16	406.5	334.4	748.2	60.0	76.6	30.00	0.022	454.51	96.4	368.92635	194.1	358.10	44.2	52.3
4	2200.0	62.0	26.0	2.84	226.57	163.15	118.88	796.99	164.5	252.4	510.1	58.2	75.5	30.00	0.014	156.33	97.5	113.90968	306.3	490.69	44.5	54.0
5	1399.9	790.1	210.6	7.29	896.80	787.62	648.51	214.04	566	283.5	1043.7	59.7	74.8	30.00	0.034	738.18	95.0	823.64022	189.63	24.41	48.7	37.6
6	1400.0	578.9	154.3	7.06	632.55	735.68	655.25	335.51	410.5	213.8	968.4	57.4	74.4	30.00	0.033	703.51	93.8	826.59944	282.0	53.47	45.6	38.2
7	1399.9	382.1	101.8	6.19	225.37	642.77	566.57	459.16	275.5	173.8	803.7	56.7	74.1	30.00	0.029	613.52	92.9	540.77898	287.8	171.33	45.4	40.5
8	587.4	1.7	0.2	2.78	223.05	248.78	185.93	905.21	16	53.8	383.5	58.0	74.2	30.00	0.014	238.23	89.8	178.04195	861.89	43.32	48.3	16.5

		GRAMS/HOUR								
WT. FAC %	Mode No	HC	CO	KNOX	KNO	FUEL	EXHAUST	CO2	NMHC	NO2/NOX RATIO
15.00	1	320.09	319.36	1721.48	1394.7146	44370	1718595	139739.27	144.7	0.19
15.00	2	296.06	134.90	1275.51	1080.8801	34380	1424497	108301.80	188.4	0.15
15.00	3	284.82	117.08	774.22	664.53038	24390	1127928	76562.11	185.5	0.14
10.00	4	269.05	153.74	174.27	129.7882	9870	725772	30329.89	167.4	0.27
10.00	5	98.95	833.38	1126.97	947.59939	33960	1034826	106489.77	11.3	0.16
10.00	6	116.35	440.92	805.64	716.81111	24630	773967	77349.40	18.6	0.11
10.00	7	122.23	120.59	539.31	476.76652	16530	589512	52047.79	45.8	0.12
15.00	8	30.25	14.98	26.29	20.27187	960	71915	2937.07	1.5	0.25

WTD AVG BHP = 137.03 KW = 102.18

	HC	CO	KNOX	KNO	FUEL	EXHAUST	CO2	NMHC
WTD AVG GM/H =	200.34	242.81	834.25	701	24114	963828	75753	99.33
AVG GM/BHPH =	**1.46**	**1.77**	**6.09**	**5.12**	**175.98**		**552.82**	**0.72**
AVG GM/KWH =	1.96	2.38	8.16	6.86	235.99		741.34	0.97

WT AVG NO2/NOX RATIO = 0.175372224

W.F.	0.15	0.15	0.15	0.10	0.10	0.10	0.10	0.15
MODE =	1	2	3	4	5	6	7	8
PARTIC. WT, MG =	0.92	0.77	0.68	0.49	1.50	0.69	0.23	0.07
Exh.Probe Mass Flow Rate (g/Sec.)=	1.087	0.868	0.682	0.441	0.859	0.671	0.567	0.137
Sample Time (Sec.)=	180	180	180	120	120	120	120	180
Dil.Exh.Sample Mass-Part.Filter (kg) =	0.20	0.16	0.1228	0.05	0.10	0.08	0.07	0.02
Dil.Tunnel Tot Flow Temp.Corr. (scmm)=	65.08	65.34	65.36	65.37	65.19	65.22	65.23	65.33
Dil.Tunnel Tot Mass Flow (kg/Hr.)=	5049.10	5069.02	5070.58	5071.52	5057.57	5060.00	5060.39	5068.18
Partic.Mass Flow Rate (g/Hr.)=	23.741	24.982	28.087	46.958	73.597	43.361	17.106	14.387
GM/BHPH=	0.093	0.127	0.213	1.809	0.349	0.281	0.168	

WTD AVG GM/H = 31.782

WEIGHTED AVG GM/BHPH = 0.232

WTD AVG GM/KWH = 0.311

OLSON-ECOLOGIC ENGINE TESTING LABORATORY
GTAT ISO-8178 8-MODE TESTING OF VISCON POLYMER
8MLP48 (MULTI-FILTER)
W/10x VISCON

Mode	EngSpd RPM	DynTrq lb-ft	EngPwr Hp	CO2 %	CO ppm	NOx ppm	NO ppm	HC FID ppm	FUEL RT GM/MIN	AirMas scfm	EngExh deg/F	ABSHUM GR/LB	Air In degF	Baro P InHga	f/aCAL FACTOR	KNOx PPM	FuelIn degF	KNO PPM	Methane ppm	NMHC ppm	Humidy %	Oil P psig
1	2200.0	609.9	255.5	5.63	202.28	686.81	559.63	407.52	739.5	494.2	912.5	59.7	70.7	30.00	0.027	660.53	93.2	538.2	224.0	183.5	53.8	53.0
2	2200.0	469.8	196.8	5.27	103.23	617.99	524.83	455.37	571	413.9	843.6	56.7	71.7	30.00	0.025	589.86	91.5	500.9	197.3	258.0	49.3	50.4
3	2200.0	314.7	131.9	4.76	114.41	478.51	409.46	559.47	406.5	336.6	739.7	58.2	72.2	30.00	0.023	458.46	93.3	392.3	196.6	362.8	49.8	51.0
4	2200.0	61.9	25.9	2.92	232.93	167.73	122.22	819.37	166	254.2	502.7	58.8	72.0	30.00	0.014	160.94	91.6	117.3	314.9	504.5	50.5	54.5
5	1400.1	790.0	210.6	7.34	902.65	772.84	852.75	215.44	563	265.1	1031.8	57.7	71.5	30.00	0.034	739.47	92.6	624.7	190.9	24.8	50.6	36.6
6	1400.1	577.7	154.1	7.03	629.49	732.11	852.07	333.88	410	212.1	961.1	56.4	71.6	30.00	0.033	698.35	94.2	622.0	280.7	53.2	49.3	38.3
7	1400.0	381.6	101.7	6.19	225.39	642.85	566.63	459.22	275.5	173.6	801.3	56.2	71.8	30.00	0.029	612.84	94.0	540.2	287.9	171.4	48.8	40.5
8	584.5	1.7	0.2	2.91	232.94	259.80	194.17	945.33	15.75	53.4	380.0	58.2	72.3	30.00	0.014	248.90	91.5	186.0	900.1	45.2	49.6	18.2

WT. FAC %	Mode No	HC	CO	KNOX	KNO	FUEL	EXHAUST	CO2	NMHC	NO2/NOX RATIO
		GRAMS/HOUR								
15.00	1	320.09	319.36	1713.22	1387.8754	44370	1731718	139739.27	144.7	0.19
15.00	2	295.03	134.43	1261.98	1069.4197	34260	1423284	107923.78	167.8	0.15
15.00	3	284.82	117.08	770.76	661.63126	24390	1113534	76562.11	185.5	0.14
10.00	4	271.50	155.14	176.10	131.14381	9960	712942	30606.45	168.9	0.27
10.00	5	98.43	828.95	1115.65	938.16962	33780	1022605	105925.36	11.3	0.16
10.00	6	116.21	440.39	802.84	714.1266	24600	776454	77255.18	18.6	0.11
10.00	7	122.23	120.59	538.65	478.18757	16530	589408	52047.79	45.8	0.12
15.00	8	29.78	14.75	25.89	19.965221	945	87863	2891.18	1.5	0.25

WTD AVG BHP = 136.88 KW = 102.07

	HC	CO	KNOX	KNO	FUEL	EXHAUST	CO2	NMHC
WTD AVG GM/H =	200.29	242.35	829.08	697	24082	960601	75651	99.38
AVG GM/BHPH =	**1.46**	**1.77**	**6.06**	**5.09**	**175.93**		**552.67**	**0.73**
AVG GM/KWH =	1.96	2.37	8.12	6.83	235.92		741.14	0.97

WT AVG NO2/NOX RATIO = 0.175372224

W.F.	0.15	0.15	0.15	0.10	0.10	0.10	0.10	0.15
MODE =	1	2	3	4	5	6	7	8
PARTIC. WT, MG =	1.01	0.74	0.54	0.36	1.50	0.72	0.30	0.12
Exh.Probe Mass Flow Rate (g/Sec.)=	1.09	0.87	0.68	0.44	0.86	0.67	0.57	0.14
Sample Time (Sec.)=	180	180	180	120	120	120	120	180
Dil.Exh.Sample Mass-Part.Filter (kg) =	0.20	0.16	0.12	0.05	0.10	0.08	0.07	0.02
Dil.Tunnel Tot Flow Temp.Corr. (scmm)=	65.04	65.24	65.36	65.37	65.22	65.25	65.25	65.37
Dil.Tunnel Tot Mass Flow (kg/Hr.)=	5046.05	5061.70	5070.70	5071.14	5059.76	5061.78	5062.22	5071.56
Partic.Mass Flow Rate (g/Hr.)=	26.05	23.97	22.3051	34.50	73.63	45.26	22.32	24.68
GM/BHPH=	0.102	0.122	0.169	1.331	0.350	0.294	0.219	

WTD AVG GM/H = 32.12

WEIGHTED AVG GM/BHPH = 0.235

WTD AVG GM/KWH = 0.315

OLSON-ECOLOGIC ENGINE TESTING LABORATORY
GTAT ISO-8178 8-MODE TESTING OF VISCON POLYMER
8MLP49 (MULTI-FILTER)

Mode	EngSpd RPM	DynTrq lb-ft	EngPwr Hp	CO2 %	CO ppm	NOx ppm	NO ppm	HC FID ppm	FUEL RT GM/MIN	AirMas scfm	EngExh deg/F	ABSHUM GR/LB	Air In degF	Baro P InHga	f/aCAL FACTOR	KNOx PPM	FuelIn degF	KNO PPM	Methane ppm	NMHC ppm	Humidy %	Oil P psig
1	2200.0	611.3	256.1	5.69	182.24	693.46	569.50	410.00	744.5	496.3	908.2	54.4	68.7	30.00	0.027	658.23	93.4	540.57	212.8	197.2	52.5	55.1
2	2200.0	469.9	196.8	5.33	98.51	612.57	519.79	452.86	576.5	415.1	840.0	56.9	70.5	30.00	0.025	585.09	97.5	496.47	183.4	269.4	51.6	52.1
3	2200.0	315.0	131.9	4.75	107.93	471.80	399.33	552.61	410	338.7	739.7	57.3	71.2	30.00	0.023	451.09	98.1	381.81	188.9	383.7	50.7	52.8
4	2200.1	62.0	28.0	2.91	224.23	168.09	121.80	799.65	170	255.4	505.3	57.1	71.3	30.00	0.014	160.62	98.2	116.39	300.1	499.5	50.4	54.7
5	1400.0	789.8	210.5	7.36	874.84	780.84	683.13	211.41	564.5	266.5	1027.4	57.3	70.9	30.00	0.035	746.57	93.1	634.03	202.4	9.1	51.2	38.4
8	1399.9	578.0	154.1	7.14	590.51	736.93	661.49	342.37	409	214.5	957.9	56.0	71.6	30.00	0.033	702.33	95.0	630.42	273.3	69.0	49.0	40.3
7	1400.0	382.1	101.8	6.40	221.12	679.58	595.42	469.39	278	172.7	801.9	58.0	71.8	30.00	0.030	650.83	93.7	570.23	286.2	183.2	50.3	42.6
8	588.1	1.8	0.2	6.05	127.42	773.91	433.29	561.38	16.75	53.0	341.2	60.1	72.2	30.00	0.028	744.96	90.9	417.09	421.6	139.7	51.4	19.0

WT. FAC %	Mode No	GRAMS/HOUR HC	CO	KNOX	KNO	FUEL	EXHAUST	CO2	NMHC	NO2/NOX RATIO
15.00	1	320.83	286.65	1700.93	1388.7995	44670	1724954	140743.36	154.9	0.18
15.00	2	293.43	128.31	1251.89	1059.8368	34590	1424129	108989.01	175.2	0.15
15.00	3	284.57	111.72	767.09	651.20011	24600	1126106	77239.85	188.0	0.15
10.00	4	272.49	153.59	180.74	133.75861	10200	732954	31369.82	171.9	0.28
10.00	5	96.64	603.79	1126.89	952.52013	33870	1022985	106257.07	4.1	0.15
10.00	8	117.15	406.15	793.60	711.69639	24540	784025	77114.98	23.7	0.10
10.00	7	121.11	114.88	554.54	487.32259	16580	572557	52156.09	47.5	0.12
15.00	8	9.30	4.24	40.75	23.02278	1005	36657	3163.38	2.3	0.44

WTD AVG BHP = 136.99   KW = 102.16

	HC	CO	KNOX	KNO	FUEL	EXHAUST	CO2	NMHC
WTD AVG GM/H =	196.96	227.48	829.68	697	24247	956029	76210	102.79
AVG GM/BHPH =	**1.44**	**1.66**	**6.06**	**5.09**	**176.99**		**556.30**	**0.75**
AVG GM/KWH =	1.93	2.23	8.12	6.82	237.35		746.01	1.01

WT AVG NO2/NOX RATIO = 0.203824786

W.F.	0.15	0.15	0.15	0.10	0.10	0.10	0.10	0.15
MODE =	1	2	3	4	5	6	7	8
PARTIC. WT, MG =	0.83	0.75	0.48	0.37	1.48	0.53	0.19	0.11
Exh.Probe Mass Flow Rate (g/Sec.)=	1.09	0.87	0.68	0.44	0.86	0.87	0.57	0.14
Sample Time (Sec.)=	180	180	180	120	120	120	120	180
Dil.Exh.Sample Mass-Part.Filter (kg) =	0.20	0.16	0.1228	0.05	0.10	0.08	0.07	0.02
Dil.Tunnel Tot Flow Temp.Corr. (scmm)=	65.04	65.32	65.32	65.34	65.19	65.23	65.23	65.32
Dil.Tunnel Tot Mass Flow (kg/Hr.)=	5045.76	5067.78	5067.81	5069.31	5057.05	5060.65	5060.61	5067.85
Partic.Mass Flow Rate (g/Hr.)=	21.40	24.33	19.82	35.44	72.61	33.31	14.13	22.61
GM/BHPH=	0.084	0.124	0.150	1.364	0.345	0.216	0.139	

WTD AVG GM/H = 28.772

WEIGHTED AVG GM/BHPH = 0.210

WTD AVG GM/KWH = 0.282

Approved ________

OLSON-ECOLOGIC ENGINE TESTING LABORATORY
GTAT ISO-8178 8-MODE TESTING OF VISCON POLYMER
8MLP50 (MULTI-FILTER)

Mode	EngSpd RPM	DynTrq lb-ft	EngPwr Hp	CO2 %	CO ppm	NOx ppm	NO ppm	HC FID ppm	FUEL RT GM/MIN	AirMas scfm	EngExh deg/F	ABSHUM GR/LB	Air In degF	Baro P InHga	f/aCAL FACTOR	KNOx PPM	FuelIn degF	KNO PPM	Methane ppm	NMHC ppm	Humidy %	Oil P psig
1	2200.0	604.0	253.0	5.78	196.94	694.88	572.07	431.53	734.5	489.7	916.7	66.4	73.4	30.20	0.027	679.71	93.4	559.57747	263.4	168.1	54.8	51.8
2	2200.0	469.8	196.8	5.35	101.70	606.35	512.20	467.35	574.5	414.2	848.0	60.6	74.1	30.20	0.025	584.50	96.1	493.73734	221.4	246.0	48.9	51.2
3	2200.0	314.8	131.8	4.79	114.09	468.26	394.01	571.51	407	337.6	748.1	63.6	74.7	30.20	0.023	454.74	96.3	382.83554	222.3	349.2	50.2	52.2
4	2200.0	62.1	26.0	2.97	222.14	172.33	124.77	824.28	167.5	254.7	509.3	65.0	74.8	30.20	0.015	167.95	96.6	121.60066	348.1	476.2	51.2	54.0
5	1399.9	789.6	210.5	7.43	902.43	760.49	641.15	235.94	566.5	268.0	1035.4	62.5	74.2	30.20	0.035	736.47	93.6	620.90079	195.2	40.7	50.3	38.8
6	1400.0	577.9	154.1	7.15	612.86	735.33	628.75	340.65	410.5	216.4	957.0	64.7	74.6	30.20	0.034	716.24	94.4	612.41848	305.1	35.5	51.4	40.4
7	1400.0	382.0	101.8	6.36	216.00	641.24	557.16	441.93	276	174.4	800.7	64.9	75.1	30.20	0.030	824.86	95.2	542.92494	312.7	129.2	50.6	42.8
8	567.6	1.0	0.1	3.55	233.99	300.09	213.51	1033.52	16	51.3	382.7	62.1	75.6	30.20	0.017	290.33	66.7	206.56721	862.9	170.8	47.7	18.3

WT. FAC %	Mode No	HC	CO	KNOX	KNO	FUEL	EXHAUST	CO2	NMHC	NO2/NOX RATIO
		GRAMS/HOUR								
15.00	1	328.21	301.09	1707.16	1398.1787	44070	1680546	138787.28	128.4	0.18
15.00	2	300.17	131.30	1239.70	1045.1359	34470	1412731	106580.98	158.6	0.18
15.00	3	289.61	116.21	760.96	642.47587	24420	1109471	76643.86	177.8	0.16
10.00	4	271.25	146.94	162.52	135.02506	10050	708981	30906.63	158.5	0.28
10.00	5	107.22	824.33	1105.21	927.70629	33990	1018765	106573.39	18.5	0.16
10.00	6	116.71	422.05	810.32	692.19714	24630	765989	77377.92	12.2	0.14
10.00	7	114.78	112.76	535.92	466.8578	16560	576695	52179.11	33.7	0.13
15.00	8	27.19	12.37	25.22	18.456877	960	57216	2950.84	4.6	0.29

WTD AVG BHP = 136.49 KW = 101.78

	HC	CO	KNOX	KNO	FUEL	EXHAUST	CO2	NMHC
WTD AVG GM/H =	202.77	234.75	823.35	688	24111	948038	75748	92.71
AVG GM/BHPH =	**1.49**	**1.72**	**6.03**	**5.04**	**176.64**		**554.95**	**0.68**
AVG GM/KWH =	1.99	2.31	8.09	6.76	236.88		744.21	0.91

WT AVG NO2/NOX RATIO = 0.167763995

W.F.	0.15	0.15	0.15	0.10	0.10	0.10	0.10	0.15
MODE =	1	2	3	4	5	6	7	8
PARTIC. WT, MG =	0.96	0.71	0.62	0.45	1.53	0.62	0.26	0.11
Exh.Probe Mass Flow Rate (g/Sec.)=	1.09	0.87	0.6820	0.44	0.66	0.67	0.57	0.14
Sample Time (Sec.)=	180	180	180	120	120	120	120	180
Dil.Exh.Sample Mass-Part.Filter (kg) =	0.20	0.16	0.1226	0.05	0.10	0.08	0.07	0.02
Dil.Tunnel Tot Flow Temp.Corr. (scmm)=	65.14	65.33	65.37	65.37	65.20	65.23	65.23	65.38
Dil.Tunnel Tot Mass Flow (kg/Hr.)=	5048.84	5063.39	5066.55	5068.62	5059.23	5059.70	5061.06	5064.61
Partic.Mass Flow Rate (g/Hr.)=	31.481	35.973	30.553	80.458	72.149	36.446	23.803	20.538
GM/BHPH=	0.124	0.183	0.232	3.098	0.343	0.237	0.234	

WTD AVG GM/H = 39.087

WEIGHTED AVG GM/BHPH = 0.289

WTD AVG GM/KWH = 0.384

OLSON-ECOLOGIC ENGINE TESTING LABORATORY
GTAT ISO-8178 8-MODE TESTING OF VISCON POLYMER
8MLP51 (MULTI-FILTER)

Mode	EngSpd RPM	DynTrq lb-ft	EngPwr Hp	CO2 %	CO ppm	NOx ppm	NO ppm	HC FID ppm	FUEL RT GM/MIN	AirMas scfm	EngExh deg/F	ABSHUM GR/LB	Air In degF	Baro P InHga	f/aCAL FACTOR	KNOx PPM	Fuelin degF	KNO PPM	Methane ppm	NMHC ppm	Humidy %	Oil P psig
1	2200.0	601.4	251.9	5.61	189.00	679.15	539.90	418.00	725	489.4	906.7	83.5	74.5	30.20	0.026	659.44	95.4	524.24	246.9	169.1	50.6	52.9
2	2200.0	470.0	196.9	5.27	104.41	622.08	509.48	457.53	576.5	413.4	851.6	84.6	76.1	30.20	0.025	605.75	97.6	496.10	220.8	236.7	48.7	50.5
3	2200.0	314.4	131.7	4.71	114.20	476.77	391.61	562.81	406	337.8	748.0	83.9	76.4	30.20	0.022	463.41	98.4	380.64	224.2	336.6	47.7	51.5
4	2200.0	62.1	26.0	2.83	225.99	175.24	125.14	805.65	167	254.9	509.0	83.5	76.4	30.20	0.014	170.17	96.7	121.52	346.4	457.2	47.4	54.1
5	1400.1	769.1	210.4	7.35	911.38	731.41	629.62	241.34	568.5	266.7	1036.4	83.1	76.2	30.20	0.034	709.50	95.9	610.76	200.6	40.6	47.4	38.4
6	1399.9	578.3	154.1	7.08	626.44	742.21	620.91	339.94	411.5	214.0	963.0	83.6	76.8	30.20	0.033	720.80	96.3	603.00	311.7	28.2	46.8	40.1
7	1400.0	382.3	101.9	6.29	225.08	635.84	545.28	456.98	276	173.6	802.2	83.2	77.0	30.20	0.030	616.92	96.1	529.06	319.7	137.3	46.2	42.8
8	576.3	1.2	0.1	3.07	267.56	334.14	247.36	1147.15	16	52.3	365.3	84.0	77.4	30.20	0.015	324.87	91.2	240.51	982.9	164.3	46.3	18.6

WT. FAC %	Mode No	GRAMS/HOUR HC	CO	KNOX	KNO	FUEL	EXHAUST	CO2	NMHC	NO2/NOX RATIO
15.00	1	323.43	293.94	1684.94	1332.2618	43500	1706412	138999.00	131.4	0.21
15.00	2	299.26	137.27	1306.36	1069.1714	34590	1438496	108956.51	155.5	0.18
15.00	3	289.43	118.05	786.96	648.52335	24380	1125152	76450.55	175.0	0.18
10.00	4	277.64	156.65	193.78	141.46758	10020	741836	30775.08	159.6	0.29
10.00	5	110.80	841.02	1075.65	921.93577	33990	1028610	106535.86	18.8	0.14
10.00	6	117.92	436.81	825.71	690.07195	24690	774978	77541.90	9.8	0.16
10.00	7	119.93	116.73	534.64	459.80621	16560	582225	52153.47	36.2	0.14
15.00	8	34.59	16.22	32.35	24.621474	960	65333	2921.45	5.1	0.26

WTD AVG BHP = 136.33 KW = 101.66

	HC	CO	KNOX	KNO	FUEL	EXHAUST	CO2	NMHC
WTD AVG GM/H =	204.65	240.14	834.87	683	24038	963074	75500	92.48
AVG GM/BHPH =	**1.50**	**1.76**	**6.12**	**5.01**	**176.32**		**553.80**	**0.68**
AVG GM/KWH =	2.01	2.36	8.21	6.71	236.45		742.66	0.91

WT AVG NO2/NOX RATIO = 0.196737998

W.F.	0.15	0.15	0.15	0.10	0.10	0.10	0.10	0.15
MODE =	1	2	3	4	5	6	7	8
PARTIC. WT, MG =	1.06	0.85	0.75	0.55	1.68	0.75	0.31	0.15
Exh.Probe Mass Flow Rate (g/Sec.)=	1.09	0.87	0.6820	0.44	0.86	0.67	0.57	0.14
Sample Time (Sec.)=	180	180	180	120	120	120	120	180
Dil.Exh.Sample Mass-Part.Filter (kg) =	0.20	0.16	0.1228	0.05	0.10	0.08	0.07	0.02
Dil.Tunnel Tot Flow Temp.Corr. (scmm)=	65.04	65.24	65.39	65.37	65.17	65.22	65.21	65.34
Dil.Tunnel Tot Mass Flow (kg/Hr.)=	5045.73	5061.35	5072.67	5071.56	5055.83	5060.13	5059.29	5069.18
Partic.Mass Flow Rate (g/Hr.)=	27.34	27.54	30.99	52.71	82.40	47.13	23.05	30.83
GM/BHPH=	0.106	0.140	0.235	2.029	0.392	0.306	0.226	

WTD AVG GM/H = 38.034

WEIGHTED AVG GM/BHPH = 0.279

WTD AVG GM/KWH = 0.374

Approved __________

OLSON-ECOLOGIC ENGINE TESTING LABORATORY
GTAT ISO-8178 8-MODE TESTING OF VISCON POLYMER
8MLP52 (MULTI-FILTER)

Mode	EngSpd RPM	DynTrq lb-ft	EngPwr Hp	CO2 %	CO ppm	NOx ppm	NO ppm	HC FID ppm	FUEL RT GM/MIN	AirMas scfm	EngExh deg/F
1	2200.0	590.0	247.2	5.64	186.42	643.11	537.92	423.07	720	479.4	905.7
2	2200.0	469.8	196.8	5.37	109.45	573.52	507.17	461.02	576	409.3	857.2
3	2200.0	315.3	132.1	4.87	129.14	444.01	396.87	572.82	409	333.3	754.9
4	2200.0	62.0	26.0	3.02	244.49	155.37	124.79	826.89	187	252.7	512.8
5	1400.0	789.0	210.3	7.55	914.79	708.34	636.93	239.95	567.5	264.6	1045.4
6	1400.0	577.7	154.0	7.34	668.85	700.70	640.72	326.97	413	212.3	972.8
7	1400.0	382.2	101.9	6.54	234.50	604.31	563.76	467.79	275.5	170.4	809.2
8	574.6	1.2	0.1	3.96	291.81	268.59	236.68	946.53	15.5	50.5	387.7

Mode	ABSHUM GR/LB	Air In degF	Baro P InHga	f/aCAL FACTOR	KNOx PPM	FuelIn degF	KNO PPM	Methane ppm	NMHC ppm	Humidy %	Oil P psig
1	64.2	77.7	30.20	0.027	625.61	99.4	523.27	259.5	163.6	45.9	53.6
2	64.2	78.8	30.20	0.025	557.91	101.8	493.37	233.5	227.5	44.3	51.3
3	64.9	79.9	30.20	0.023	432.60	102.2	386.68	240.2	332.6	43.1	51.9
4	64.1	79.9	30.20	0.015	151.10	102.1	121.36	361.5	467.2	42.7	53.4
5	63.6	79.5	30.20	0.035	687.92	99.2	816.57	183.8	56.1	42.8	38.1
6	63.7	80.1	30.20	0.034	680.63	99.8	822.36	318.8	8.1	42.0	39.8
7	63.5	80.4	30.20	0.031	586.82	100.5	547.44	333.6	134.1	41.6	42.1
8	64.0	80.6	30.20	0.019	261.10	95.2	230.09	946.5	0.0	41.5	18.3

WT. FAC %	Mode No	HC	CO	KNOX	KNO	FUEL	EXHAUST	CO2	NMHC	NO2/NOX RATIO
		GRAMS/HOUR								
15.00	1	323.26	286.31	1578.52	1313.4707	43200	1685740	136056.48	125.8	0.16
15.00	2	295.69	141.10	1181.64	1042.7405	34560	1411710	108666.26	146.5	0.12
15.00	3	286.60	129.87	714.74	640.99105	24540	1096429	77013.94	167.2	0.11
10.00	4	267.28	158.51	160.94	132.0557	10020	695116	30805.49	152.5	0.20
10.00	5	107.48	823.68	1017.60	911.11791	34050	1005615	106764.56	25.2	0.10
10.00	6	109.78	451.17	754.50	689.12641	24780	751660	77831.83	2.7	0.09
10.00	7	117.86	118.78	488.24	456.80825	16530	560215	52064.45	34.0	0.07
15.00	8	21.74	13.46	19.81	17.860183	930	49914	2870.64	0	0.12

WTD AVG BHP = 135.64 KW = 101.15

	HC	CO	KNOX	KNO	FUEL	EXHAUST	CO2	NMHC
WTD AVG GM/H =	199.33	240.82	766.34	671	24023	937830	75468	87.34
AVG GM/BHPH =	**1.47**	**1.78**	**5.65**	**4.95**	**177.10**		**556.37**	**0.64**
AVG GM/KWH =	1.97	2.38	7.58	6.64	237.50		746.10	0.86

WT AVG NO2/NOX RATIO = 0.120660396

W.F.	0.15	0.15	0.15	0.10	0.10	0.10	0.10	0.15
MODE =	1	2	3	4	5	6	7	8
PARTIC. WT, MG =	1.04	0.71	0.71	0.58	1.72	0.72	0.60	0.11
Exh.Probe Mass Flow Rate (g/Sec.)=	1.09	0.87	0.6820	0.44	0.86	0.67	0.57	0.14
Sample Time (Sec.)=	180	180	180	120	120	120	120	180
Dil.Exh.Sample Mass-Part.Filter (kg) =	0.20	0.16	0.12	0.05	0.10	0.08	0.07	0.02
Dil.Tunnel Tot Flow Temp.Corr. (scmm)=	65.07	65.23	65.35	65.34	65.23	65.21	65.25	65.35
Dil.Tunnel Tot Mass Flow (kg/Hr.)=	5048.02	5060.38	5069.91	5069.41	5060.63	5058.61	5062.34	5069.51
Partic.Mass Flow Rate (g/Hr.)=	26.83	23.00	29.32	55.56	84.44	45.23	44.64	22.61
GM/BHPH=	0.109	0.117	0.222	2.138	0.402	0.294	0.438	

WTD AVG GM/H = 38.252

WEIGHTED AVG GM/BHPH = 0.282

WTD AVG GM/KWH = 0.378

OLSON-ECOLOGIC ENGINE TESTING LABORATORY
GTAT ISO-8178 8-MODE TESTING OF VISCON POLYMER
8MLP53 (MULTI-FILTER)

Mode	EngSpd RPM	DynTrq lb-ft	EngPwr Hp	CO2 %	CO ppm	NOx ppm	NO ppm	HC FID ppm	FUEL RT GM/MIN	AirMas scfm	EngExh deg/F	ABSHUM GR/LB	Air In degF	Baro P InHga	f/aCAL FACTOR	KNOx PPM	FuelIn degF	KNO PPM	Methane ppm	NMHC ppm	Humidy %	Oil P psig	nH/nC RATIO
1	2200.0	598.1	250.6	5.71	206.90	664.74	538.36	405.81	734	479.4	922.7	64.5	80.4	30.20	0.027	647.00	100.4	524.00	246.5	159.3	42.2	53.4	1.8
2	2200.0	469.9	196.8	5.38	113.12	611.36	512.42	489.03	578.5	408.9	864.6	81.9	81.9	30.20	0.025	591.17	103.0	495.49	226.3	242.7	38.8	51.1	1.8
3	2200.1	314.6	131.8	4.82	119.44	478.56	400.73	572.66	407	331.7	759.7	81.8	81.7	30.20	0.023	462.66	103.3	387.42	224.4	348.2	38.7	51.7	1.8
4	2200.0	62.0	26.0	2.92	227.00	177.40	131.79	831.10	166	253.2	516.3	59.3	81.0	30.20	0.014	170.43	103.4	126.62	337.9	493.2	38.1	53.2	1.8
5	1400.0	788.5	210.2	7.41	910.86	781.73	637.99	227.06	568	268.3	1050.6	59.8	79.5	30.20	0.035	732.69	101.1	813.87	177.4	49.7	40.3	37.3	1.8
6	1400.0	576.0	154.1	7.15	661.36	761.36	648.33	328.07	412	213.4	974.7	59.2	79.0	30.20	0.034	731.36	101.9	622.78	303.9	24.2	40.8	39.5	1.8
7	1400.1	382.1	101.9	6.36	233.08	661.18	579.43	472.10	278.5	173.3	811.2	59.5	78.8	30.20	0.030	835.53	101.3	556.98	320.9	151.2	41.3	41.6	1.8
8	569.3	1.2	0.1	3.17	304.73	368.19	262.60	1100.47	15.25	51.4	387.0	61.1	78.5	30.20	0.018	355.31	96.3	253.42	923.8	176.9	42.5	18.0	1.8

		GRAMS/HOUR								
WT. FAC %	Mode No	HC	CO	KNOX	KNO	FUEL	EXHAUST	CO2	NMHC	NO2/NOX RATIO
15.00	1	312.19	319.95	1643.89	1323.6835	44040	1698405	138712.72	123.1	0.19
15.00	2	301.59	148.20	1255.28	1050.0132	34710	1414955	109317.13	156.7	0.16
15.00	3	288.50	120.95	769.71	646.71566	24420	1103004	76639.92	176.3	0.16
10.00	4	275.85	151.45	186.80	141.8949	9960	714145	30598.53	165.5	0.26
10.00	5	103.89	836.13	1104.95	921.27801	34080	1023386	106852.51	22.7	0.18
10.00	6	112.75	456.89	830.04	705.99786	24720	787834	77622.18	8.4	0.15
10.00	7	122.83	121.89	546.02	479.98817	16590	577230	52234.85	39.5	0.12
15.00	8	30.68	17.08	32.71	24.121784	915	60455	2789.18	5.1	0.29

WTD AVG BHP = 136.11 KW = 101.50

	HC	CO	KNOX	KNO	FUEL	EXHAUST	CO2	NMHC
WTD AVG GM/H =	201.46	247.26	821 99	682	24148	949782	75850	92 78
AVG GM/BHPH =	**1.48**	**1.82**	**6.04**	**5.01**	**177.42**		**557.28**	**0.68**
AVG GM/KWH =	1 98	2.44	8 10	6.72	237.92		747.32	0 91

WT AVG NO2/NOX RATIO = 0.189363726

W.F.	0.15	0.15	0.15	0.10	0.10	0.10	0.10	0.15
MODE =	1	2	3	4	5	6	7	8
PARTIC. WT, MG =	1.08	0.83	0.62	0.56	1.72	0.76	0.35	0.15
Exh.Probe Mass Flow Rate (g/Sec.)=	1.09	0.87	0.68	0.44	0.86	0.67	0.57	0.14
Sample Time (Sec.)=	180	180	180	120	120	120	120	180
Dil.Exh.Sample Mass-Part.Filter (kg) =	0.20	0.16	0.12	0.05	0.10	0.08	0.07	0.02
Dil.Tunnel Tot Flow Temp.Corr. (scmm)=	65.04	65.29	65.38	65.35	65.20	65.25	65.22	65.32
Dil.Tunnel Tot Mass Flow (kg/Hr.)=	5045.83	5064.86	5072.26	5070.10	5058.18	5061.98	5059.60	5067.37
Partic.Mass Flow Rate (g/Hr.)=	27.85	26.91	25.62	53.65	84.40	47.78	26.03	30.82
GM/BHPH=	0.111	0.137	0.194	2.067	0.402	0.310	0.255	

WTD AVG GM/H = 37.866

WEIGHTED AVG GM/BHPH = 0.278

WTD AVG GM/KWH = 0.373

TITLE: Sampling Protocol for Volatile Organic Compounds in Exhaust Emissions

SOP NUMBER: VOC Sampling Protocol VERSION 6

WRITTEN BY:____
Technical Specialist: Nathan Imus Date

APPROVED BY:____
President: Don Olson Date

SOP MANUAL CONTROL NO._____:

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1.0 Scope and Application

1.1 This exhaust gas sampling protocol is specifically designed for sampling dilute exhaust generated from heavy-duty diesel engines being operated over the EPA transient cycle or steady state emission test as described in 40 CFR Part 86.

1.2 For transient cycle operation, this official testing protocol involves continual sample integration of all gaseous emissions along with pertinent engine and ambient variables for 1200 seconds (20 minutes). For eight-mode steady state operation, this official testing protocol involves modal sample collection for a total of 20 minutes. Modes 1, 2, 3 and 8 are collected for 3 minutes of the 5 minute mode, while modes 4, 5, 6 and 7 are collected for 2 minutes.

1.3 The constant volume sampling system (CVS) continually dilutes the exhaust gas with finely filtered room air to maintain a constant volume of exhaust gas plus dilute air over the test interval. Coincidentally a second bag is being filled continuously with the same air used to dilute the exhaust gas. Therefore at the end of each test there are bag samples of the proportional and integrated dilute exhaust and the filtered air that was used to dilute the exhaust.

2.0 Method Summary

2.1 Samples analyzed for Volatile Organic Compounds (VOC's) are collected from the integrated bag samples that have been continuously filled during the test cycle. One bag is filled with dilution air, while the other is filled with dilute exhaust. A Teflon diaphragm pump is T-connected through a valve to the constant volume sampling system to fill a Tedlar bag with either dilution air or dilute exhaust. For every emission sample and tunnel blank sampled, a dilution air sample must be co-sampled for background correction. Tedlar bag samples are analyzed by gas chromatography (GC).

3.0 Health and Safety

3.1 The toxicity or carcinogenicity of chemicals used in this procedure has not been precisely defined. Each chemical should be treated as a potential health hazard, and exposure to these chemicals should be minimized.

3.2 All sampling should be done while using proper protective equipment to minimize exposure to vapor. Minimum personal protection includes the use of laboratory safety glasses, a lab coat or apron, and protective gloves.

4.0 Sample Preservation, Containers, Handling, and Storage

4.1 Samples are collected and stored in 1 L Tedlar bags.

4.2 Tedlar bags may not be exposed to heat or excessive light. Black Tedlar bags may be used to eliminate photochemically induced reactions.

4.3 Samples must be analyzed within 24 hours of collection.

4.4 To prevent sample contamination, Tedlar bags are used only once.

5.0 Interferences and Potential Problems

5.1 To maximize sample integrity, Tedlar bags should not leak or be exposed to excessive light or heat. Tedlar bags must be shielded from direct sunlight to avoid photochemically induced reactions of any reactive hydrocarbons.

5.1.1 The compound 1,3-butadiene, resulting mostly during cold-start testing by the combustion of olefins, is extremely unstable as it easily polymerizes in the presence of oxygen. Therefore all samples analyzed for 1,3-butadiene must be run within 1 hour of collection.

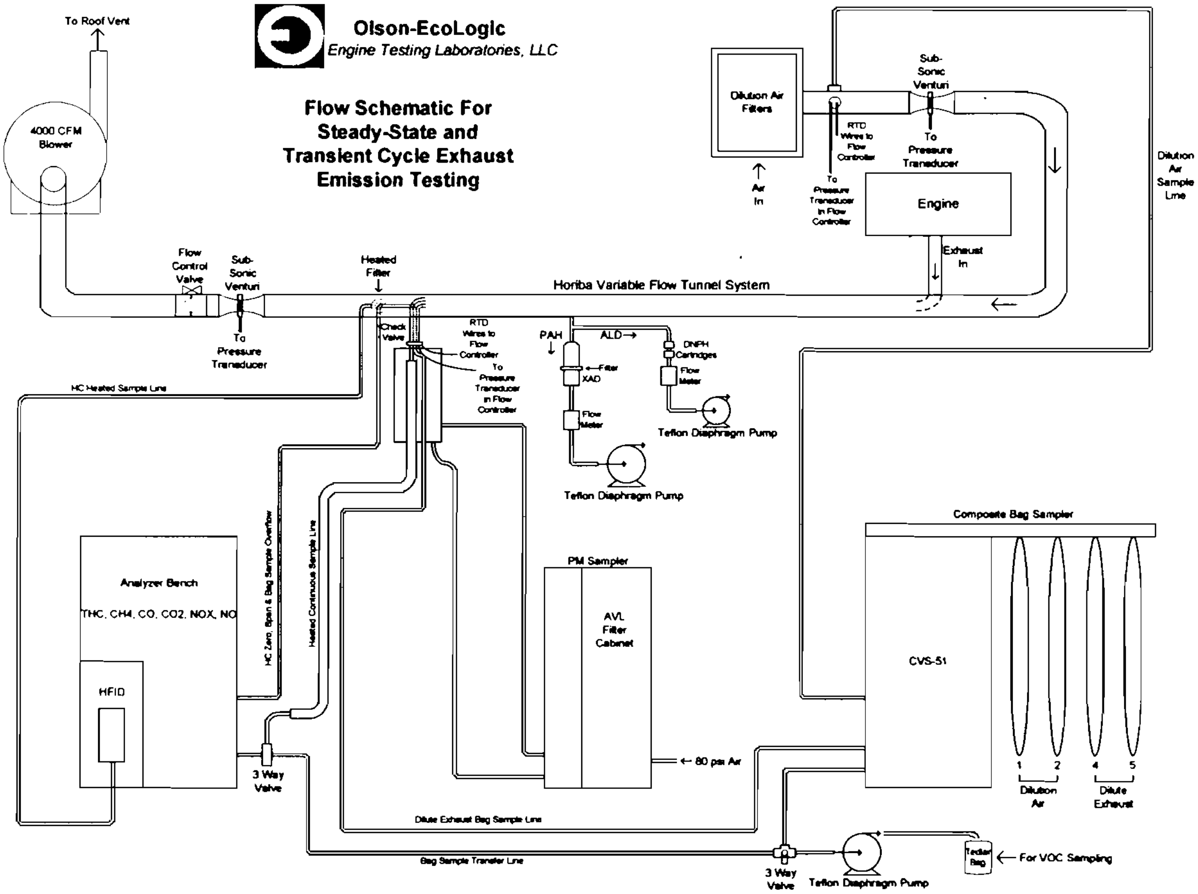
6.0 Equipment/Apparatus

6.1 Tedlar bags: SKC, Inc., 1 L in capacity, or equivalent

6.2 Super Syringe: Fisher Scientific, 1 L

6.3 Teflon diaphragm vacuum-pressure pump: Barnant Co., or equivalent

6.4 Sampling Train Schematic



7.0 Procedure

7.1 Sample collection

7.1.1 After the analysis of the bag samples collected from the emission test, a T-connected valve is turned enabling the sample to flow through the Teflon diaphragm pump to the Tedlar bag.

7.1.2 A dilution air sample is collected first by setting the CVS to "read bag 1 or 2". Before connecting the Tedlar bag to the pump, the pump should be run for about 30 seconds to flush any contaminants from previous samples. The Tedlar bag is then attached to the pump and powered on to collect the sample.

7.1.3 A tunnel blank or dilute exhaust sample is collected next by setting the CVS to "read bag 4 or 5". Before connecting the Tedlar bag to the pump, the pump should be run for about 30 seconds to flush any contaminants from previous samples. The Tedlar bag is then attached to the pump and powered on to collect the sample.

7.1.4 The dilution and work is noted for each dilute exhaust sample taken for final calculations.

7.1.5 The Tedlar bag samples are quickly taken into the laboratory and shaded from direct light for analysis by GC.

8.0 Quality Control/Quality Assurance

8.1 Dilution Air Sample

8.1.1 A dilution air sample is collected for every emission sample and tunnel blank to correct for background levels in the ambient dilution air.

8.2 Tunnel Blank Sample

8.2.1 A tunnel blank sample is collected each analysis day to note any hydrocarbon contamination that may be in the tunnel.

8.3 Duplicate Sample

8.3.1 A duplicate emission sample is collected each analysis day for quality purposes.

8.4 Data Comparisons

8.4.1 The VOC sampling protocol provides the same gas sample used in the official calculation of results from the emission test. The hydrocarbon (HC) data can be compared to the GC data.

8.4.2 The primary bag gas data are printed out on every test report automatically along with other engine operating data. The dilution ratio and work for the entire test is also printed out on each report from the precise CVS flow data. Accordingly, there is generally no need to dilute the Tedlar bag samples before GC analysis.

8.5 Leak Checks

8.5.1 Sampling Train

8.5.1.1 To leak check any part of the sampling train, the suspected leak area should be isolated and pressurized or put under vacuum. A gauge may then be used to check if a leak exists.

8.5.2 Tedlar Bags

8.5.2.1 Tedlar bags may be leak checked by filling the bag and leaving it under pressure overnight. If the bag deflates, it should not be used for sample collection.

8.6 Flow Rates

8.6.1 The flow rate into the CVS bags is controlled by the Horiba CVS with needle valves. The flow rate over the 20 minute transient test cycle is 5 L/min, while the flow rate over the 40 minute steady state test cycle is 2.5 L/min.

TITLE: Determination Of C_2-C_5 Hydrocarbons In Automotive Source Samples By Gas Chromatography

Method 1002

SOP NUMBER: 1002 C_2-C_5 Hydrocarbons VERSION 2

WRITTEN BY:____
Technical Specialist: Nathan Imus Date

APPROVED BY:____
President: Don Olson Date

SOP MANUAL CONTROL NO._____:

1.0 Scope and Application

1.1 This SOP is based on CARB Method 1002 and describes the use of gas chromatography (GC) coupled with flame ionization detection (FID) for the determination of C_2-C_5 hydrocarbons (light-end hydrocarbons) in the ppbC range from automotive source samples. The compounds listed below may be determined by this method:

Compound	CAS Registry No.
ethene	00074-85-1
ethyne	00074-86-2
ethane	00074-84-0
propene	00115-07-1
propane	00074-98-6
1,2-propadiene	00463-49-0
1-propyne	00074-99-7
2-methylpropane	00075-28-5
2-methylpropene (isobutene)	00115-11-7
1-butene	00106-98-9
1,3-butadiene	00106-99-0
n-butane	00106-97-8
trans-2-butene	00624-64-6
2,2-dimethylpropane	00463-82-1
1-butyne	00107-00-6
cis-2-butene	00590-18-1
3-methyl-1-butene	00563-45-1
2-methylbutane	00078-78-4
2-butyne	00503-17-3
1-pentene	00109-67-1
2-methyl-1-butene	00563-46-2
n-pentane	00109-66-0
2-methyl-1,3-butadiene	00078-79-5
trans-2-pentene	00646-04-8
3,3-dimethyl-1-butene	00558-37-2
cis-2-pentene	00627-20-3
1-buten-3-yne	00689-97-4
2-methyl-2-butene	00513-35-9
1,3-cyclopentadiene	00542-92-7
2,2-dimethylbutane	00075-83-2
cyclopentene	00142-29-0
4-methyl-1-pentene	00691-37-2
3-methyl-1-pentene	00760-20-3
cyclopentane	00287-92-3
2,3-dimethylbutane	00079-29-8
1-methyl-tert-butyl-ether	01634-04-4
4-methyl-cis-2-pentene	00691-38-3
2-methylpentane	00107-83-5
4-methyl-trans-2-pentene	00674-76-0
3-methylpentane	00096-14-0

2-methyl-1-pentene	00763-29-1
1-hexene	00592-41-6
n-hexane	00110-54-3

1.2 This method is restricted to use by, or under the supervision of, analysts experienced in the use of gas chromatographs. Analysts should also be skilled in the interpretation of gas chromatograms. Each analyst must demonstrate the ability to generate acceptable results with this method.

2.0 Method Summary

2.1 This method provides GC/FID conditions for the detection of the target analytes. Exhaust samples are introduced to the GC from Tedlar bags by means of gas sampling valves. Separation of the sample hydrocarbons takes place in a 50 m 0.32 mm ID PLOT fused silica column. Quantitative analysis is performed by the FID using an external standard approach. The computerized GC data acquisition system identifies the hydrocarbons and concentrations are determined by peak area response factors.

2.2 Prior to the use of this method, appropriate sample collection techniques must be used.

2.2.1 Samples are collected from the exhaust in Tedlar bags. Dilutions may apply and must be accounted for in final calculations.

3.0 Health and Safety

3.1 The toxicity or carcinogenicity of chemicals used in this procedure has not been precisely defined. Each chemical should be treated as a potential health hazard, and exposure to these chemicals should be minimized.

3.2 All sampling should be done while using proper protective equipment to minimize exposure to vapor. Minimum personal protection includes the use of laboratory safety glasses, a lab coat or apron, and protective gloves.

4.0 Sample Preservation, Containers, Handling, and Storage

4.1 Samples are collected and stored in 1 L Tedlar bags.

4.2 Tedlar bags may not be exposed to heat or excessive light. Black Tedlar bags may be used to eliminate photochemically induced reactions.

4.3 Samples must be analyzed within 24 hours of collection.

5.0 Interferences and Potential Problems

5.1 To maximize sample integrity, Tedlar bags should not leak or be exposed to excessive light or heat. Tedlar bags must be shielded from direct sunlight to avoid photochemically induced reactions of any reactive hydrocarbons.

5.1.1 The compound 1,3-butadiene, resulting mostly during cold-start testing by the combustion of olefins, is extremely unstable as it easily polymerizes in the presence of oxygen. Therefore all samples analyzed for 1,3-butadiene must be run within 1 hour of collection.

5.2 Any component present in the sample with a retention time very similar to that of a target hydrocarbon would interfere or coelute. If separation cannot be achieved, confirmation of identification should be done using a different column for separation, or an alternate detector, e.g., mass spectrometer (MS), photoionization detector (PID), etc.

6.0 Equipment/Apparatus

6.1 GC/FID

6.1.1 Gas Chromatograph (GC) – Varian CP-3800 with programmable oven temperatures, 10 mL fixed volume injection loop for automated transfer of gaseous samples from the Tedlar bag to the GC, and analytical column interfaced with a flame ionization detector (FID).

6.1.1.1 GC Column – Varian CP 7515 PLOT fused silica, 50 m x 0.32 mm ID, or equivalent.

6.1.2 Data System – Dell-PC computer with Varian Star software capable of continuous acquisition and storage of all data obtained throughout the duration of the chromatographic program.

6.2 Nitrogen, compressed and liquid. Minimum purity of 99.998 %.

6.3 Helium, compressed. Minimum purity of 99.995 %.

6.4 Hydrogen, compressed. Minimum purity of 99.995 %.

6.5 Air, compressed. "Zero" grade (<1 ppmC total hydrocarbon contamination), or better.

6.6 Tedlar bags: SKC, Inc., 5 to 10 L in capacity, or equivalent.

6.7 Super Syringe: Fisher Scientific, 1 L.

7.0 Reagents

7.1 NIST-certified SRM or secondary NIST-traceable standards shall be used in all tests. A secondary standard is obtained by a comparison between a SRM and a candidate standard.

7.2 Calibration Standard

7.2.1 The quantitative calibration standard for all target hydrocarbons is propane.
Lehner/Martin, Inc. Propane Std. in zero air – 2955 ppbC, or equivalent

7.3 Control Standard

7.3.1 Quality control standard, containing at least ethane, propane, n-butane, 2-methylpropene and 1,3-butadiene at concentrations between 200 and 3000 ppbC based on a propane standard. This standard is used as a daily update of control charts and a daily determination of marker retention time windows.

Scott-Marrin, Inc. 23 Component custom blend in nitrogen, or equivalent

7.4 A high concentration standard (higher than the calibration standard), containing the target hydrocarbons listed in Section 7.3.1, is used for linearity determinations. The high concentration standard must have concentrations verified against a NIST-traceable propane standard.

7.5 A low concentration standard (5 to 10 times the estimated MDL), containing the target hydrocarbons listed in Section 7.3.1, is used for MDL determinations. The low concentration standard must have concentrations verified against a NIST-traceable propane standard.

7.5.1 In lieu of a low concentration standard, a higher concentration standard may be diluted.

8.0 Procedure

8.1 Sample collection

8.1.1 Specific sample collection procedures can be found in the VOC Sampling Protocol.

8.1.2 In general, samples are collected from the integrated bag samples that have been continuously filled during the 1200 second transient test cycle. One bag is filled with dilution air, while the other is filled with dilute exhaust. A Teflon diaphragm pump is T-connected through a valve to the constant volume sampling system to fill a Tedlar bag with either dilution air or dilute exhaust.

8.2 GC chromatographic conditions:

Injection volume:	10 mL fixed loop
Injector temperature:	-180 C (hold 7.10 min) to 250 C (hold 61.25 min) @ 200 C/min
Helium carrier flow:	3 mL/min
Nitrogen aux. flow:	27 mL/min
Hydrogen flow:	30 mL/min
Air flow:	300 mL/min
Column temperature:	0 C (hold 10 min) to 200 C (hold 20 min) @ 5 C/min
Detector temperature:	250 C

8.3 Samples in Tedlar bags are connected to one of sixteen ports on the autosampler and the analytical process then begins.

8.4 The sample is introduced into the carrier gas stream through the injection valve.

8.5 Each separated analyte exits the column into the FID where a response is generated.

8.6 Hydrocarbon concentrations are calculated in parts per billion of carbon (ppbC) by Varian's Star software from the NIST-traceable propane calibration standard.

8.7 Analytes with concentrations higher than demonstrated in the instruments range of linearity must be diluted and rerun.

8.8 Peak identification and integration are checked and corrected if necessary by the analyst.

8.9 Target compounds that coelute are reported as the major component.

8.10 The PLOT fused silica analytical column is heated to 200 C to prevent carry over and assure all compounds are eluted before the next run.

9.0 Calculations

9.1 The target hydrocarbon concentrations, in ppbC, are calculated by the data system using propane as an external standard.

$$\text{Concentration}_{\text{sample}}\ (\text{ppbC}) = \text{Peak Area}_{\text{sample}} \times \text{Response Factor}$$

where the response factor (RF) is calculated during daily calibration by:

$$\text{RF} = \frac{\text{Concentration of propane standard (ppbC)}}{\text{area of propane peak}}$$

10.0 Quality Control/Quality Assurance

10.1 Instrument Blank Run

10.1.1 An instrument blank of pure nitrogen is run each analysis day. All target hydrocarbon concentrations from the blank analysis must be below the method detection limit (MDL) before the analysis may proceed.

10.1.1.1 If the blank shows a peak greater than the MDL in the region of interest, the source of contamination must be investigated and remedied.

10.2 Calibration Run

10.2.1 The calibration standard is analyzed each analysis day to generate the response factor used to quantify the sample concentrations.

10.3 Control Standard Run

10.3.1 The quality control standard is analyzed at least once each analysis day. Measurements of all compounds specified in Section 7.3.1 must fall within the control limits to ensure the validity of the sample analyses that day. To meet this requirement, it may be necessary to inspect and repair the GC, and rerun the calibration and/or control standards.

10.4 Control Charts

10.4.1 A quality control chart is maintained for each component of the control standard listed in Section 7.3.1, and is performed for new instruments, after making instrument modifications that can affect recovery, and at least once every year. The control charts, used on a daily basis, establish that the method is "in control." The following describes how to construct a typical control chart:

1. Obtain at least 20 daily control standard results;
2. Calculate the control standard mean concentration and standard deviation for the target hydrocarbon; and
3. Create a control chart for the target hydrocarbon by placing the concentration on the Y-axis and the date on the X-axis. Establish upper and lower warning limits at either two standard deviations (2s) or 5 percent, whichever is greater, above and below the average concentration.
4. A control standard measurement is considered to be out-of-control when the analyzed value exceeds the control limit or two successive control standard measurements of the same analyte exceed the warning limit.
5. If 20 control standard measurements are not yet available to create a control chart (e.g., the control standard was expended and replaced prior to obtaining 20 points with the new standard), measurements must be within 15% relative standard deviation (RSD) of the certified concentration. If the control standard is not a NIST standard, the cylinder should be certified by the laboratory against a NIST standard.

The measured concentrations of all target hydrocarbons contained in the control standard must be within the control limits (in control) for the sample results to be considered acceptable.

10.5 Duplicates

10.5.1 A duplicate analysis of one sample is performed at least once per analysis day. The relative percent difference (RPD) is calculated for each duplicate run:

$$\text{RPD}(\%) = \frac{\text{Difference between duplicate and original measurement}}{\text{Average of duplicate and original measurement}} \times 100$$

For each compound specified in Section 7.3.1, the allowable RPD depends on the average concentration level for the duplicate runs, as shown in the following table:

Average Measurement for the Duplicate Runs		Allowable RPD (%)
1 to 10	times MDL	100
10 to 20	" "	30
20 to 50	" "	20
Greater than 50	" "	15

If the results of the duplicate analyses do not meet these criteria for all compounds specified in Section 7.3.1, the sample may be reanalyzed. If reanalysis is not feasible or if the criteria are still not met on reanalysis, all sample results for that analysis day are invalid.

10.6 Linearity

10.6.1 A multipoint calibration to confirm instrument linearity is performed for the target hydrocarbons in the control standard for new instruments, after making instrument modifications that can affect linearity, and at least once every year. The multipoint calibration consists of at least five concentration or mass loading levels (using smaller or larger volume sample sizes of existing standards is acceptable), each above the MDL, distributed over the range of expected sample concentration. A linear regression analysis is performed using concentration and average area counts to determine the regression correlation coefficient (r). The r must be greater than 0.995 to be considered sufficiently linear for one-point calibrations.

10.7 MDL

10.7.1 The MDL for the target hydrocarbons in the control standard must be determined for new instruments, after making instrument modifications that can affect linearity and/or sensitivity, and at least once every year. To make the calculations, it is necessary to run at least seven replicate determinations at a concentration of 5 to 10 times the estimated MDL. The MDL is calculated using the following equation:

$$\text{MDL} = t \times s$$

where s is the standard deviation of the replicates and t is the t-factor for 99 percent confidence for a one-sided normal (Gaussian) distribution. The number of degrees of freedom is equal to the number of replicates, minus one. An abbreviated t-table is:

Degrees of Freedom	t-value
4	3.7
5	3.4
6	3.1
7	3.0

10.7.1.1 The maximum allowable MDL for each compound is 1 ppbC. The calculated laboratory MDL must be equal to or lower than the maximum allowable MDL. All peaks identified as target compounds that are equal to or exceed the maximum allowable MDL must be reported. If the calculated laboratory MDL is less than the maximum allowable MDL, the laboratory may choose to set its reporting limit at the maximum allowable MDL, the calculated laboratory MDL, or any level in between.

10.7.1.2 For the purpose of calculating the total mass of all species, the concentrations of all compounds below the MDL are considered to be zero.

10.8 Method 1002/1003 Crossover Check

10.8.1 A crossover check is analyzed at least once each analysis day, and is performed by choosing a compound from a sample to be measured and compared by both Method 1002 and 1003. The crossover compound shall be a compound that can reasonably be expected to be found and measured by both methods in the laboratory performing the analysis. The maximum relative percent difference (RPD) allowed from the results obtained by the two methods is 15%.

11.0 References

11.1 California Environmental Protection Agency, Air Resources Board, Method 1002, Revision IV, July 2002

TITLE: Determination Of C_6-C_{12} Hydrocarbons In Automotive Source Samples By Gas Chromatography

Method 1003

SOP NUMBER: 1003 C_6-C_{12} Hydrocarbons VERSION 2

WRITTEN BY:____
Technical Specialist: Nathan Imus Date

APPROVED BY:____
President: Don Olson Date

SOP MANUAL CONTROL NO._____:

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1.0 Scope and Application

1.1 This SOP is based on CARB Method 1003 and describes the use of gas chromatography (GC) coupled with flame ionization detection (FID) for the determination of C_6-C_{12} hydrocarbons (mid-range hydrocarbons) in the ppbC range from automotive source samples. The compounds listed below may be determined by this method:

Compound	CAS Registry No.
n-hexane	00110-54-3
trans-3-hexene	13269-52-8
cis-3-hexene	07642-09-3
trans-2-hexene	04050-45-7
3-methyl-trans-2-pentene	00616-12-6
2-methyl-2-pentene	00625-27-4
3-methylcyclopentene	01120-62-3
cis-2-hexene	07688-21-3
1-ethyl-tert-butyl-ether	00637-92-3
3-methyl-cis-2-pentene	00922-62-3
2,2-dimethylpentane	00590-35-2
methylcyclopentane	00096-37-7
2,4-dimethylpentane	00108-08-7
2,2,3-trimethylbutane	00464-06-2
3,4-dimethyl-1-pentene	07385-78-6
1-methylcyclopentene	00693-89-0
benzene	00071-43-2
3-methyl-1-hexene	03404-61-3
3,3-dimethylpentane	00562-49-2
cyclohexane	00110-82-7
2-methylhexane	00591-76-4
2,3-dimethylpentane	00565-59-3
cyclohexene	00110-83-8
3-methylhexane	00589-34-4
trans-1,3-dimethylcyclopentane	01759-58-6
cis-1,3-dimethylcyclopentane	02532-58-3
3-ethylpentane	00617-78-7
trans-1,2-dimethylcyclopentane	00822-50-4
1-heptene	00592-76-7
2,2,4-trimethylpentane	00540-84-1
trans-3-heptene	14686-14-7
n-heptane	00142-82-5
2-methyl-2-hexene	02738-19-4
3-methyl-trans-3-hexene	03899-36-3
trans-2-heptene	14686-13-6
3-ethyl-2-pentene	00816-79-5
2,4,4-trimethyl-1-pentene	00107-39-1
2,3-dimethyl-2-pentene	10574-37-5
cis-2-heptene	06443-92-1
methylcyclohexane	00108-87-2

2,2-dimethylhexane	00590-73-8
2,4,4-trimethyl-2-pentene	00107-40-4
ethylcyclopentane	01640-89-7
2,5-dimethylhexane	00592-13-2
2,4-dimethylhexane	00589-43-5
1,2,4-trimethylcyclopentane	02815-58-9
3,3-dimethylhexane	00563-16-6
2,3,4-trimethylpentane	00565-75-3
2,3,3-trimethylpentane	00560-21-4
toluene	00108-88-3
2,3-dimethylhexane	00584-94-1
2-methylheptane	00592-27-8
4-methylheptane	00589-53-7
3-methylheptane	00589-81-1
(1a,2a,3b)-1,2,3-trimethylcyclopentane	15890-40-1
cis-1,3-dimethylcyclohexane	00638-04-0
trans-1,4-dimethylcyclohexane	02207-04-7
2,2,5-trimethylhexane	03522-94-9
trans-1-methyl-3-ethylcyclopentane	02613-65-2
cis-1-methyl-3-ethylcyclopentane	16747-50-5
1-octene	00111-66-0
trans-4-octene	14850-23-8
n-octane	00111-65-9
trans-2-octene	13389-42-9
trans-1,3-dimethylcyclohexane	02207-03-6
cis-2-octene	07642-04-8
2,3,5-trimethylhexane	01069-53-0
2,4-dimethylheptane	02213-23-2
cis-1,2-dimethylcyclohexane	02207-01-4
2,6-dimethylheptane	01072-05-5
ethylcyclohexane	01678-91-7
3,5-dimethylheptane	00926-82-9
ethylbenzene	00100-41-4
2,3-dimethylheptane	03074-71-3
m-&p-xylene	00108-38-3
4-methyloctane	02216-34-4
2-methyloctane	03221-61-2
3-methyloctane	02216-33-3
styrene (ethenylbenzene)	00100-42-5
o-xylene	00095-47-6
1-nonene	00124-11-8
n-nonane	00111-84-2
(1-methylethyl)benzene	00098-82-8
2,2-dimethyloctane	15869-87-1
2,4-dimethyloctane	04032-94-4
2,6-dimethyloctane	02051-30-1
n-propylbenzene	00103-65-1
1-methyl-3-ethylbenzene	00620-14-4
1-methyl-4-ethylbenzene	00622-96-8

1,3,5-trimethylbenzene	00108-67-8
1-methyl-2-ethylbenzene	00611-14-3
1,2,4-trimethylbenzene	00095-63-6
n-decane	00124-18-5
(2-methylpropyl)benzene	00538-93-2
(1-methylpropyl)benzene	00135-98-8
1-methyl-3-(1-methylethyl)benzene	00535-77-3
1,2,3-trimethylbenzene	00526-73-8
1-methyl-4-(1-methylethyl)benzene	00099-87-6
2,3-dihydroindene (indan)	00496-11-7
1-methyl-2-(1-methylethyl)benzene	00527-84-4
1,3-diethylbenzene	00141-93-5
1,4-diethylbenzene	00105-05-5
1-methyl-3-n-propylbenzene	01074-43-7
1-methyl-4-n-propylbenzene	01074-55-1
1,2-diethylbenzene	00135-01-3
1-methyl-2-n-propylbenzene	01074-17-5
1,4-dimethyl-2-ethylbenzene	01758-88-9
1,3-dimethyl-4-ethylbenzene	00874-41-9
1,2-dimethyl-4-ethylbenzene	00934-80-5
1,3-dimethyl-2-ethylbenzene	02870-04-4
n-undecane (hendecane)	01120-21-4
1,2-dimethyl-3-ethylbenzene	00933-98-2
1,2,4,5-tetramethylbenzene	00095-93-2
1-methyl-2-n-butylbenzene	01595-11-5
1,2,3,5-tetramethylbenzene	00527-53-7
1-(1,1-dimethylethyl)-2-methylbenzene	01074-92-6
1,2,3,4-tetramethylbenzene	00488-23-3
n-pentylbenzene	00538-68-1
1-(1,1-dimethylethyl)-3,5-dimethylbenzene	00098-19-1
naphthalene	00091-20-3
n-dodecane	00112-40-3
n-tridecane	00629-50-5

1.2 This method is restricted to use by, or under the supervision of, analysts experienced in the use of gas chromatographs. Analysts should also be skilled in the interpretation of gas chromatograms. Each analyst must demonstrate the ability to generate acceptable results with this method.

2.0 Method Summary

2.1 This method provides GC/FID conditions for the detection of the target analytes. Exhaust samples are introduced to the GC from Tedlar bags by means of gas sampling valves. Separation of the sample hydrocarbons takes place in a 60 m 0.32 mm ID WCOT fused silica column. Quantitative analysis is performed by the FID using an external standard approach. The computerized GC data acquisition system identifies the hydrocarbons and concentrations are determined by peak area response factors.

2.2 Prior to the use of this method, appropriate sample collection techniques must be used.

2.2.1 Samples are collected from the exhaust in Tedlar bags. Dilutions may apply and must be accounted for in final calculations.

3.0 Health and Safety

3.1 The toxicity or carcinogenicity of chemicals used in this procedure has not been precisely defined. Each chemical should be treated as a potential health hazard, and exposure to these chemicals should be minimized.

3.2 All sampling should be done while using proper protective equipment to minimize exposure to vapor. Minimum personal protection includes the use of laboratory safety glasses, a lab coat or apron, and protective gloves.

4.0 Sample Preservation, Containers, Handling, and Storage

4.1 Samples are collected and stored in 1 L Tedlar bags.

4.2 Tedlar bags may not be exposed to heat or excessive light. Black Tedlar bags may be used to eliminate photochemically induced reactions.

4.3 Samples must be analyzed within 24 hours of collection.

5.0 Interferences and Potential Problems

5.1 To maximize sample integrity, Tedlar bags should not leak or be exposed to excessive light or heat. Tedlar bags must be shielded from direct sunlight to avoid photochemically induced reactions of any reactive hydrocarbons.

5.2 Any component present in the sample with a retention time very similar to that of a target hydrocarbon would interfere or coelute. If separation cannot be achieved, confirmation of identification should be done using a different column for separation, or an alternate detector, e.g., mass spectrometer (MS), photoionization detector (PID), etc.

6.0 Equipment/Apparatus

6.1 GC/FID

6.1.1 Gas Chromatograph (GC) – Varian CP-3800 with programmable oven temperatures, 30 mL fixed volume injection loop for automated transfer of gaseous samples from the Tedlar bag to the GC, and analytical column interfaced with a flame ionization detector (FID).

6.1.1.1 GC Column – Varian CP 8870 WCOT fused silica, 60 m x 0.32 mm ID, or equivalent.

6.1.2 Data System – Dell-PC computer with Varian Star software capable of continuous acquisition and storage of all data obtained throughout the duration of the chromatographic program.

6.2 Nitrogen, compressed and liquid. Minimum purity of 99.998 %.

6.3 Helium, compressed. Minimum purity of 99.995 %.

6.4 Hydrogen, compressed. Minimum purity of 99.995 %.

6.5 Air, compressed. "Zero" grade (<1 ppmC total hydrocarbon contamination), or better.

6.6 Tedlar bags: SKC, Inc., 5 to 10 L in capacity, or equivalent.

6.7 Super Syringe: Fisher Scientific, 1 L

7.0 Reagents

7.1 NIST-certified SRM or secondary NIST-traceable standards shall be used in all tests. A secondary standard is obtained by a comparison between a SRM and a candidate standard.

7.2 Calibration Standard

7.2.1 The quantitative calibration standard for all target hydrocarbons is propane.

Lehner/Martin, Inc. Propane Std. in zero air – 2955 ppbC, or equivalent

7.3 Control Standard

7.3.1 Quality control standard, containing at least n-hexane, benzene, toluene, n-octane, ethylbenzene, m&p-xylene, o-xylene and n-decane at concentrations between 200 and 2000 ppbC based on a propane standard. This standard is used as a daily update of control charts and a daily determination of marker retention time windows.

Scott-Marrin, Inc. 23 Component custom blend in nitrogen, or equivalent

7.4 A high concentration standard (higher than the calibration standard), containing the target hydrocarbons listed in Section 7.3.1, is used for linearity determinations. The high concentration standard must have concentrations verified against a NIST-traceable propane standard.

7.5 A low concentration standard (5 to 10 times the estimated MDL), containing the target hydrocarbons listed in Section 7.3.1, is used for MDL determinations. The low concentration standard must have concentrations verified against a NIST-traceable propane standard.

7.5.1 In lieu of a low concentration standard, a higher concentration standard may be diluted.

8.0 Procedure

8.1 Sample collection

8.1.1 Specific sample collection procedures can be found in the VOC Sampling Protocol.

8.1.2 In general, samples are collected from the integrated bag samples that have been continuously filled during the 1200 second transient test cycle. One bag is filled with dilution air, while the other is filled with dilute exhaust. A Teflon diaphragm pump is T-connected through a valve to the constant volume sampling system to fill a Tedlar bag with either dilution air or dilute exhaust.

8.2 GC chromatographic conditions:

Injection volume:	30 mL fixed loop
Injector temperature:	-180 C (hold 7.10 min) to 250 C (hold 61.25 min) @ 200 C/min
Helium carrier flow:	3 mL/min
Nitrogen aux. flow:	27 mL/min
Hydrogen flow:	30 mL/min
Air flow:	300 mL/min
Column temperature:	10 C (hold 9 min) to 250 C (hold 13 min) @ 5 C/min
Detector temperature:	300 C

8.3 Samples in Tedlar bags are connected to one of sixteen ports on the autosampler and the analytical process then begins.

8.4 The sample is introduced into the carrier gas stream through the injection valve.

8.5 Each separated analyte exits the column into the FID where a response is generated.

8.6 Hydrocarbon concentrations are calculated in parts per billion of carbon (ppbC) by Varian's Star software from the NIST-traceable propane calibration standard.

8.7 Analytes with concentrations higher than demonstrated in the instruments range of linearity must be diluted and rerun.

8.8 Peak identification and integration are checked and corrected if necessary by the analyst using the following procedure and criteria:

1. The primary peak identification is done by the computer using the relative retention times based on reference calibration runs.
2. Confirm that the relative peak heights of the sample run ("fingerprint") match the typical fingerprint seen in past sample runs.
3. Compare the relative retention times of the sample peaks with those of reference runs.
4. Any peak with a reasonable doubt is labeled 'Unidentified'.

8.9 Target compounds that coelute, with the exception of m&p-xylene, are reported as the major component. Due to the difficulty in separation of m-xylene and p-xylene, they are reported together as m&p-xylene.

8.10 The WCOT fused silica analytical column is heated to 250 C to prevent carry over and assure all compounds are eluted before the next run.

8.10.1 After running a particularly "dirty" sample, the analyst should run a blank before proceeding to the next sample as there may be sample carry over, or flush the sampling system with air.

9.0 Calculations

9.1 The target hydrocarbon concentrations, in ppbC, are calculated by the data system using propane as an external standard.

$$\text{Concentration}_{\text{sample}}\ (\text{ppbC}) = \text{Peak Area}_{\text{sample}} \times \text{Response Factor}$$

where the response factor (RF) is calculated during daily calibration by:

$$\text{RF} = \frac{\text{Concentration of propane standard (ppbC)}}{\text{area of propane peak}}$$

10.0 Quality Control/Quality Assurance

10.1 Instrument Blank Run

10.1.1 An instrument blank of pure nitrogen is run each analysis day. All target hydrocarbon concentrations from the blank analysis must be below the method detection limit (MDL) before the analysis may proceed.

10.1.1.1 If the blank shows a peak greater than the MDL in the region of interest, the source of contamination must be investigated and remedied.

10.2 Calibration Run

10.2.1 The calibration standard is analyzed each analysis day to generate the response factor used to quantify the sample concentrations.

10.3 Control Standard Run

10.3.1 The quality control standard is analyzed at least once each analysis day. Measurements of all compounds specified in Section 7.3.1 must fall within the control limits to ensure the validity of the sample analyses that day. To meet this requirement, it may be necessary to inspect and repair the GC, and rerun the calibration and/or control standards.

10.4 Control Charts

10.4.1 A quality control chart is maintained for each component of the control standard listed in Section 7.3.1, and is performed for new instruments, after making instrument modifications that can affect recovery, and at least once every year. The control charts, used on a daily basis, establish that the method is "in control." The following describes how to construct a typical control chart:

1. Obtain at least 20 daily control standard results;
2. Calculate the control standard mean concentration and standard deviation for the target hydrocarbon; and

3. Create a control chart for the target hydrocarbon by placing the concentration on the Y-axis and the date on the X-axis. Establish upper and lower warning limits at either two standard deviations (2s) or 5 percent, whichever is greater, above and below the average concentration.
4. A control standard measurement is considered to be out-of-control when the analyzed value exceeds the control limit or two successive control standard measurements of the same analyte exceed the warning limit.
5. If 20 control standard measurements are not yet available to create a control chart (e.g., the control standard was expended and replaced prior to obtaining 20 points with the new standard), measurements must be within 15% relative standard deviation (RSD) of the certified concentration. If the control standard is not a NIST standard, the cylinder should be certified by the laboratory against a NIST standard.

The measured concentrations of all target hydrocarbons contained in the control standard must be within the control limits (in control) for the sample results to be considered acceptable.

10.5 Duplicates

10.5.1 A duplicate analysis of one sample is performed at least once per analysis day. The relative percent difference (RPD) is calculated for each duplicate run:

$$\mathrm{RPD}\,(\%) = \frac{\text{Difference between duplicate and original measurement}}{\text{Average of duplicate and original measurement}} \times 100$$

For each compound specified in Section 7.3.1, the allowable RPD depends on the average concentration level for the duplicate runs, as shown in the following table:

Average Measurement for the Duplicate Runs		Allowable RPD (%)
1 to 10	times MDL	100
10 to 20	" "	30
20 to 50	" "	20
Greater than 50	" "	15

If the results of the duplicate analyses do not meet these criteria for all compounds specified in Section 7.3.1, the sample may be reanalyzed. If reanalysis is not feasible or if the criteria are still not met on reanalysis, all sample results for that analysis day are invalid.

10.6 Linearity

10.6.1 A multipoint calibration to confirm instrument linearity is performed for the target hydrocarbons in the control standard for new instruments, after making instrument modifications that can affect linearity, and at least once every year. The multipoint calibration consists of at least five concentration or mass loading levels (using smaller or larger volume sample sizes of existing standards is acceptable), each above the MDL, distributed over the range of expected sample concentration. A linear regression analysis is performed using concentration and average area counts to determine the regression correlation coefficient (r). The r must be greater than 0.995 to be considered sufficiently linear for one-point calibrations.

10.7 MDL

10.7.1 The MDL for the target hydrocarbons in the control standard must be determined for new instruments, after making instrument modifications that can affect linearity and/or sensitivity, and at least once every year. To make the calculations, it is necessary to run at least seven replicate determinations at a concentration of 5 to 10 times the estimated MDL. The MDL is calculated using the following equation:

$$\mathrm{MDL} = t \times s$$

where s is the standard deviation of the replicates and t is the t-factor for 99 percent confidence for a one-sided normal (Gaussian) distribution. The number of degrees of freedom is equal to the number of replicates, minus one. An abbreviated t-table is:

Degrees of Freedom	t-value
4	3.7
5	3.4
6	3.1
7	3.0

10.7.1.1 The maximum allowable MDL for each compound is 1 ppbC. The calculated laboratory MDL must be equal to or lower than the maximum allowable MDL. All peaks identified as target compounds that are equal to or exceed the maximum allowable MDL must be reported. If the calculated laboratory MDL is less than the maximum allowable MDL, the laboratory may choose to set its reporting limit at the maximum allowable MDL, the calculated laboratory MDL, or any level in between.

10.7.1.2 For the purpose of calculating the total mass of all species, the concentrations of all compounds below the MDL are considered to be zero.

10.8 Method 1002/1003 Crossover Check

10.8.1 A crossover check is analyzed at least once each analysis day, and is performed by choosing a compound from a sample to be measured and compared by both Method 1002 and 1003. The crossover compound shall be a compound that can reasonably be expected to be found and measured by both methods in the laboratory performing the analysis. The maximum relative percent difference (RPD) allowed from the results obtained by the two methods is 15%.

11.0 References

11.1 California Environmental Protection Agency, Air Resources Board, Method 1003, Revision IV, July 2002

TITLE: Sampling Protocol for Polycyclic Aromatic Hydrocarbons (PAH) in Exhaust Emissions

SOP NUMBER: PAH Sampling Protocol VERSION 6

WRITTEN BY:____
Technical Specialist: Nathan Imus Date

APPROVED BY:____
President: Don Olson Date

SOP MANUAL CONTROL NO._____:

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The document may not be provided to a third party, such as consultants or other governmental agencies, unless said third party agrees to the terms stated above.

1.0 Scope and Application

1.1 This exhaust gas sampling protocol is specifically designed for sampling dilute exhaust generated from heavy-duty diesel engines being operated over the EPA transient cycle or steady state emission test as described in 40 CFR Part 86.

1.2 For transient cycle operation, this official testing protocol involves continual sample integration of all gaseous emissions along with pertinent engine and ambient variables for 1200 seconds (20 minutes). For eight-mode steady state operation, this official testing protocol involves modal sample collection for a total of 20 minutes. Modes 1, 2, 3 and 8 are collected for 3 minutes of the 5 minute mode, while modes 4, 5, 6 and 7 are collected for 2 minutes.

1.3 Dilute exhaust samples are collected from the dilution tunnel.

2.0 Method Summary

2.1 Samples analyzed for particulate and gaseous phase polycyclic aromatic hydrocarbons (PAH) are collected continuously by pulling the dilute exhaust from the dilution tunnel, using a Teflon diaphragm pump, through a particulate filter and XAD cartridge.

2.2 Once received by the laboratory, samples are taken through a concentration extraction and analyzed via gas chromatography/mass spectrometry (GC/MS).

3.0 Health and Safety

3.1 The toxicity or carcinogenicity of chemicals used in this procedure has not been precisely defined. Each chemical should be treated as a potential health hazard, and exposure to these chemicals should be minimized.

3.2 The following method analytes have been classified as known or suspected human or mammalian carcinogens: benzo(a)anthracene and dibenzo(a,h)anthracene. A guideline for the safe handling of carcinogens can be found in Section 5209 of Title 8 of the California Administrative Code.

3.3 All sampling should be done while using proper protective equipment to minimize exposure to vapor. Minimum personal protection includes the use of laboratory safety glasses, a lab coat or apron, and protective gloves.

4.0 Sample Preservation, Containers, Handling, and Storage

4.1 Particulate samples are collected and stored on particulate filers, while gaseous samples are collected and stored on XAD cartridges.

4.2 Sealed XAD cartridges must be stored away from light and refrigerated, at a temperature less than 4 C, upon receipt from manufacturer, until ready for use.

4.3 From the time of collection to extraction, maintain all samples at 4 C or lower and protect from light. All samples must be extracted within 21 days of collection, and all extracts must be analyzed within 40 days of extraction.

5.0 Interferences and Potential Problems

5.1 Transformation of PAH and the formation of artifacts can occur in the sampling train. PAH degradation and transformation on the sampling train filters have been demonstrated. Certain reactive PAH such as benzo(a)pyrene, benzo(a)anthracene, and fluoranthene when trapped on filters can readily react with stack gases. These PAH are transformed by reaction with low levels of nitric acid and higher levels of nitrogen oxides, ozone, and sulfur oxides.

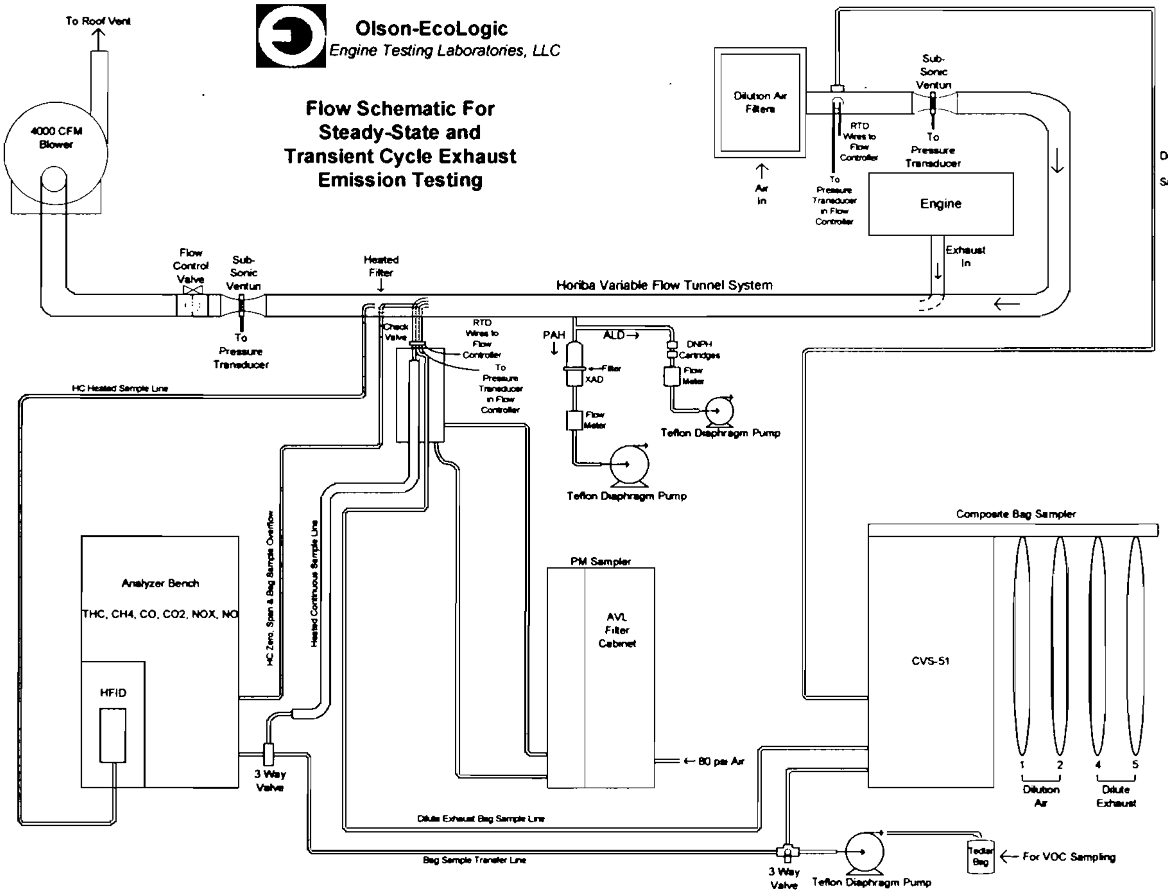
6.0 Equipment/Apparatus

6.1 Sampling Train Schematic

6.1.1 8' Gas line from the tunnel to the PAH/ALD sampling system is as follows:

6.1.1.1 Siltek®/Sulfinert® treated ½" 316L grade stainless steel tubing: Restek, or equivalent.

6.1.2 After the "T" connection, all PAH sampling line is ¼" Teflon tubing.



6.2 Amberlite XAD cartridges: Acros, or equivalent

6.3 PALLFLEX Fiberfilm T60A20 90 mm particulate filter: Pall Life Sciences, or equivalent.

6.4 Digital flow meter: TSI, Inc., or equivalent.

6.5 Teflon diaphragm vacuum-pressure pump: MFG Corp., or equivalent.

7.0 Procedure

7.1 Sample collection

7.1.1 A particulate filter and XAD cartridge is connected into the sample flow path.

7.1.2 Particulate and gaseous phase dilute exhaust samples are collected onto the particulate filter and XAD cartridges by turning on the power to the Teflon diaphragm pump.

7.1.2.1 For transient test cycle sample collection, the Teflon diaphragm pump is turned on for the duration of the 1200 second emission test.

7.1.2.2 For steady state cycle sample collection, the Teflon diaphragm pump is turned on for 3 minutes at the end of modes 1, 2, 3 and 8; and 2 minutes at the end of modes 4, 5, 6 and 7.

7.1.3 The flow rate through the particulate filter and XAD cartridge should be 100 L/min.

7.1.3.1 Flow rate should be continuously monitored and adjusted if necessary during sampling.

7.1.4 The dilution and work is noted for each dilute exhaust sample taken for final calculations.

7.1.5 Particulate filters and XAD cartridges are refrigerated immediately after sample collection and extraction, below a temperature of 4 C, until analyzed by GC/MS.

8.0 Calculations

8.1 Volumetric flow conversions are as follows:

$$1\,\text{SCFM} = 0.0283\ \text{m}^3/\text{min} = 28.317\ \text{L/min}$$

9.0 Quality Control/Quality Assurance

9.1 Tunnel Blank Sample

9.1.1 A tunnel blank sample must be collected each analysis day. The levels of any unlabelled analyte quantified in the tunnel blank must not exceed 20 % of the level of that analyte in the dilute exhaust sample. If this criterion cannot be met, calculate a reporting limit that is five times the blank value. Do not subtract the blank value from the sample value.

9.2 Field Blank Sample

9.2.1 At least one XAD and particulate filter per batch is analyzed as a field blank. The levels of any unlabelled analyte quantified in the tunnel blank must not exceed 20 % of the level of that analyte in the dilute exhaust sample. If this criterion cannot be met, calculate a reporting limit that is five times the blank value.

9.3 Leak Checks

9.3.1 Sampling Train

9.3.1.1 A leak check must be performed each analysis day to ensure correct sampling system flow rates.

9.3.1.2 To leak check any part of the sampling train, the suspected leak area should be isolated and pressurized or put under vacuum. A gauge may then be used to check if a leak exists.

9.3.1.3 Flow rate must be kept within 2 L/min of the set sampling flow rate of 100 L/min.

9.4 Flow Rates

9.4.1 The flow rate into the particulate filter and XAD cartridge is controlled with a digital flow meter. The flow rate over the transient or steady state emission test cycle is 100 L/min.

10.0 References

10.1 Desert Research Institute, 4 Channel Sequential FP/SVOC Sampler, 1-750.4, Revision 05, July 2002.

TITLE: Sampling Protocol for Aldehyde and Ketone Compounds in Exhaust Emissions

SOP NUMBER: ALD Sampling Protocol VERSION 6

WRITTEN BY:______________________________ ______________________
Technical Specialist: Nathan Imus Date

APPROVED BY:_____________________________ ______________________
President: Don Olson Date

SOP MANUAL CONTROL NO._____:

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The document may not be provided to a third party, such as consultants or other governmental agencies, unless said third party agrees to the terms stated above.

1.0 Scope and Application

1.1 This exhaust gas sampling protocol is specifically designed for sampling dilute exhaust generated from heavy-duty diesel engines being operated over the EPA transient cycle or steady state emission test as described in 40 CFR Part 86.

1.2 For transient cycle operation, this official testing protocol involves continual sample integration of all gaseous emissions along with pertinent engine and ambient variables for 1200 seconds (20 minutes). For eight-mode steady state operation, this official testing protocol involves modal sample collection for a total of 20 minutes. Modes 1, 2, 3 and 8 are collected for 3 minutes of the 5 minute mode, while modes 4, 5, 6 and 7 are collected for 2 minutes.

1.3 Dilute exhaust samples are collected from the dilution tunnel.

2.0 Method Summary

2.1 Samples analyzed for aldehyde and ketone compounds (carbonyls) are collected continuously by pulling the dilute exhaust from the dilution tunnel, using a Teflon diaphragm pump, through a series of two DNPH cartridges.

2.2 The absorbing solution (2,4-DNPH) complexes the carbonyl compounds into their diphenylhydrazone derivatives.

2.3 Once received by the laboratory, cartridges are eluted with 5 mL acetonitrile and analyzed via high performance liquid chromatography (HPLC).

3.0 Health and Safety

3.1 The toxicity or carcinogenicity of chemicals used in this procedure has not been precisely defined. Each chemical should be treated as a potential health hazard, and exposure to these chemicals should be minimized.

3.2 All sampling should be done while using proper protective equipment to minimize exposure to vapor. Minimum personal protection includes the use of laboratory safety glasses, a lab coat or apron, and protective gloves.

4.0 Sample Preservation, Containers, Handling, and Storage

4.1 Samples are collected and stored in DNPH-impregnated cartridges.

4.2 DNPH cartridges must be sealed and refrigerated, at a temperature less than 40° F, upon receipt from manufacturer, until ready for use.

4.3 If samples are not analyzed the same day as collected, they must be refrigerated at a temperature below 40° F.

4.4 Refrigerated samples are stable for up to 30 days.

5.0 Interferences and Potential Problems

5.1 To decrease the chance of background contamination variables and oxygenated impurities, DNPH-impregnated cartridges are used rather than impingers.

6.0 Equipment/Apparatus

6.1 Sep-Pak® DNPH-impregnated cartridges: Waters Corporation, or equivalent

6.2 Digital flow meter: Dwyer Instruments, Inc., or equivalent.

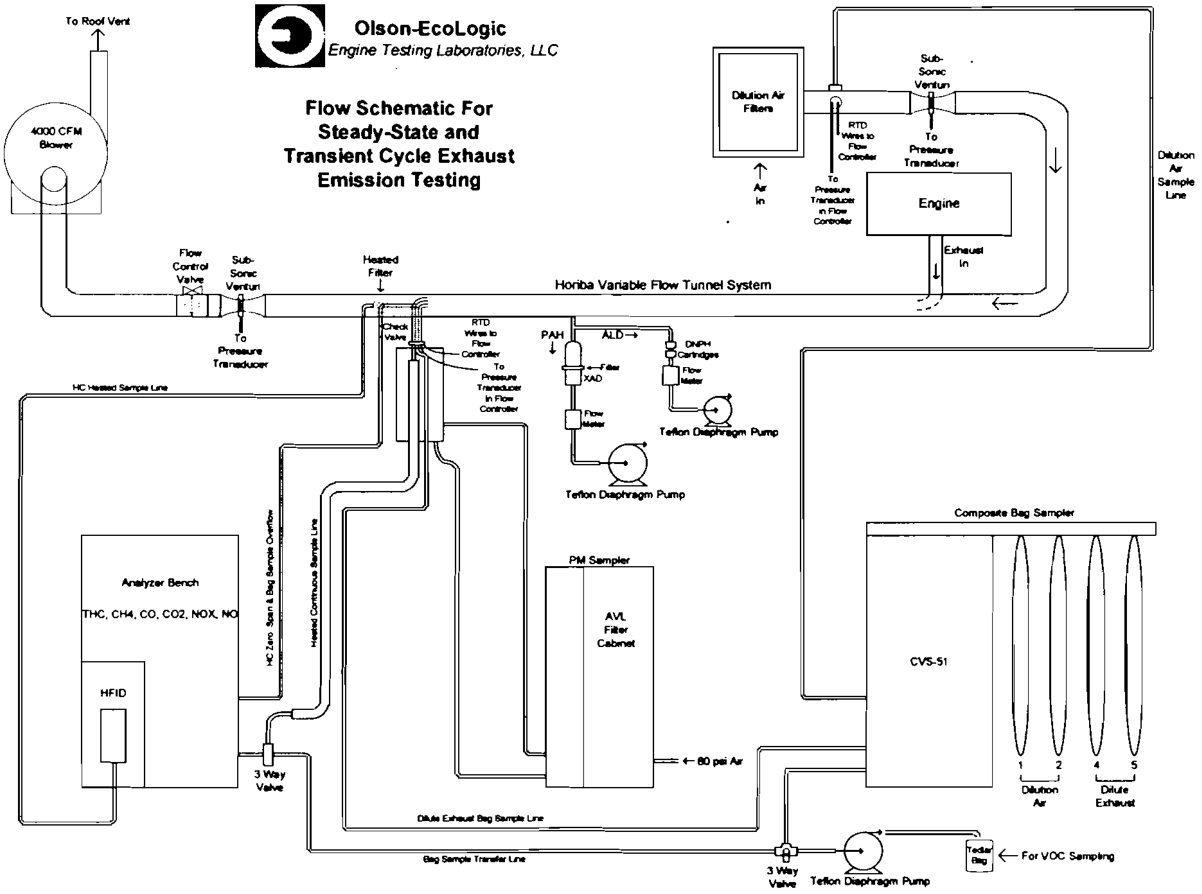
6.3 Teflon diaphragm vacuum-pressure pump: MFG Corp., or equivalent.

6.4 Sampling Train Schematic

6.4.1 8' Gas line from the tunnel to the PAH/ALD sampling system is as follows:

6.4.1.1 Siltek®/Sulfinert® treated ½" 316L grade stainless steel tubing: Restek, or equivalent.

6.4.2 After the "T" connection, all ALD sampling line is ¼" Teflon tubing.



7.0 Procedure

7.1 Sample collection

7.1.1 Two DNPH cartridges connected into the sample flow path.

7.1.2 Dilute exhaust samples are collected onto the DNPH cartridges by turning on the power to the Teflon diaphragm pump.

7.1.2.1 For transient test cycle sample collection, the Teflon diaphragm pump is turned on for the duration of the 1200 second emission test.

7.1.2.2 For steady state cycle sample collection, the Teflon diaphragm pump is turned on for 3 minutes at the end of modes 1, 2, 3 and 8; and 2 minutes at the end of modes 4, 5, 6 and 7.

7.1.3 The flow rate through the DNPH cartridges should be 1 L/min.

7.1.3.1 Flow rate should be continuously monitored and adjusted if necessary during sampling.

7.1.4 The dilution and work is noted for each dilute exhaust sample taken for final calculations.

7.1.5 DNPH cartridges are refrigerated immediately after sample collection, below a temperature of 40° F, until analyzed by HPLC.

8.0 Calculations

8.1 Volumetric flow conversions are as follows:

$$1\,\text{SCFM} = 0.0283\,\text{m}^3/\text{min} = 28.317\,\text{L/min}$$

9.0 Quality Control/Quality Assurance

9.1 Tunnel Blank Sample

9.1.1 A tunnel blank sample must be collected each analysis day. If the tunnel blank shows a peak greater than the method detection limit (MDL) in the region of interest, the source of the contamination must be investigated and remedied. Do not subtract the blank value from the sample value.

9.2 Field Blank Sample

9.2.1 At least one cartridge per batch is analyzed as a field blank. If the cartridge blank shows a peak greater than the method detection limit in the region of interest, the source of the contamination must be investigated and remedied.

9.3 Leak Checks

9.3.1 Sampling Train

9.3.1.1 A leak check must be performed each analysis day to ensure correct sampling system flow rates.

9.3.1.2 To leak check any part of the sampling train, the suspected leak area should be isolated and pressurized or put under vacuum. A gauge may then be used to check if a leak exists.

9.3.1.3 Flow rate must be kept within 0.2 L/min of the set sampling flow rate of 1 L/min.

9.4 Flow Rates

9.4.1 The flow rate into the DNPH cartridge is controlled with a digital flow meter. The flow rate over the transient or steady state emission test cycle is 1 L/min.

10.0 References

10.1 Desert Research Institute, DRI Carbonyl Sampler, 1-710.3, Revision 03, June 1997.

1.0 PURPOSE/APPLICABILITY

This analytical method applies to dinitrophenylhydrazine-impregnated cartridges through which air samples have been passed for the collection of carbonyl compounds. Carbonyl compounds react rapidly with 2,4-dinitrophenylhydrazine (DNPH) in acidic media to form yellow to orange-colored hydrazones. The color depends on the type of carbonyl compound, and the amount of the product formed is dependent on the quantity of carbonyl compound provided to the reagent.

Samples are collected by drawing a known volume of air through the DNPH-impregnated cartridges. These exposed cartridges are then returned to the laboratory for isolation, separation, and quantification of the hydrazone products by high-performance liquid chromatography (HPLC). The ambient air concentration of various carbonyl compounds is determined from the quantity of the associated hydrazones found in the exposed cartridges and the volume of air samples. Typically C_1-C_6 carbonyl compounds, including benzaldehyde, are measured effectively by this technique, with a detection limit of ~ 0.1 ppbv.

This method follows the procedure described in EPA Method TO-11A (January 1997, EPA/625/R-96/010b).

2.0 MATERIALS/APPARATUS

2.1 DNPH Cartridges

Waters Sep-Pak XPoSure Aldehyde Samplers are purchased from Waters (WAT047205) and sampled directly from the manufacturer without need for laboratory preparation.

3.0 SAMPLE ANALYSIS

Aldehydes collected in the cartridge (as the hydrazones) are eluted with acetonitrile and the eluent is analyzed using reverse phase high performance liquid chromatograph (HPLC) (Fung and Grosjean, 1981). Gradient elution is used with a sufficiently polar mobile phase for the separation of acetone, acrolein, and propanal. The mobile phase polarity is then decreased steadily to allow the elution of the higher aldehydes.

3.1 Sample Shipping/Storage

The cartridges are returned to the laboratory in secondary aluminum envelopes provided by the manufacturing, labeled with unique Project Media Identification (PMI) numbers, in a cooler at 4°C. In the laboratory, they are stored in a refrigerator until analysis. The time between sampling and extraction should not exceed two weeks. Sample elutes are stable at 4 °C for up to one month.

3.2 Sample Preparation

Uncap the cartridge and place it in a small test tube holder. Elute the cartridges with 2 ml of acetonitrile into a volumetric flask and transfer into a septum vial. Cap the vial and write the cartridge number on the side using a permanent marker. If not analyzed the same day, place the extracts in a clean refrigerator.

3.3 Standard Solutions

Prepare stock solutions of the hydrazone standards provided by AccuStandard in acetonitrile at carbonyl concentration of 5 µg/mL.

Dilute the stock standards to obtain working solutions in the range of 0.1 to 10 µg/mL concentrations for most applications. Higher concentrations may be needed occasionally if the air carbonyl concentrations exceed ~20 ppb during sampling. At least three concentrations of working standards bracketing the sample concentrations should be prepared for the calibration.

A secondary standard from Restek is used to verity the calibration.

3.5 Instrument Conditions

The HPLC instrument is a Waters 2695 Alliance Separation Module with a photo diode array (PDA) detector with Empower software. Data are collected between a wavelength range of 190-450 nm.

Water Alliance 2695 Gradient Acquisition Method for Carbonyls

Solvent A:	100% HPLC Water
Solvent B:	100% Optima Acetonitrile
Solvent C:	100% Optima Methanol
Column:	Polaris C18-A, 4.6x15, 3um
Detector:	PDA, 360 nm

Table 1. Gradient elution solvent conditions.

Time (min)	**Flow (mL)**	**%A**	**%B**
0.01	1.50	70.0	30.0
1.00	1.50	70.0	30.0
20.00	1.50	60.0	40.0
32.00	1.50	55.0	45.0
41.00	1.50	37.0	63.0
45.00	1.50	37.0	63.0
50.00	1.50	30.0	70.0
55.00	1.50	70.0	30.0

The column is conditioned with 50:50 water/methanol for 10 minutes at the end of each sequence.

3.6 Calibrations

Following the Millennium^{32} 3.20 PDA document, five calibration standards are analyzed using concentrations in Table 2 (see Figures 2 for example of calibration curve). The curve is forced through zero and is acceptable with a $R^2 \geq 0.95$. A secondary standard from Restek is used to verify the calibration.

Once the linear response factor has been documented, an intermediate concentration standard near the anticipated level of each component (but at least ten times the detection limit) is used for a daily calibration check standard. A sample chromatogram is shown in Figure 1.

3.7 Data Acquisition and Processing

The calibration equation below is used to determine the amount of carbonyls in the samples (this step is performed by the HPLC baseline data system).

Table 2. Calibration Levels

	Level 1	Level 2	Level 3	Level 4	Level 5
Conc. (ug/mL)	1	0.5	0.25	0.1	0.025
Formaldehyde	7.036	3.518	1.759	0.703	0.351
Acetaldehyde	5.13	2.565	1.282	0.513	0.256
Acetone	4.1	2.05	1.025	0.41	0.205
Acrolein	4.366	2.183	1.091	0.436	0.218
Propionaldehyde	4.113	2.056	1.028	0.411	0.2055
Crotonaldehyde	3.57	1.785	0.892	0.357	0.178
2-Butanone (MEK)	3.5	1.75	0.875	0.35	0.175
Methacrolein	3.57	1.785	0.892	0.357	0.178
n-Butyraldehyde	3.51	1.755	0.877	0.351	0.1755
Benzaldehyde	2.7	1.35	0.675	0.27	0.135
Valeraldehyde	3.122	1.561	0.78	0.312	0.156
Glyoxal	0.92	0.46	0.23	0.046	0.023
m-Tolualdehyde	2.506	1.253	0.626	0.25	0.125
Hexaldehyde	3.116	1.558	0.779	0.311	0.155

3.8 Calculations

$$C_A = \frac{W_d}{V_m \text{ (or } V_s\text{)}} \times 1000$$

where:

C_A = concentration of analyte (ng/L) in the original sample
W_d = total quantity of analyte (µg) in sample, blank corrected

$$W_d = W \times V_E$$

where:

W = Concentration of analyte in the cartridge (µg)
V_E = final volume (ml) of sample extract
V_m = total sample volume (L) under ambient conditions
V_s = total sample volume (L) at 25 °C and 760 mm Hg

The analyte concentrations can be converted to ppbv using the following equation:

$$C_A\,(\text{ppbv}) = C_A\,(\text{ng/L}) \times \frac{24.4}{MW_A}$$

where:

C_A(ppbv) = concentration of analyte in parts per billion by volume
C_A(ng/L) is calculated using V_s

MW_A = molecular weight of analyte.

3.9 Quality Control

After calibration, an intermediate concentration calibration check standard is analyzed every 10 samples with a ±10% recovery.

3.9.1 Blanks

At least one field blank or 10% of the field samples, whichever is larger, should be shipped and analyzed with each group of samples. The field blank is treated identically to the samples except that no air is drawn through the cartridge.

Instrument blanks are analyzed after high concentrations.

3.9.2 Method Precision and Accuracy

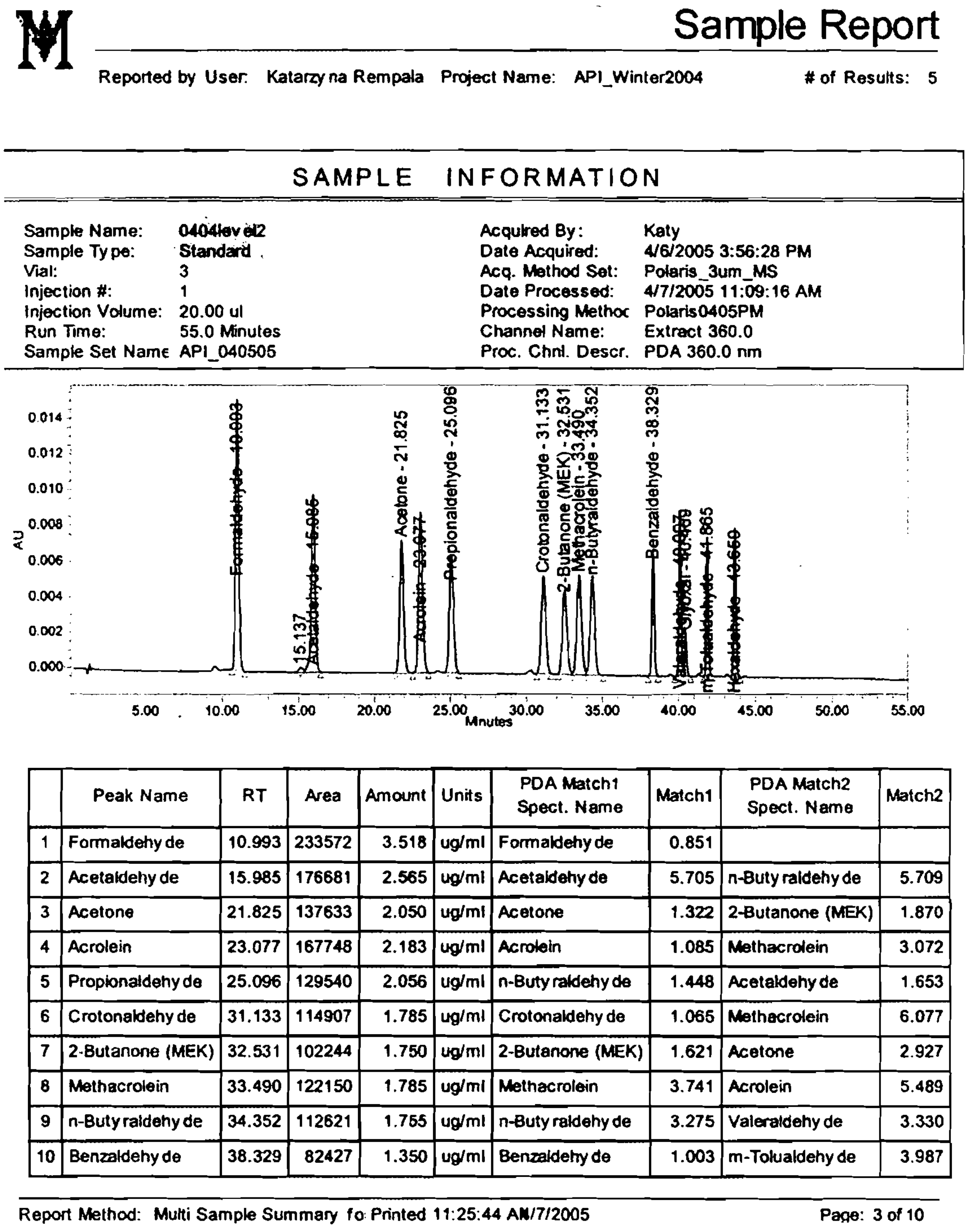
10% of the samples are analyzed twice for replicate precision which typically falls within ±10%.

4.0 REFERENCES

Fung, K., and D. Grosjean (1981). "Determination of Nanogram Amounts of Carbonyls as 2,4, dinitrophenylhydrazones by High Performance Liquid Chromatography." *Analy. Chem.*, 53, 168.

U.S. EPA, "Method TO-11A: Determination of Formaldehyde in Ambient Air Using Adsorbent Cartridge Followed by High Performance Liquid Chromatography (HPLC) [Active Sampling Methodology]," EPA/625/R-96/010b, in *Compendium of Methods for the Determination of Toxic Organic Compounds in Ambient Air.*

Winberry, W.T., Jr., N.T. Murphy, and R.M. Riggan (1988). *Method TO11 in Compendium of Methods for the Determination of Toxic Organic Compounds in Ambient Air.* EPA/600/4-89/017, U.S. Environmental Protection Agency, Research Triangle Park, NC.



Sample Report

Reported by User: Katarzy na Rempala Project Name: API_Winter2004 # of Results: 5

SAMPLE INFORMATION

Sample Name:	0404lev el2	Acquired By:	Katy
Sample Ty pe:	Standard	Date Acquired:	4/6/2005 3:56:28 PM
Vial:	3	Acq. Method Set:	Polaris_3um_MS
Injection #:	1	Date Processed:	4/7/2005 11:09:16 AM
Injection Volume:	20.00 ul	Processing Methoc	Polaris0405PM
Run Time:	55.0 Minutes	Channel Name:	Extract 360.0
Sample Set Name	API_040505	Proc. Chnl. Descr.	PDA 360.0 nm

	Peak Name	RT	Area	Amount	Units	PDA Match1 Spect. Name	Match1	PDA Match2 Spect. Name	Match2
1	Formaldehy de	10.993	233572	3.518	ug/ml	Formaldehy de	0.851		
2	Acetaldehy de	15.985	176681	2.565	ug/ml	Acetaldehy de	5.705	n-Buty raldehy de	5.709
3	Acetone	21.825	137633	2.050	ug/ml	Acetone	1.322	2-Butanone (MEK)	1.870
4	Acrolein	23.077	167748	2.183	ug/ml	Acrolein	1.085	Methacrolein	3.072
5	Propionaldehy de	25.096	129540	2.056	ug/ml	n-Buty raldehy de	1.448	Acetaldehy de	1.653
6	Crotonaldehy de	31.133	114907	1.785	ug/ml	Crotonaldehy de	1.065	Methacrolein	6.077
7	2-Butanone (MEK)	32.531	102244	1.750	ug/ml	2-Butanone (MEK)	1.621	Acetone	2.927
8	Methacrolein	33.490	122150	1.785	ug/ml	Methacrolein	3.741	Acrolein	5.489
9	n-Buty raldehy de	34.352	112621	1.755	ug/ml	n-Buty raldehy de	3.275	Valeraldehy de	3.330
10	Benzaldehy de	38.329	82427	1.350	ug/ml	Benzaldehy de	1.003	m-Tolualdehy de	3.987

Report Method: Multi Sample Summary fo Printed 11:25:44 AM/7/2005 Page: 3 of 10

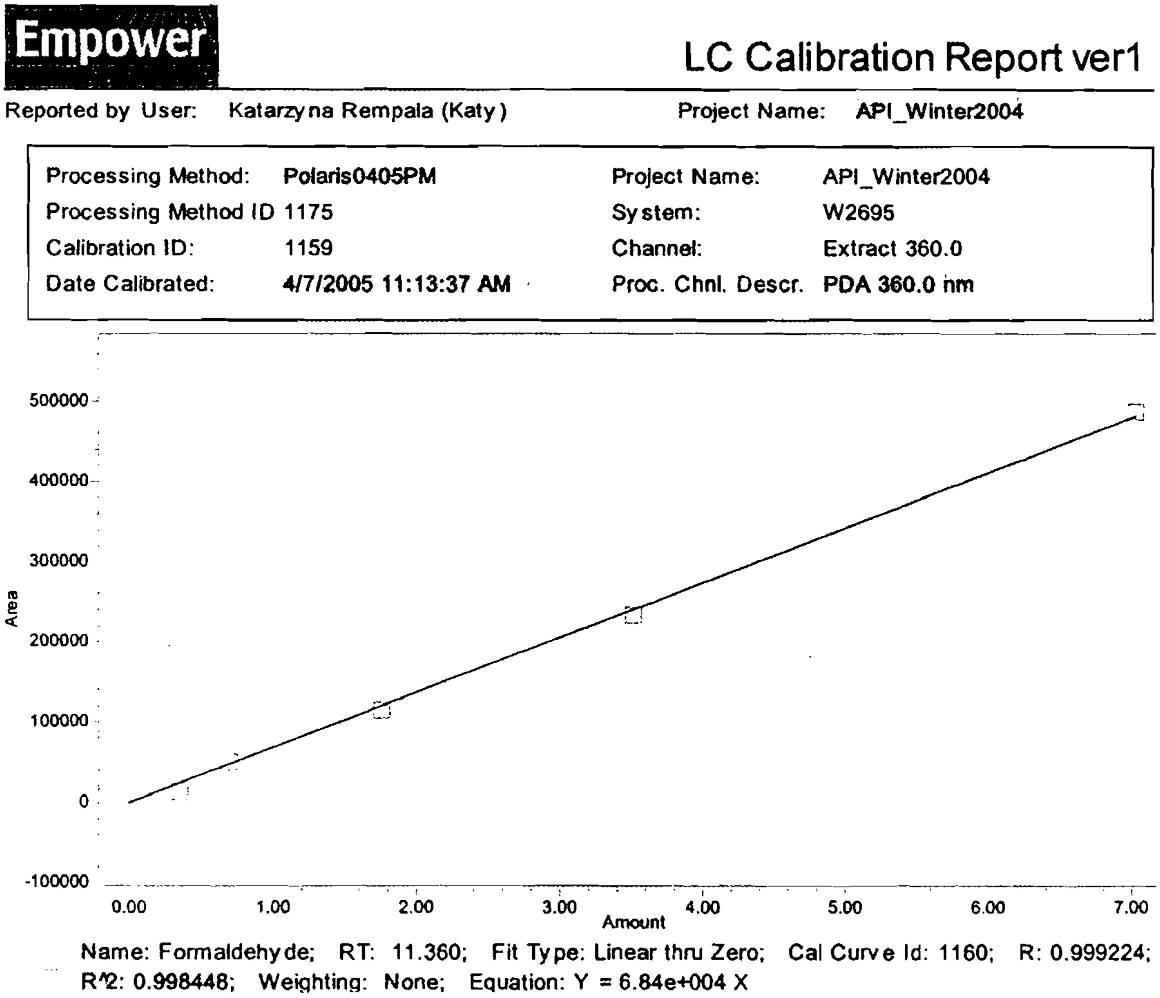
Figure 1a. Chromatograph of Level 2 standard.

Sample Report

Reported by User: Katarzyna Rempala Project Name: API_Winter2004 # of Results: 5

	Peak Name	RT	Area	Amount	Units	PDA Match1 Spect. Name	Match1	PDA Match2 Spect. Name	Match2
11	Valeraldehyde	40.097	97770	1.561	ug/ml	Valeraldehyde	5.956	n-Butyraldehyde	6.388
12	Glyoxal	40.469	21352	0.460	ug/ml				
13	m-Tolualdehyde	41.865	70294	1.253	ug/ml	m-Tolualdehyde	0.975	Benzaldehyde	3.809
14	Hexaldehyde	43.659	84775	1.558	ug/ml	Hexaldehyde	1.304	Valeraldehyde	1.531

Figure 1b. Chromatograph of Level 2 standard.



Empower

LC Calibration Report ver1

Reported by User: Katarzyna Rempala (Katy)
Project Name: API_Winter2004

Processing Method:	Polaris0405PM	Project Name:	API_Winter2004
Processing Method ID	1175	System:	W2695
Calibration ID:	1159	Channel:	Extract 360.0
Date Calibrated:	4/7/2005 11:13:37 AM	Proc. Chnl. Descr.	PDA 360.0 nm

Name: Formaldehyde; RT: 11.360; Fit Type: Linear thru Zero; Cal Curve Id: 1160; R: 0.999224; R^2: 0.998448; Weighting: None; Equation: Y = 6.84e+004 X

Figure 2. Calibration curve for formaldehyde.

1.0 PURPOSE/APPLICABILITY

This method describes the analysis of semi-volatile organic compounds (SVOC) in air. The SVOCs include non-polar analysis of Polycyclic Aromatic Hydrocarbons (PAH), Aliphatic Hydrocarbon Analysis (Alkanes), Hopanes and Steranes, and Polar analysis. The method uses a sampling train consisting of a Teflon-impregnated glass fiber (TIGF) filter backed up by a PUF/XAD/PUF sandwich solid adsorbent. The separate portions of the sampling train are extracted and combined dependent on analyses. The analysis method is gas chromatography/mass spectrometry (GC/MS). Mass spectrometry provides definitive identification of SVOCs.

This method follows the procedure described in EPA Method TO-13 (June 1988, EPA/600-4-89/017). The exceptions are that 1) the DRI procedure uses a XAD-4 sandwich adsorbent trap where TO-13 recommends either PUF or XAD-2, and 2) the DRI procedure calls for more rigorous cleaning than the EPA method.

2.0 MATERIALS/APPARATUS

2.1 Sampling Substrates

100 mm TIGF filters (Pall Gellman, ultrapure quality), PUF, and XAD-4 (Fisher Scientific) are obtained. Cleaning is as per Section 4 below. All solvents are Fisher Scientific Opitma or HPLC grade.

2.2 GC/MS

The chromatographic system consists of a Varian CP-3800 gas chromatograph equipped with an 8200 CX Autosampler and interfaced to a Vairan Saturn 2000 Ion Trap Mass Spectrometer. The alternative system consists of a Varian CP-3800 gas chromatograph with a model CP-8400 Autosampler and interfaced to a Saturn 2000 Ion Trap Mass Spectrometer. Column is a CP-Sil8 30mx0.25 mmX025XX (Chrompack).

3.0 PERSONNEL QUALIFICATION

This SOP assumes that personnel performing the procedures are familiar with basic laboratory practice and operation of Dionex Accelerated Solvent Extractor (ASE), rotary evaporators, and the Varian GC/MS system and Saturn Workstation 5.2 computer software. Specific requirements for these instruments are found in the appropriate manuals.

4.0 SUBSTRATE CLEANING PROCEDURE

4.1. Filters

Teflon-impregnated glass fiber (TIGF) filters (Pall Life Sciences, Type T60A20) are cleaned by sonication for 10 minutes in dichloromethane (CH_2Cl_2) twice, with the solvent replaced and drained, and sonicated for 10 minutes in methanol twice with the solvent replaced. Filters are then dried in a vacuum oven at –15 to –20 in Hg, 50° C for minimum of 24 hours, weighed (if necessary), placed in foil packages that have been fired at 500° C for 4 hours, placed in Uline metallic ZipTop static shielding bags, and stored at room temperature.

If quartz filters (Pall Gellman, ultrapure quality), are used, they are baked at 900 °C for 4 hr before use.

4.2 PUF Plugs

PUF plugs are cleaned by first washing with distilled water, followed by Dionex ASE extraction for 15min/cell with ~170 mL acetone at 1500 psi and 80°C, followed by Dionex ASE extraction for 15min/cell with ~170 mL of 10% diethyl ether in hexane under the same conditions. The extracted PUF plugs are dried in a vacuum oven at -15 to –20 in Hg, 50° C for approximately 3 days or until no solvent odor is detected . If storage is necessary, PUF plugs are stored in clean 1L glass jars with Teflon lined lids wrapped in aluminum foil. Powder-free nitrile gloves are worn at all times when handling PUF plugs.

4.3 XAD-4

New XAD-4 is washed with Liquinox™ soap and hot water, followed by DI water. It is then placed in a Buchner funnel under vacuum, then transferred to the Dionex ASE and extracted for 15min/cell with ~170 mL of methanol at 1500 psi and 80°C, followed by dichloromethane (CH2Cl2), then acetone under the same instrument conditions. The XAD-4 is then dried in a vacuum oven at –15 to –20 in Hg and 50°C. The cleaned XAD-4 is then transferred to a clean 1L glass jars with an air tight teflon-lined lid. The jar is wrapped with aluminum foil to protect the XAD-4 from light, and stored in a clean room at room temperature.

4.4 Certification of Substrate

An aliquot of each batch of cleaned XAD-4 (20g) and TIGF filters are extracted same as samples. Deuterated standards are added to the sample prior to extraction in the Dionex

ASE with ~170 mL dichloromethane (CH2Cl2) for 15 min/cell at 1500 psi and 80°C, followed by ~170 mL acetone extraction under the same conditions. The extract is then concentrated to 1ml and analyzed by GC/MS. Any batch determined to have excessive impurities (more than 10 ng/ul of naphthalene and other compounds in method) will be re-cleaned and checked again for purity.

4.5 Assembly of XAD and PUF/XAD/PUF Cartridge

The glass cartridges and screen assemblies are washed with Liquinox™ soap and hot water followed by DI water and oven dried. Powder-free nitrile gloves are worn at all times during the cartridge assembly. For XAD-4 cartridges, one assembly of spring, o-ring and screen is placed at the bottom of a clean glass cartridge followed by 20g of XAD-4 and another assembly of screen, o-ring and spring. The XAD cartridge is then placed in Uline ZipTop metallic static shielding bags and stored in ca clean room at room temperature.

For PUF/XAD-4/PUF cartridges, one PUF plug is put at the bottom of a clean glass cartridge followed by 10 g of XAD-4 and a second PUF plug. The PUF/XAD/PUF cartridge is then placed in Uline ZipTop metallic static shielding bags and stored at room temperature.

5.0 SAMPLE SHIPPING, RECEIPT, AND STORAGE

XAD-4 cartridge and filter sets are assigned a unique Project Media Identification (PMI) number and logged (date stamped) into the Laboratory Information Management System (LIMS) when assembled and shipped. Cartridges are packed in a tin can with field data sheets with the same unique PMI number and shipped in coolers on blue ice prior overnight.

In the field, exposed samples are stored at 0-4°C in a refrigerator or freezer and shipped to DRI priority overnight in ice chest (DRI's original shipping containers) with blue ice. Upon receipt by the laboratory, the samples are logged into the LIMS by PMI number, and field data is recorded (sampling location, date, and start and stop time, elapse timer, and flow rate). If the time span between sample login and extraction is greater than 24 hours, the samples must be kept cold at 0-4°C in a freezer or refrigerator. The exposure of the sample media to ultraviolet light emitted by fluorescent lights must be minimized.

6.0 EXTRACTION OF SUBSTRATE

6.1 Addition of Internal Standards

6.1.1 Polycyclic Aromatic Hydrocarbon (PAH), non-polar

Prior to extraction, the following deuterated internal standards are added to each sample (filter, PUF/XAD/PUF):

naphthalene-d_8	9.486	ng/μl
biphenyl-d_{10}	7.008	ng/μl
acenaphthene-d_{10}	5.997	ng/μl
phenanthrene-d_{10}	5.991	ng/μl
anthracene-d_{10}	5.000	ng/μl
pyrene-d_{12}	4.993	ng/μl
benz(a)anthracene-d_{12}	2.004	ng/μl
chrysene-d_{12}	1.997	ng/μl
benzo[k]fluoranthene-d_{12}	1.000	ng/μl
benzo[e]pyrene-d_{12}	0.700	ng/μl
benzo[a]pyrene-d_{12}	0.703	ng/μl
benzo[g,h,i]perylene-d_{12}	0.600	ng/μl
coronene-d_{12}	0.500	ng/μl

The amount of internal standards added should correspond to the expected range of concentrations found in real samples and the final volume of extracts during analysis.

6.1.2 Hopane and Sterane, non-polar

Prior to extraction, the following deuterated internal standards are added to each sample (filter, PUF/XAD/PUF):

cholestane- d_6	0.375	ng/μl

The amount of internal standards added should correspond to the expected range of concentrations found in real samples.

6.1.3 Aliphatic Hydrocarbon Analysis (Alkanes), non-polar

Prior to extraction, the following deuterated internal standards are added to each sample (filter, PUF/XAD/PUF):

dodecane-d_{26}	10.9	ng/μl
hexadecane-d_{34}	2.36	ng/μl
eicosane-d_{42}	1.88	ng/μl
octacosane-d_{58}	4.9	ng/μl
tetracosane-d_{50}	1.89	ng/μl

hexatriacontane-d_{74}	10.2	ng/µl

The amount of internal standards added should correspond to the expected range of concentrations found in real samples.

6.1.4 Polar Organic Compounds, polar

Prior to extraction, the following deuterated internal standards are added to each sample (filter-sorbent pair):

cholesterol-2,2,3,4,4,6-d_6	9.85	ng/µl
levoglucosan-u-13C_6	31.25	ng/µl
hexanoic-d_{11} acid	4.5	ng/µl
benzoic-d_3 acid	4.5	ng/µl
decanoic-d_{19} acid-	4.5	ng/µl
palmitic-d_{31} acid	4.5	ng/µl
heptadecanoic-d_{33} acid	4.4	ng/µl
myristic-d_{27} acid	3.3	ng/µl
succinic-d_4 acid	2.55	ng/µl
phthalic 3,4,5,6-d_4 acid	4.6	ng/µl

The amount of internal standards added should correspond to the expected range of concentrations found in real samples and the final volume of extracts during analysis.

6.2 Extraction of PUF, XAD-4, and Filter

Depending on analyses, PUF, XAD-4 and Filter will be extracted in the following combinations. Solvents are selected to optimize the polarity range desired for analyses.

6.2.1 Non-Polar Analysis Only

Filters and XAD-4 are extracted twice with approximately ~170 mL of dichloromethane (CH_2Cl_2) using the Dionex ASE for 15 min/cell at 1500 psi and 80°C.

Since PUF media degrades when extracted with dichloromethane, the PUFs are extracted twice with ~170 mL of acetone using the Dionex ASE for 15 min/cell at 1500 psi and 80°C. This method gives good recovery for PAH, aliphatic hydrocarbons (alkanes), and hopanes and steranes.

6.2.2 Polar and Non-Polar Analyses

Filters and XAD-4 are extracted with ~170 mL dichloromethane (CH_2Cl_2) using the Dionex ASE for 15 min/cell at 1500 psi and 80°C followed by ~170 mL acetone extraction under the same conditions.

Since PUF media degrades when extracted with dichloromethane, the PUFs are extracted twice with ~170 mL of acetone using the Dionex ASE for 15 min/cell at 1500 psi and 80°C. This method gives good recovery for PAH, aliphatic hydrocarbons (alkanes), hopanes and steranes, and polar organic compounds.

6.3 Treatment of Extracts

6.3.1 Non-Polar Analysis Only

Extracts are concentrated to ~1ml by rotary evaporation at 35 °C under gentle vacuum, and filtered through a 0.2 µm Anotop™ 10 Whatman leur-lock filter on 4 mL glass syringe), rinsing the flask 3 times with 1 ml dichloromethane and acetone (50/50 by volume) each time. Filtrate is collected in a 4 mL amber glass vial for a total volume of ~4 mL.

Approximately 200 µl of acetonitrile is added at this time and the extract is split into two fractions. Each fraction is then concentrated using a Pierce Reacti-Therm under a gentle stream of ultra-high purity (UHP) nitrogen with a water trap (Chrompack CP-Gas-Clean moisture filter 17971) to 100-200 µL. The final extract volume is adjusted to 100 µL with acetonitrile.

6.3.2 Polar and Non-Polar Analyses

Extracts are concentrated to ~1ml by rotary evaporation at 35 °C under gentle vacuum, and filtered through a 0.2 µm PTFE disposable filter device (Whatman Pura disc™ 25TF), rinsing the flask 3 times with 1 ml dichloromethane and acetone (50/50 by volume) each time. Filtrate is collected in a 4 mL amber glass vial for a total volume of ~4 mL.

Approximately 200 µl of acetonitrile is added at this time and the extract is split into two fractions. Each fraction is then concentrated under a gentle stream of ultra-high purity (UHP) nitrogen with hydrocarbon and water traps to 100-200 µL. The final extract volume is adjusted to 100 µL with acetonitrile.

6.4 Cleanup of Samples (non-polar analysis)

For complex samples that contain analytical interference, the following method is used to clean up the sample using silica gel semi-prep Solid Phase Extraction (SPE 6-mL 0.5-g LC-SI, Supelco Silica).

1. Assuming SVOC in 100 µL acetonitrile, concentrate to 25 µL and add 25µL dichloromethane and 150 µL hexane.
2. Condition SPE-Silica cartridge with 1.5 mL hexane/benzene (1:1), followed by 1.5 mL hexane.
3. Transfer sample into the SPE-Silica cartridge.
4. Elute sample with 1.5 mL hexane, followed by 3 mL hexane/benzene (1:1) in separate 4 mL vials.
5. Concentrate to 100 µL (only hexane should remain) and transfer to GC vial insert and concentrate to 20 µL.
6. Rinse original vial with 100 µL dichloromethane and concentrate to 40 µL (hexane/DCM (1:1)) and dilute to total volume of 100 µL with acetonitrile.

The hexane fraction contains the non-polar aliphatic hydrocarbons (alkanes), and hopanes and steranes, and the hexane/benzene fraction contains the PAH and N-PAH.

6.5 Silylation of Polar Organic Compounds (polar analysis)

If extracts have been split for polar and non-polar analysis, the fraction for the polar analysis is derivatized using a mixture of bis(trimethylsilyl)trifluoroacetamide and pyridine to convert the polar compounds into their trimethylsilyl derivatives for analysis of organic acids, cholesterol, sitosterol, and levoglucosan. Depending upon the expected range of analytes, it is recommended to split the second fraction into two equal fractions, thus providing a second opportunity for a clean silylation reaction.

1. The extract is reduced to a volume of 50 µL using a Pierce Reacti-Therm under a gentle stream of ultra-high purity (UHP) nitrogen with a water trap (Chrompack CP-Gas-Clean moisture filter 17971.
2. 50 µL of silylation grade pyridine is added to vial.
3. 150 µL of bis(trimethylsilyl)trifluoroacetamide is added slowly to each vial and immediately capped.
4. The sample is then placed into thermal plates (custom) containing individual vial wells with the temperature maintained at 70°C for 3 hours.
5. The samples are then analyzed by GC/MS within18 hours.

7.0 ANALYSIS

7.1 Instrument Method

The samples are analyzed by the electron impact (EI) GC/MS technique, using a Varian CP-3800 gas chromatograph equipped with a 8200 CX Autosampler and interfaced to a Vairan Saturn 2000 Ion Trap Mass Spectrometer or Varian CP-3400 gas chromatograph with a model CP-8400 Autosampler and interfaced to a Saturn 2000 Ion Trap Mass Spectrometer

Injections are 1 µl in size in the splitless mode onto a 30m long 5% phenylmethylsilicone fused silica capillary column (J&W Scientific type DB-5ms): CP-Sil8 Chrompack (30m x 0.25mm x 0.25 mm) for PAH, hopanes and steranes, alkanes and polars; and CP-Sil24 Chrompack (30m x 0.25mm x 0.25 mm) for N-PAH.

Identification and quantification of the analytes are made by Selected Ion Storage (SIS), by monitoring the molecular ions of each analyte and each deuterated analyte.

7.2 Preparation Stage

A. The instrument (GC/MS) preparation steps are as follows:

1) Check for air and water in the system (Ion Time = 100, a total ion current (TIC) below 700 is preferred).
2) Adjust calibration gas pressure for Ion Trap instrument (75% preferred).
3) Check calibration gas pressure ~ 75%.
4) Perform autotune for electron multiplier setting, mass calibration, and RF ramp.

Identification and quantification of the analytes are made by Selected Ion Storage (SIS), by monitoring the molecular ions of each analyte and each deuterated analyte.

7.3 Calibration

Calibration curves are made by the molecular ion peaks of the analytes using the corresponding deuterated species as internal standards. If there is no corresponding deuterated species, the one most closely matching in volatility and retention characteristics is used.

National Institute of Standards and Technology (NIST) Standard Reference Material (SRM) 1647 (certified PAH), with the addition of the internal standards listed in Section 6.1.1-6.1.4 and the targeted PAH not present in this mixture, is used to make calibration solutions. Six concentration levels for each analyte of interest are employed. Table 1 lists the concentration levels of standard compounds in calibration solutions. The calibration curve for each calibrated compound is constructed; Figures 1 through 6 show examples of acceptable calibration curves. After the calibration is completed, a standard solution is injected to perform calibration checks. If deviations from the true values exceed ±20%, the calibration procedure is repeated or new calibration levels must be prepared. One replicate analysis and one calibration chick is performed for every 10 injections of samples. If difference between true and measured concentrations exceeds ±20%, the system is recalibrated. During batch processing, calibration is performed before each batch.

8.0 REPORTING

Each sample is reported initially in terms of mass per sample (µg/sample). Ambient concentrations in terms of mass per volume (i.e., ng/m^3 or other units if requested) are reported based upon the sample volume adjusted for ambient temperature and pressure, or reported as "standard" volume.

All information for the sample is recorded and combined into both a printed report and an Excel file for inclusion in the database (see Appendix).

8.1 Method Detection Limits (MDLs)

Method detection limits are 0.01-0.03 ng/µl for PAH, hopane and sterane, and alkane compounds, and 0.03-0.04 ng/µl for polar compounds.

8.2 Measurement Uncertainty

Measurement uncertainty is reported as one-sigma standard deviation between replicate tests (when 3 tests conducted under same conditions) or the combined root mean square of the analytical measurement uncertainty, which is defined by the following equation:

$$\sqrt{(\text{replicate precision} * \text{analyte concentration})^2 + (\text{analyte detection limit})^2}$$

This equation incorporates the analyte detection limit for each compound so when concentrations approach zero the error is reported as the analyte detection limit. When multiple samples are pooled the difference between samples is typically greater than the precision of any of the analytical techniques employed. Most data has relatively small reported measurement uncertainty's which shows the reproducibility of the samples. When larger errors (>30% of reported concentration) are observed, it is typically because the concentrations of the analyte were close to the detection limit of the measurements.

Table 1. Calibration Levels for PAH analysis (bold compounds co-elute and are quantified together)

Compound	Level 1 (ng/uL)	Level 2 (ng/uL)	Level 3 (ng/uL)	Level 4 (ng/uL)	Level 5 (ng/uL)	Level 6 (ng/uL)
1-ethylnaphthalene	0.359	0.718	1.436	2.873	11.491	45.965
1,2-dimethylnaphthalene	0.361	0.722	1.444	2.887	11.548	46.193
1,4-chrysenequinone	0.240	0.479	0.958	1.917	7.667	30.667
1,6 + 1,3 dimethylnaphthalene	**0.719**	**1.438**	**2.876**	**5.753**	**23.012**	**92.047**
1,8-dimethylnaphthalene	0.240	0.481	0.962	1.924	7.695	30.781
1-methylfluorene	0.298	0.596	1.192	2.383	9.533	38.133
1-methylphenanthrene	0.200	0.400	0.799	1.598	6.392	25.568
1-methylpyrene	0.240	0.481	0.961	1.922	7.688	30.752
1-phenylnaphthalene	0.199	0.398	0.796	1.591	6.365	25.461
2-ethylnaphthalene	0.357	0.714	1.428	2.856	11.424	45.696
1,4+1,5+2,3-dimenaphlene	**1.078**	**2.156**	**4.313**	**8.625**	**34.501**	**138.005**
2,6-dimethylnaphthalene	0.352	0.704	1.408	2.817	11.267	45.067
2-methylbiphenyl	0.360	0.720	1.441	2.881	11.525	46.102
2-methylphenanthrene	0.246	0.492	0.983	1.967	7.867	31.467
2-phenylnaphthalene	0.358	0.716	1.433	2.866	11.463	45.853
3,6-dimethylphenanthrene	0.203	0.406	0.813	1.625	6.500	26.000
3-methylbiphenyl	0.361	0.721	1.442	2.884	11.537	46.149
4H-cyclopenta(def)phenanthrene	0.000	0.000	0.000	0.000	0.000	0.000
4-methylbiphenyl	0.369	0.738	1.475	2.950	11.800	47.200
4-methylpyrene	0.240	0.479	0.958	1.917	7.667	30.667
5+6 methylchrysene	**0.559**	**1.119**	**2.237**	**4.475**	**17.899**	**71.595**
7-methylbenz(a)anthracene	0.279	0.558	1.117	2.233	8.933	35.733
7-methylbenzo(a)pyrene	0.290	0.579	1.158	2.317	9.267	37.067
9,10-dihydrobenzo(a)pyren-7(8H)-one	0.281	0.561	1.122	2.244	8.976	35.904
9-anthraldehyde	0.371	0.742	1.483	2.967	11.867	47.467
9-fluorenone	0.280	0.560	1.120	2.240	8.961	35.845
9-methylanthracene	0.239	0.479	0.958	1.916	7.663	30.653
acenaphthene*	0.201	0.402	0.804	1.609	6.435	25.739
acenaphthenequinone	0.202	0.404	0.808	1.617	6.467	25.867
acenaphthylene	0.200	0.400	0.800	1.600	6.400	25.600
anthrone	0.277	0.554	1.108	2.217	8.867	35.467
BaP*	0.160	0.321	0.642	1.283	5.133	20.533
benz(a)anthracene*	0.200	0.400	0.799	1.599	6.395	25.579

benz(a)anthracene-7,12-dione	0.279	0.558	1.117	2.233	8.933	35.733

Compound	Level 1 (ng/uL)	Level 2 (ng/uL)	Level 3 (ng/uL)	Level 4 (ng/uL)	Level 5 (ng/uL)	Level 6 (ng/uL)
benzanthrone	0.360	0.720	1.440	2.880	11.518	46.073
anthracene*	0.159	0.319	0.638	1.276	5.103	20.411
anthraquinone	0.280	0.559	1.119	2.237	8.949	35.795
benzo(k*+b+j)fluoranthene	**0.397**	**0.794**	**1.587**	**3.174**	**12.697**	**50.789**
benzo(g,h,i)perylene*	0.200	0.400	0.800	1.600	6.401	25.602
benzo(c)phenanthrene	0.200	0.400	0.800	1.601	6.403	25.613
benzonaphthothiophene	0.240	0.479	0.958	1.917	7.667	30.667
BeP*	0.202	0.403	0.807	1.613	6.453	25.813
chrysene*	0.190	0.379	0.758	1.517	6.067	24.267
coronene*	0.160	0.320	0.640	1.280	5.118	20.474
dibenz(ah+ac)anthracene	**0.323**	**0.645**	**1.291**	**2.582**	**10.327**	**41.307**
dibenzofuran	0.278	0.556	1.111	2.223	8.890	35.560
fluorene	0.241	0.481	0.963	1.925	7.700	30.800
fluoranthene	0.252	0.503	1.006	2.013	8.050	32.200
indeno(1,2,3-cd)pyrene	0.161	0.321	0.642	1.284	5.136	20.544
perinaphthenone	0.279	0.558	1.116	2.232	8.928	35.712
perylene	0.200	0.400	0.800	1.600	6.400	25.600
phenanthrene*	0.201	0.401	0.802	1.604	6.417	25.667
pyrene*	0.196	0.392	0.783	1.567	6.267	25.067
retene	0.277	0.555	1.109	2.219	8.875	35.499
2,3,5-trimethylnaphthalene	0.199	0.399	0.797	1.594	6.378	25.511
2,4,5-trimethylnaphthalene	0.277	0.554	1.108	2.217	8.867	35.467
1,4,5-trimethylnaphthalene	0.239	0.478	0.957	1.914	7.654	30.616
xanthone	0.240	0.481	0.961	1.923	7.691	30.763
1-methylnaphthalene	0.361	0.723	1.446	4.338	17.351	69.403
2,7-dimethylnaphthalene	0.300	0.599	1.198	3.594	14.377	57.507
bphenyl*	0.360	0.720	1.440	4.319	21.597	107.983
bibenzyl	0.362	0.724	1.448	4.345	21.723	108.617
2-methylnaphthalene	0.430	0.860	1.720	5.160	25.800	129.000
nphthalene*	0.359	0.717	1.435	5.739	34.432	206.592

*deuterated forms of these compounds are added to samples prior to extraction as surrogate for quantitation

Table 2. Calibration Levels for Hopanes and Steranes Analysis

Compound	Level 1 ng/uL	Level 2 ng/uL	Level 3 ng/uL	Level 4 ng/uL	ng/uL
cholestane-d6*	0.750	0.750	0.750	0.750	0.750
cholestane	0.250	0.500	1.000	2.000	4.000
17α-21β(H) Hopane (19)	0.250	0.500	1.000	2.000	4.000
17β(H)-30-Norhopane (17a)	0.250	0.500	1.000	2.000	4.000
17β(H)-21β(H) Hopane (23)	0.250	0.500	1.000	2.000	4.000

*deuterated forms of these compounds are added to samples prior to extraction as surrogate for quantitation

Table 3. Calibration Levels for Aliphatic Hydrocarbon Analysis (Alkanes), bold compounds co-elute and are quantified together

Compound	Level 1 ug/uL	Level 2 ug/uL	Level 3 ug/uL	Level 4 ug/uL	Level 5 ug/uL	Level 6 ug/uL	Level 7 ug/uL	Level 8 ug/uL
2,6,10-trimethylundecane_(norfarnesane)	0.050	0.500	1.000	100.000	200.000	2.500	5.000	10.000
n-heptylcyclohexane	0.050	0.500	1.000	100.000	200.000	2.500	5.000	10.000
2,6,10-trimethyldodecane_(farnesane)	0.050	0.500	1.000	100.000	200.000	2.500	5.000	10.000
n-tetradecane	0.050	0.500	1.000	100.000	200.000	2.500	5.000	10.000
n-pentadecane	0.050	0.500	1.000	100.000	200.000	2.500	5.000	10.000
n-octylcyclohexane	0.050	0.500	1.000	100.000	200.000	2.500	5.000	10.000
n-nonylcyclohexane	0.050	0.500	1.000	100.000	200.000	2.500	5.000	10.000
n-heptadecane + 2,6,10,14-tetramethylpentadecane_ pristane	0.050	0.500	1.000	100.000	200.000	2.500	5.000	10.000
n-hexadecane	0.050	0.500	1.000	100.000	200.000	2.500	5.000	10.000
2,6,10-trimethylpentadecane_norpristane	0.050	0.500	1.000	100.000	200.000	2.500	5.000	10.000
n-decylcyclohexane	0.050	0.500	1.000	100.000	200.000	2.500	5.000	10.000
n-undecylcyclohexane	0.050	0.500	1.000	100.000	200.000	2.500	5.000	10.000
n-nonadecane	0.050	0.500	1.000	100.000	200.000	2.500	5.000	10.000
n-octadecane	0.050	0.500	1.000	100.000	200.000	2.500	5.000	10.000
2,6,10,14-	0.050	0.500	1.000	100.000	200.000	2.500	5.000	10.000

tetramethylhexadecane_phytane

Compound	Level 1 ug/uL	Level 2 ug/uL	Level 3 ug/uL	Level 4 ug/uL	Level 5 ug/uL	Level 6 ug/uL	Level 7 ug/uL	Level 8 ug/uL
n-dodecylcyclohexane	0.050	0.500	1.000	100.000	200.000	2.500	5.000	10.000
n-tridecylcyclohexane	0.050	0.500	1.000	100.000	200.000	2.500	5.000	10.000
n-tetradecylcyclohexane	0.050	0.500	1.000	100.000	200.000	2.500	5.000	10.000
n-heneicosane	0.050	0.500	1.000	100.000	200.000	2.500	5.000	10.000
n-eicosane	0.050	0.500	1.000	100.000	200.000	2.500	5.000	10.000
n-pentadecylcyclohexane	0.050	0.500	1.000	100.000	200.000	2.500	5.000	10.000
n-docosane	0.050	0.500	1.000	100.000	200.000	2.500	5.000	10.000
n-tricosane	0.050	0.500	1.000	100.000	200.000	2.500	5.000	10.000
n-tetracosane-d50*	0.050	0.500	1.000	100.000	200.000	2.500	5.000	10.000
n-heptadecylcyclohexane	0.050	0.500	1.000	100.000	200.000	2.500	5.000	10.000
n-octadecylcyclohexane	0.050	0.500	1.000	100.000	200.000	2.500	5.000	10.000
n-tetracosane* + n-hexadecylcyclohexane	0.050	0.500	1.000	100.000	200.000	2.500	5.000	10.000
n-pentacosane	0.050	0.500	1.000	100.000	200.000	2.500	5.000	10.000
n-nonadecylcyclohexane	0.050	0.500	1.000	100.000	200.000	2.500	5.000	10.000
n-heptacosane	0.050	0.500	1.000	100.000	200.000	2.500	5.000	10.000
n-eicosylcyclohexane	0.050	0.500	1.000	100.000	200.000	2.500	5.000	10.000
n-hexacosane	0.050	0.500	1.000	100.000	200.000	2.500	5.000	10.000
n-octacosane	0.050	0.500	1.000	100.000	200.000	2.500	5.000	10.000

*deuterated forms of these compounds are added to samples prior to extraction as surrogate for quantitation

Table 4. Calibration Levels for Polar Organic Compounds Analysis

Compound	Level 1 ng/uL	Level 2 ng/uL	Level 3 ng/uL	Level 4 ng/uL	Level 5 ng/uL	Level 6 ng/uL
4-pentenoic	0.323	2.155	6.464	10.773	15.083	18.315
hexanoic acid	0.300	2.400	7.199	12.960	18.144	21.384
heptanoic	0.334	2.228	6.685	11.142	15.598	18.941
me-malonic	0.321	2.570	7.710	12.850	17.990	21.203
guaiacol	0.268	2.680	7.370	15.075	20.100	25.125
benzoic acid	0.300	2.400	7.199	12.960	18.144	21.384

octanoic	0.314	2.091	6.272	10.453	14.635	17.771
glycerol	0.348	2.320	6.960	11.600	16.240	19.720

Compound	Level 1 ng/uL	Level 2 ng/uL	Level 3 ng/uL	Level 4 ng/uL	Level 5 ng/uL	Level 6 ng/uL
maleic	0.328	2.620	7.860	13.100	18.340	21.615
succinic acid	0.300	2.400	7.199	12.960	17.820	21.060
4-methylguaiacol	0.385	3.851	10.591	21.664	28.885	36.106
methylsuccinic acid	0.300	2.400	7.199	12.960	17.820	21.060
o-toluic	0.313	2.500	7.500	12.500	17.500	20.625
picolinic acid	0.300	2.400	7.199	12.960	18.144	21.384
m-tolic	0.327	2.613	7.840	13.067	18.293	21.560
1,2,4-butanetriol	0.300	2.400	7.199	12.960	18.144	21.384
nonanoic	0.318	2.120	6.360	10.600	14.840	18.020
p-toluic	0.169	1.128	3.384	5.640	7.896	9.588
3-methylpicolinic	0.321	2.568	7.704	12.840	17.976	21.186
6-methylpicolinic	0.319	2.550	7.650	12.750	17.850	21.038
2,6-dimethylbenzoic	0.269	2.150	6.450	10.750	15.050	17.738
4-ethylguaiacol	0.260	2.598	7.146	14.616	19.488	24.360
syringol	0.266	2.655	7.301	14.934	19.913	24.891
glutaric acid	0.300	2.400	7.199	12.960	17.820	21.060
2-methylglutaric	0.319	2.550	7.650	12.750	17.850	21.038
2,5-dimethylbenzoic	0.260	2.080	6.240	10.400	14.560	17.160
3-methylglutaric	0.261	2.085	6.256	10.427	14.597	17.204
2,4-dimethylbenzoic	0.263	2.100	6.300	10.500	14.700	17.325
3,5-dimethylbenzoic	0.256	2.050	6.150	10.250	14.350	16.913
2,3-dimethylbenzoic	0.272	2.172	6.516	10.860	15.204	17.919
n-decanoic acid	0.300	2.400	7.199	12.960	17.820	21.060
4-allylguaiacol	0.284	2.843	7.817	15.990	21.320	26.650
4-methylsyringol	0.283	2.832	7.788	15.930	21.240	26.550
3,4-dimethylbenzoic	0.269	2.153	6.460	10.767	15.073	17.765
adipic acid	0.300	2.400	7.199	12.960	17.820	21.060
t-2-decenoic	0.318	2.123	6.368	10.613	14.859	18.043
cis-pinoic acid	0.300	2.400	7.199	12.960	17.820	21.060
3-methyladipic	0.328	2.623	7.868	13.113	18.359	21.637
4-formylguaiacol	0.283	2.832	7.788	15.930	21.240	26.550
undecanoic	0.315	2.523	7.570	12.617	17.663	20.818
isoeugenol	0.300	3.000	8.250	16.875	22.500	28.125
pimelic acid	0.300	2.400	7.199	12.960	17.820	21.060

acetovanillone	0.266	2.655	7.301	14.934	19.913	24.891
lauric acid	0.300	2.400	7.199	12.960	17.820	21.060

Compound	Level 1 ng/uL	Level 2 ng/uL	Level 3 ng/uL	Level 4 ng/uL	Level 5 ng/uL	Level 6 ng/uL
phthalic acid	0.300	2.400	7.199	12.960	17.820	21.060
levoglucosan	0.300	2.400	7.199	12.960	18.144	21.384
syringaldehyde	0.266	2.655	7.301	14.934	19.913	24.891
tridecanoic acid	0.300	2.400	7.199	12.960	17.820	21.060
suberic acid	0.300	2.400	7.199	12.960	17.820	21.060
isophthalic acid	0.300	2.400	7.199	12.960	17.820	21.060
azelaic acid	0.300	2.400	7.199	12.960	17.820	21.060
myristoleic	0.307	2.046	6.138	10.230	14.322	17.391
myristic acid	0.300	2.400	7.199	12.960	17.820	21.060
sebacic	0.165	1.098	3.294	5.489	7.685	9.332
pentadecanoic acid	0.300	2.400	7.199	12.960	17.820	21.060
undecanedioic	0.165	1.099	3.296	5.493	7.691	9.339
palmitoleic	0.318	2.120	6.360	10.600	14.840	18.020
palmitic acid	0.300	2.400	7.199	12.960	18.144	21.384
isostearic	0.312	2.080	6.240	10.400	14.560	17.680
dodecanedioic acid	0.165	1.099	3.296	5.493	7.691	9.339
heptadecanoic	0.323	2.585	7.756	12.927	18.097	21.329
1,11-undecanedicarboxilic	0.171	1.141	3.424	5.707	7.989	9.701
oleic acid	0.300	2.400	7.199	12.960	18.144	21.384
elaidic acid	0.300	2.400	7.199	12.960	17.820	21.060
stearic acid	0.300	2.400	7.199	12.960	18.144	21.384
1,12-dodecanedioic	0.166	1.105	3.315	5.525	7.735	9.393
nonadecanoic acid	0.300	2.400	7.199	12.960	17.820	21.060
dehydroabietic acid	0.300	2.400	7.199	12.960	17.820	21.060
eicosanoic acid	0.300	2.400	7.199	12.960	17.820	21.060
pentadecanedioic acid	0.166	1.105	3.315	5.525	7.735	9.393
abietic acid	0.300	2.400	7.199	12.960	18.144	21.384
heneicosanoic acid	0.300	2.400	7.199	12.960	17.820	21.060
docosanoic acid	0.300	2.400	7.199	12.960	17.820	21.060
tricosanoic acid	0.300	2.400	7.199	12.960	17.820	21.060
tetracosanoic acid	0.300	2.400	7.199	12.960	17.820	21.060
cholesterol	0.750	5.999	17.998	32.400	44.550	52.650
b-sitosterol	0.750	5.999	17.998	32.400	44.550	52.650

APPENDIX

SVOC Program Information

I. Before Running

A. Each project must be listed in the database "H:\db_prg\oalproj.dbf.". Fill in the following columns:

Column	**Value**
NUM	Use the next number in sequence
PROJ_NAME	A short description you will recognize
PROJ_CODE	The two-digit project code MUST be unique
ROOT_DIR	The directory where the project data are stored
STATUS	"c" for current, or "o" for old
SVOC	enter 1 to run the SVOC programs, 0 otherwise.

B. For each project, there is a list of target compounds for analysis. This list is in the directory "H:\db_calib\svoc\" and it is called AAcmpd.dbf, where AA is the project code in the oalproj.dbf database. In this same directory is a database called "Template.dbf" which is a template you can copy to make the new ones. The fields you must fill in are:

Column	**Description**
Field_Name	The mnemonic for the PAH or PAH uncert.
Field_Type	ignore this
Field_Len	ignore this
Field_Dec	ignore this
Compound	The long name for the compounds only, enter nothing for uncert. This MUST exactly match the way it is in the mass spec calibration file.
Type	Enter "c" for a compound, nothing for uncert.

C. If you intend to import GCMS data, you must use Lantastic to attach the GC/MS computer's c: (hard) drive to a drive on the local machine.

II. Running

A. Run the genbatch program and follow inputs.

B. IF this is the first time you have worked on this project, you must first run the option "N" which creates a new set of files. This will make the files you will need.

C. You now can quit the programs and enter samples into the 'lab' database. This is the database the import program uses to determine what to import.

D. If the sample is run diluted, that file name and process status are also noted. When there is no diluted sample, just leave the name blank and set the dil_f_proc bit to zero. After the samples are imported, the program automatically enters a 2 for the proc bit.

Column	**Description**
PID	Standard ID
XMSFLAG	Mass Spec flag
F_NAME	Mass Spec file name for main analysis
F_PROC	Process bit for main (0=do nothing, 1= import normally, 2=import done).
DIL_F_NAME	Mass Spec file name for diluted analysis (if done)
DIL_F_PROC	Process bit for diluted (0=do nothing, 1= import normally, 2=import done).
SAMPLNO	Sample number
LOT	Lot numbers
ANALDATE	Date of analysis
COMMENTS	Notes

E. Once the import is done, AND the field data have been entered, you may continue with the rest of the processing, simply by following the sequence.

F. For the first batch of any project, the menu looks like:

```
** FILE CREATING FOR BATH 1 ONLY **
   N  FOR Creating New Project Files
   6  FOR Importing XMS data.
** Copying files from current Batch \data to \report
   3  FOR Copying Field data.
   4  FOR Copying analysis (xms) data.
** Continue Processing Field
   5  FOR Processing Field data file.
** Continue Processing Analysis (xms) file.
   7  FOR Running REP.
   8  FOR Merge FLD and XMS files to CHM file.
   9  FOR Calculate blank values and blank uncertainty.
   10  FOR Convert chm file to con file (ug/m3).
```

Simply follow the sequence through. Note, before going to Step 3 and beyond, you must first make sure the field and xms data are all input.

III. Continuing a Project: Batch 2 and Following.

A. The menu for batch 2 and following looks like:

**** Copying files from previous Batch \report to current \data directories**
1 FOR Copying Field data from Batch (prev) to (current).
2 FOR Copying analysis (xms) and LAB data from Batch (prev) to (current).
6 FOR Importing XMS data.
**** Copying files from current Batch \data to \report**
3 FOR Copying Field data.
4 FOR Copying analysis (xms) data.
**** Continue Processing Field**
5 FOR Processing Field data file.
**** Continue Processing Analysis (xms) file.**
7 FOR Running REP.
8 FOR Merge FLD and XMS files to CHM file.
9 FOR Calculate blank values and blank uncertainty.
10 FOR Convert chm file to con file (ug/m^3).

This is basically the same as before, except you simply want to copy the previous Field, lab and xms files.

SVOC2 - The Sequel

Background

We have to analyze for more than just the PAH species, so a second processing program has been written. This program follows the PAH analysis program sequence with a number of exceptions.

Exceptions

The second SVOC program uses the same lab and field files as the regular program and thus these need to be finished at the same time.

The option exists in this program to define which compounds will be imported from the regular samples and which from diluted ones. This must be the same for all compounds in a project, although some adjustments can be made if necessary. In any case, all compounds must be imported the first pass through and then a sub-group can be imported from a second (called diluted) on file.

Everything is case sensitive, especially the compound names.

Steps

1. Tell the Data Processing Manager which projects need this so the OALProj database

and the other necessary files can be updated.

2. Update the compound list file. This file is project-specific and it is located in the H:\db_calib\svoc\ directory in the general form xx2cmpd.dbf, where xx is the project code. The template is nf2cmpd.dbf. This needs to be filled out in the following format:

Field_name	This is the mnemonic that will become the field name. Each compound must be followed by its associated uncertainty, just as in the example.
Field_type	Leave alone
Field_len	Leave alone
Field_dec	Leave alone
Compound	For the compound only (not the uncert.), insert the compound name EXACTLY as it is in the HP GC/MS calibration file. If this is not spelled EXACTLY as it is in the calibration file on the HP GC/MS nothing will work. Do not put in anything for the uncertainties.
Type	Put in "c" for compounds, nothing for uncertainties. EVERY compound in the list MUST have a "c" in this field.
Dil	Put in "d" for compounds that will be imported from diluted files, nothing otherwise.

3. Update the Lab database. There are five new fields in the lab database for the second SVOC files. These are:

F2_name	Mass spec file name for primary analysis
F2_proc	Process status for above (1= ready to import, 2= done)
Dil_f2_nam	MS file name for diluted run
Dil_f2_pro	Process status for above (1= ready to import, 2= done)
Date2	Analysis date for second compound list.

This should follow the conventions used in the normal data processing for PAH species.

4. Do genbatch and follow the instructions. When you select a project you will be prompted to select either SVOC or Additional SVOC compounds. Selecting the latter (option 7) will take you to the SVOC2 programs. First use the "N" option to build new files and then continue by importing the mass spec data and continuing the processing. This will create XM2 (the raw mass spec data), the CH2 file, and the CN2 (ng/m3) file.

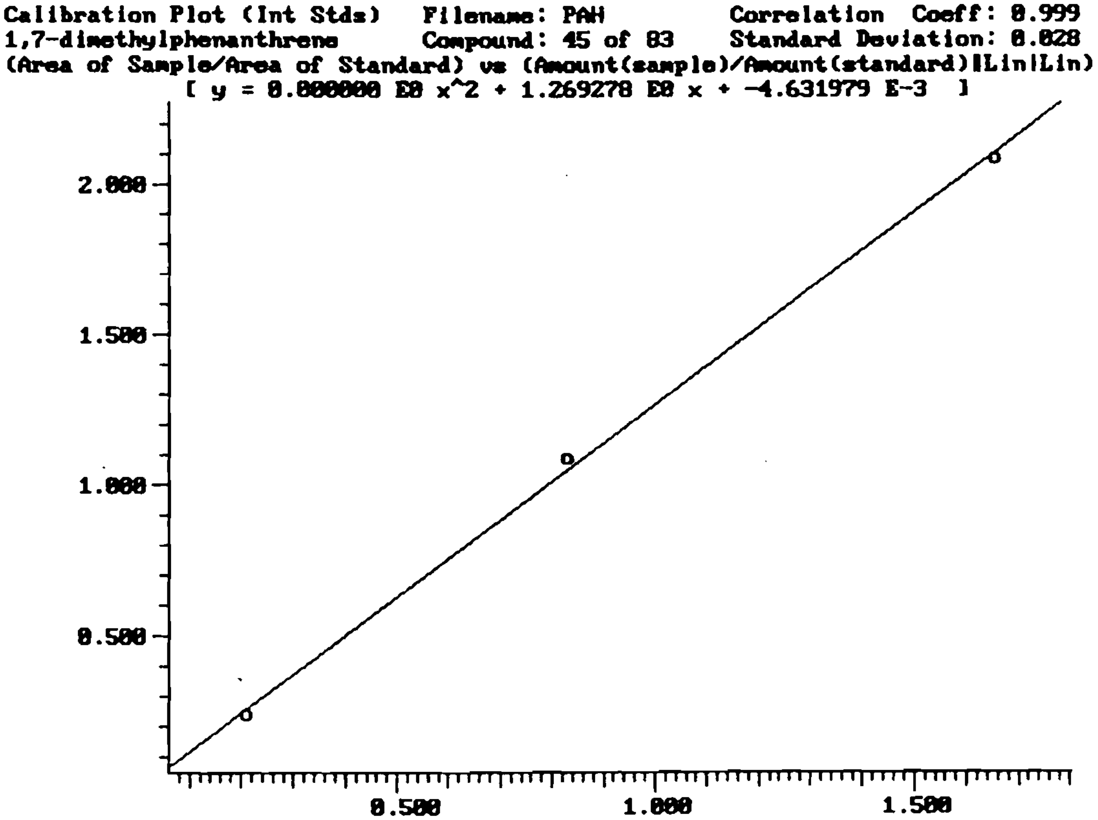

Calibration Plot (Int Stds) Filename: PAH Correlation Coeff: 0.999
1,7-dimethylphenanthrene Compound: 45 of 83 Standard Deviation: 0.028
(Area of Sample/Area of Standard) vs (Amount(sample)/Amount(standard)|Lin|Lin)
[y = 0.000000 E0 x^2 + 1.269278 E0 x + -4.631979 E-3]
2.000
1.500
1.000
0.500
0.500
1.000
1.500

Figure 1

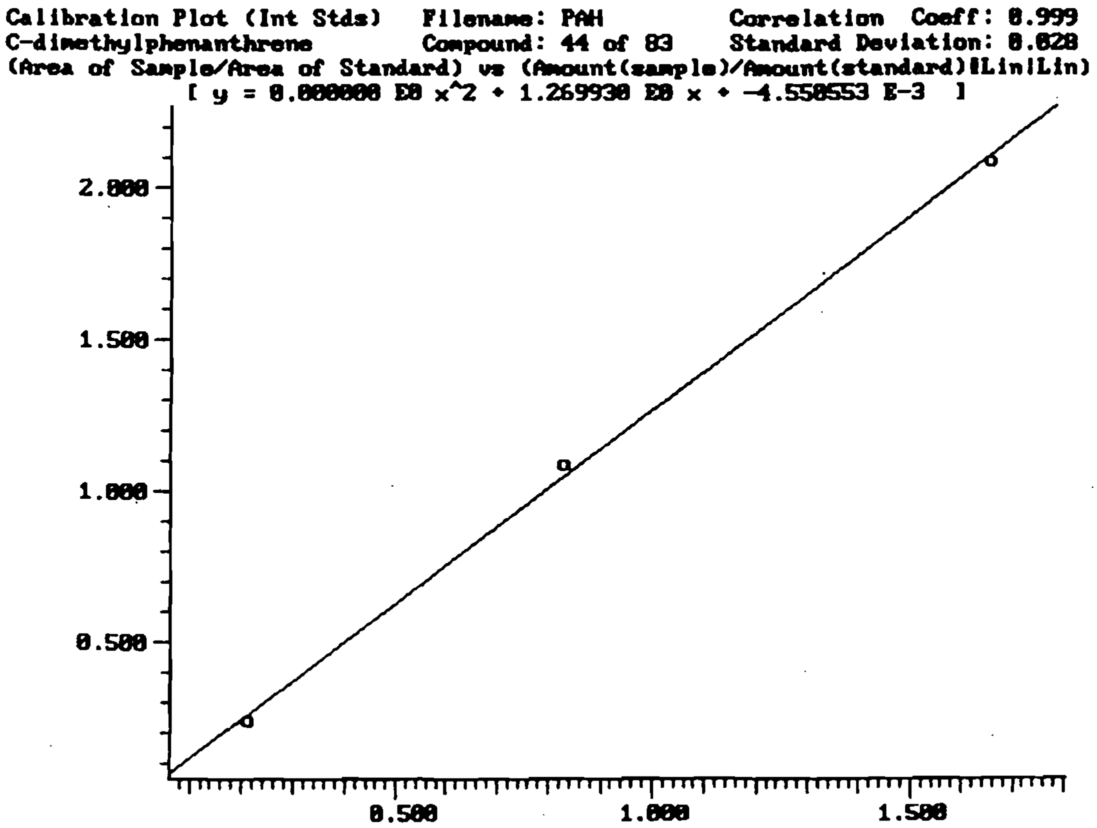
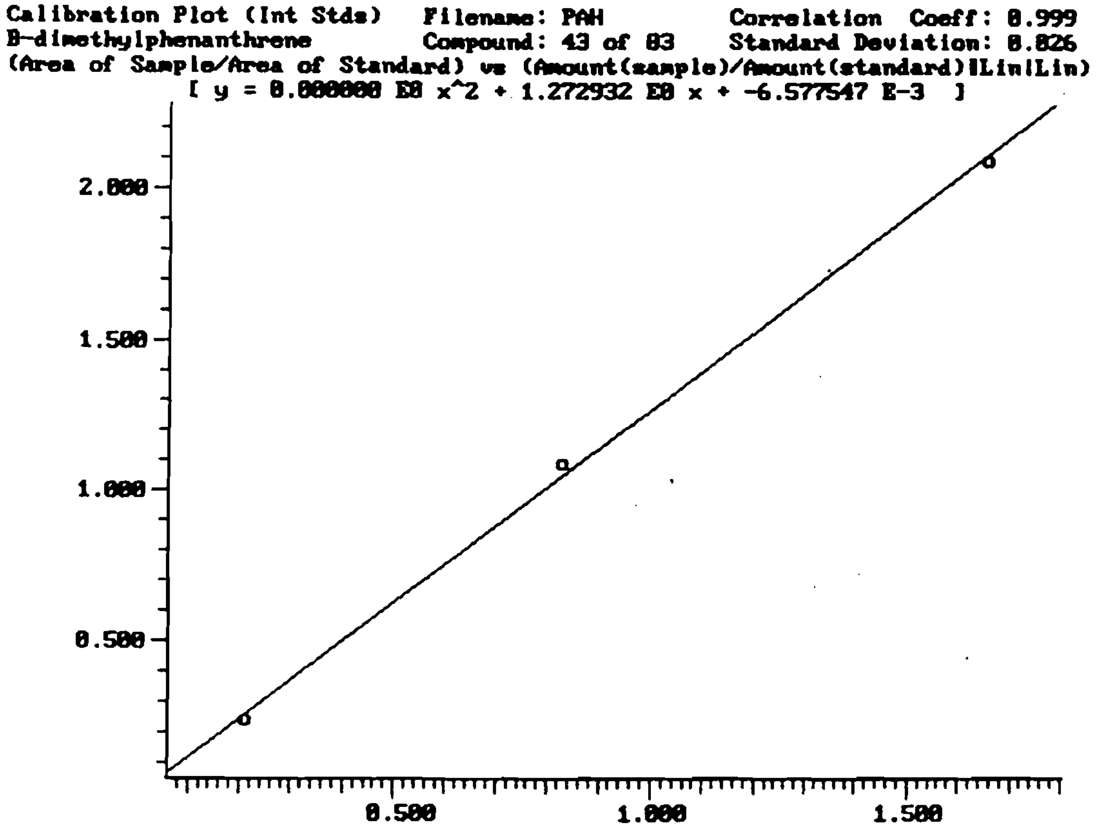

Calibration Plot (Int Stds)
Filename: PAH
Correlation Coeff: 0.999
C-dimethylphenanthrene
Compound: 44 of 83
Standard Deviation: 0.028
(Area of Sample/Area of Standard) vs (Amount(sample)/Amount(standard)!Lin!Lin)
[y = 0.000000 E0 x^2 + 1.269930 E0 x + -4.550553 E-3]
2.000
1.500
1.000
0.500
0.500
1.000
1.500

Figure 2



```
Calibration Plot (Int Stds)   Filename: PAH          Correlation  Coeff: 0.999
B-dimethylphenanthrene        Compound: 43 of 83    Standard Deviation: 0.026
(Area of Sample/Area of Standard) vs (Amount(sample)/Amount(standard)|Lin|Lin)
          [ y = 0.000000 E0 x^2 + 1.272932 E0 x + -6.577547 E-3  ]
```

Figure 3

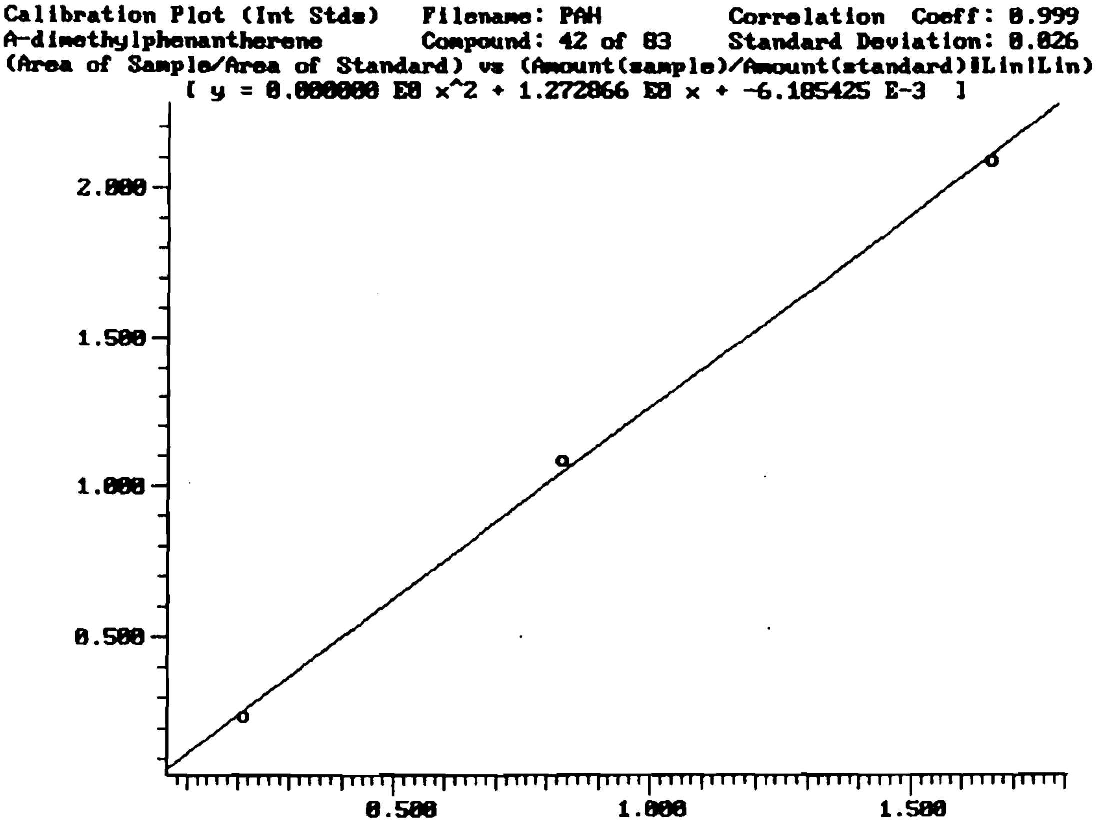
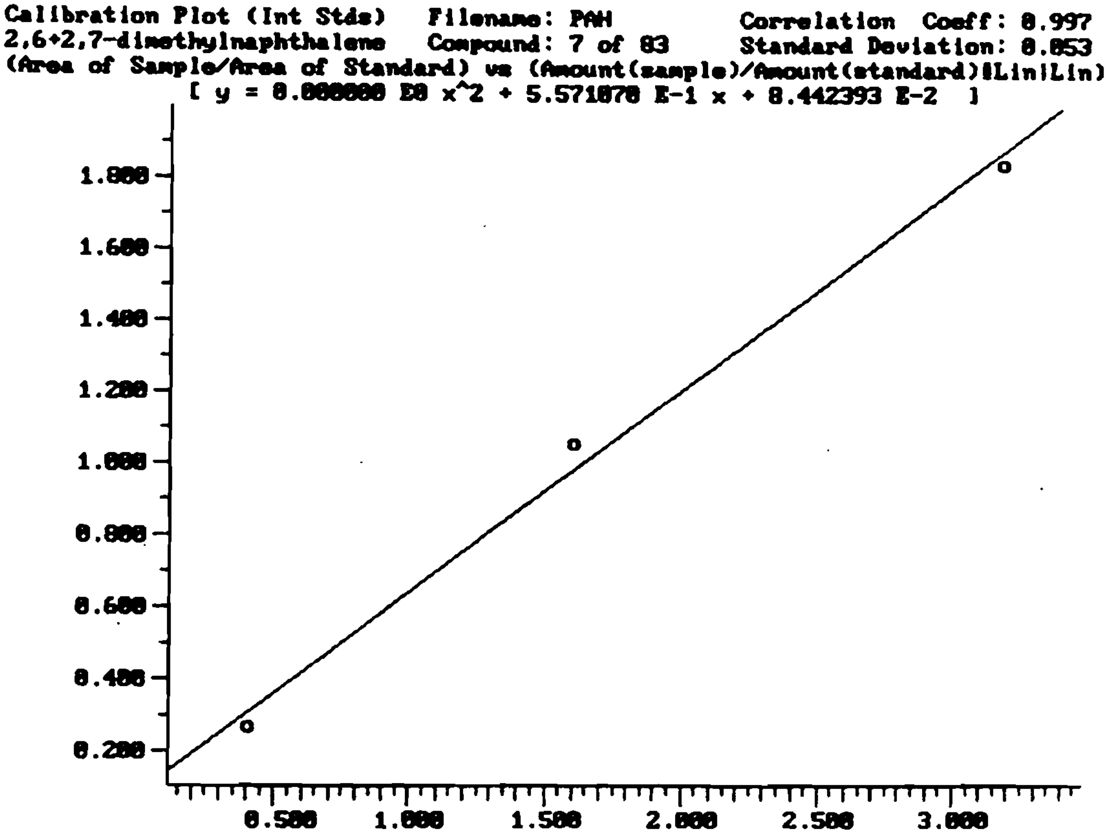

Calibration Plot (Int Stds)
Filename: PAH
Correlation Coeff: 0.999
A-dimethylphenantherene
Compound: 42 of 83
Standard Deviation: 0.026
(Area of Sample/Area of Standard) vs (Amount(sample)/Amount(standard)|Lin|Lin)
[y = 0.000000 E0 x^2 + 1.272866 E0 x + -6.185425 E-3]
2.000
1.500
1.000
0.500
0.500
1.000
1.500

Figure 4



Calibration Plot (Int Stds)   Filename: PAH   Correlation Coeff: 0.997
2,6+2,7-dimethylnaphthalene   Compound: 7 of 83   Standard Deviation: 0.053
(Area of Sample/Area of Standard) vs (Amount(sample)/Amount(standard)!Lin!Lin)
[y = 0.000000 E0 x^2 + 5.571070 E-1 x + 8.442393 E-2]

Figure 5

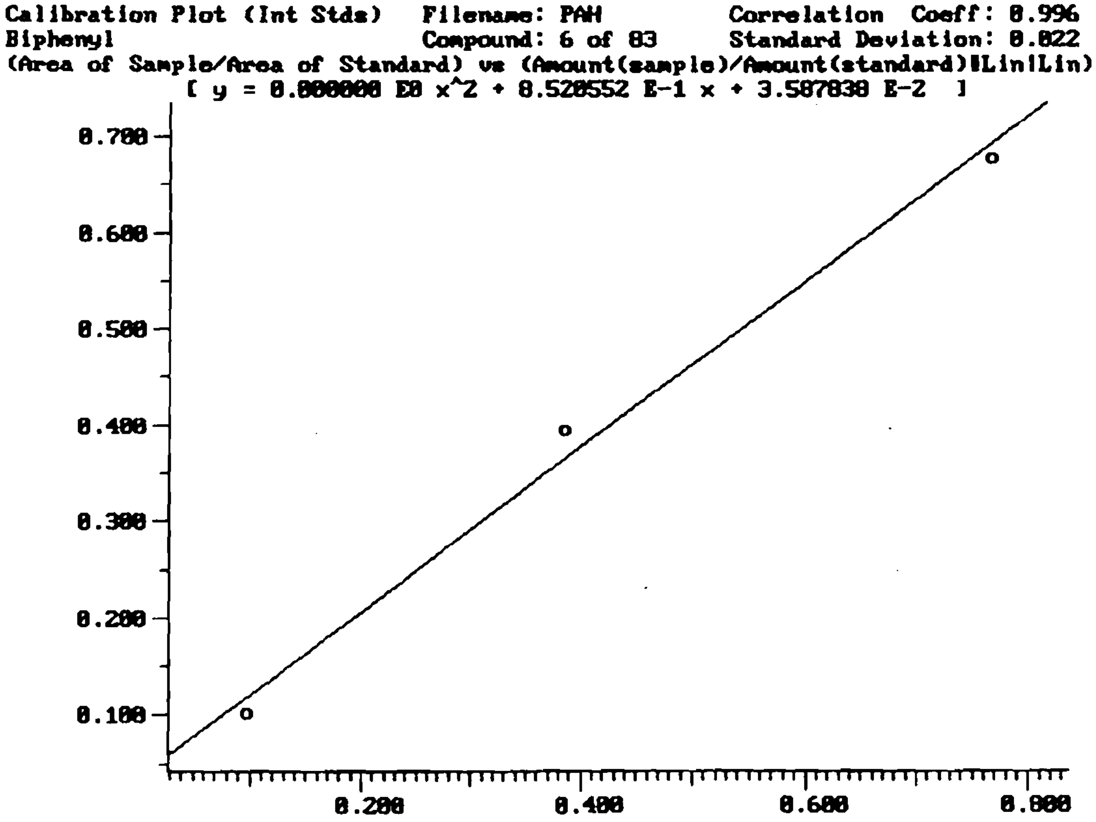

Calibration Plot (Int Stds)
Filename: PAH
Correlation Coeff: 0.996
Biphenyl
Compound: 6 of 83
Standard Deviation: 0.022
(Area of Sample/Area of Standard) vs (Amount(sample)/Amount(standard)|Lin|Lin)
[y = 0.000000 E0 x^2 + 8.520552 E-1 x + 3.587838 E-2]
0.700
0.600
0.500
0.400
0.300
0.200
0.100
0.200
0.400
0.600
0.800

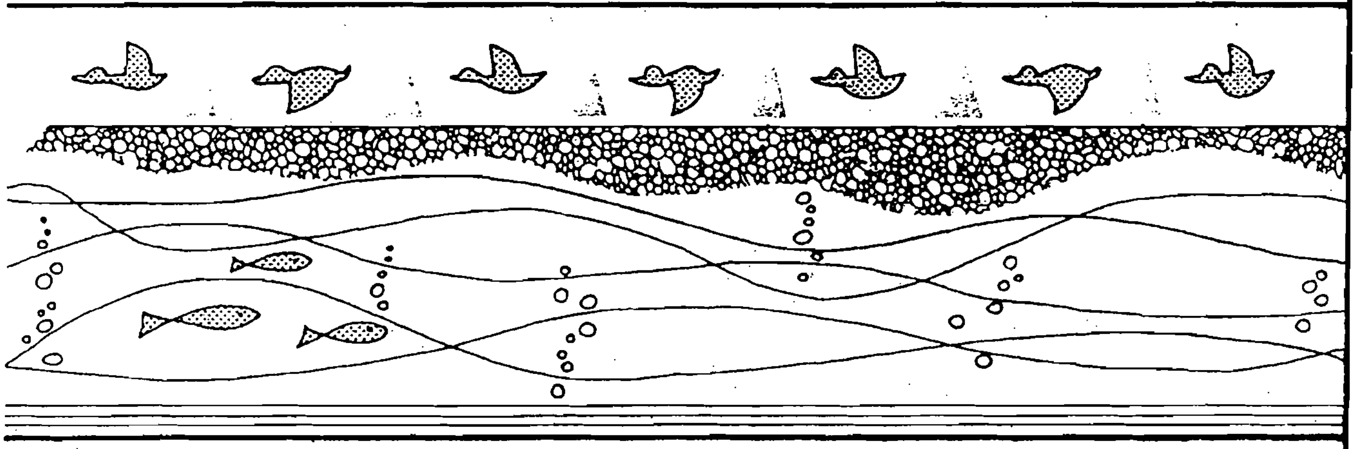
Figure 6

Attachment 9

Oil Spill Recovery Using Elastol, Report 1

Environment Canada
Environnement Canada

SPILL TECHNOLOGY NEWSLETTER



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The Spill Technology Newsletter was started with modest intentions in 1976 to provide a forum for the exchange of information on spill countermeasures and other related matters. We now have over 2000 subscribers in over 40 countries.

To broaden the scope of this newsletter, and to provide more information on industry and foreign activities in the field of spill control and prevention, readers are encouraged to submit articles on their work and views in this area.

INTRODUCTION

The first article of this issue is by Rick McKelvey of the Canadian Wildlife Service. Rick summarizes the oiled-bird problem and gives details on how to build a portable hot-water system for cleaning birds. The second article summarizes spill statistics for Atlantic Canada over the past fourteen years. The trends and significant occurrences are reviewed.

The third article is by Merv Fingas and Ed Tennyson who review their joint U.S. and Canadian project to evaluate Elastol and Demoussifier, two new spill treating agents. Both agents functioned well over a series of tests ranging from laboratory to large field scale.

EVALUATION OF TWO NEW OIL SPILL CHEMICAL ADDITIVES: ELASTOL AND DEMOUSSIFIER

Submitted by: Merv Fingas
Environment Canada
Ottawa, Ontario

Ed Tennyson
U.S. Minerals Management Service
Reston, Virginia

Introduction

A new oil spill treating agent, Elastol, has been developed for enhancing the recovery potential of oil. When added to oil, the powder renders oil visco-elastic making it adhesive to oil spill recovery equipment. Elastol is composed of a non-toxic polymer, polyisobutylene and is hydrophobic and not water soluble. A major study was undertaken jointly by the U.S. Minerals Management Service and Environment Canada to evaluate this new spill additive. Laboratory testing was done and studies were conducted in large-scale test tanks and in a major field exercise off Canada's east coast.

At the same time, another new spill treating agent, demoussifier, was tested in large outdoor tanks and at sea. This product, which also consists of a mixture of long-chain polymers which have no measurable toxicity to humans or to aquatic life, was developed at Environment Canada's River Road Labs. The product breaks up water-in-oil emulsions and prevents their formation.

Laboratory Testing of Elastol

The laboratory work on Elastol involved several different tests. The effect on a suite of different oils was determined by measuring the time to initiate change and the degree of elasticity formed. These oils included: Prudhoe Bay, Alberta Sweet Mix Blend, Norman Wells, Bent Horn, Hibernia, Tarsiut, Atkinson, Amauligak crudes, diesel fuel and a Bunker C mix. All oils displayed viscoeleastic properties when treated with doses of 600 to 6000 ppm Elastol. In general, more viscous oils tended to attain a higher degree of elasticity than non-viscous oils, but did so over a longer period of time. No simple correlation could be established between an oil property and Elastol effectiveness. Elastol effectiveness is enhanced by mixing and by higher temperatures, although the latter may be the effect of decreasing oil viscosity.

Under low mixing energy conditions, oils exhibited some degree of elasticity within 15 minutes of Elastol application. A high degree of elasticity was not observed until after one hour. Less viscous oils took less time to reach maximum elasticity and viscous oils more time. If left to weather, Elastol-treated oil became more elastic with the increasing viscosity of the oil. In fact, some samples left for 30-day periods became elastic as rubber bands sold for stationery purposes. This effect has been ascribed to the effect of the increasing viscosity of the oil with weathering (evaporation) and not the progressive reaction of the Elastol.

Elastol causes a minor reduction in the rate of oil evaporation, but not significant enough to reduce its flash point. Elastol reduces slick spreading to a limited degree, especially at high concentrations. This effect, about 20%, is not believed to have a significant useful benefit by itself in real applications. When Elastol is applied in very large doses, >1%, the slick would actually contract somewhat, but again, the effect would not be beneficial in a field situation.

The addition of Elastol either had no effect or an inhibiting effect on the formation of water-in-oil emulsions, except in the case of the Amauligak and Tarsiut oils from the Beaufort Sea region. In two cases, the application of Elastol to emulsified oil actually led to measurable de-emulsification. Application of Elastol to stable water-in-oil emulsions sometimes had little effect. Testing with commercial de-emulsifiers and the Environment Canada "demoussifier", showed that Elastol had no effect on the operation of these chemicals and that they could be used together.

Elastol reduces chemical dispersant effectiveness by as much as one order of magnitude. Elastol also reduces natural dispersion of oil into water by as much as three orders of magnitude. This property, while superficially appearing negative, is actually quite useful. If Elastol was used in situations where the aquatic life is very sensitive and important, it could reduce water concentrations of the oil in the water to threshold levels.

Elasticity was measured using a die swell apparatus in which oil is pushed through a small opening and the fluid responds by swelling to a size corresponding to its elasticity. This is measured by photographing the swell, measuring it with a vernier caliper and comparing untreated versus treated oil to yield a ratio which is described as "elasticity" in this paper. The instrument displayed good sensitivity to polymer concentration and to the degree of observed elasticity. This instrument could also be used in field conditions and is relatively insensitive to debris and water in the oil.

Tank Scale Testing of Elastol and Demoussifier

An application device was developed for each of the two products, as commercial devices do not exist for delivering treatments at the low ratios required. Elastol would be tested at 500 to 5000 ppm and demoussifier would be tested at 150 to 2000 ppm. A search of commercial devices revealed that nothing suitable was available off-the-shelf but that sandblaster-type equipment could be satisfactorily modified. A commercial blaster (Sears) was modified so that it could spray low quantities. One modification was necessary for the solid Elastol, and another for the liquid demoussifier. The modified applicator was tested on each product to ensure that uniform spacial distribution was achieved and that application rates could be controlled over the necessary range by adjusting the air pressure when applying the product from a boat travelling at approximately 3 knots. A series of test tank runs were performed to ensure that results obtained previously with hand distribution techniques and with pre-mixing were duplicated with the new applicators. Success was achieved in all cases, and no detrimental effects were observed during application of either product, such as herding and other phenomena that have decreased the field effectiveness of dispersants so dramatically (Bobra et al., 1988).

Part of this study involved large-scale tank testing of both products using the Esso tank in Calgary, Alberta. The tank measures 15 x 19 m with a depth of 0.8 to 2 m. Two test days were devoted to demoussifier and two to Elastol. Testing was performed in two boomed areas inside the tank. This permitted the simultaneous testing of a control and a treated slick under identical conditions. The demoussifier prevented the formation of water-in-oil emulsions on both test days and did so at ratios as low as 1:2000 (500 ppm).

Elastol was added to a test crude oil at 4000 ppm and the test slick was released several hours later when the oil was highly elastic. Despite this high elasticity, the oil was not thick enough to burn. The oil was recovered by a rotating disk skimmer and the effect of Elastol was to increase the recovery rate of this unit significantly. In fact, the pump could not keep pace with all the oil being recovered. On the fourth day of testing, crude oil was treated with 2000 ppm of Elastol and recovered with a skimmer. The recovery rate was again high and exceeded the capacity of the pump to remove it. On this particular day, the oil in the untreated boom had formed an emulsion. This was treated with demoussifier as was the Elastol-treated slick. The demoussifier broke the emulsion in the untreated slick and no emulsion formed in the treated slick, nor were any other effects noted. During the first two trial days, the use of demoussifier reduced the effectiveness of the recovery operation significantly. It was concluded, therefore, that on a preliminary basis, demoussifier and Elastol could be used together to enhance recovery and eliminate emulsion.

The tank scale tests showed that there were no scaling effects for either the Elastol or the demoussifier. Both products worked well for the intended purpose. Elastol increased the visco-elasticity of the oil and greatly increased the recovery by the oil skimmer. Elastol, however, did not reduce the spreading or increase the thickness of the slick sufficiently to allow in-situ burning. Demoussifier prevented the formation of water-in-oil emulsion and also broke emulsion already formed. Although demoussifier causes the oil to be less adhesive and lowers the recovery rate of skimmers, the two products can be applied together to achieve positive results.

Large-scale Field Testing

The tests conducted in the tank were repeated on five-barrel slicks during a field trial 50 miles offshore of Nova Scotia (Seakem, 1988). Five slicks were laid for each of the products and each product was tested both premixed and by application-at-sea, to confirm that application effects were not a factor. The treatments and results of the trial are summarized in Table 1.

The demoussifier trials were performed by laying down a five-barrel oil slick, treating it with the product at the specified ratio, taking samples at subsequent intervals and measuring the water content and the viscosity. One slick was left untreated throughout as a control and another slick was left to form mousse (water-in-oil emulsion) and then treated at the 240-minute interval to test the demoussifier's ability to break emulsion at sea. As can be seen by dramatic reduction in viscosity (105 000 to 22 600 cSt; 1050 to 226 cm^2/s) over the 30-minute period between samples, the product worked well in breaking up the emulsion.

The product also worked well over the five-hour test period to prevent the formation of emulsions. This is illustrated in Figure 1 which also shows that there is a

TABLE 1 TREATMENTS AND RESULTS OF TRIALS

			Sample 1					Sample 2				
Trials	Slick	Treatment (ppm)	Time (min.)	Viscosity (cSt)*	Water Content	Elasticity	Comments	Time (min.)	Viscosity (cSt)*	Water Content	Elasticity	Comments
Demoussifier	1	1000	60	10 000	84%		No mousse formed	300	84 250	90%		No mousse noted
	2	250	60	2 700	54%		No mousse formed	300	62 250	93%		No mousse noted
	3	control	60	6 350	88%		Heavy mousse	270	320 000	95%		Heavy mousse
	4	post-4000	60	2 200	72%		Moderate mousse	pre-240	105 000	90%		Heavy mousse
								post-270	22 600	78%		Treatment broke mousse
	5	pre-1000	15	970	32%		No mousse formed	280	38 500	80%		No mousse formed
Elastol	6	3000	130	29 300		1.33	Moderately elastic	280	300 000		1.35	Highly elastic
	7	1000	145	32 250		1.28	Low elasticity	280	228 000		1.33	Moderately elastic
	8	control	135	187 000		0.99	No elasticity, widespread	290	242 000		0.99	No elasticity, widespread
	9	9000	120	93 000		1.99	High elasticity	330	696 000		2.63	Super elastic
	10	pre-3000	115	170 500		1.35	Moderate elasticity	315	156 000		1.57	Highly elastic

* 1 cSt = 1×10^{-2} cm^2/s

strong correlation between the viscosity and the amount of treatment. The greater the treatment, the less the viscosity, because of the lesser water content. The water content was universally high, even in those slicks that visibly did not form water-in-oil emulsions. Although water content is indicative of the formation of water-in-oil emulsification, the stability of the emulsion would have to be determined because the unstable emulsions lost water slowly. The water content of the slicks is interesting in that all the slicks laid over the two day test period rapidly took up water, including those slicks that were treated with Elastol. This was noted despite the fact that the oil viscosity was higher, although not as high as that expected from an emulsion, and the oil did not have the appearance of an emulsion. The appearance of the unemulsified oil is also significant, the water droplets were often of sufficient size to be seen. An emulsion is reddish-brown in colour, has a high viscosity and the water droplets are too small to be seen.

The Elastol tests were performed in an analogous manner, with one control slick laid and one slick being pretreated to test the effect of at-sea treatment. The slicks were sampled periodically, and both viscosity and elasticity were measured immediately on board the ship.

The high elasticity of the treated slicks was significantly higher than that of the untreated slicks and corresponded to that experienced in the laboratory, in fact, as shown in Figure 2, it actually exceeded laboratory results at the higher doses. This unexpected result is probably due to the better mixing achieved in the field situation. Interestingly, the dose and elasticity in the field appear to be linear, a phenomenon that had not been noted previously.

The elasticity of the oil was sufficient to cause stringing of the product when samples were recovered. This is indicative of a very high state of elasticity and would result in high oil recovery rates if a skimmer was used. The elasticity appeared to be uniform throughout the slicks despite the typical uneven distribution of treating agent at sea.

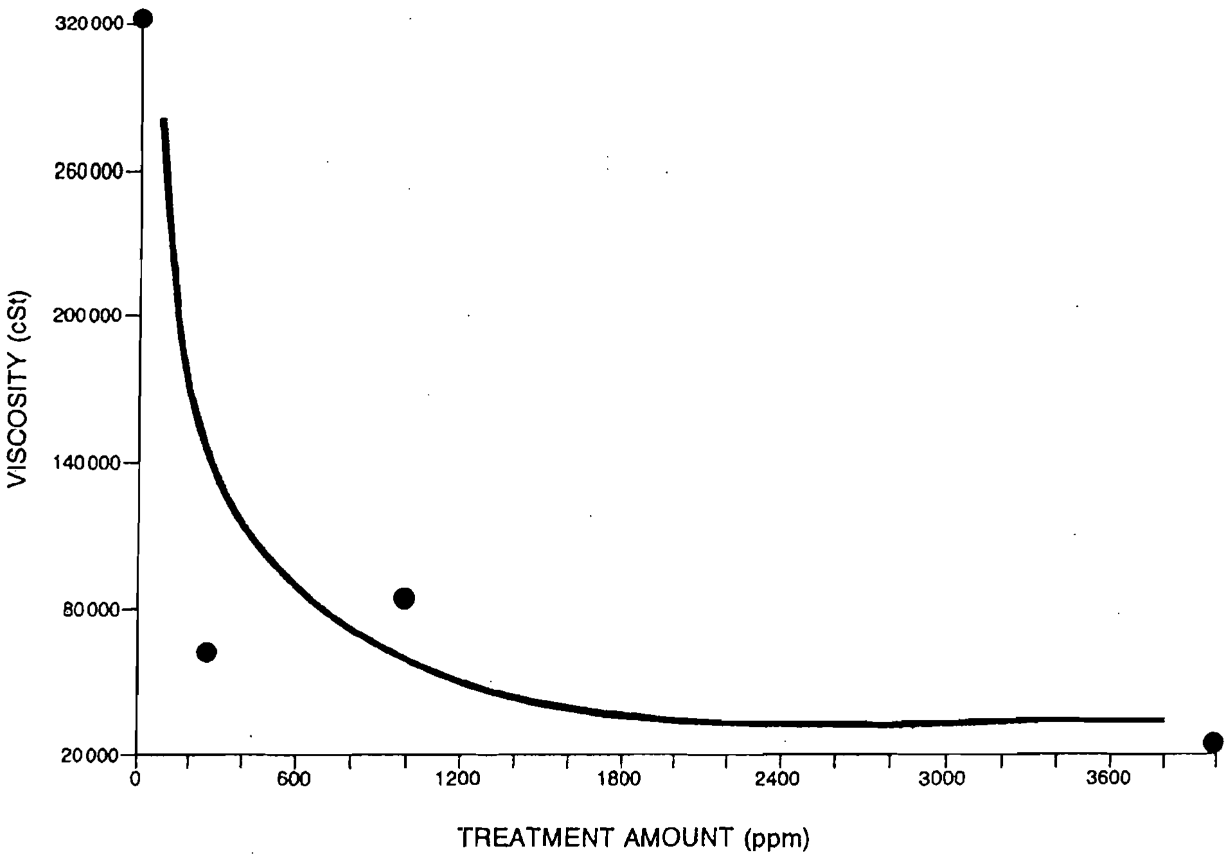

FIGURE 1 THE EFFECT OF DEMOUSSIFIER APPLICATION ON VISCOSITY

The slicks were monitored by a remote sensing aircraft, but the analysis of slick areas was not complete at the time of writing. Slicks treated with Elastol, however, appeared to be smaller to shipboard observers and the size of the slick appeared to correlate well with the amount of Elastol. In fact, one was able to distinguish slicks by their size, with the 9 000-ppm-treated slick being the smallest.

Summary and Conclusions

1. Elastol functioned well in the laboratory, test tank and in field situations; it caused oil to become viscoelastic in all applications.

2. Elastol is able to float with and mix with oil so that application is not critical as it is with dispersants.

3. Demoussifier has the same application insensitivity as Elastol.

4. The effects of Elastol improves oil skimmer recovery.

5. Elastol retards slick spreading; however, this effect, for physical reasons, is not sufficient for countermeasures purposes such as in-situ burning of oil on water.

6. The demoussifier prevented emulsion in the test slicks over the five-hour test period.

7. The demoussifier broke water-in-oil emulsions in 10 to 15 seconds after application.

8. Results of field application such as herding and loss of effectiveness, seen with dispersants, were not noted at all with either product.

9. Water content is not a good indicator of mousse formation as all slicks at the offshore trial accumulated a large amount of water. Stable mousse formation is indicated by a stable water content, small water droplet size, red colouring and a very high viscosity.

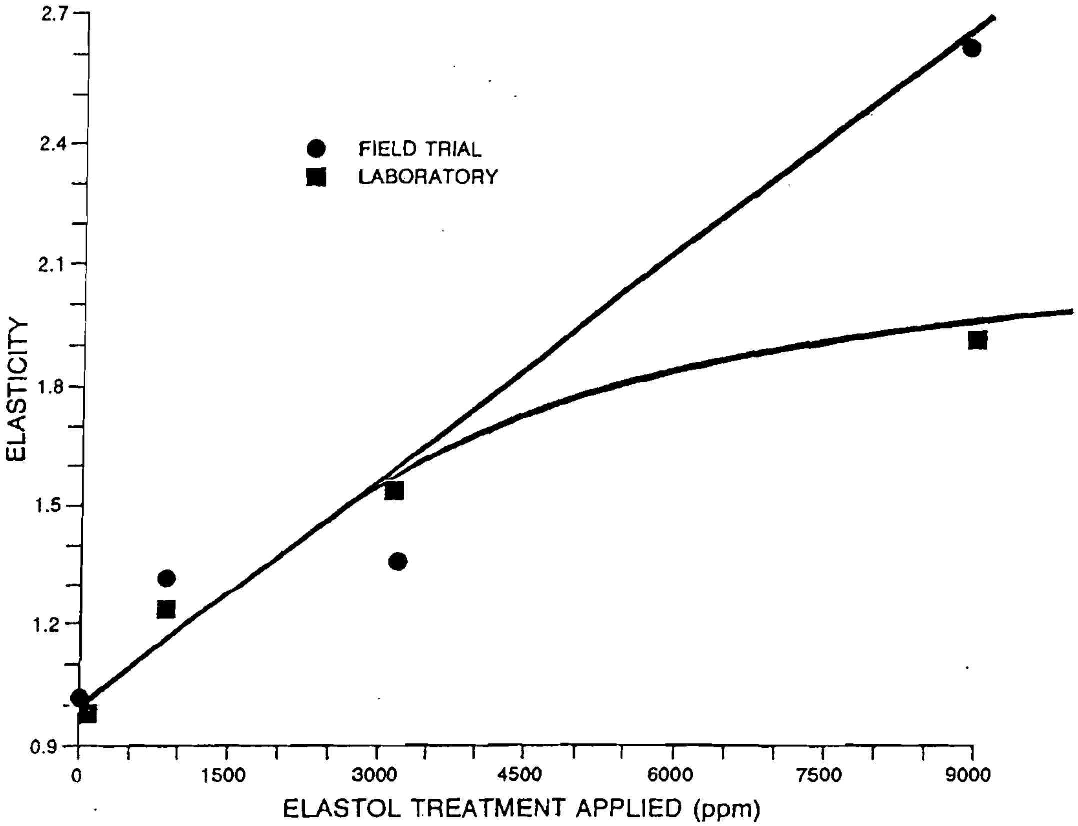

FIGURE 2 ELASTICITY OF OILS AFTER ELASTOL TREATMENT

References

Bobra, M.A., P.I. Kawamura, M. Fingas and D. Velicogna, Laboratory and Tank Test Evaluation of Elastol, Environment Canada Manuscript Report Number EE-94, Ottawa, Ontario (1987).

Bobra, M.A., P.I. Kawamura, M. Fingas and D. Velicogna, Mesoscale Application and Testing of and Oil Spill Demulsifying Agent and Elastol, Environment Canada Manuscript Report Number EE-104, Ottawa, Ontario (1988).

Seakem Oceanography, Field Test of Two Spill Treating Agents, Environment Canada, Manuscript Report Number EE-XX, in press (1988).

Attachment 10

Oil Spill Recovery Using Elastol, Report 2

MEMORANDUM

TO: All

FROM: Al Hadermann

DATE: July 7, 1992

SUBJECT: Elastol and Corals and Seagrasses (with footnote)

Anitra Thorhaug* has tested Elastol powder and various weathered oils for toxicity to seagrasses and corals. Tests were conducted on species in 50 gallon glass tanks containing 100,000 ml of seawater. Tests were run at 0.00125%, 0.0075% and 0.01235% oil, i.e., approximately 1.25 ml, 7.5 ml and 12.5 ml. When Elastol was added it was used at 10 mg, or 0.010 g. This corresponds to treatment concentrations of approximately 8,000, 1,333 and 800 ppm for 1.25 ml, 7.5 ml, and 12.5 ml of oil, respectively. Although the Elastol was not used as a slurry, and overtreatment obviously occurred at the 12.5 ppm oil level, the results showed that Elastol treatment reduced the toxicity of the oil.

The exposure times to oil and oil and Elastol were 6 and 10 hours for coral and seagrasses, and 10 hours for mangroves. Agitation was provided by air bubbling. The seawater was replaced after the incubation (exposure) time.

Dr. Thorhaug reported that:

> "The corals continued with their polyp feeding patterns with the Elastol-oil mixture in the tank. This was an extraordinary result compared to the other compounds used in the test which were a variety of dispersed-oil products."

> "The quantitative data for the various concentrations and various oils show that the oil plus the Elastol at concentrations at 125 ppm were appreciably less toxic than oil alone for corals and seagrasses."

Since oil alone at 125 ppm did not affect mangroves, no basis for improvement with Elastol was seen.

In Summary, Dr. Thorhaug states:

> "The toxicity of oil alone was definitely greater than the Elastol treatments in almost all the concentrations tested."

*Anitra Thorhaug is a researcher at Florida International University, P.O. Box 490559, Miami, FL 33149.

ELASTOSOL, an oil spill control agent: Toxicity effects on tropical and subtropical seagrass, corals, fish and mangroves.

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The toxicity of other than dispersant oil spill control agents (solidifiers, gels, sorbent and bioremediation agents) for cleaning oil spills has received very little attention (NRC, 1989; Thorhaug, 1991; IMO, 1991). This is the beginning of an attempt to give the same attention to the toxicity of these products to critical tropical/subtropical matrix organisms and fisheries species.

The product elastosol contains polyisobuylene and an oleophilic surfactant. Although it is proprietary, it has undergone chemical analysis and field testing (Fingas, 1989; Bobras, 1987a&b, 1988a&b; Fingas and Tennyson, 1988). A wide variety of crude oils became elasticized within 15 minutes more-or-less after elastosol treatment. These were retained in solidified condition up to 30 days with viscoelastic properties maintained over this time period. The properties appear to be that slicks are prevented from spreading and can be picked up by skimmers efficiently. With sensitive ecosystems, the major use of elastosol clearly will be relatively small confined spills probably at ports, marinas, oil refineries or in bays or estuaries. Thus, the tolerance of critical habitat organisms to elastosol is important.

METHODS:

Toxicity studies

Laboratory investigations. Standardized procedures used by the U.S. Environmental Protection Agency (EPA) and various agencies (FAO, UNESCO, UNEP) for testing tropical matrix organisms were employed so that standardized test results could be produced. The hope was to compare results with temperate results, along with UNEP European dispersed-oil toxicity data.

Table 1. Elastosol concentrations versus toxicity of seagrasses, corals and mangroves. 7 to 12 specimen
at each concentration per treatment.

SPECIES	TIME IN HRS	CONC OIL	% MORTAL. W/ELAST.	% MORTAL. CONTROL	% MORTAL. OIL ALONE	OIL TYPE	CONC. OIL	% MORT. ELAST.	% MORTAL. CONTROL	% MORTAL. OIL ALONE	CONC. OIL	% MORT. ELAST	% MORT. CONTROL	% MORT. OIL ALONE
SEAGRASS														
Thal. test.	6	125	15	11	30		75	10	7	10	12.5	8	0	10
Hal. wri.	6	125	46	9	28		75	11	5	16	12.5	10	5	12
Syr. fil.	6	125	12	10	24		75	12	4	18	12.5	8	4	14
CORAL														
Por. por.	6	125	18	0	52	Kuw	75	0	0	12	12.5	0	0	0
Mont. ann.	6	125	0	0	55	Kuw	75	0	0	6	12.5	0	0	0
Acrop.	6	125	4	29	100	Kuw	75	0	0	8	12.5	0	0	0
MANGROVE														
Rhizi.	10	125	4	0	0	Kuw	75	0	0	0	12.5	0	0	0
Avicen	10	125	0	0	0	Kuw	75	0	0	0	12.5	0	0	0
Lang.	10	125	0	0	0	Kuw	75	0	0	0	12.5	0	0	0

Thal. test. =*Thalassia testudium*; Hal. wri = *Halodule wrightii*; Syr. fil. = *Syringodium filiforme*; Por. por. =*Poriates poriates*; Mont. ann. = *Montastrea annularis*; Acrop. = *Acropora palmata*; Rhizi. = *Rhizophora mangle* ; Avicen. = *Avicennio*; Lang. = *Languncularia*

Selection of critical matrix organisms for tropical shorelines was a choice based on (1) importance to the food web, (2) rate and difficulty of replacement once decimated, (3) shoreline stabilization characteristics, and (4) usefulness to the nation (fisheries, tourism). Local experts such as Jeremy Woodley, director of the Discovery Bay Marine Laboratory and preeminent Jamaican coral reef expert, were asked to choose indicator species for the project.

Standardization among techniques for various groups was attempted so that the results of each group could be compared. Thus, the standardized portion will be explained first.

Laboratory conditions. The procedure was described in detail by Thorhaug and Marcus (1985). Fifty-gallon glass aquaria were used in out-of-door conditions (such as fluctuating light, temperatures, and running water) and, except for the mangroves and seagrasses, were protected from rain and wind. Temperatures ranged from 26° to 30°C, with fluctuation of 1°C ± 0.5°C. Seawater ranged from 30% to 33% (except for the mangroves). In seagrasses, three inches of beach sand was at the bottom. Corals tanks were bare. For seagrasses, a minimum of 15 blade groups of each species was placed in each tank (1 tank per treatment). Great care was taken in transport and holding conditions for the coral and mangrove specimens. Time for equilibration of specimens was allowed. 100,000 cc of seawater was placed in each treatment.

Laboratory procedures. Oil-only was a treatment in each set. Time for weathering of oil was 24 hours at 28°C in shallow plastic pans. The control tank was handled exactly the same as treatments. The dispersant was applied to oil floating on the tank surface with 1 minute of vigorous stirring. The dispersed oil formed a brown cloud of free-floating material, visually homogeneous throughout the tank (depended somewhat on concentration and dispersant). The coral and seagrasses were not touching the oil floating on the top; the mangroves were in contact on the bark. All specimens were in contact with the dispersant mousse.

The application of elastosol was 12.5 ppm oil, 75 ppm oil and 125 ppm oil with 10 mg (1 package) of elastosol. The exposure times were 6 and 10 hours for corals and seagrasses, 10 hours for mangroves. The treatment was immediately removed, and the water cleaned and changed in all treatments.

The specimens were incubated up to 14 days (coral, seagrass) and 9 months (mangroves). The observation period included daily or bi-weekly readings of health. Seagrasses had young green blades tagged and numbered. These were graded for discoloration, spotting, wilting and other morbidly symptoms. Corals were graded by bleaching, spotting, browning, wilted polyps, extruded polyps, and mucous secretion. Mangroves were graded by leaf drop, twig drop, root death and discoloration, leaf coloration, leaf spots, and leaf wilt. These symptoms of mortality and illness were made quantitative by experts and organisms were graded. The tables showing the results are not of heath but of mortality.

Morphologically, the results of elastosol included the observation that the oil flowing on the surface of the tanks within a few minutes of treatment with elastosol congealed into long lines. There appeared to be no film on the glass sides of the aquaria or on the water. The mixture of elastosol and oil was complete.

There were a series of biological and morphological observations.

1) The corals continued with their polyp feeding patterns with the elastosol-oil mixture in the tank. This was an extraordinary result compared to the other compounds used in the test which were a variety of dispersed-oil products. Color and vigor of the polyps of all species was retained.
2) The elastosol had no apparent effect on seagrass or mangrove vigor or color.

The quantitative data for the various concentrations and various oils show that the oil plus the elastosol at concentrations of 125 ppm were appreciably less toxic than oil alone for corals and seagrasses. Mangroves had no effect from elastosol. Oil alone did not affect mangroves at these concentrations. Corals were the most sensitive to oil. The response of decreased toxicity by application of elastosol is seen dramatically at 125 ppm oil in corals where the control had a higher mortality than the oil plus the elastosol. The mangroves were far more tolerant of oil, plus oil and clean-up product of any kind than were seagrasses or corals.

CONCLUSIONS:

The herder or solidifier Elastosol does not appear to have marked toxic effects on the tropical/subtropical matrix organisms studied, even at high concentrations. Oil alone at the higher concentrations does have a toxic effect on seagrasses and corals. The results of dispersants at these same concentrations were highly toxic on the seagrasses, corals and mangroves for many of the products tested.

The elastosol in all tests was the least toxic of a series of oil spill clean-up formulations. The toxicity of oil alone was definitely greater than the elastosol treatments in almost all the concentrations tested.

The difficulty of application of elastosol would indicate use for a smaller spill such as a harbor or estuarine spills. The fact of very low toxicity corals would make this extremely well-adapted to spills near or over coral reefs. It may also be very helpful to control oil when spills are within mangrove swamps. Certainly, spills which cannot be mechanically handled or chemically dispersed may warrant the expense and application methods for elastosol.

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Attachment 11

Oil Spill Recovery Using Elastol, Report 3

The 1987 Newfoundland Oil Spill Experiment

An Overview

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Abstract

A joint Canadian-United States exercise involving the intentional spilling of approximately 20,000 gallons of specially-treated crude oil was conducted off Newfoundland in September 1987 to evaluate the containment and recovery capabilities of three state-of-the-art booms and skimmers. As part of the exercise, data were collected on a specially-instrumented oil spill boom in an attempt to verify a proposed performance test procedure for open-ocean oil spill booms. A visco-elastic chemical additive was used, after the equipment evaluation was completed to enhance recovery operations. Additional observations were made on the persistence of spilled oil slicks in advanced sea states. The containment and recovery effort was one of the most successful on record and was conducted in winds and sea states commonly thought to be beyond existing capabilities.

Introduction

An intentional oil spill of 18,000 U.S. gallons was conducted on September 24, 1987, offshore of St. John's Newfoundland to evaluate the containment and recovery capability of three booms and skimmers. The spill also provided an opportunity to verify a nonpolluting performance evaluation procedure for offshore oil containment booms. The spill was conducted approximately 25 nautical miles east of St. John's. Ocean dumping permit requirements included SSW currents and westerly winds to minimize chance of shoreline contact; water depths of at least 100 meters; the site had to be at least 25 nautical miles from shore, and the area had to be within 2 to 3 hours steaming from St. John's. The center of the area selected was 47 degrees, 40 minutes North and 52 degrees, 03 minutes West.

A crude similar to the typical high wax Grand Banks crude was unavailable. Brent crude from the North Sea was alledgely treated by adding 1 percent slack wax by volume to yield an oil of similar physical properties to the Grand Banks crudes. The modified oil was to have a density of 839.8 kg/m^3 and a viscosity of 20 m Pas at 12 degrees C (Ross, 1987a). Recent information indicates that insufficient slack wax was added to reach the 1 percent by volume target level.

Meteorological conditions were recorded on the Canadian Coast Guard (CCG) Cutter "Grenfell" at 15 minute intervals. These include corrected wind velocities and air and water temperatures.

A wave rider was deployed at the test site but failed to function during the exercise. Consequently, sea conditions were estimated, with reasonable agreement, by various trained observers.

The test plan called for the deployment of three booms as follows: A 250 meter length of the specially instrumented Oil and Hazardous Material Simulated Environmental Test Tank (OHMSETT) boom would be deployed in normal catenary. Approximately 20,000 gallons of treated Brent Crude would be spilled by the command/recovery ship Terra Nova Sea into the catenary. The oil would be held in the boom for approximately 1 hour while freeboard and draft data and visual observations of oil retention were recorded. During this period, 200 meters of the Canadian Coast Guard's RO-BOOM would be deployed behind the OHMSETT boom. The tow speed would be increased to significant loss speed (0.5-1.0 knot). One end of the boom would then be released and the oil discharged into the RO-BOOM. Oil would be held in the RO-BOOM for approximately 1 hour while the oil retention capabilities were observed. The St. John's Coast Guard Vikoma Ocean Pack boom (400 meters) would be deployed behind the RO-BOOM during the observation period. The last procedure involving lost tow speeds would be repeated with the RO-BOOM, and the oil would be released into the Vikoma.

Oil would be retained in the Vikoma for approximately 1 hour. The Terra Nova Sea would then commence skimmer evaluations. Two skimmers, the Framo ACW400, and an innovative Coast Guard Heavy Oil Skimmer (HOS) would be evaluated for 20 minutes each and the remaining contained oil would be recovered by the skimmer with the better performance (Ross, 1987b).

The intent of the OHMSETT boom deployment would be to verify the hypothesis that a boom's ability to contain oil is correlated with its ability to sea keep or comply with wave-induced surface motion. If this hypothesis could be verified and quantified, future performance evaluations of offshore containment booms could be restricted to measuring seakeeping capabilities in a range of sea states. No further spills of the 20,000 gallon size of light and heavy oils would be required, in a range sea states, to evaluate each type of boom. Ocean dumping permits are difficult to obtain and intentional oil spill exercises of this magnitude approach the million dollar funding level. Intentional spills also constitute a risk of potential damage to the immediate environment. Clearly a cost-effective and nonpolluting evaluation procedure for offshore equipment is necessary to develop a predictive capability for the performance of offshore response equipment. Wind conditions desired were sea state 2 to 4, and winds from 10 to 20 knots.

Practice Run - September 21, 1987

The ships and smaller vessels sailed at 6:00 a.m. and proceeded to a location 5.5 miles off Torbay point. The CCG Grenfell then deployed the OHMSETT boom and passed one end to the CCG cutter 212 which took the boom in tow. The CCG cutter 206 then attempted to pick up the trailing end of the boom, a job which took 45 minutes. As soon as the 206 had the end of the boom secured, the two cutters attempted to tow the boom, in a "U" configuration, into a position astern of the Terra

Nova Sea. This resulted in the OHMSETT boom immediately beginning to twist on itself, and 1 hour was lost in straightening the boom. Eventually the boom was positioned relative to the Terra Nova Sea and simulated discharge of the oil was carried out. Data collection, without oil, for almost 1 hour followed.

While the OHMSETT boom was being deployed and positioned, the RO-BOOM was deployed from the CCG Sir Humphrey Gilbert and passed to CCG cutter 214. This procedure took almost 2 hours and, the RO-BOOM was rapidly positioned with respect to the OHMSETT boom because both the Cutter 214 and a Boston Whaler were able to tow the boom at speeds of 5 knots. With the RO-BOOM in position, the CCG cutters 212 and 206 commenced to maneuver, presumably to form a "J." The CCG cutter 206 then snagged the OHMSETT cable in her screws and cut it, disabling herself. This resulted in delay in the exercise while the cable was freed and, because CCG cutter 214 and the Boston Whaler were now approaching closely, the Cutter 212 took the boom and Cutter 206 in tow and cleared the area so as not to impede the exercise.

During the period in which the RO-BOOM was being deployed, the CCG Grenfell deployed the Vikoma boom. Once the simulated oil release was over, the Terra Nova Sea took the other end of the boom and the vessels formed a Catenary. After holding position relative to the RO-BOOM for a period, the ships formed a "J" with the boom and practiced deploying the skimmers.

All ships returned to harbour by 5:00 p.m.

Period Between the Dry Run and the Trial

Several meetings of the senior people involved in the exercise occurred between September 21 and September 23, 1987. It was decided to remove CCG cutter 206 from the exercise. The Boston Whaler was able to tow and hold the boom in sea state 1, but it was recognized that this would be difficult, with oil, in the desired weather. The Newfoundland Fisheries department had provided a vessel, the Bernier, and it was decided to use her and a second chartered OSV to tow the RO-BOOM.

Concern was registered that the weather might, surprisingly, be too calm on September 24, the day which looked best for the actual trail. It was, therefore, decided to interchange the OHMSETT and RO-BOOMs to take advantage of the higher winds and waves expected later in the day.

The long time required to deploy the RO-BOOM from the Sir Humphrey Gilbert led to the decision to deploy that boom from the second OSV, the Triumph Sea. Repairs were carried out on the OHMSETT boom cabling and the boom with instrumentation, was functional by 5:00 p.m. on September 23.

Since the Terra Nova Sea had oil recovery tanks on board, it was decided to dispense with the dumb barge and to release the oil directly from that OSV.

Trial with Oil on September 24, 1987

The Triumph Sea and the Bernier sailed at 3:00 a.m. All other vessels sailed at 4:00 a.m., and everyone was on station by 6:45 a.m. The Triumph Sea commenced deployment of the RO-BOOM enroute and by 7:30 a.m., the boom was ready to receive oil. Once the OHMSETT boom was deployed, at 8:15 a.m., the oil was pumped into the RO BOOM with supervision from the helicopter and a small boat.

All oil was in the boom by 9:00 a.m.

It was decided to give the news media a chance to view the test from the air and this was done from 9:00 a.m. to 10:00 a.m. During this period, the CCG cutters 212 and 214 attempted to pull the OHMSETT boom into proper position astern of the RO-BOOM and keep it there. Every attempt to move the boom, in a catenary, in the 15 knot winds blowing at the time resulted in the boom twisting. As a result the OHMSETT boom fell progressively further astern of the RO-BOOM.

At 10:30 a.m. the oil in the end of the pocket of the RO-BOOM was 30 cm thick, the wind was 15 knots, and some splash-over and significant drainage under the boom were occurring. The vessels, therefore, formed a "J" and released one end of the boom to allow the oil to flow into the OHMSETT boom. The OHMSETT boom was approximately 1 km astern, and the vessels were having trouble towing the boom in a catenary without the boom twisting. It was, therefore, decided to direct the cutters with the OHMSETT boom, to the oil, by helicopter, keeping the boom in a straight tow. After 20 minutes, the cutters were adjacent to the thick oil, and, after a further 20 minutes approximately 80 percent of the thick oil was in the OHMSETT boom. The remaining 20 percent was contained in the Vikoma boom. Data collection on the OHMSETT boom started as soon as the oil was captured and continued for 56 minutes. The CCG cutters then stopped across the path of the vessels towing the Vikoma boom and released one end of the boom. The oil spilled into the Vikoma boom catenary, and one CCG cutter trailed the OHMSETT boom at the throat of the catenary allowing the waves to wash the oil into the Vikoma boom.

The CCG Grenfell and Terra Nova Sea towed the oil filled Vikoma boom for approximately 1 hour. During this time, the wind had freshened to 15 knots to 20 knots. The boom was moving at over 1.1 knots relative to the sea, and some oil was being lost (approximately 3 mm thick). The CCG Grenfell then attempted to move ahead to form the "J" for the skimmers. Not being very maneuverable, she quickly reached 3.4 knots and the oil was lost.

With the oil now lost, the weather abated slightly. The RO boom was still streaming astern of the Triumph Sea so it was decided that she and the Bernier would form the boom into a catenary and attempt to recover the oil downwind. The helicopter had been lost to the exercise for approximately 1 hour at this time. As soon as it returned, it was refueled and sent up to assist. In the interim a small boat was used to guide the tow vessels into the heaviest portions of the slick. When the helicopter was over the thick oil, it was apparent that the vessels with the RO-BOOM were adjacent to some of the oil and unable to see it. They were, therefore, directed from the air and small boat, and managed to collect 80 to 90 percent of the thick oil which was on the surface at the time.

Oil was successfully contained and recovery was attempted using the three skimmers on board the recovery-command vessel. The first skimmer, the Heavy Oil Skimmer (HOS), was deployed and no measurable recovery was observed. The oil used was modified by adding petroleum wax so that it would resemble a typical Grand Banks crude oil. This type of oil is uncharacteristic of most crudes in that it possesses low adhesive properties. Therefore, oleophilic skimmers, which depend upon the adhesive nature of the recovered oil, do not perform well with high parafin-based oils. This was again proven with the oleophilic HOS skimmer. The skimmer was recovered after several trained observers were satisfied that the HOS skimmer had had sufficient evaluation time in the contained slick. Problems with the ability of the support arms, used to suspend both the HOS and Framo skimmers, to adjust to the roll of the vessel and short period wave action resulted in both skimmers being frequently submerged so that oil and water were washed into the sump of the skimmer.

The second skimmer the "Framo ACW-400" was deployed. The overall rate of oil recovery of the Framo was 60 gallons per minute with unknown amounts of the recovery resulting from frequent partial submergence.

At this point, it was decided by the On-scene Commander that the skimmer evaluation was complete. Additional measures were needed to ensure recovery of the remaining contained oil because the weather was deteriorating and night was falling. Accordingly, approximately 7 pounds of the visco-elastic agent "Elastol" were spread from an 8-ounce styrofoam coffee cup into the estimated 7,400 gallons of oil and oil water emulsion in the containment boom. Elastol was added because previous research funded by the Minerals Management Service and Environment Canada had shown that the elastic and adhesive properties of the oil could be increased by addition of the agent, thus making the oil more readily capturable with these types of skimmers. The Framo ACW-400 was retrieved from the slick as the "Elastol" was added and because of the operational constraints on the recovery operation, due to the weather and lateness of the day, the skimmer was not redeployed.

The weir-type skimmer, Pharos Marine GT-185, was deployed into the treated slick and recovered near capacity rates of 85 gallons per minute of oil and oil emulsion with no free water. This recovery rate was higher than anticipated and may have been even higher if the oil had been untreated. Treatment significantly increased the viscosity of the oil. The skimmer was removed from the slick, cleaned, and stored on board.

The HOS skimmer was redeployed and failed to function because of a piece of steel in the return pump. The skimmer was recovered, the steel piece removed, and then the skimmer was redeployed.

The HOS skimmer yielded a recovery rate of 50 gallons per minute with a portion of the oleophilic fabric on one of its two drums damaged. Debris was collected at this time in the ventury system used to measure recovery fluid flow rates. The debris may have contributed to the subsequent failure of the HOS skimmer return hose. No flow-rate measurements were taken before the failure. Visual observations on the amount of oil adhering to the oleophilic fabric of the HOS skimmer indicated that recovery rates were significantly increased by the addition of "Elastol."

Operations were suspended because of the advancing sea states and increasing darkness.

An overflight of the area, by helicopter, was carried out during the skimming operation. This revealed a sheen approximately 2.5 by 0.5 nautical miles with 3 patches of brown oil. It is estimated that no more than 260 gallons of oil remained in the thick patches. A further flight 18 hours later showed that only small brown patches and sheen remained, and this was rapidly dispersing.

Lessons Learned or Relearned

- Thorough proficiency with the recovery equipment to be used is essential.

  Routine practice is required.

- Large volumes of oil are necessary to realistically evaluate performance of offshore response equipment.
- The use of helicopters to direct the placement of tow vessels and the use of small vessels to monitor and advise on boom conditions are essential to maximize the efficiency of conventional recovery operations.
- Accurate measurements of the meteorological and sea conditions are necessary for accurate analysis of the evaluations.
- The requirements for slow-speed towing and manuevering of large containment booms necessitate the use of vessels with variable pitched propellers, thrusters, and good seamen in control.
- It was not possible to form a recovery configuration with two vessels while towing upwind. The third vessel was necessary for recovery in normal catenary.
- The upper meteorological and sea state limits for downwind containment and recovery were not reached during this test.
- Upwind collection proved impossible when winds approached 15 knots. This is consistent with many past observations for containment operations conducted upwind.
- Steps should be taken to avoid loss of contained oil by shipboard discharges such as cooling water impinging upon the slick.
- Tankage should be available for recovery of several times as much fluid as discharged to account for the oil and water emulsions and free water recovered.
- Analysis of the correlation of the ability of a boom to seakeep with its ability to contain oil is continuing.

- Recovery of high wax oils similar to Newfoundland crudes in 10 degrees C water is significantly enhanced by the use of "Elastol."

Disclaimer

Mention of specific products in this paper does not constitute or infer endorsement or acceptance by the Minerals Management Service, the Conservation and Protection, or the authors.

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Attachment 12

Toxicity and Soil Penetration

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Laboratory tests of ELASTOL$^{T.M.}$ (Oil Spill Combat Agent)

H.M. Laun and R. Hingmann

I. Introduction

ELASTOL$^{T.M.}$* was developed by GTA with the assistance of BASF. It is manufactured in the form of a white powder with particle sizes between 100 µm and 1000 µm (Fig.1).

Fig.1: The powder form of ELASTOL$^{T.M.}$ simplifies application.

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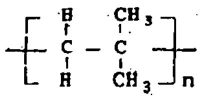
* in USA registered trademark of General Technology Applications (GTA) Inc., Manassas, Virginia; in other countries of Elastogran Polyurethane GmbH, a company of BASF group

The powder contains about 50% by weight of Polyisobutylene (PIB) of extremely high molar mass ($M_w = 6 \cdot 10^6$ g/mol). PIB is a non-toxic polymer that only consists of carbon and hydrogen atoms. The chemical composition is



$$\left[\overset{H}{\underset{H}{C}} - \overset{CH_3}{\underset{CH_3}{C}} \right]_n .$$

Fully extended the polymer chain would reach a length of about 17 µm. Granules of polymeric material are coated with water-insoluble $Ca_5(PO_4)_3OH$ salt in order to obtain an easily spreadable, non-agglomerating powder. Only the PIB-component is soluble in oil. When dissolved the macromolecules give rise to a distinct viscoelasticity as well as a drastic increase in the elongational viscosity of the solution even at PIB concentrations of only a few hundred ppm.

These properties make ELASTOL$^{T.M.}$ a very interesting oil spill treating agent [1]. The performance of skimmers is improved, the resistance to spreading and break-up is greater, and the speed of collecting barriers can be increased.

In this work we report laboratory tests with ELASTOL$^{T.M.}$ applied to different oils at various concentrations. The intention is on one hand to give quantitative data on both the rheological properties of the ELASTOL$^{T.M.}$ treated oils and on the dissolving kinetics of the powder. On the other hand we try to illustrate the basic mechanisms that are responsible for the observed properties of the solution. These properties are mainly due to the stretching and orientation of the dissolved polymer chain. These are purely physical effects which work independently of possibly present chemically active additives.

In Table 1 the fractionated oils and crude oils used in this investigation are listed. η_0 is the zero shear rate viscosity of the oils at 25 °C.

Table 1: List of oils used in this investigation and their zero shear rate viscosities η_0 at 25 °C.

fractionated oils	η_0 [mPa·s]
petroleum	1.42
fuel oil	3.65
diesel oil (Columbia diesel)	6.9
spindle oil	7.0
transmission lubricant/petroleum 1/1 (mixture)	10.5
transformer oil	13.0
MARCOL$^{T.M.}$ 82 (Exxon)	21.6
fine mechanics lubricant	34.3
vacuum pump oil	190
transmission lubricant	713

crude oils	η_0 [mPa·s]
Quaibo	4.6
Arabmed	18.0
Venezolana/Quaibo 61/39 (mixture)	70.0

II. Rheological properties of ELASTOL$^{T.M.}$ oil solutions

1. Dependence of the solution viscosity on the type of oil

The oils listed in Table 1 were treated with both 2 000 ppm and 10 000 ppm (0.2 and 1% by weight) ELASTOL$^{T.M.}$. The solutions were produced by rolling the powder-oil mixtures in closed glass bottles at about 120 rpm and 23 °C for a time period of 30 to 70 hours.

The viscosity of the resulting solutions was determined by means of a high precision Couette Rheometer (Contraves LS 30). This instrument can measure shear stresses ranging from about $3\cdot10^{-4}$ Pa to 4 Pa in a shear rate range between $3\cdot10^{-3}$ s^{-1} and 100 s^{-1}.

In general the PIB solutions are non-Newtonian, viz. the viscosity of the fluid is dependent on the shear rate. In our measurements, therefore, shear rates small enough to get the constant viscosity η_s at the limit of small shear rates (zero shear rate viscosity) were used. The data are listed in Table 2.

Table 2: Viscosity increase due to ELASTOL$^{T.M.}$ (dissolved by rolling) in various oils for powder concentrations of 2 000 and 10 000 ppm. Viscosities were measured at 25 °C.

oil		c = 2 000 ppm		c = 10 000 ppm	
	η_0 [mPa·s]	η_s [mPa·s]	η_r	η_s [mPa·s]	η_r
petroleum	1.42	3.02	2.13	23.3	16.3
fuel oil	3.65	7.54	2.07	52.3	14.3
spindle oil	7.0	15.1	2.16	97.1	13.9
transmission lubricant/ petroleum 1/1	10.45	17.1	1.64	83.4	7.9
transformer oil	13.0	22.7	1.75	122.6	9.4
MARCOL$^{T.M.}$ 82	21.6	36.1	1.67	178	8.2
vacuum pump oil	190	238.4	1.25	908	4.8
transmission lubricant	713	845.6	1.19	1656	2.3
Quaibo	4.6	8.5	1.85	46.2	10.0
Arabmed	18.0	24.0	1.33	74.6	4.1
Venezolana/ Quaibo 61/39	70	83.7	1.20	241	3.4

In the case of the most viscous oils (vacuum pump oil, transmission lubricant) and a powder concentration of 10 000 ppm the PIB could not entirely be dissolved even after a rolling time of > 70 h. For these two samples the η_s-values only represent lower limits of the viscosity of a homogeneous solution.

The relative viscosities η_r

$$\eta_r = \eta_s/\eta_0 \tag{1}$$

also listed in Table 2 are the ratios of solution viscosity and oil viscosity. η_r increases with increasing powder concentration. It is also seen that the relative viscosity increase due to ELASTOL$^{T.M.}$ becomes smaller with increasing viscosity of the oil. For 1% concentration we get a relative viscosity of 16.3 for petroleum, compared to 4.8 for vacuum pump oil.

In Figure 2 and Figure 3 the relative viscosities are plotted versus the logarithm of the oil viscosity for 2 000 ppm and 10 000 ppm powder, respectively. It is interesting to note that for the

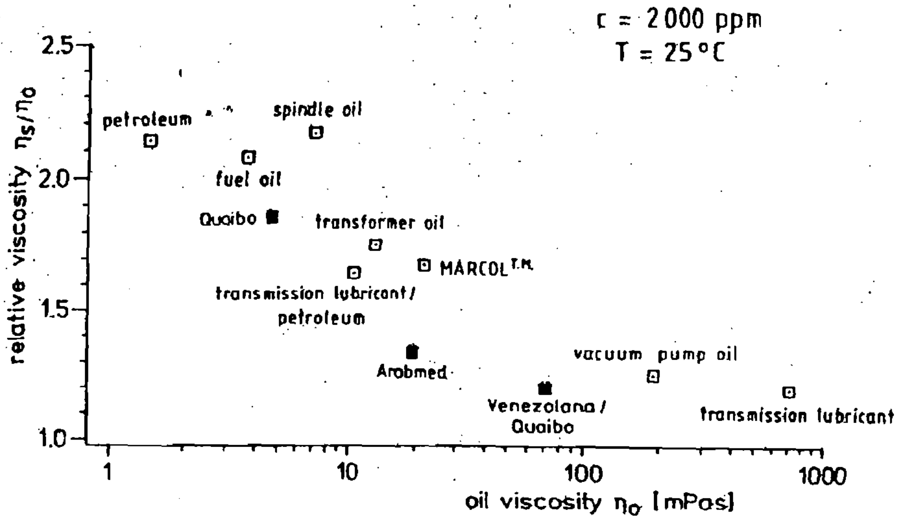


Fig.2: Relative viscosities η_r for various oils as obtained after rolling powder oil mixtures with an ELASTOL$^{T.M.}$ concentration of 2 000 ppm at 25 °C. Open symbols represent fractionated oils, full symbols crude oils.

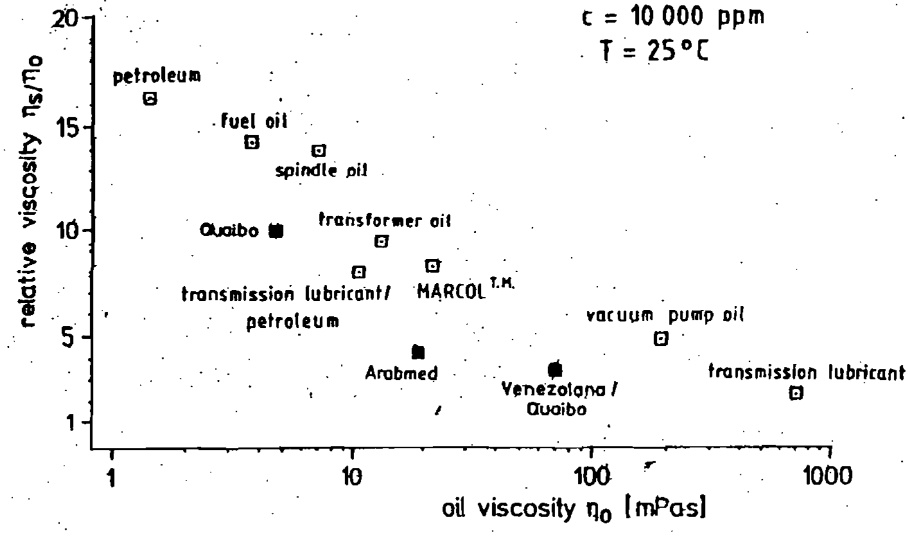


Fig.3: Same as Fig.1 for an ELASTOL$^{T.M.}$ concentration of 10 000 ppm.

1/1 mixture of petroleum and transmission lubricant as well as for the crude oils, the relative viscosities are significantly smaller compared to fractionated oils of similar viscosity. A possible explanation for the observed effect might be the reduction of the coil extension in the oil mixtures due to changes in the average polymer-solvent interaction.

2. Dependence of solution viscosity on powder concentration

Zero shear rate viscosities η_s were measured on solutions in petroleum and fuel oil at various concentrations. For this purpose base solutions having 6 000 ppm ELASTOL$^{T.M.}$ were prepared and subsequently diluted by adding solvent. The resulting data are shown in Figure 4.

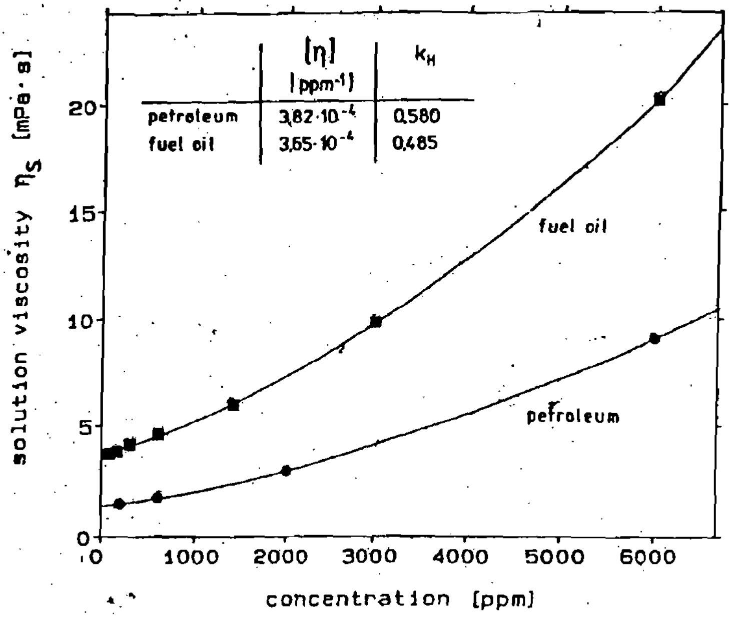


Fig.4: Solution viscosity η_s versus ELASTOL$^{T.M.}$ concentration for petroleum and fuel oil. Full lines represent the fit by the Huggins equation (see text) using the parameters given in the inserted table.

The viscosity of the solutions increases stronger than proportional to the powder concentration in the range tested. The experimental results are nicely described by a polynomial of order 2 (full lines) as proposed by Huggins [2]:

$$\eta_s = \eta_0 \left(1 + [\eta]c + k_H [\eta]^2 c^2\right) \quad , \qquad (2)$$

$[\eta]$ being the intrinsic viscosity and k_H the Huggins constant. The values determined by a best fit to the data points are given in the diagram.

3. Viscoelasticity of ELASTOL$^{T.M.}$ solutions

The solutions were submitted to small amplitude oscillatory shear in a rotational rheometer using bi-cone geometry. The apparatus is schematically depicted in Figure 5. A gap angle of $\alpha = 3.8°$ and angular frequencies $\omega = 2\pi f$ (f frequency of the oscillation) in the range of 0.2 to 18 s^{-1} were used. The shear amplitude was $\hat{\gamma} = 0,5$.

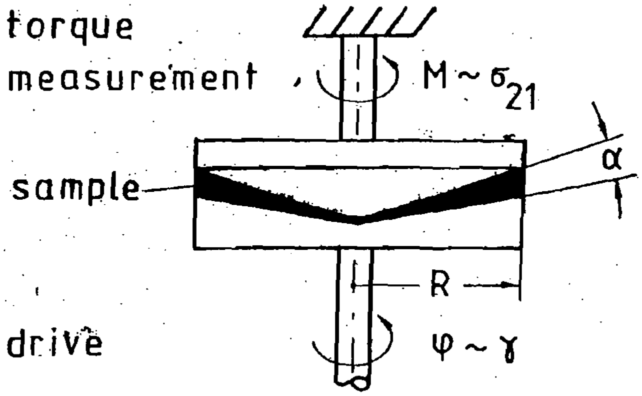


Fig.5: Schematic drawing of the bi-cone geometry used for small amplitude oscillatory shear.

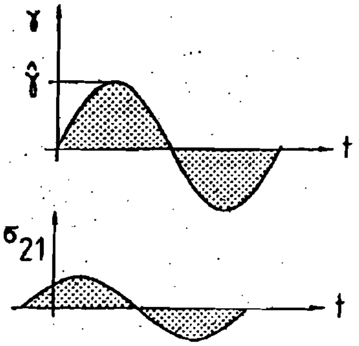
The resulting shear stress σ_{21} is oscillating at the same frequency but is phase shifted compared to the shear strain γ [3] (see Fig.6). It can be decomposed into Sine and Cosine components by means of a frequency response analyzer.

The direct output of the measurements are the storage modulus G' and the loss modulus G" as functions of the angular frequency ω. In our experiments the contribution of inertia forces to G' has been corrected for analytically.

shear strain γ:

$$\gamma = \hat{\gamma} \sin \omega t$$

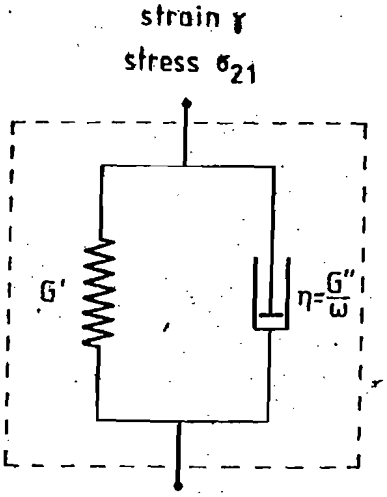
shear stress σ_{21}:



$$\sigma_{21} = \hat{\gamma}\,[\underbrace{G'}_{\text{storage modulus}} \sin \omega t + \underbrace{G''}_{\text{loss modulus}} \cos \omega t]$$

Fig.6: Decomposition of the phase shifted oscillating shear stress into two components yields the storage modulus G' and the loss modulus G".

In general the response of solutions to oscillatory shear can be described by an elastic spring G' and a dashpot $\eta = G''/\omega$ arranged in parallel [3] (Fig.7). A purely viscous fluid of viscosity η can be represented by the dashpot alone and the shear stress is proportional to the shear rate $\dot{\gamma}$ which yields a phase shift of 90 degrees between stress and strain. The dissipated energy per cycle is proportional to the loss modulus G". An elastic material (e.g. ideal rubber) can be represented by the spring. Here the stress is proportional to the strain (no phase shift). The storage modulus G' represents the spring constant and is proportional to the stored energy per cycle. A viscoelastic material has both components. The quantity G'/G" is equal to the ratio of stored and dissipated energy.



$$\sigma_{21}=G'\gamma+\eta\dot{\gamma}=G'\gamma+\frac{G''}{\omega}\dot{\gamma}$$

Fig.7: Representation of the response a viscoelastic fluid to oscillatory shear by a spring and dashpot arranged in parallel (G' and G" are frequency dependent).

The behaviour of long polymer chains dissolved in a viscous fluid (PIB macromolecules dissolved in oil in our case) can be understood as follows: at rest the molecules have a random coil like equilibrium conformation (left side of Fig.8). In a flow field the random coils immobilize part of the solvent giving rise to the observed viscosity increase with increasing polymer concentration.

If the equilibrium coil conformation remains undisturbed the solution would behave in a purely viscous manner.

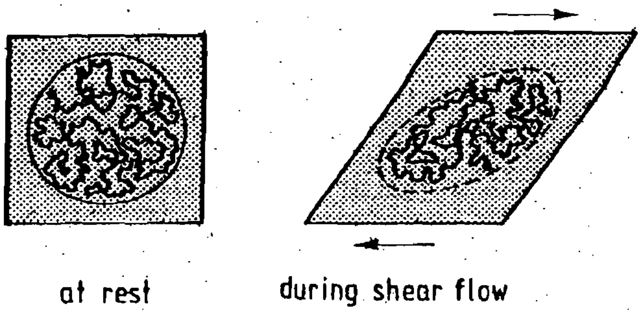


Fig.8: Equilibrium conformation (random coil) at rest and deformed state during flow of a macromolecule in solution (schematic).

In reality, during flow the molecule attains an ellipsoidal conformation (right side of Fig.8) and will partially be oriented parallel to the direction of flow. This deformation of the coil, however, is reversible. When the flow is stopped the molecule will re-establish its equilibrium conformation. This process takes some time and is governed by a characteristic retardation time τ. An estimate for the characteristic time is possible based on the moduli G' and G'':

$$\tau = G'/\omega G'' \quad . \qquad (3)$$

It must also be mentioned that, if the solution is not kept under shape constraint after removal of the shear deformation, the re-attainment of the equilibrium random coil conformation will result in a reversed shear of the sample (Fig.9). The total recoverable strain γ_r, although difficult to measure on dilute solutions, may also be used as a direct measure of the elasticity of the sample besides the ratio G'/G''.

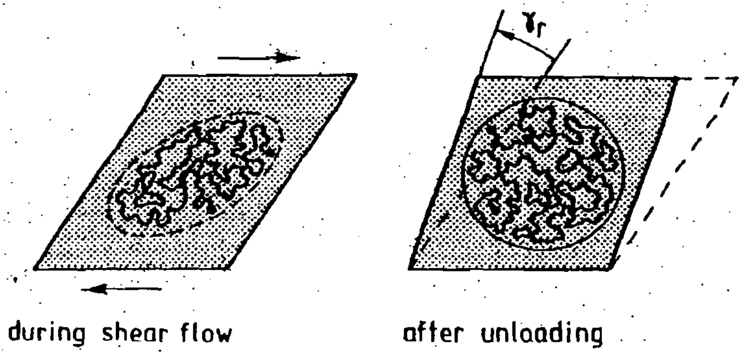


Fig.9: Recoverable shear strain of a viscoelastic solution after unloading due to the desorientation of deformed molecules.

Coming back to our measurements of the moduli G' and G" it is important to note that small amplitude oscillatory shear measures the viscoelasticity of the solution at small deviations from the equilibrium (coil-like) conformation of the dissolved PIB molecules.

As an example Figure 10 shows the measured dynamic moduli of a 16 000 ppm solution of ELASTOL$^{T.M.}$ in petroleum. The pronounced viscoelasticity of the solution is evident from the fact that besides the loss modulus a distinct storage modulus can be measured. The ratio G'/G" increases with growing angular frequency.

The viscosity $|\eta^*|$ represented by the full symbols is calculated from the moduli according to

$$|\eta^*| = \frac{1}{\omega} \sqrt{G'^2 + G''^2} \quad . \tag{4}$$

This quantity is very close to the value of the viscosity in steady shear flow if ω is equal to the shear rate [4]. Thus, the decrease of $|\eta^*(\omega)|$ with increasing angular frequency reflects the non-

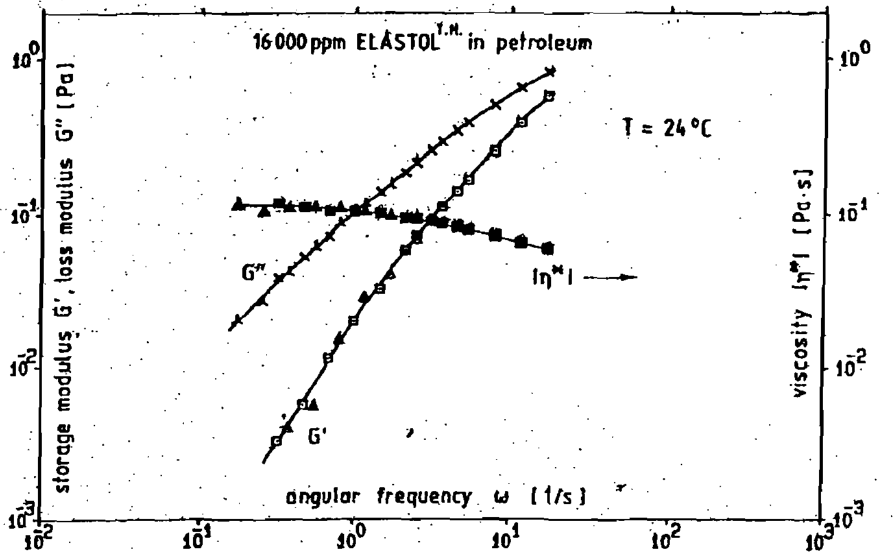


Fig.10: Storage and loss moduli (open symbols) and viscosity (full symbols) versus angular frequency of an ELASTOL$^{T.M.}$ solution in petroleum at 16 000 ppm and 24 °C.

Newtonian behaviour of the solution, viz. the shear viscosity decreases with increasing shear rate. Again, this behaviour can be understood in terms of Fig.8. Deformed and partially oriented macromolecules give rise to a viscosity decrease depending on the shear rate.

Figure 11 shows the concentration dependence of the moduli in diesel oil. The pure oil (full circles) is Newtonian and does not have a measurable storage modulus. In that case G" increases proportional to ω, the ratio G"/ω being equal to the viscosity η of the oil [3].

With increasing ELASTOL$^{T.M.}$ concentration the storage modulus grows stronger than the loss modulus. For ω = 1 s^{-1} (0.13 Hz) a fourfold increase in concentration (4 000 ppm to 16 000 ppm) yields a G" growth of less than a factor of 20 whereas the storage modulus

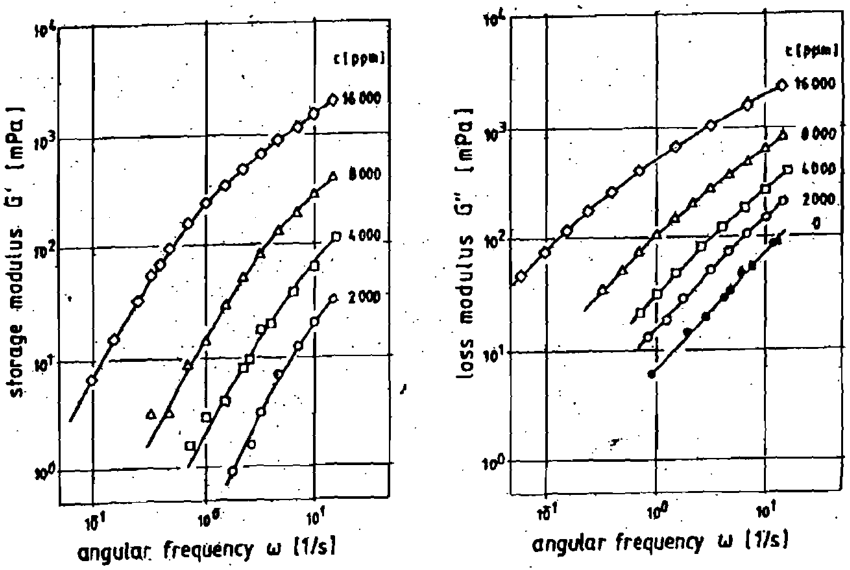


Fig.11: Storage modulus (left diagram) and loss modulus (right diagram) versus angular frequency of ELASTOL$^{T.M.}$ solutions in diesel oil at various concentrations and 24 °C. The pure oil does not have a measurable storage modulus.

increases approximately 100-fold. As a result, the ratio G'/G" at a given frequency (cf. Table 3), taken as a quantitative measure of the viscoelasticity, increases considerably. It is also seen that in the same sequence the increase of G" is less than proportional to ω.

A comparison of the dynamic moduli for a constant ELASTOL$^{T.M.}$ concentration of 2 000 ppm in various oils of different viscosities is shown in Figure 12.

Table 3 gives a compilation of the moduli measured on various solutions. Here, the G' and G" are compared at a constant angular frequency of $\omega = 1.26\ s^{-1}$ (f = 0.2 Hz) and 24 °C. Besides the

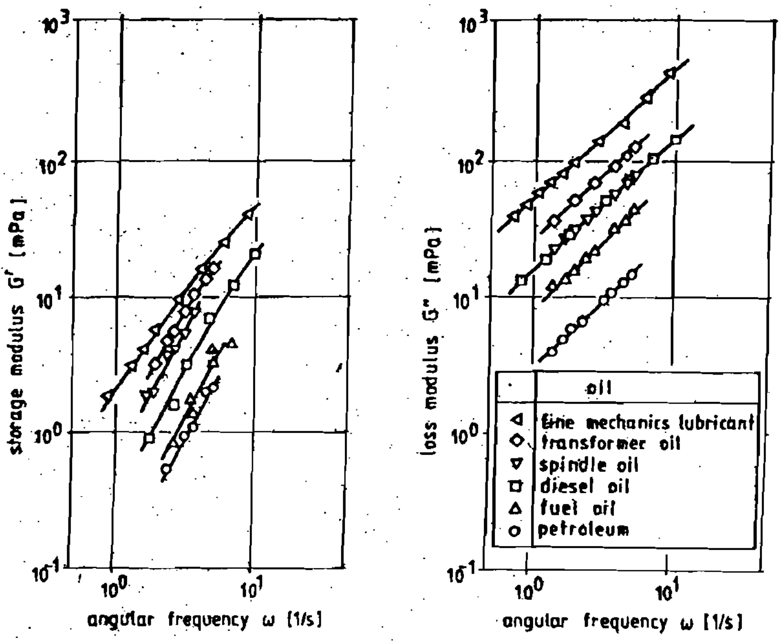


Fig.12: Storage modulus (left diagram) and loss modulus (right diagram) versus angular frequency for ELASTOL$^{T.M.}$ soulutions in various oils at a constant concentration of 2 000 ppm and 24 °C.

viscosity $|\eta^*|$ (Equ. (4)) and the ratio G'/G" this table also gives the characteristic relaxation time τ (Equ. (3)). For each oil both G'/G" and τ increase with growing concentration. The most pronounced changes are observed in the characteristic time.

Table 3: Dynamic moduli and viscoelastic properties of various solutions measured at $\omega = 1.26\ s^{-1}$ by means of small amplitude oscillatory shear.

	c [ppm]	G" [mPa]	G' [mPa]	$\lvert\eta^*\rvert$ [mPa·s]	G'/G"	τ [ms]
petroleum	0	1.6	-	1.3	-	-
./.	8 000	23	1.6	18	0,07	55
./.	16 000	125	25.6	102	0.21	140
fuel oil	0	4.8	-	3.8	-	-
./.	4 000	12	0.35	8.8	0.03	23
./.	8 000	24	1.1	19	0.05	36
diesel oil	0		-		-	-
./.	2 000	20	≈ 0.4	16	≈ 0,02	≈ 16
./.	4 000	39	3.2	31	0.08	65
./.	8 000	125	21.6	105	0.17	137
./.	16 000	590	290	523	0.49	390
spindle oil	0	8.9	-	7.1	-	-
./.	2 000	18	0.65	14	0.04	29
./.	4 000	33	2.1	26	0.06	51
./.	8 000	85	12.6	68	0.15	118
transformer oil	0	16	-	13	-	-
./.	2 000	34	2.3	27	0.07	54
fine mechanics lubricant	0	42	-	33	-	-
./.	2 000	67	3.0	53	0.04	35

4. Drawability (elongational viscosity) of ELASTOL$^{T.M.}$ solutions

One of the most striking effects of ELASTOL$^{T.M.}$ dissolved in oil is the dramatic increase in resistance to elongational flows. When the solution is stretched the PIB molecules are oriented which yields an elongational viscosity greater than three times the shear viscosity [5]. This behaviour is best demonstrated in the ductless siphon test [6] (Fig.13).

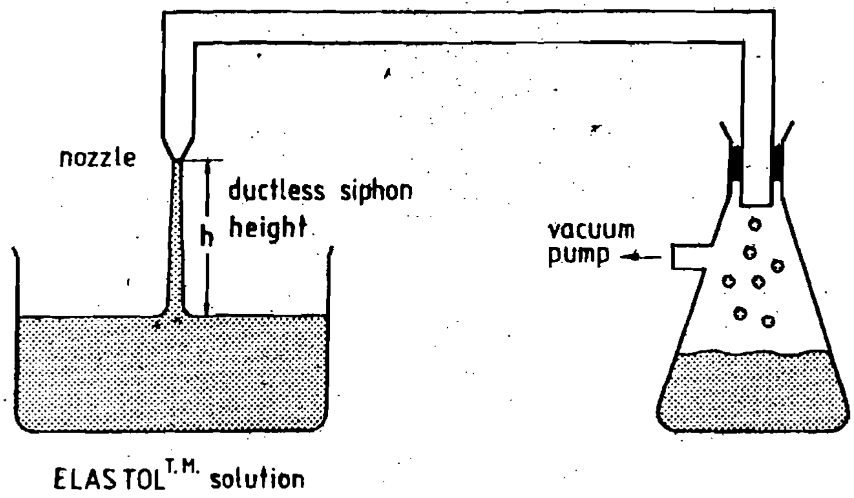


Fig.13: Schematic drawing of the ductless siphon test method. The ductless siphon height is gradually increased until break of the filament at h_{max}.

A pipe being connected to a vacuum pump carries a nozzle at its other end. The solution is contained in a beaker. When the nozzle is brought into contact with the meniscus of the solution the latter is sucked out of the beaker. The distance h between nozzle and solution meniscus is increased either by slowly lowering the container position or just due to the decreasing meniscus height for a fixed beaker position. The solution will still flow upward until at a maximum ductless siphon height h_{max} the filament breaks.

For an untreated oil, in general, the maximum ductless siphon height will be in the order of 1 mm. With ELASTOL$^{T.M.}$ h_{max} is much greater and may reach values of half a meter or more. This behaviour is of tremendous importance for the performance of collecting devices used for oil spill combat.

A photograph of the spinline in the ductless siphon test is shown in Fig.14 for a 4 000 ppm solution in fine mechanics lubricant (with red dye) and a nozzle diameter of 1 mm. The distance between the nozzle and the solution meniscus was 20 cm.

Fig.14: Ductless siphon test on a 4 000 ppm solution in fine mechanics lubricant. Nozzle diameter 1 mm.

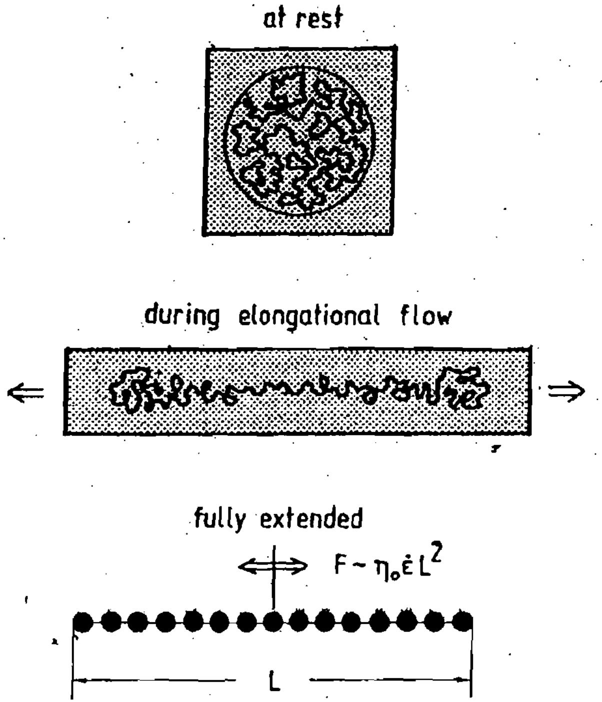


Fig.15: Stretching of the polymer chain when the solution is subjected to an elongational flow field (schematic).

The physical reason for the high elongational viscosity is schematically depicted in Fig.15. At rest the molecule has a coil like conformation, but in an extensional flow field, the molecule is stretched. The degree of stretching is dependent on the rate of strain of the solution and the duration of extensional flow. The sum of friction forces due to the surrounding solvent molecules has an opposite sign on both sides of the center of mass. Therefore, the extensional forces acting on the molecule are maximal in the middle of the chain and the orientation of chain segments parallel to the direction of strain is most pronounced in that region.

For the extreme case of a fully extended chain (bottom diagram in Fig.15) it is easy to show that the force F acting in the center of the molecule is proportional to the chain length L, the solvent viscosity η_0, and the strain rate $\dot{\varepsilon}$ [7]. The force F may even become higher than the chemical bond of the backbone. Under that condition the molecule will break [7].

It is obvious that in the case of long molecules the resistance to elongational flow is mainly governed by the force F that can be transmitted by each single molecule from one volume element to another and the concentration of dissolved macromolecules. In summary, we expect the elongational viscosity μ [5] of the solution

$$\text{elongational viscosity } \mu = \frac{\text{tensile force/cross section}}{\text{extension rate}} \qquad (5)$$

to increase with strain rate, solvent viscosity, and polymer concentration.,

It should also be noted here that the stretched molecules store energy since the orientation process is fully reversible (chain rupture excluded). When the strain rate is set to zero the deformation of the molecule will decay with time until the coil conformation is re-established. Without shape constraint this process will cause a shrinkage (recoverable strain) of an elongated solution filament.

The measured ductless siphon heights h_{max} of petroleum, fuel oil, and spindle oil versus ELASTOL$^{T.M.}$ concentration are plotted in Figure 16. We observe a monotone increase of h_{max} with increasing powder concentration in petroleum. For fuel oil and spindle oil, however, h_{max} goes through a reproducible minimum. It appears that the concentration corresponding to the filament length minimum is shifted to smaller values when the oil viscosity is increased. Most probably this effect is not caused by a minimum in the true resistance of the filament to stretching but by problems in the nozzle flow due to the shear viscosity which increases with concentration.

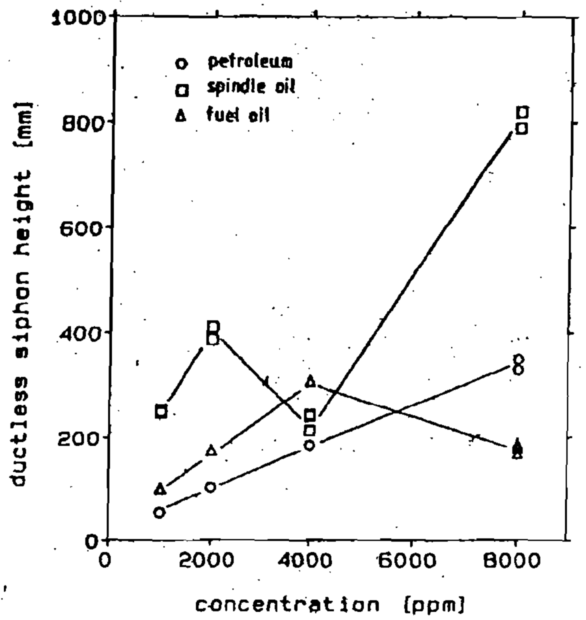


Fig.16: Maximum ductless siphon heights at room temperature for three oils versus ELASTOL$^{T.M.}$ concentration (nozzle diameter 1 mm).

Thus, for a direct comparison of the effect of ELASTOL$^{T.M.}$ on the drawability in various oil solutions one should restrict the measurements to concentrations below the minimum. In that range the behaviour may be approximated by the power law

$$h_{max} = K_{DS}\ c^{\alpha} \quad , \qquad (6)$$

the exponent α having values in the range of 0.75 to 0.95.

Table 4: Ductless siphon heights h_{max} at filament break for various oils and at an ELASTOL$^{T.M.}$ concentration of 2 000 ppm.

oil	η_0 [mPa·s]	h_{max} [mm]
petroleum	1.42	100
fuel oil	3.8	187
spindle oil	7.0	380
transformer oil	13.0	471
fine mechanics lubricant	34.3	805
petroleum + SEPAROL$^{T.M.}$ AF 27	-	99

Table 4 gives a compilation of the measured h_{max} values in various oils for a constant ELASTOL$^{T.M.}$ concentration of 2 000 ppm. The maximum ductless siphon height strongly increases with increasing oil viscosity. Therefore, the higher the oil viscosity, the lower the concentration of ELASTOL$^{T.M.}$ required to obtain a given value of h_{max}.

As already mentioned, the drawability of ELASTOL$^{T.M.}$ solutions is an exclusively physical phenomenon. The application of chemical additives (for instance emulsion breakers) should have no influence on the ductless siphon heights. This was experimentally verified for petroleum treated with 2 000 ppm ELASTOL$^{T.M.}$ and 100 ppm SEPAROL$^{T.M.}$* AF 27 (emulsion breaker). The same value of h_{max} as given in Table 4 for the pure petroleum was observed.

The drawability increase due to ELASTOL$^{T.M.}$ is of great advantage in collecting oil floating on a water surface by means of a vacuum skimmer. A field test with crude oil from ERM (= refinery Mannheim) spread on water in a training basin gave the following results: In the case of untreated oil 90% water and only 10% oil were collected. After the application of 6 000 ppm ELASTOL$^{T.M.}$ powder 95% oil and only 5% water were collected [8]. Fig.17 shows that the oil film is pulled from the water surface without rupture and can easily be sucked by the vacuum skimmer over a distance of about 15 cm.

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Fig.17: Example of the improved performance of a vacuum skimmer in collecting crude oil (ERM) from a water surface [8].

5. Consequences of ELASTOL$^{T.M.}$ on droplet formation

Fig.18 shows schematically the break up of an oil droplet into two smaller droplets due to an elongational flow field. Once a neck is formed the neck is elongated until break of the strap. The formation of smaller droplets continues until the rheological forces can no longer overcome the stabilizing effect of the interfacional tension.

With dissolved macromolecules, however, it is possible to prevent the formation of very small droplets [6]. Here, the limiting drop size is governed by the resistance of the strap to stretching. When the elongational viscosity in the neck is increased the break up process will come to an end at a bigger droplet size.

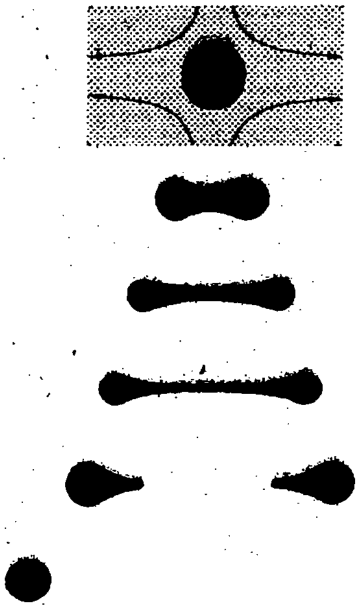

Fig.18: Formation of smaller droplets in an elongational flow field (schematic).

The consequence for oil/water mixtures is demonstrated by Fig.19. Two glass bottles were partially filled with water. In the right bottle pure Heizöl was used whereas in the left bottle the oil was treated with 10 000 ppm ELASTOL$^{T.M.}$. The closed bottles were shaked by hand for a given time period. After a settling time of about 10 seconds we observe in the right bottle a milky emulsion of very small oil droplets in water. The water and oil phases are hardly separated. In the case of the ELASTOL$^{T.M.}$ treated oil (right) we get a coarse emulsion by shaking. The separation of water and oil is nearly complete after 10 seconds.

Fig.19: Diesel oil/water mixtures after shaking and a settling time of 10 seconds. Pure oil (right), oil treated with 10 000 ppm ELASTOL$^{T.M.}$ (left).

III. Dissolving behaviour of ELASTOL$^{T.M.}$ powder

a) General behaviour

The efficiency of ELASTOL$^{T.M.}$ in treating oil spills is strongly dependent on the dissolving speed of the powder after being spread onto oil layers floating on water. To simulate this situation on a laboratory scale a beaker of 150 mm diameter was partially filled with water. Oil was layered onto the water surface to a thickness of 5 mm. ELASTOL$^{T.M.}$ powder corresponding to 10 000 ppm of the weight of oil was "homogeneously" spread on the oil layer.

Fig.20: Side view of an oil layer floating on water. ELASTOL$^{T.M.}$ was spread on top of the oil and sedimented to the oil/water interface from where it dissolves.

After application, the powder rapidly sedimented to the water/oil interface (Fig.20). From there, the PIB component gradually dissolved in the oil phase, whereas the water-insoluble salt remained in particulate form at the interface. As a measure of the effective solution concentration we determined the oil solution viscosity as a function of time. For this purpose small samples were withdrawn at different time intervals using a syringe. Precautions were taken not to collect undissolved PIB.

b) Solution viscosity with and without agitation

Figure 21 shows the solution viscosity versus logarithmic time as measured for fuel oil at a powder concentration of 10 000 ppm. In a first test series depicted by full circles the dissolving of ELASTOL$^{T.M.}$.

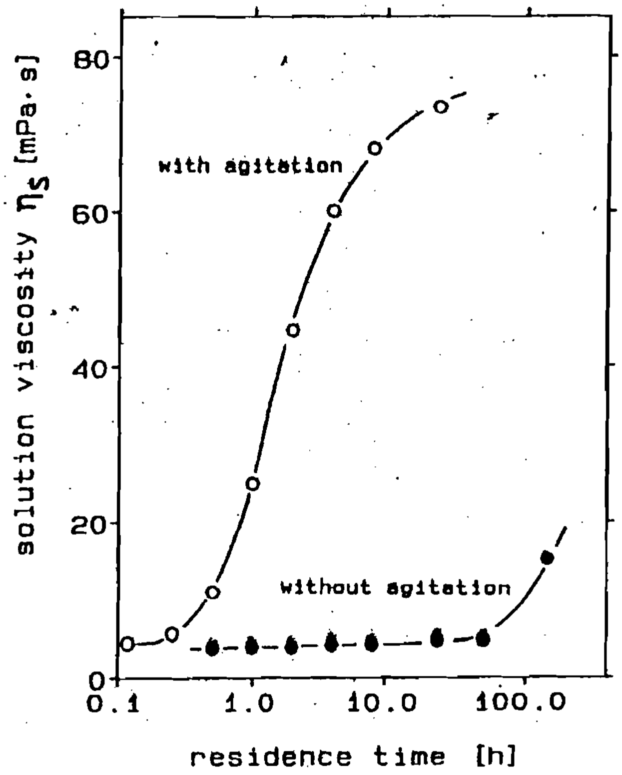

Fig.21: Relative solution viscosities of fuel oil layers (5 mm thickness) floating on top of water versus time elapsed after application of ELASTOL$^{T.M.}$ by spraying (concentration 10 000 ppm related to the total weight of oil) with (open circles) and without (full circles) gentle stirring.

took place without any agitation. Obviously, in that case a significant increase of the solution viscosity is only observed at times greater than 100 hours.

In a second series of tests a gentle agitation was attained by stirring. A schematic drawing of the arrangement is shown in Figure 22. The rotary speed of the stirrer was 0.5 revolutions per second. As can be seen from Fig.21 the gentle agitation drastically increases the speed of dissolving (open circles). A significant increase in the oil solution viscosity was observed after only 0.5 hours.

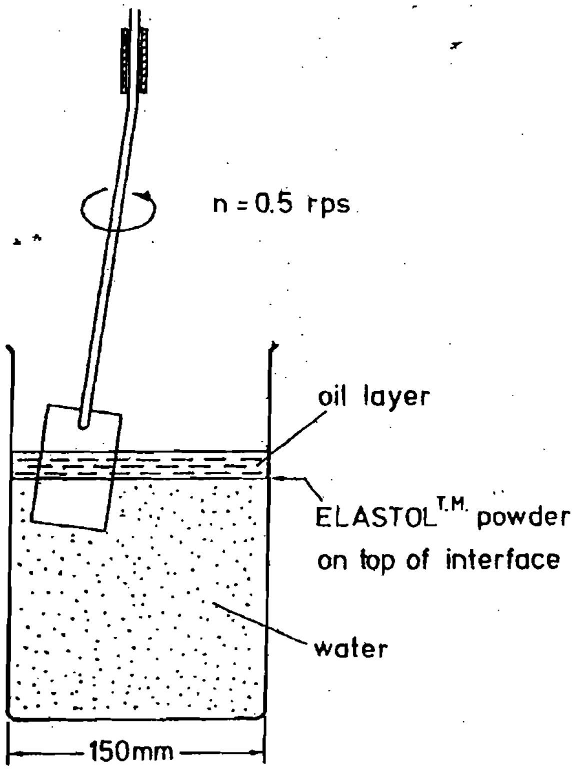

Fig.22: Experimental arrangement for the dissolving tests with stirring.

Similar dissolving tests with stirring were performed with various oils. The relative solution viscosities η_r (solution viscosity related to the oil viscosity) versus the oil viscosity η_0 are plotted in Figure 23. The data obtained by this method are more complex to interpret than those obtained by rolling (cf. Figs. 2 and 3). This is because partial evaporation of the oil has to be taken into account which is different for the various solvents. This explains why viscosities from the stirring experiment may be higher than those for solutions prepared by rolling in closed glass bottles.

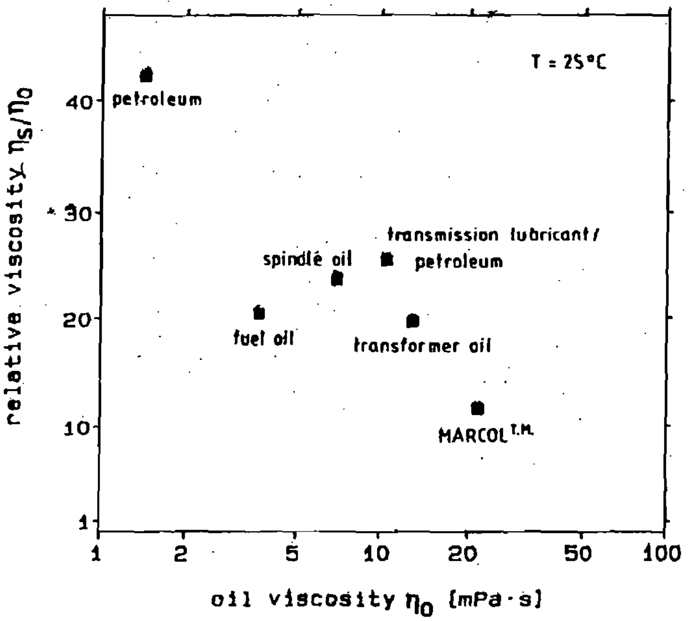

Fig.23: Relative viscosities of the various oil layers measured at the end of a 24 h stirring period. The initial powder concentration was 10 000 ppm related to the total weight of the oil on water.

c) Comparison of dissolving speeds

By comparing the viscosities determined for solutions prepared by rolling and the results obtained in the dissolving tests with gentle stirring (neglecting the influence of partial evaporation) we can evaluate the time necessary to dissolve an effective concentration of 2 000 ppm ELASTOL$^{T.M.}$ out of a total powder concentration of 10 000 ppm. The necessary times are plotted in Figure 24 as a function of the oil viscosities η_0 (double-log representation). The increasing dissolving time is approximately proportional to the oil viscosity.

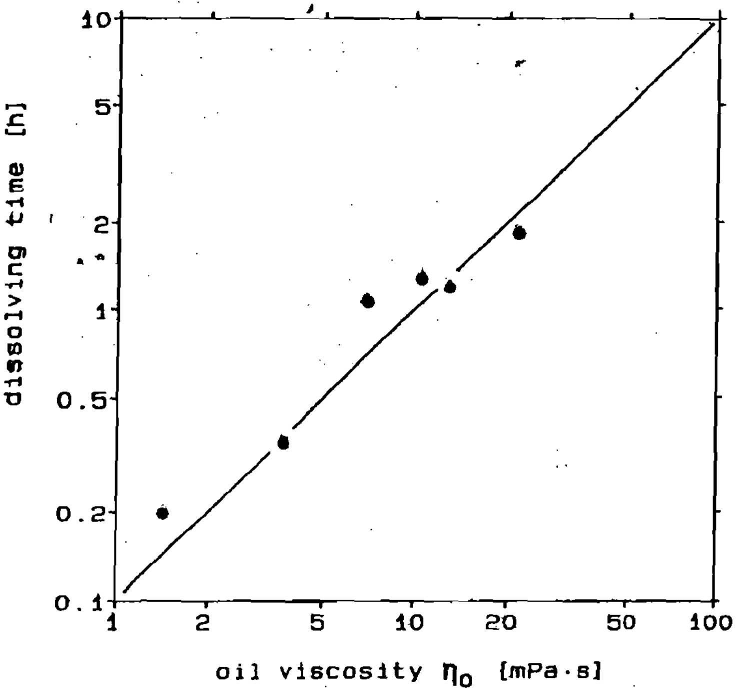

Fig.24: Dissolving time for 2 000 ppm ELASTOL$^{T.M.}$ out of an initial powder concentration of 10 000 ppm versus oil viscosity. The effect of partial evaporation during stirring is neglected here.

The data in Fig.24 can at least approximately be generalized to estimate the effect of temperature on the dissolving time. For instance, if the viscosity of the oil increases by a factor x when the temperature is lowered by ΔT compared to room temperature, the necessary dissolving time of the powder will be longer by the same factor x.

d) Dissolving speeds at various concentrations

The effect of powder concentration on the speed of dissolving is demonstrated in Table 5 for petroleum. ELASTOL$^{\text{T.M.}}$-concentrations of 10 000 ppm (as in Fig.24) and of 4 000 ppm were used. It is clearly seen that the necessary time to dissolve 20% of the initial powder is significantly shorter for the smaller concentration (11.8 and 8.4 min, respectively). This means that the dissolving times given in Fig.24 for 10 000 ppm powder cannot be generalized for other concentrations. However, since for practical applications the ELASTOL$^{\text{T.M.}}$ concentrations will presumably be lower, we can regard the data of Fig.24 to represent an upper limit of dissolving times for the relatively weak kind of agitation used in our tests.

Table 5: Comparison of dissolving times for two different ELASTOL$^{\text{T.M.}}$ concentrations in petroleum (evaporation neglected) with stirring as in Fig.22.

powder concentration [ppm]	dissolved fraction [ppm]	necessary dissolving time [min]	solution viscosity [mPa·s]
4 000	800	8.4*	1.93
4 000	4 000	39	5.51
10 000	800	6.0	1.93
10 000	2 000	11.8*	2.99
10 000	10 000	78	18.9

* 20%-values

Another result that can be deduced from Table 5 concernes the dissolving time for a given absolute concentration of the solution, e.g. 800 ppm. Whereas for 4 000 ppm applied powder a dissolving time of 8.4 min is necessary the same concentration will be achieved within only 6.0 min if 10 000 ppm of powder are spread onto the oil layer. This result is not at all surprising but has to be kept in mind for practical applications.

IV. Water/crude oil emulsions

The formation of extremely stable water-in-crude oil emulsions, often called "chocolate mousse", is a major problem in combatting oil spills at sea. These emulsions are highly viscous and their water content can be as high as 90%. They are difficult to collect and even more difficult to dispose of. According to Bredie et al. [9] the formation of these mousses depends on the presence of both wax and aspalthenes in the crude oil. These authors suggest that wax/asphaltene crystals may stabilize small water droplets in the oil, leading to a dramatic increase in viscosity.

In order to produce "chocolate mousse" on a laboratory scale we performed experiments with various water-in-oil mixtures. In one series of tests different oil-water mixtures were treated with a shaker ("red devil") in closed bottles for 15 min. As expected the formation of a stable emulsion could not be observed for dewaxed and deasphaltenized oils like transformer oil or MARCOL$^{T.M.}$ 82. After a settling time of several minutes the water and oil phases separated. For the crude oils listed in Table 2, however, stable water-in-oil emulsions were easily produced by shaking. Even after a settling period of 24 hours no phase separation was observed.

The most stable "mousse" could be produced with Arabmed (η_0 = 18 mPa·s) for which a sudden rise in viscosity of the emulsion was observed with increasing water content. For a 70% water-in-oil emulsion a viscosity of 20 mPa·s was measured, whereas for 80% (90%) water content 6.1 (8.1) Pa·s were observed.

When the same experiments were repeated on Arabmed treated with 2 000 ppm ELASTOL$^{T.M.}$ the sudden rise in viscosity in going from 70% to 80% water content was reduced by at least a factor of 4. For both 80% and 90% water content viscosities of about 1.5 Pa·s were measured indicating that ELASTOL$^{T.M.}$ improves the pumpability of "chocolate mousse".

Fig.25: Stiff "chocolate mousse" obtained by shaking Arabmed with 90% water for 15 min in the red devil (right). Crude oil treated with 2 000 ppm ELASTOL$^{T.M.}$ (left).

Fig.25 demonstrates that without ELASTOL$^{T.M.}$ a stiff and stable emulsion with yield stress forms. When treated with ELASTOL$^{T.M.}$, however, the Arabmed/water mixture was fluid even at very low shear stresses and had to be kept in a container. Also a tendency to phase separation between water and oil was evident

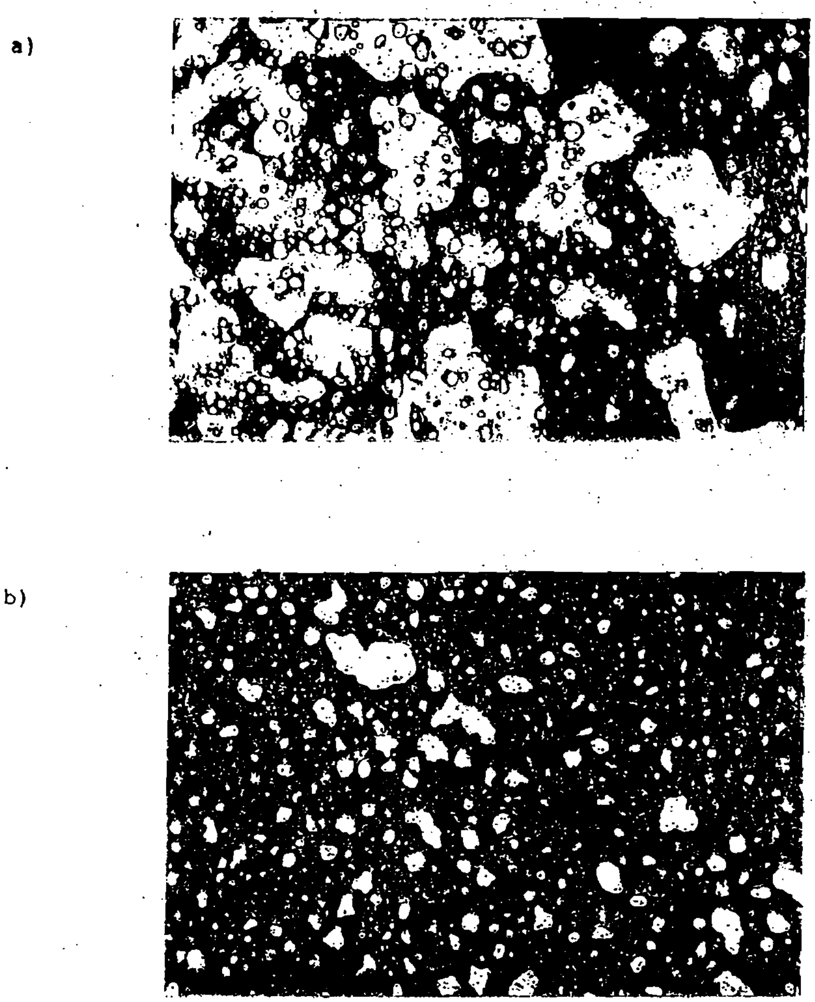

Fig.26: Light micrographs of 90% water-in-oil emulsions with Arabmed (magnification: 66 fold)
a) without ELASTOL$^{T.M.}$ b) with 2 000 ppm ELASTOL$^{T.M.}$

Microscopic analysis of emulsions produced from Arabmed and 90% water was carried out (Fig.26). Panel (a) shows the "chocolate mousse" formed with untreated Arabmed whereas Panel (b) demonstrates the effect of inclusion of 2 000 ppm ELASTOL$^{T.M.}$. Both pictures illustrate the water-in-oil character of this emulsion, but for ELASTOL$^{T.M.}$ treated Arabmed the size of the water droplets is significantly smaller.

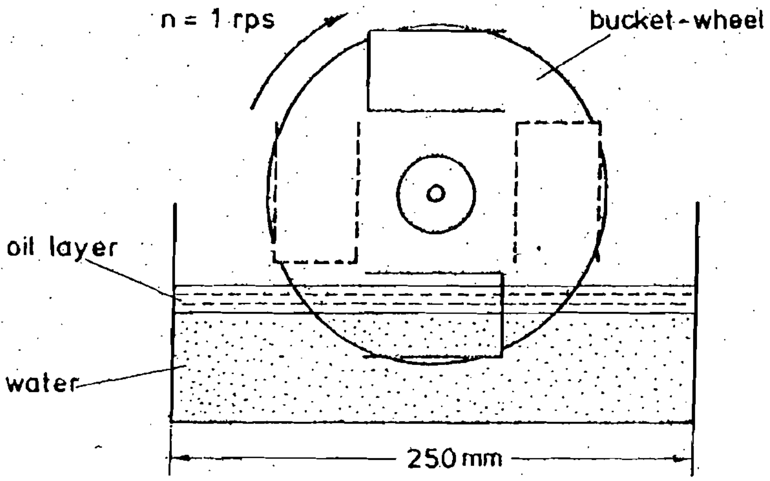

Fig.27: Experimental arrangement for the formation of "chocolate mousses" from crude oil layers floating on water.

In order to simulate the formation of "chocolate mousse" from crude oil layers floating on water more realistically, the apparatus schematically depicted in Fig.27 was used. Here the fluid was repeatedly picked up by a bucket-wheel and subsequently poured out onto the surface. In this arrangement the formation of stable emulsions was observed after stirring for less than 4 hours. After 4 hours the "chocolate mousse" formed with untreated Arabmed had a viscosity of 2 Pa•s.

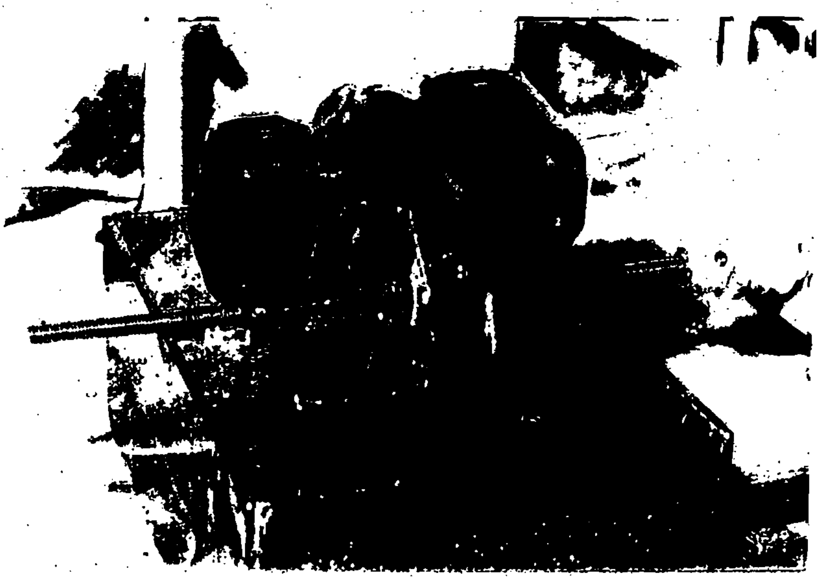

Fig.28: "Chocolate mousse" obtained with Arabmed in the bucket-wheel arrangement.

In addition, the bucket-wheel arrangement clearly shows the influence of evaporation. In Table 6 the emulsion viscosities measured after various stirring and evaporation periods are listed.

Table 6: Viscosities for "chocolate mousse" formed with Arabmed in the bucket-wheel arrangement (shear rate 2 s^{-1}).

stirring time [h]	residence time [h]	η_0 [Pa·s] untreated crude oil	η_0 [Pa·s] with 2 000 ppm ELASTOL$^{T.M.}$
4	4	2.0	1.4
8	32	7.8	2.0
12	100	12.2	2.7
16	104	5.4*	

* Addition of 2 000 ppm ELASTOL$^{T.M.}$ to the "chocolate mousse" obtained from untreated Arabmed after 100 hours .

Stirring intervals of 4 hours and various rest periods have been applied. The first column gives the total stirring time and the second column the total residence time of Arabmed in the bucket-wheel test. For the untreated crude oil the first stirring interval yields a "chocolate mousse" of 2 Pa·s. With increasing residence time due to evaporation the "mousse" viscosity increased up to 12.2 Pa·s (100 h).

When 2 000 ppm ELASTOL$^{T.M.}$ powder were spread on the mousse a drop in the emulsion viscosity to 5.4 Pa·s was observed after another stirring period of 4 hours (last line in Table 6). This means that the pumpability of the emulsion is improved and the advantage of elasticity is obtained by application of ELASTOL$^{T.M.}$ even after the formation of a stiff "mousse". When ELASTOL$^{T.M.}$ was spread on the oil layer at the beginning of the test, viz. before the formation of a "chocolate mousse", the effect of viscosity reduction was even more pronounced (fourth column).

Acknowledgement

The authors are indepted to W. Reuther, J. Steidel and Ch. Kaduk for performing the measurements and to M. Reuther for the support in preparing the diagrams.

November 1987

Appendix

Results on ELASTOL$^{T.M.}$ treated oils abtained by other authors

a) Environmental Emergencies Technology Division, Ottawa

In an extensive study Bobra and Fingas et al. [10] investigated the effect of ELASTOL$^{T.M.}$ on eight different crude oils as well as diesel in both small scale laboratory experiments and large tank tests with and without waves.

In order to measure the elastic properties of ELASTOL$^{T.M.}$/oil solutions these investigators made use of the die swell phenomenon: The diameter of a viscoelastic fluid extruded through a small capillary is greater than the die diameter, depending on the degree of elasticity of the solution. A distinct die swell was observed for ELASTOL$^{T.M.}$/oil solutions. The effect increased with increasing mixing energy, powder concentration, and temperature.

ELASTOL$^{T.M.}$ had no effect on flash point and evaporation data.

It could be shown that the spreading of oil slicks on calm water is reduced by addition of larger amounts of ELASTOL$^{T.M.}$ (> 5 000 ppm). The reduction depends on the quantity of ELASTOL$^{T.M.}$ actually dissolved in the oil. In the case of Alberta Sweet Mixed Blend (ASMB) crude oil with $\eta_0 = 9.2$ mPa·s and a powder concentration of 6 000 ppm the spreading was reduced to 1/3 of the value without ELASTOL$^{T.M.}$!

Concerning the formation of water-in-crude oil emulsions it is reported that ELASTOL$^{T.M.}$ has only a weak influence on the emulsion formation tendency, but the water content of the "chocolate mousse" is reduced considerably. For instance, 1 litre "Emulsifying Mix" (= ASMB/Bunker C 1:1) forms 10 litres of stable emulsion; after addition of 6 000 ppm ELASTOL$^{T.M.}$ only 4.3 litres are produced. This behaviour is to some extent still valid when ELASTOL$^{T.M.}$ is added after the emulsification process.

In small scale wave generating tank tests (35 litres content) it was found that ELASTOL$^{T.M.}$ treated oils have a lower fraction dispersed in the water phase than untreated oils. Furthermore, for most of the oils the water content of ELASTOL$^{T.M.}$ treated emulsions was significantly reduced (on average 65% less for 6 000 ppm). At the same time the increase in viscosity due to emulsification was strongly suppressed by ELASTOL$^{T.M.}$.

The authors report that the effect of ELASTOL$^{T.M.}$ on viscoelasticity in the presence of salt water was only slightly smaller than with fresh water.

The application of a dispersant and ELASTOL$^{T.M.}$ at the same time reduced the dispersant effectivity by 70%, however, the amount of dissolved oil was still by a factor of 1 000 higher than without dispersant.

ELASTOL$^{T.M.}$ did not negatively affect the efficiency of an emulsion inhibitor applied at the same time.

Large scale thank tests with waves (75 l Norman Wells crude oil) showed that the dissolving speed of the ELASTOL$^{T.M.}$ powder is increased with growing wave height (mixing energy). Furthermore, is was observed that in the case of waves the powder may be spread in a random manner without disadvantages for the dissolving speed and the homogenity of the final solution.

An oil spill of 75 l kept in booms (waves height 10 cm) could nearly completely (70 l) be recovered by a Morris MI-2C skimmer after the addition of 6 700 ppm ELASTOL$^{T.M.}$.

The positive results of further tests with ELASTOL$^{T.M.}$ performed off-shore by M. Fingas (Environment Canada) will be published in the near future.

b) Berlin Model Basin, VWS Berlin

At the Versuchsanstalt für Wasserbau und Schiffbau (VWS) H.O. Oebius [11] performed containment tests in a 60 m long and 2.5 m wide basin. An amount of 5 l of oil was placed on one side of a boom which could be moved by a towing carriage at variable speeds. The quantity of interest was the boom velocity at which the first droplets appear on the backside of the boom (drainage failure).

In the case of calm water a concentration of only 1 000 ppm ELASTOL$^{T.M.}$ was sufficient to increase the critical velocity from 0.24 m/s to 0.48 m/s for an oil of η_0 = 22 mPa·s viscosity (MACROL$^{T.M.}$ 82). For an oil of higher viscosity (PRIMOL$^{T.M.}$ 352, η_0 = 713 mPa·s) the increase was not so pronounced, an effect which most probably is due to incomplete dissolving of the ELASTOL$^{T.M.}$ powder at the applied mixing time of 1 h.

With waves of wave length 1.5 m and 0.13 m wave height a critical boom velocity of about 0.30 m/s was measured on MARCOL$^{T.M.}$ 82. The application of 1 000 ppm and 3 000 ppm ELASTOL$^{T.M.}$ increased the critical velocity up to 0.36 and 0.42 m/s, respectively.

Acknowledgement

The authors are grateful to Dr. M. Fingas, Environment Canada, for making test results available prior to publication.

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Attachment 13

Oil Dispersant Toxicity Test

United States Testing Company, Inc.
Biological Services

1415 Park Avenue
Hoboken, New Jersey 07030
Tel: 201-792-2400
Fax: 201-656-0636

March 17, 1992

Jack Scambos
Environmental Recovery Resources
35 Smith Ridge Road
South Salem, New York 10590

Dear Mr. Scambos:

This letter is with regard to our conversation earlier today. You were interested in further interpretation of testing performed by USTC versus your product "Elastol". The study you were concerned with was performed for General Technology Applications, Inc. in March and April of 1987 (USTC Report #06589). You wanted an interpretive summary, since none was given with the report. The numerical summary follows:

Toxicant	Artemia 48hr LC50	Fundulus 96hr LC50
Elastol	>18,000 ppm	>18,000 ppm
Elastol + Oil	>3,200 ppm	>18,000 ppm
#2 Fuel Oil	600 ppm	3,200 ppm
DSS (ref tox)	12 ppm	18 ppm

Review of the report indicates that the product demonstrated no acute toxicity to either <u>Artemia salina</u> (brine shrimp), or <u>Fundulus heteroclitus</u> (killi fish), at exposure levels up to 18,000 ppm (the highest product concentration tested).

When mixed with #2 Fuel Oil (1:10 ratio of product to oil), the product demonstrated no toxicity to <u>A. salina</u> at an exposure level of 3200 ppm. At 3200 ppm, the product/oil mixture contained 320 ppm Elastol and 2,880 ppm #2 Fuel Oil. Since the toxicity of #2 Fuel Oil was determined to be 600 ppm, Elastol caused an apparent toxicity reduction.

When mixed with #2 Fuel Oil, the product demonstrated no toxicity to <u>F. heteroclitus</u> at an exposure level of 18,000 ppm. At 18,000 ppm, the product/oil mixture contained 1,800 ppm Elastol and 16,200 ppm #2 Fuel Oil. Since the toxicity of #2 Fuel Oil was determined to be 3,200 ppm, Elastol caused an apparent toxicity reduction.

Bear in mind that I was not involved in the above mentioned testing, and can only interpret what was reported. If you have any questions, or if I can be of further service, do not hesitate to call me.

Sincerely,

Daniel Cooke

Daniel Cooke
Mgr, Ecotoxicology

EST. 1880

United States Testing Company, Inc.

Biological Services Division
1415 PARK AVENUE • HOBOKEN, NEW JERSEY 07030 • 201-792-2400

REPORT OF TEST

EPA Standard Dispersant
Toxicity Tests
of
ELASTOL

Conducted for:

General Technology Applications Inc.
7720 Mason King Court
Manassas, Virginia 22110

April 14, 1987

TEST REPORT NO. 06589

SIGNED FOR THE COMPANY

Prepared by:

Robert Lippencott
Biologist

BY

Daniel Drozdowski
V.P., Mgr, Biological Services Division

Laboratories in: New York • Chicago • Los Angeles • Houston • Tulsa • Memphis • Reading • Richland

A Member of the SGS Group (Societe Generale de Surveillance)

United States Testing Company, Inc.

Client: General Technology Applications Inc.

06589
4/14/87

Project: EPA Revised Standard Oil Dispersant Toxicity Test (July 1984)

Sample: An oil coagulant submitted and identified by the Client as:

Elastol (fine white powder)

Procedure: Tests were in accordance with the EPA "Revised Standard Dispersant Toxicity Test", Federal Register, 49:139, p. 29204-29207.

Note: When blended and mixed with the salt water test medium, as specified by the EPA method, Elastol remained largely undissolved. Elastol-oil combinations formed into a sticky, rubbery substance.

Summary of Results:

	Artemia salina		Fundulus heteroclitus	
Toxicant	48 hour LD_{50} (ppm)	95% CI	96 hour LD_{50} (ppm)	95% CI
Elastol	>18,000	N/A	>18,000	N/A
#2 fuel oil	600		3200	
1:10 mixture, Elastol and #2 fuel oil	>3200	N/A	>18,000	N/A
DSS (reference toxicant)	12		18	

Client: General Technology Applications Inc.

06589
4/14/87

Toxicity Testing Results

Sample: Elastol

Test Dates: 3/26 - 3/30/87

Organism: *Fundulus heteroclitus*

Test Conc. (ppm)	% Mortality (hours) 24	48	72	96	Initial D.O.	Initial pH	Final D.O.	Final pH
Control	0	0	0	0	7.0	7.8	7.0	7.9
10,000	0	0	0	0	7.0	7.8	4.0	8.0
18,000	0	0	0	0	7.0	7.8	4.0	7.9

Temperature: 22°C

Dilution water: Artificial Sea Water

Salinity: 20 ppt

Test organism: Source: Scientific Suppliers
$\bar{x}$ weight: 1 - 1.5 g
$\bar{x}$ length: 40 - 50 mm
no./conc: 10

Summary:

LC_{50}: >18,000 ppm

Client: General Technology Applications Inc.

06589
4/14/87

Toxicity Testing Results

Sample: Elastol #2 Fuel Oil (10:1)

Test Dates: 3/26 - 3/30/87

Organism: *Fundulus heteroclitus*

Test Conc. (ppm)	% Mortality (hours) 24	48	72	96	Initial D.O.	pH	Final D.O.	pH
Control	0	0	0	0	7.0	7.8	7.0	7.9
10,000	10	10	10	10	7.0	7.8	4.0	7.9
18,000	10	10	10	10	7.0	7.8	4.0	7.9

Temperature: 22°C

Dilution water: Artificial Sea Water

Salinity: 20 ppt

Test organism: Source: Scientific Suppliers
$\bar{x}$ weight: 1 - 1.5 g
$\bar{x}$ length: 40 - 50 mm
no./conc: 10

LC_{50}: >18,000 ppm

Client: General Technology Applications Inc.

06589
4/14/87

Toxicity Testing Results

Sample: Elastol

Test Dates: 3/26 - 3/28/87

Organism: *Artemia salina*

Test Conc. (ppm)	% Mortality (hours)		Initial		Final	
	24	48	D.O.	pH	D.O.	pH
Control	0	0	7.0	7.8	7.0	8.0
10,000	0	0	7.0	7.8	7.0	8.0
18,000	0	0	7.0	7.8	7.0	8.0

Temperature: 22°C

Dilution water: Artificial Sea Water

Salinity: 20 ppt

Test organism: Source: In-house culture
age : 24 - 48 hrs
no./conc: 100

Summary:

LC_{50}: >18,000 ppm

Client: General Technology Applications Inc.

06589
4/14/87

Toxicity Testing Results

Sample: Elastol 1:10 with #2 Fuel Oil

Test Dates: 4/3 - 4/5/87

Organism: *Artemia salina*

Test Conc. (ppm)	% Mortality (hours)		Initial		Final	
	24	48	D.O.	pH	D.O.	pH
Control	0	0	8.0	7.8	6.5	7.9
32	3	3	8.0	7.8	6.5	7.9
100	0	0	8.0	7.8	6.5	7.9
320	0	0	8.0	7.8	6.5	7.9
1000	0	0	8.0	7.8	6.5	7.9
3200	0	3	8.0	7.8	6.5	7.9

Temperature: 21°C

Dilution water: Artificial Sea Water

Salinity: 22 ppt

Test organism: Source: In-house culture
age : 24 - 48 hrs
no./conc: 100*

*Note: n=60 organisms/conc. were used for confirmation tests.

Summary:

LC_{50}: >3,200 ppm

United States Testing Company, Inc.

Client: General Technology Applications Inc.

06589
4/14/87

Toxicity Testing Results

Sample: No. 2 Fuel Oil alone

Organism: Fundulus heteroclitus

Test Dates: 3/5/87 - 3/9/87

Test Conc. (ppm)	Percent Mortality (hours) (24)	(48)	(72)	(96)	Initial D.O.	pH	Final D.O.	pH
Control (0)	0	0	0	0	9.0	7.7	8.0	7.6
100	0	0	0	0	8.8	7.6	8.0	7.6
1000	0	0	0	0	8.6	7.6	8.0	7.6
10000	0	0	70	100	8.0	7.6	7.0	7.6

Temperature: 19±1°C

Dilution water: Artificial Sea Water

Salinity: 20 0/00

Test organism: Source: Scientific Suppliers (Massachusetts & N.H.)
$\bar{x}$ weight: 1.0-1.5g
$\bar{x}$ length: 45 mm
no./conc.: 10

Summary:

LC_{50}: 3,200 ppm

Laboratory Note: The above test was run for reference purposes only. In five separate tests conducted previous to this project, dating from 1983 to 1986, the toxicity of #2 fuel oil to Fundulus has been reported as >1,000 ppm to >10,000 ppm. At 10,000 ppm (1% in water) there is a significant oil slick which can directly adhere to and irritate swimming organisms.

United States Testing Company, Inc.

Client: General Technology Applications Inc.

06589
4/14/87

Toxicity Testing Results

Sample: No. 2 Fuel Oil only

Organism: Artemia salina

Test Dates: 3/6/87 - 3/8/87

Test Conc. (ppm)	Percent Mortality (hours) (24)	(48)	Initial D.O.	pH	Final D.O.	pH
Control (0)	0	0	7.0	7.6	7.0	7.6
100	0	20	7.0	7.6	7.0	7.7
1000	0	70	7.0	7.6	7.0	7.5
10000	0	100	7.0	7.6	7.0	7.4

Observation: Physical entrapment of organisms in surface oil contributed to mortality.

Temperature: 21±1°C

Dilution water: Artificial Sea Water

Salinity: 20 0/00

Test organism: Source: San Fransisco Bay Type (cysts)
age : newly hatched lab culture
no./conc.: 100

Summary:

LC_{50}: Approximately 600 ppm (range 1000 - 10,000)

Laboratory Note: The above test was run for reference purposes only. In five separate tests conducted previous to this project dating from 1983 to 1986, the toxicity of #2 fuel oil to Artemia has been reported in the range of 600 ppm to >3200 ppm. The organism is very small (less than 1mm) and thereby susceptible to scavenging by oil droplets or slicks. Mortality is not always attributable to chemical toxicity.

Client: General Technology Applications Inc.

06589
4/14/87

Toxicity Testing Results

Sample: Dodecyl sodium sulfate (reference material)

Organism: Fundulus heteroclitus

Test Dates: 3/5/87 - 3/9/87

Test Conc. (ppm)	Percent Mortality (hours) (24)	(48)	(72)	(96)	Initial D.O.	Initial pH	Final D.O.	Final pH
1	0	0	0	0	9.0	7.1	7.8	7.0
3.2	0	0	0	0	8.8	7.2	7.8	7.1
10*	0	0	0	0	8.8	7.2	7.6	7.1
32	100	-	-	-	9.0	7.1	7.8	7.1
100	100	-	-	-	9.0	7.2	8.6	7.2

*10 ppm exhibited stress, but no death

Temperature: 20±1°C

Dilution water: Artificial Sea Water

Salinity: 20 0/00

Test organism: Source: Scientific Suppliers (Massachusetts & N.H.)
$\bar{x}$ weight: 1.0-1.5g
$\bar{x}$ length: 45 mm
no./conc.: 10

Summary:

LC_{50}: 18 ppm

Laboratory Note: The above test was run for reference purposes only. In five separate tests conducted previously, dating from 1983 to 1986, the toxicity of DSS to Fundulus has been reported as 2.7 ppm ± 1.4 ppm.

Client: Gamlen Chemical (Division of Sybron)

06589
4/14/87

Toxicity Testing Results

Sample: Dodecyl sodium sulfate (reference material)

Organism: *Artemia salina*

Test Dates: 3/11/87 - 3/13/87

Test Conc. (ppm)	Percent Mortality (hours) (24)	(48)	Initial D.O.	pH	Final D.O.	pH
1	0	15	7.0	7.8	7.0	7.8
3.2	0	25	7.0	7.8	7.0	7.8
10	0	45	7.0	7.8	7.0	7.8
32	15	60	7.0	7.9	7.0	7.9

Temperature: 21±1°C

Dilution water: Artificial Sea Water

Salinity: 20 0/00

Test organism: Source: San Fransisco Bay Type (cysts)
age : newly hatched lab culture
no./conc.: 100

Summary:

LC_{50} (and 95% confidence limits): 12 ppm (4.8 - 30 ppm)

Laboratory Note: The above test was run for reference purposes only. In five separate tests conducted previously, dating from 1983 to 1986, the toxicity of DSS to Artemia has been reported as 4.5 ppm ± 2.7 ppm.

United States Testing Company, Inc.

Client: General Technology Applications Inc.

06589
4/14/8

Project: EPA Revised Standard Oil Dispersant Toxicity Test
(July 1984)

Sample: An oil coagulant submitted and identified by the Client as:

Elastol (fine white powder)

Procedure: Tests were in accordance with the EPA "Revised Standard Dispersant Toxicity Test", Federal Register, 49:139, p. 292
29207.

Note: When blended and mixed with the salt water test medium, as specified by the EPA method, Elastol remained largely undissolv
Elastol-oil combinations formed into a sticky, rubbery substanc

Summary of Results:

	Artemia salina		Fundulus heteroclitus	
Toxicant	48 hour LD_{50} (ppm)	95% CI	96 hour LD_{50} (ppm)	95% (
Elastol	>18,000	N/A	>18,000	N/
#2 fuel oil	600		3200	
1:10 mixture, Elastol and #2 fuel oil	>3200	N/A	>18,000	N/
DSS (reference toxicant)	12		18	

United States Testing Company, Inc.

Client: General Technology Applications Inc.

06589
4/14/8

Project: EPA Revised Standard Oil Dispersant Toxicity Test (July 1984)

Sample: An oil coagulant submitted and identified by the Client as:

Elastol (fine white powder)

Procedure: Tests were in accordance with the EPA "Revised Standard Dispersant Toxicity Test", Federal Register, 49:139, p. 292 29207.

Note: When blended and mixed with the salt water test medium, as specified by the EPA method, Elastol remained largely undissolve Elastol-oil combinations formed into a sticky, rubbery substance

Summary of Results:

	Artemia salina		Fundulus heteroclitus	
Toxicant	48 hour LD$_{50}$ (ppm)	95% CI	96 hour LD$_{50}$ (ppm)	95% (
Elastol	>18,000	N/A	>18,000	N/
#2 fuel oil	600		3200	
1:10 mixture, Elastol and #2 fuel oil	>3200	N/A	>18,000	N/
DSS (reference toxicant)	12		18	

Attachment 14

Abalone Larval Development Test Memorandum

MEMORANDUM

TO: All

FROM: Al Hadermann

DATE: June 29, 1992

SUBJECT: Abalone Larval Development Test

I read "Abalone Larval Development Short-Term Toxicity Test Protocol," which I received from the California State Water Resources Control Board. This information can be used to better understand the significance of the results on Elastol.

The Organism

Male and female abalone (7-10 cm length) are used to provide fertilized eggs under controlled conditions. Eggs are placed in saline solutions, containing potential toxicants, before the first division occurs. Thus, all division and growth of the single cell embryo to a trochophore larva, which hatches and develops into a veliger larva, occurs in the presence of the potential toxicant. This all occurs in 48 hours. At the end of 48 hours, formalin is used to fix the larvae. The larvae are then individually inspected for evidence of normal and abnormal development. Although not inclusive, abnormal development involves shell development defects.

Toxicity Determination

Toxicity is expressed as % of larvae with normal development. A control laboratory sample, with no added toxicant, typically can show 83.4% normally developed larvae. A reference toxicant containing 18 micrograms/liter of zinc ion could show 77.6% normally developed larvae, which is not statistically significant. On the other hand, at 32 micrograms of zinc ion/liter, only 6.6% of normally developed larvae were seen. The no effect concentration (NOEC) in this case is 18 micrograms/liter of zinc ion, while the low effect concentration (LOEC) concentration is 32.

All of the following Elastol extract concentrations showed fewer abnormally developed abalone larvae than either the control-lab or blank samples run at the same time: 0.1, 1.0, 3.2, 5.6, 10.0, 18.0, 32.0 and 56.0%. None of these Elastol samples differed significantly from the percent of larvae with normal development in the reference samples. Actually, however, all Elastol results were slightly less toxic than the "non-toxic" references. No other Elastol extract tests were run between 56.0% and 100.0%. Since the 100.0% test suggests that there was no "saline habitat" for the larvae, the number of abnormal larvae may be an artifact of the test.

Conclusion

Elastol did not interfere with the normal development of abalone larvae. The test at 100.0% was forced beyond the characteristics of the medium to support the organisms. Therefore, the NOEC of 56.0% and the LOEC of 100.0% are conservative.

Attachment 15

2003 & 2004 CARB

Pre & Post Durability Results

ETS

A division of
Olson Engineering, Inc.

SUMMARY REPORT

Emission and Fuel Consumption Data
Obtained in Accordance with CARB Verification Protocol

For Verification of Particulate and NOx Reductions When Operating with Viscon Polymer Treated Diesel Fuel

August 19, 2003

Conducted for
Las Palmas Oil and Dehydration, Inc.
3121 Standard St.
Bakersfield, CA 93308

By
Emission Testing Services
A division of Olson Engineering, Inc.
At their CARB and EPA Recognized
ECOlogic Engine Testing Laboratories
Fullerton, California

Note: This report may only be copied and distributed in its entirety.

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www.etsusa.net www.ecologiclabs.com

ETS

Executive Summary

This report provides a summary of the data used to verify PM and NOx reduction effectiveness of Viscon, a polymer additive, when mixed with No. 2 California specification diesel fuel for operation of heavy-duty off-road diesel engines.

Particulate emissions were reduced 37% and NOx was reduced 21% with the Viscon treated fuel at standard concentrations when compared to baseline data operating on diesel fuel alone without the additive. These results are based on steady-state 8-mode engine dynamometer testing of a Caterpillar Model 3306 diesel engine. The 8-mode emission/fuel consumption testing was done in exact accordance with CARB, California Code of Regulations, Title 13, Chapter 14 and EPA regulations as defined in the applicable sections of 40 CFR, Part 89. This emission testing protocol is designated for heavy-duty diesel engines in off-road applications.

All emission and fuel consumption testing was accomplished by Emission Testing Services, a division of Olson Engineering, Inc. at their ISO 9000-2001 registered ECOlogic Engine Testing Lab (EETL) in Fullerton, California. The companies are CARB/EPA recognized and listed as qualified emission testing facilities for the work reported here. The particular test cell where all the work was done consists of a full electric 450 horsepower engine dynamometer for precise control of speed and load. All fuel consumption was measured gravimetrically and exhaust emissions of HC, CO, CO2, NOx and NO were sampled and measured as raw emissions with conventional Horiba and Rosemont analyzers. Particulates were sampled and properly diluted with a Sierra state-of-the-art Model BG-2 particulate sampler and captured on pre-weighed filter media. All raw data measurements were corrected with the applicable factors for humidity, temperature and pressure and both raw and corrected emissions are tabulated in the Results section. Baseline test protocols and test protocols with the Viscon treated fuel were conducted in exactly the same manner in the same test cell with the same instrument complement.

Average differences between the five baseline tests and the five tests with the Viscon treated fuel for NOx and PM are as shown below:

	--------Grams per bhp-hr-----------			
	NOx	PM	Fuel	Avg. HP
Baseline – diesel fuel	7.09	0.308	178.10	137.7
With Viscon treated fuel	5.57	0.194	177.30	137.5
% Improvement	**21.4**	**37.0**	**0.4**	

These results satisfy the CARB requirements for 20% NOx reduction and Level 1 PM reduction (25-50% reduction).

Introduction

This report summarizes the emission data and describes the testing protocol for satisfaction of the California Air Resources Board (CARB) Verification Protocol for additive fuel solutions to reduce particulates (PM) and oxides of nitrogen (NOx).

The test protocol is designed to verify the emissions for off-road engine applications in accordance with 40 CFR, Part 89.

Test Engine

A six cylinder Caterpillar Model 3306 diesel engine rated at 265 horsepower was used in this project. This manually controlled engine was rebuilt by the Caterpillar Corporation and preliminary testing started with only a few hours of previous operation.

Test Fuel

A California specification commercial No. 2 diesel fuel was used for all the testing (See Table 1). The additive was mixed into the baseline fuel in standard concentrations, by the client, for testing emission reduction effectiveness.

Test Protocol and Procedures

All emission testing was done by use of the EPA/CARB specified 8-mode steady-state test protocols defined in the applicable Federal Register (40 CFR Part 89) for off-road heavy-duty engine applications. Raw emissions were sampled and measured under each of eight operating modes, corrected for temperature, humidity and barometric pressure and finally weighted to reach the final emission result stated in grams per brake horsepower hour (gm/bhp-hr). Particulates were simultaneously sampled, captured on a pre-weighed filter media for all eight modes, weighed and also reported in grams per brake horsepower hour (gm/bhp-hr).

The test procedure involves engine warm-up under prescribed conditions with instrument zero and span checks immediately followed by engine operation for five minutes at each of the eight test modes. Emissions are averaged from second-by-second recordings for the last two minutes of each mode, corrected, weighted for the individual modes and displayed. PM filters are stored in a humidity and temperature controlled environment and weighed within one day of collection.

Project Objective

The objective of this work was to collect the initial emission data required to initiate the CARB procedure for verification of a proprietary diesel fuel additive to reduce exhaust PM and NOx when compared to the baseline emission levels. CARB requires a minimum of 25% reduction in PM and as an option, at least 15% reduction in NOx emissions, to obtain official verification.

Test Additive

The diesel fuel additive used in this project is named "Viscon". It is a high-molecular weight, pure hydrocarbon polymer. The base chemical component for Viscon is polyisobutylene (PIB) polymer. This additive was mixed with the diesel fuel by the client in a concentration of 1 ounce to 20 gallons of diesel fuel for all official testing.

Test Equipment and Instrumentation

The engine dynamometer test cell is equipped with a 450 HP full electric dynamometer capable of holding the engine to speeds and loads within the required ± 2% variation. Engine air flow is measured and recorded continuously with a calibrated Sierra mass flow sensor. Inlet air temperature is measured within 20 cm. of the turbocharger inlet and relative humidity is measured continuously at the engine air inlet. Fuel flow is measured gravimetrically using a calibrated scale with measurements recorded during the last two operating minutes of each mode.

Exhaust gas is sampled through a heated probe and pre-filter at the exhaust stack. It then passes through a heated sample line (350°F) to the Horiba flame ionization detector hydrocarbon analyzer. Another sample line routes raw exhaust gas through a refrigerated condensate trap/filter to the Horiba conventional CO and CO2 NDIR analyzers. This same exhaust stream is also routed simultaneously to the parallel connected and heated Rosemont NOx and NO chemiluminescent analyzers. Another sample probe as part of the Sierra PM sampler system in the exhaust stack routes the exhaust gas into a dilution chamber (with programmed air dilution ratios for the different operating modes) for ultimate capture on pre-weighed filter media. The Sierra BG-2 Particulate Sampler is a state-of-the-art sampling system that has been accepted by EPA as an appropriate instrument for the proper capture of exhaust gas particulates. It is calibrated prior to every test.

The dynamometer operation, all calibration functions and collection of data is controlled and performed through a proprietary Windows based Wonderware program. This program stores all the raw data and conducts preliminary calculations on the raw data. The final calculations are performed separately using a proprietary computer template

encompassing all the CFR corrections and related formulas. The raw and corrected data are then printed out in the format shown in this report. All test numbers are consecutive and if a test is aborted or discontinued the next test will automatically record the subsequent test number.

The NO2/NOx Issue

The CARB protocol stipulates simultaneous measurement of NOx and NO to calculate the NO2 (NOx-NO = NO2). This CARB requirement is based on data that demonstrates NO2 is formed to some extent in particulate traps without an apparent overall NOx increase. This is not generally an issue with additive treated fuels and simultaneous measurement of NOx and NO in this project showed that both NOx and NO measurements were always the same within normal test variance (see Results table).

Special Sampling for Exhaust Gas Analysis at Disparate Locations

Analysis of some exhaust gas constituents had to be done at an outside laboratory (Truesdail Laboratories). The test engine was operated at equilibrium steady-state conditions with plastic bag or steel vessel containers being used to capture representative samples. The analyses of these emissions by Truesdail Laboratories is the subject of a separate report.

Emission Testing Services (ETS)

ETS is a wholly owned division of Olson Engineering, Inc. The company conducted all of the dynamometer work reported here at their ISO 9000-2001 registered ECOlogic Engine Testing Lab in Fullerton, California. Both ETS and ECOlogic are CARB and EPA recognized and listed as facilities capable of conducting emission testing in accordance with CARB/EPA protocols and requirements as defined in the applicable Federal Register and in the California Code of Regulations – Title 13. All of the work reported here has been conducted by qualified and experienced technicians under the direct supervision and responsibility of Donel R. Olson, a registered professional engineer in the State of California

Test Data Accumulation

Prior to accumulation of official 8-mode test data the engine was operated over a repetitive load cycle for approximately 100 hours on the engine dynamometer while operating with the baseline diesel fuel. This preliminary operation was to stabilize the engine and reach equilibrium baseline emission levels. Five official baseline tests were then conducted (test nos. 8MBL024-8MBL028) and the averages were used for subsequent comparison to the additive treated fuel.

Upon completion of baseline emission testing the engine was operated over the same repetitive cycle for an additional 100 hours with the additive treated baseline fuel. Finally, a set of official 8-mode tests were conducted using the Viscon additive treated baseline fuel (test nos. 8MLPF 12-8MLPF 16).

All five sets of data for each emission and fuel consumption average have been used to calculate the standard deviation of the data and the corresponding 95% confidence limits. All data are within a typical range with normal variances.

Prior to starting the official baseline emission tests and again prior to starting tests with the additive treated fuel the engine oil and oil filters and fuel filters were changed to provide the same start-up conditions for baseline and additive treated fuel operation. All test conditions, calibrations and operating protocols were within CARB specified limits and the same from test-to-test.

Test Results

The emission and fuel consumption results of this comparative testing are summarized in the following Table 2. The raw data for each mode and individual calculations for each test are provided in the Appendix for the five baseline and five additive treated test sets.

Table 1

Test Fuel Analysis

Table 2

Summary of Results

Effect of Viscon Polmyer Additive on Exhaust Emissions and Fuel Consumption
Las Palmas Oil and Dehydration Company
Caterpillar Model 3306 Diesel Engine

8-Mode Engine Dynamometer Data

Baseline Data (No Additive)

	............Grams per bhp-hr............					Weighted
Test No.	**THC**	**CO**	**KNOx**	**PM**	**Fuel**	**HP**
8MBL024	1.35	2.75	6.73	0.31	181.03	137.71
8MBL025	1.26	2.47	6.75	0.33	176.68	137.46
8MBL026	1.24	2.56	7.46	0.32	176.24	137.63
8MBL027	1.30	2.52	7.14	0.29	178.18	137.77
8MBL028	1.30	2.51	7.38	0.29	178.35	137.75
5-Test Averages	**1.29**	**2.562**	**7.092**	**0.308**	**178.096**	**137.664**
Std. Dev.	0.0424	0.1099	0.3423	0.0179	1.8795	0.1260
95% C.L.	0.0372	0.0963	0.3000	0.0157	1.6474	0.1105

With Viscon Polymer Additive at 1 ounce to 20 gallons

8MLPF12	1.51	1.83	5.59	0.20	177.55	137.55
8MLPF13	1.50	1.78	5.51	0.20	177.18	137.58
8MLPF14	1.56	1.73	5.79	0.17	176.79	137.55
8MLPF15	1.51	2.28	5.48	0.21	177.39	137.54
8MLPF16	1.54	2.28	5.50	0.19	177.61	137.29
5-Test Averages	**1.524**	**1.98**	**5.574**	**0.194**	**177.304**	**137.502**
Std. Dev.	0.0251	0.2761	0.1278	0.0152	0.3321	0.1195
95% C.L.	0.0220	0.2420	0.1120	0.0133	0.2911	0.1047
Average Differences	-0.234	0.582	1.518	0.114	0.792	0.162
% Improvement	**-18.14**	**22.72**	**21.40**	**37.01**	**0.44**	**0.12**

Note: 95% Confidence Limits define the plus/minus range within which the true average is expected to fall with 95% confidence

Olson-EcoLogic
Engine Testing Laboratories, LLC

ISO 9001:2000 Registered

Preliminary

SUMMARY REPORT

Emission and Fuel Consumption Data

Obtained in Accordance with CARB Retrofit Verification Protocol.

For Verification of Particulate and NOx Reductions When Operating with Viscon Polymer Treated Diesel Fuel

November 26, 2004

Conducted for
Las Palmas Oil and Dehydration Company
3121 Standard Street
Bakersfield, California 93308

By

Olson-EcoLogic Engine Testing Laboratory
ISO 9001-2000 Registered

Note: This summary report provides all of the corrected data for the tests listed in each table, but the individual emission test data sheets showing measured and corrected data for all gaseous and particulate data plus the measured operating and ambient variables for each test have not been included in this summary report. Those data will all be included in the complete and final emission test report.

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Executive Summary:

This summary report contains a compilation and listing of all emission data accumulated during the Las Palmas project to measure effectiveness of the Viscon Polymer additive when mixed with California specification No. 2 diesel fuel and used in the operation of a Model 3306 Caterpillar heavy-duty diesel engine for off-road applications.

A previous summary report dated August 19, 2003 provided the data comparisons for baseline testing with diesel fuel only and with the same fuel containing the nominal concentration of the Viscon Polymer additive. This summary report provides the average data from that previous testing for reference purposes. Subsequently the test engine was relocated at the client's facility and operated by the client 1000 hours over a repetitive cycle for durability testing using the same diesel fuel treated with the Viscon Polymer additive. The engine was then returned to the Olson-Ecologic Engine Testing Lab in Fullerton, California to obtain the additional emission test data reported here.

After 1000 hours of durability testing particulates (PM) were reduced by 48.4% and NOx by 25.4% when operated on the Viscon treated fuel as compared to the baseline emission measurements with diesel fuel only at the beginning of the project. These results were based on steady-state 8-mode engine dynamometer testing of a Model 3306 Caterpillar diesel engine. The 8-mode emission/fuel consumption testing was done in exact accordance with CARB, Califomia Code of Federal Regulations, Title 13, Chapter 14 and EPA regulations as defined in the applicable sections of 40 CFR, Part 89. This emission testing protocol is designated for heavy-duty diesel engines in off-road applications.

A complementary emission comparison after the 1000 hours of durability testing was also accomplished with a 5% blend of biodiesel fuel in the Viscon treated diesel fuel. This fuel mixture consisted of 5% biodiesel fuel and 1 ounce/20 gallons of Viscon mixed into the same baseline diesel fuel as was used in all of the other testing. The mixture is labeled Super B5 Biodiesel Fuel. With this fuel the PM emissions were reduced 45.4%and the NOx emissions were reduced 24.3% compared to the original baseline data.

Emission data with the Viscon additive mixed into the diesel fuel at 10 times the normal concentration were also required by CARB. Triplicate tests showed that there was no adverse effects on emissions when compared to the baseline data or to the Viscon data admixed with normal concentrations. With this heavy dose concentration of Viscon the PM emissions were reduced 50.5% and the NOx emissions were reduced 26.4%.

All emission and fuel consumption testing was accomplished by Olson-EcoLogic Engine Testing Laboratories in Fullerton, California at their ISO 9001-2000 registered facility. The company is CARB/EPA recognized and listed as a qualified emission testing facility for the work reported here. The particular emission test cell where all the work was done consists of a full electric 450 horsepower engine dynamometer for precise control of speed and load. All fuel consumption was measured gravimetrically. Raw gaseous emissions of THC, CO and CO_2 were measured with Horiba analyzers. NOx and NO measurements wire made with heated Beckman/Rosemont chemiluminscent analyzers. PM was sampled and properly diluted with a Sierra state-of-the-art Model BG-2 particulate sampler and captured on pre-weighed filter media. All raw data measurements were corrected with the applicable factors for humidity, temperature and pressure and both raw and corrected emissions are tabulated in the individual test data sheets. Baseline test protocols and test protocols with the Viscon and Biodiesel treated fuels were conducted in exactly the same manner in the same test cell with the same instrument complement.

The average PM and NOx differences between the five baseline tests at the project beginning, the five tests with only Viscon treated fuel after 1000 durability miles, the five tests with the Super B5 Biodiesel Fuel after 1000 hours of durability testing and the final testing with a heavy dose of Viscon are provided in attached Tables 1 and 2 and are summarized below.

	Grams per bhp-hour	
	PM	NOx
Original baseline testing with diesel fuel only	0.308	7.09
1. With Viscon treated fuel after 1000 hours of durability	0.159	5.29
Percent improvement with Viscon treated fuel		
Compared to the baseline data	48.4%	25.4%
2. With Super B5 Biodiesel Fuel	0.167	5.36
Percent improvement with Super B5 Biodiesel Fuel		
Compared to the baseline data	45.8%	24.3%
3. With heavy dose (10X) of Viscon treated fuel	0.152	5.22
Percent improvement with heavy dose of Viscon		
Compared to the baseline data	50.5%	26.4%

These data demonstrate that for the engine tested in this project admixture of the Viscon Polymer additive reduces PM in the range of 45-50% and NOx on the order of 25% for both diesel fuel only and for diesel fuel with 5% biodiesel fuel admixed.

Introduction:

This report summarizes the emission data and describes the testing protocol for satisfaction of the California Air Resources Board (CARB) Verification Protocol for additive fuel solutions to reduce particulates (PM) and optionally oxides of nitrogen (NOx)

The test protocol is designed to verify the emissions for off-road engine applications in accordance with 40 CFR, Part 89

Test Engine:

A six-cylinder Model 3306 Caterpillar diesel engine rated at 265 horsepower was used in this project. The Caterpillar Corporation prior to beginning of the project rebuilt this manually controlled diesel engine and preliminary testing started with only a few hours of previous operation.

Test Fuel:

A California specification commercial No. 2 diesel fuel was used for all of the testing before, during and after durability testing (see fuel inspection data in the Appendix). The Viscon additive was mixed into the baseline fuel in standard concentrations by the client, and biodiesel fuel was added to the baseline fuel to provide a 5% biodiesel concentration in the Viscon treated diesel fuel.

Test Protocol and Procedures:

All emission testing was done by use of the EPA/CARB specified 8-mode steady-state test protocols defined in the applicable Federal Register (40 CFR Part 89) for off-road heavy-duty engine applications. Raw emissions were sampled and measured under each of eight operating modes, corrected for temperature, humidity and barometric pressure and finally weighted to reach the final emission result stated in grams per brake horsepower hour (gm/bhp-hr). Particulates were simultaneously sampled, captured on a pre-weighed filter media for all eight modes, weighed and also reported in grams per brake horsepower hour (gm/bhp-hr).

The test procedure involves engine warm-up under prescribed conditions with instrument zero and span checks immediately followed by engine operation for five minutes at each of the test modes. Emissions are averaged from second-by-second recordings for the last two minutes of each mode, corrected, weighted for the individual modes and displayed. PM filters are stored in humidity and temperature controlled environment and weighed within one day of collection.

Project Objective:

The objective of this work was to collect the emission data required by CARB to satisfy the CARB Verification protocol for retrofit applications with a proprietary diesel fuel additive and to quantify the magnitude of reductions obtained when operating a typical diesel heavy-duty engine for off-road applications. CARB requires a minimum 25% reduction in PM and as an option, at least 15% reduction in NOx emissions to obtain official recognition of verification.

Test Additive:

The diesel fuel additive used in this project is named "Viscon". It is a high-molecular weight, pure hydrocarbon polymer. The base chemical component for Viscon is polyisobutylene (PIB) polymer. This additive was mixed with the diesel fuel by the client in a concentration of 1 ounce to 20 gallons of diesel fuel for all official testing.

Test Equipment and Instrumentation:

The engine dynamometer test cell is equipped with a 450 Hp full electric dynamometer capable of holding the engine to speeds and loads within the required +/- 2% variation. Engine airflow is measured and recorded continuously with a calibrated Sierra mass flow sensor. Inlet air temperature is measured within 20 cm. of the turbocharger inlet and relative humidity is measured continuously at the engine air inlet. Fuel consumption is measured gravimetrically using a calibrated scale with measurements recorded during the last two operating minutes of each mode.

Exhaust gas is sampled through a heated probe and pre-filter at the exhaust stack. It then passes through a heated sample line (350 degrees F) to the Horiba flame ionization detector hydrocarbon analyzer. Another sample line routes raw exhaust gas through a refrigerated condensate trap/filter to the Horiba conventional CO and CO2 NDIR analyzers. This same exhaust stream is also routed simultaneously to the parallel connected and heated Rosemont NOx and NO chemiluminescent analyzers. Another sample probe as part of the Sierra PM sampler system in the exhaust stack routes the exhaust gas into a dilution chamber (with programmed air dilution ratios for the different operating modes) for ultimate capture on pre-weighed filter media. The Sierra BG-2 Particulate Sampler is a state-of-the-art sampling system that has been accepted by EPA and CARB as an appropriate instrument for the proper capture of exhaust gas particulates. It is calibrated prior to every test.

The dynamometer operation, all calibration functions and collection of raw data are controlled and performed through a proprietary Windows based and modified Wonderware program. This program stores all the raw data and conducts preliminary calculations on the raw data. The final calculations are performed separately using a proprietary computer template encompassing all the CFR corrections and related

Finally, triplicate emission tests were conducted with the same baseline test fuel treated with a ten times (10X) dosage of Viscon (10 ounces/20 gallons of diesel fuel). This heavy dosage operation is a required task of the CARB retrofit verification protocol. The tests are numbered 8MLPH01-8MLPH03.

All sets of data for emission and fuel consumption averages have been used to calculate the standard deviation of the data and the corresponding 95% confidence limits of the mean values. All data are within a typical range with normal variances.

Prior to starting the official baseline emission tests and again prior to starting tests with the Viscon treated fuel the engine oil and oil filters and fuel filters were changed to provide the same start-up conditions for baseline and additive treated fuel operation. All test conditions, calibrations and operating protocols were within CARB specified limits and the same from test-to-test.

Test Results:

The exhaust emission and fuel consumption results of this comparative testing are summarized in the following Tables 1 and 2 (and in the Executive Summary) for the testing conducted after the 1000 hours of durability operation was completed. The original data obtained before the 1000 hour durability operation are provided and described in an earlier report dated August 19, 2003, but the baseline emissions (without Viscon treatment) are referenced here and the averages are listed in this report for defining effectiveness of the Viscon additive treatment as compared to the original baseline data at the beginning of the testing project.

The raw data for each mode and individual calculations for each test are provided in the Appendix for all the tests along with the fuel inspections.

Table 1
Summary of Results
Effect of Las Palmas Viscon Polymer Additive on Exhaust Emissions and Fuel Consumption
After 1000 Hours of Durability Testing
Caterpillar Model 3306 Diesel Engine

Hot Start ISO-8178 8-Mode Engine Dynamometer Data

		................................Grams per bhp-hour......................				
Test No.	Avg. HP	THC	CO	NOX	NO	PM
8MLPC012	137.3	0.93	1.60	5.43	4.96	0.163
13	136.8	0.94	1.60	5.37	4.98	0.165
14	136.6	0.92	1.54	5.06	4.58	0.155
15	136.6	0.98	1.60	5.30	4.80	0.156
16	136.5	0.95	1.61	5.27	4.77	0.156
Std. Deviation	0.321	0.023	0.028	0.141	0.163	0.005
95% C.L. of Average *	0 281	0.020	0.025	0.123	0.142	0.004
Viscon Average After Durability Testing	**136.76**	**0.94**	**1.59**	**5.29**	**4.82**	**0.159**
Baseline Average Before Durability Testing	**137.66**	**1.29**	**2.56**	**7.09**		**0.308**
% Improvement Compared to Baseline	**-0.7**	**26.8**	**37.9**	**25.4**		**48.4**

Heavy Viscon Dosage at 10 Times Normal Concentrations
10 oz/20 gallons of fuel

		................................Grams per bhp-hour......................				
Test No.	Avg. HP	THC	CO	NOX	NO	PM+H7
8MLPHD01	136.4	0.92	1.52	5.28	4.80	0.154
8MLPHD02	136.5	0.88	1.49	5.12	4.60	0.147
8MLPHD03	136.6	0.88	1.57	5.25	4.72	0.156
Viscon Heavy Dose After 1000 ho	**136.5**	**0.89**	**1.53**	**5.22**	**4.71**	**0.152**
Std Deviation	0.10	0.02	0.04	0.09	0.10	0.00
95% C.L.	0.11	0.03	0.05	0.10	0.11	0.01
% Improvement Compared to Baseline	**-0.8**	**30.7**	**40.4**	**26.4**		**50.5**

* Provides the +/- confidence interval of the average values. The average or mean value is expected to be within this +/- range with 95% confidence.

All data were obtained at the ISO 9000-2001 Registered Olson-EcoLogic Engine Testing Laboratory in Fullerton, California

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Table 2

Las Palmas Super Biodiesel
Caterpillar Model 3306 Diesel Engine

All Data Obtained at Olson-EcoLogic Independent Engine Testing Laboratory
ISO 8178 8-Mode Steady-State Test Protocol

		Grams per BHP-Hr			
	HP	**THC**	**CO**	**NOx**	**PM**
5 test Baseline average before durability testing	**137.7**	**1.29**	**2.56**	**7.09**	**0.308**

Super Biodiesel B5 in No. 2 diesel fuel
after 1000 hours of durability engine operation

		..............Grams per BHP-Hr..................			
Test No.	**HP**	**THC**	**CO**	**NOx**	**PM**
8MBIOC01	135.9	0.93	1.57	5.41	0.174
8MBIOC02	137.1	0.92	1.47	5.40	0.181
8MBIOC03	135.4	0.93	1.43	5.30	0.170
8MBIOC04	136.6	0.94	1.50	5.37	0.167
8MBIOC05	136.4	0.95	1.46	5.34	0.149
Average of 5 tests	**136.28**	**0.934**	**1.486**	**5.364**	**0.168**
Std. Dev.	0.653	0.011	0.053	0.045	0.012
95% C.L.	0.573	0.010	0.047	0.039	0.010
% Improvement Compared to Baseline	**-1.0%**	**27.6%**	**42.0%**	**24.3%**	**45.4%**

Table 3 (preliminary)
Las Palmas Oil and Dehydration Company
Caterpillar Model 3306 Diesel Engine
ISO 8178 8-Mode Steady-State Emission Testing
All Testing was Accomplished at Olson-EcoLogic Engine Testing Laboratory

Super Biodiesel B20 in No. 2 diesel fuel
after 1000 hours of durability engine operation

		............Grams per BHP-Hr............				
Test No.	**HP**	**THC**	**CO**	**NOx**	**NO**	**PM**
8MBIOC06	136.9	0.80	1.29	5.89	4.92	0.150
8MBIOC07	135.1	0.75	1.29	5.93	4.91	0.169
8MBIOC08	136.7	0.76	1.31	6.00	4.80	0.169
Average of 3 tests	**136.21**	**0.770**	**1.297**	**5.940**	**4.877**	**0.163**
Std. Dev.	0.968	0.026	0.012	0.056	0.067	0.011
95% C.L.	1.096	0.030	0.013	0.063	0.075	0.012
% Improvement Compared to Baseline	**-1.1%**	**40.3%**	**49.3%**	**16.2%**		**47.2%**