Legal Claims
Against Lubrizol Corporation

By
Mark L. Nelson

Co-Founder, Co-Inventor
CEO
Polar Molecular Holding Corporation
Parent of Polar Molecular Corporation

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Volume III
Exhibits 11-17, Footnote 2

Business Research Report B313

PETROLEUM ADDITIVES

Project Director:

Teresa L. Hayes

June 1992

The Freedonia Group, Inc.
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additive whose demand is expected at least to double by the mid-1990s in response to 1990 Clean Air Act standards.

TABLE IV-7

GASOLINE AND OTHER FUEL DETERGENTS
(million dollars)

Item	1980	1985	1991	1996	2000
Gasoline Production (bil gal)	100.5	98.8	106.7	107	106
$/000 gal	0.29	0.64	1.11	1.50	1.93
Detergents Demand	29	63	118	160	205
% detergents	0.02	0.04	0.03	0.02	0.02
Total Petroleum Additives	1765	1780	3555	9990	13590

Gasoline and Other Fuel Deposit Modifiers

Demand for deposit modifiers in gasoline and other fuels is expected to grow nearly nine percent through 1996 to $35 million. Growth expectations for these additives are based on current trends in engine design, crude production and growing consumer awareness of proper engine maintenance and functioning. A major impetus for growth in this category will come from recent Clean Air Act legislation. Beginning in January 1995, deposit control additives will be required in all gasolines sold in the US in order to meet emission standards.

Deposit modifiers, also called dispersants, remove carbon deposits from port fuel injectors or carburetors. These additives also can inhibit the formation of deposits on manifolds, intake valves and other fuel line equipment. Uncontrolled ignition and spark plug fouling are inhibited by eliminating or dispersing the deposits. Most deposit modifiers are based on either polybutene or polyether amines. Chevron's Oronite Additives Division is a leading producer of deposit modifiers. Other manufacturers include Lubrizol and Citgo.

Additives are also being developed to control combustion chamber deposits to reduce octane requirement increase (ORI). ORI develops as an engine ages and deposits build up in the combustion chambers. These deposits cause the octane requirement of the engine to increase by several octane numbers during the first thousand miles of its lifetime. Nearly one-third of US passenger cars may have engines with higher octane requirements than they were designed for.

Polar Molecular Corporation has developed an additive, which it sells under the DURALT tradename, to solve the problem of ORI. In 1992, Polar Molecular announced an agreement with Dow Chemical under which Dow has the option to license this fuel additive technology. During the option period, Dow will assess the opportunities for the technology in the US and overseas. Texaco Additive Company has also developed a product that it says will provide octane requirement decrease (ORD).

TABLE IV-8

DEPOSIT MODIFIERS FOR GASOLINE AND OTHER FUELS
(million dollars)

Item	1980	1985	1991	1996	2000
Gasoline Production (bil gal)	100.5	98.8	106.7	107	106
$/000 gal	0.10	0.14	0.22	0.33	0.39
Deposit Modifiers Demand	10	14	23	35	41
% deposit modifiers	.006	.008	.006	.004	.003
Total Petroleum Additives	1765	1780	3555	9990	13590

SECTION VI

INDUSTRY STRUCTURE & COMPETITIVE STRATEGIES

General

The $3.6 billion petroleum additive industry is highly competitive in terms of price, product performance and customer services. The industry is dominated by major petroleum companies and large chemical manufacturers. However, there are a variety of smaller manufacturing and blending companies that compete strongly within specialized niches of the industry. Manufacturers include: major multinational petroleum refining and chemical companies, such as Exxon, Chevron, Amoco and Texaco; leading specialty chemical manufacturers, such as Lubrizol, Ethyl, and Du Pont; and other small producers, distributors, and formulators of specialty chemical products, including Vanderbilt, STP, Hastings and Polar Molecular. Approximately 80 companies are involved in petroleum additive production in the United States, with substantial industry concentration due to the involvement of large refining and chemical operations in the additives business. Roughly 25 percent of gasoline and other fuel additives are consumed captively, while this figure drops to less than ten percent for lubricant additives.

The overlap of producers of additives for fuels (excluding MTBE) and lubricants is getting wider as automotive and truck-market engine oil and fuel additive chemistries converge. As manufacturers are faced with more stringent environmental standards and changing product performance demands, an intimate knowledge of both chemistries is increasing in importance. Extensive product lines in both fuel and lubricant additives are becoming more important as a certain volume of activity is necessary to support the increasingly expensive research, development and registration activities necessary to stay competitive in petroleum additives. This is evidenced by the fact that most of the leading producers, for example Lubrizol and Texaco, are expanding there operations to include both categories of additives.

Gasoline & Other Fuel Additives Industry

Gasoline and other fuel additive manufacturers are somewhat more fragmented than suppliers of lubricant additives, especially due to the continued diffusion of MTBE production in the US. With the explosive demand for MTBE in recent years, the scope of gasoline and other fuel additives manufacturers has broadened from its "specialties" exclusivity to a more wide ranging commodity basis. Major suppliers of MTBE only partially overlap the ranks of overall gasoline and other fuel additive manufacturers, making a case for considering these groups separately.

MTBE -- A total of 22 companies competed in the US MTBE industry in 1991, a number which will expand with the incredible growth prospects facing MTBE and other ether-based anti-knock agents through the year 2000. MTBE production concentration is high, with three companies -- Atlantic Richfield (ARCO), Texas Petrochemicals (Total), and Enron -- controlling nearly two-thirds of total capacity. Remaining production is highly fragmented, with each company having less than six percent of total capacity.

Manufacturing

Manufacturing requirements in the US petroleum additives industry can represent a deterrent to entry. Capital requirements are large, giving existing commodity and specialty chemical producers an advantage. Spending for a start-up operation may require up to $100 million to support the necessary personnel, fund R&D and marketing, and purchase equipment and construct facilities. However, capital requirements are moderate for existing chemical manufacturers. Vertical integration (lubricant and fuel formulators moving upstream, purchasing additive chemical operations) is a viable option for large oil recovery and refining concerns able to outlay the necessary funding, and has been popular in the lubricant and fuel additives industry.

Many additives, such as BHT and MTBE, are commodity chemicals manufactured in continuous processing plants. While they require very little labor, continuous processing operations are highly capital intensive. Labor is most intense in formulating plants which produce specialty chemicals in small batches.

Marketing

The marketing of petroleum additives is generally achieved through company sales personnel and sales engineers to the purchasing agent or buyer employed with the petroleum product manufacture. Additive manufacturers supplying chemicals to the approximately 100 motor gasoline producers face different marketing challenges than those faced by additive suppliers to the over 200 lubricant manufacturers. However, both end-use segments are dominated by a number of large, well capitalized firms, followed by smaller, less formidable producers.

Purchasing policies vary by company, but in many cases supply relationships are negotiated at the headquarter's purchasing departments for chemicals destined for more than one formulating facility.

Due to the high level of competition in the automotive fluids and fuel industries, marketing additives to the automotive products segments (including fuels and lubricants) requires a greater effort than marketing to other end use markets, such as industrial fluids. Additives manufacturers, as with most chemical manufacturers, must command a thorough understanding of end-use industry dynamics and customer needs. Additive suppliers can augment product offerings with strong technical servicing departments, effective and reliable distribution and price competitiveness.

A majority of additives are now marketed in packages. These have become more common throughout the industry, as the sophistication of additives increases and raises the potential for incompatible chemical combinations. Mobil, for example, offers a cost-effective, high performance gear oil additive package labeled MOBALID G221. Utilizing the same proprietary technology, Mobil is now developing other automotive and industrial gear oil additive packages with improved thermal stability. Marketing is further enhanced by product endorsement from high-end European automobile manufacturers, such as BMW, who allow petroleum product formulators to use their name and insignia to signal product quality. Attainment of these endorsements requires meeting the highest standards set by these car manufacturers, who test products on their sites.

Advertising in trade journals such as <u>CPI Purchasing</u>, <u>Hydrocarbon Processing</u>, and <u>Oil and Gas Journal</u> is important to new product development for additive chemicals. A chemical company's marketing service department can aid in generating customer inquiries through advertising, trade shows, trade releases and customer releases. These departments also produce product literature, films, and supporting documentation for both marketing and end-user training.

National and international auto racing networks (NASCAR, SCCA, IROC, IMSA, Indy, Formula One, etc.) often provide high visibility advertising and product promotion for petroleum companies and formulators of gasoline and lubricants. Through team sponsorship, race sponsorship, merchandizing and other avenues, petroleum formulators can create brand awareness and tap into the extensive motorsport following at home and abroad, estimated at 50 million enthusiasts. Companies that market their products this way include STP, Texaco (HAVOLINE), and Ashland (VALVOLINE).

Distribution

The chemicals that are added to petroleum to make specialized, high performance products reach end users through a number of channels. These include established distribution channels for the commodity chemicals market, and channels adapted for the smaller order sizes and greater servicing needs associated with specialty chemicals. Lubricant additives are sold directly to refiners producing lubricants and to compounder blenders. They are qualified through extensive proof-of-performance testing by suppliers for both customers and equipment manufacturers.

Intra-company transfers are significant for additives manufacturers that operate as part of a large petroleum refining entity. Most large purchasers that do not formulate chemicals in-house prefer to buy additives directly from the manufacturer, especially if the quantities involved are purchased in bulk on an annual contract basis. As with many commodity and most specialty chemical producers, the makers of additive chemicals maintain technical servicing centers and warehousing facilities, often close (within 200 miles) to major end users in the petroleum processing industry.

Additives are transported by trucks and trains in drums (55-gallon non-returnable steel) or bulk tank containers. Often toxic liquids mandate the use of stainless steel construction and additional precautions. Transportation costs average less than ten percent of sales for lubricant additives and some specialty fuel additives. However, this figure drops to a small fraction of total sales for additives considered commodity chemicals such as MTBE and BHT.

Direct sales account for most petroleum additive sales. The technical nature of some additives precludes the use of manufacturers' agents and distributors. Distributors are utilized in some cases, however, mainly in the case of lubricant additives. Distributors stock chemicals close the the point of demand, assume all of the risks involved in managing inventory, and provide rapid turnarounds in delivery.

Acquisitions and Divestititures

In response to the increasingly competitive petroleum additives market, widespread industry consolidation has occured in recent years. Due to the prohibitive research and development costs associated with the business, it is necessary to have a large operation in order to distribute these costs over volume. Many companies with smaller petroleum additives operations have, therefore, sold off these operations.

TABLE VI-2

SELECTED ACQUISITIONS & DIVESTITURES

Company	Acquiring	From Whom	Date
Berkshire Hathaway (K&W Products)	USA-1 Products (packaged petroleum additives)	--	1991
Chevron Corporation	Orogil SA (France-petroleum additives)	Rhone-Poulenc SA (France)	4/90
ENRON Corporation	MTBE business	Tenneco Incorporated	1991
Ethyl Corporation	Amoco Petroleum Additives	Amoco Corporation	1992 (pending)
Great Lakes Chemical	Additional 36.7 percent of Octel Associates (UK-gas additives)	Shell UK	1991
Petroleos de Venezuela	Citgo Petroleum (deposit control additives/MTBE)	Southland Corporation	2/90
Rhone-Poulenc SA (France)	surfactants business	GAF Corporation	2/90
Total (France)	Texas Petrochemicals (MTBE)	--	11/91

Dow Chemical Company
2300 Willard H. Dow Center
Midland, MI 48640
(517) 636-1000

Dow operates in five lines of business: Chemicals and Performance Products (chemicals used as processing aids and raw materials in the manufacture of other products); Plastic Products (thermoplastics, thermosets and plastic products); Consumer Specialties (agricultural chemicals, pharmaceuticals, and consumer products); Hydrocarbons & Energy (fuels, olefins, aromatics, styrene and cogeneration); and Unallocated (insurance). Dow recorded 1991 sales of $18.8 billion. The Company employs 62,200.

The Chemicals & Performance Products segment produces a variety of chemicals including alkanolamines, ethanolamines, ethyleneamines, glycerine, hydrogen chloride, phenol, propylene glycols, propylene oxide, surfactants, antimicrobials, glycol ethers, cellulosic products, chelating agents, polyglycols, de-icing fluids, lubricants, and other products. The Company's basic chemicals are used in the manufacture of lubricating oils and fuel additives to help protect engines from corrosion and the build-up of deposits.

Although Dow does not produce any finished petroleum additive products, the Company is a significant supplier of raw materials for these products. In 1991, Dow began construction of a new 60 million pound ethyleneamines plant in Freeport, Texas which is expected to be operational in 1992. Ethyleneamines are used in lube oil and gasoline additives. The Company predicts growing demand for its ethyleneamines through the early 1990's, despite slowdown in world economies. Demand for triethylenetetramine (TETA), tetraethylenepentamine (TEPA) and pentaethylenehexamine (PEHA) will rise because of stricter regulations for cleaner burning fuels, especially diesel fuels. Dow has 100 million pounds of annual capacity, second in the US to Union Carbide.

In addition, Dow has signed an option to license fuel additive technology developed by Polar Molecular Corporation. This may signal Dow's entry into the finished petroleum additives market. Dow will assess opportunities for the technology in the US and certain overseas markets. The option includes the acquisition of know how, and licensing rights to the technology. The technology controls combustion chamber deposits and reduced octane requirement increase in older vehicles.

Phillips Petroleum Corporation
Phillips Building
Bartlesville, OK 74004
(918) 661-6600

Phillips Petroleum operates in three lines of business: Petroleum (exploration and production, gas and gas liquids, and petroleum products); Chemicals (resins, engineering plastics, olefins, aromatics, chemicals, hydrocarbons, catalysts, fibers and pipe); and Other (minerals). Revenues in 1991 totaled $13.3 billion. The Company employs 22,700. Petroleum additives offered by Phillips include PHILJET anti-icing, anti-microbial additive for jet fuel.

Phillips produces MTBE at a unit at Sweeny, Texas at an annual capacity of 280 million pounds per year. A unit at Borger, Texas is planned for 1993 start up, with an annual capacity of 680 million pounds per year. The Borger unit, which will also be able to produce ethyl tert-butyl ether, will use the STAR dehydrogenation process to produce MTBE.

Polar Molecular Corporation
4901 Towne Centre Road
Saginaw, MI 48604
(517) 790-4764

Polar Molecular has developed a unique line of petroleum additive products which are sold under the DURALT and DUROIL tradenames. These products, which are manufactured for PMC by Pfizer Incorporated, are used in gasoline and diesel fuels. Sales for the Company in 1991 totaled $2 million. Polar Molecular employs 10.

The Company offers the DURALT line of fuel conditioners. These additives are patented combustion modifiers. Enhanced combustion prior to opening the exhaust valves yield cooler exhaust gas temperatures and better fuel economy. Cooler exhaust temperatures, coupled with DURALT's inhibition of peroxy free radicals, reduces valve seat wear. These effects result in more complete combustion, reduced octane requirement, and improved driveability. DURALT additives are designed to allow most vehicles to use lower octane gasoline without loss of performance.

DURALT fuel conditioners are designed to increase power, improve fuel mileage, reduce valve seat wear, reduce octane requirement increase in gasoline engines, cleans the combustion chamber, reduces the formation of gums and sediments, increases diesel cetane, inhibits algae and bacteria, reduces diesel injector fouling and reduces hydrocarbon emission in both gasoline and diesel engines.

DURALT fuel conditioners are multi-purpose fuel additives composed of carbon, hydrogen and oxygen, designed for use in both gasoline and diesel engines. The additive acts as a combustion modifier which positively affects a number of engine functions. DURALT additives contain no metallic ingredients, no methanol or ethanol and no nitrogen or phosphorus compounds.

DURALT additives have been declared "substantially similar" under the Clear Air Act by the Environmental Protection agency. This allows DURALT additives to be bulk blended in gasoline sold as unleaded. Polar Molecular bases its claims that DURALT products are excellent substitutes for leaded gasoline on two characteristics of the DURALT additives. First, they reduce valve seat wear and, second, they reduce octane requirement increase in gasoline engines.

Polar Molecular has announced an agreement with Dow Chemical under which Dow has the option to license fuel additive technology developed by PMC. During the option period, Dow will assess the opportunities for the technology in the US and overseas. The option concerns PMC technology which has demonstrated the ability to control combution chamber deposits and to reduce octane requirement increase (ORI) which occurs in autos as they get older.

PMC has also sold Amway Corporation expanded marketing rights and certain technology rights as part of a broadened supply and marketing contract. Amway has marketed PMC's DURALT fuel additives under the brand name FREEDOM fuel additive under a 1988 agreement with PMC. The agreement gives Amway exclusive worldwide rights to the four products within Amway's direct seller field use.

elf antar france

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téléphone 78 02 61 00
télex elf cros 300 591

centre de recherche

POLAR MOLECULAR CORPORATION
Mark L. NELSON
7261 Terry Road
Saginaw, Michigan 48609
U.S.A.

RD/F/CRES/RS - 95/844
LG/MG

Solaize, le 5 décembre 1995

Dear Mark,

I am pleased to send you the two copies of the mutual confidentiality agreement signed by Mr Gérard BAUDOUIN, Director of the Research Centre.

Would you please have them signed and send me back one copy.

We will need a sample of DURALT FC to run the tests we plan to start at the beginning of next year.

I will inform you on the exact quantity we need when I define the program.

Best regards.

L. GERMANAUD

NB : The two copies of the agreement have been mailed today, but you could receive them later than expected due to the fact that French Administration and Postmen are on strike.

proposition 1995

MUTUAL CONFIDENTIALITY AGREEMENT

Agreement made this 4 day of December, 1995 by and between Polar Molecular Corporation, a ~~Delaware~~ Corporation having a principal office at 231 W. Lake Lansing Road, Suite 200, East Lansing, Michigan 48823, United States of America ("Polar") and Elf France, S.A., a French Corporation with an office at Place de la Coupole -2, La Defense 6, 92 400 Courbevoise, France ("Elf").

1. Background. Elf and Polar intend to engage in discussions and negotiations concerning the establishment of a business relationship between them. In the course of such discussions and negotiations, it is anticipated that either party may disclose or deliver to the other party certain of its trade secrets or confidential or proprietary information for the purpose of enabling the other party to evaluate the feasibility of such business relationship. The parties have entered into this Agreement in order to assure the confidentiality of such trade secrets and confidential or proprietary information in accordance with the terms of this Agreement. As used in this Agreement, the party disclosing Proprietary Information (as defined below) is referred to as the "Disclosing Party"; the party receiving such Proprietary Information is referred to as the "Recipient".

2. Proprietary Information. As used in this Agreement, the term "Proprietary Information" shall mean all trade secrets or confidential or proprietary information designated as such in writing by the Disclosing Party, whether by letter or by the use of an appropriate proprietary stamp or legend, prior to or at the time any such trade secret or confidential or proprietary information is disclosed by the Disclosing Party to the Recipient. Notwithstanding the foregoing, information which is orally or visually disclosed to the Recipient by the Disclosing Party, or is disclosed in writing without an appropriate letter, proprietary stamp or legend, shall constitute Proprietary Information if the Disclosing Party, within thirty (30) days after such disclosure, delivers to the Recipient a written document or documents describing such Proprietary Information and referencing the place and date of such oral, visual or written disclosure and the names of the employees or officers of the Recipient to whom such disclosure was made.

3. Disclosure of Proprietary Information. The Recipient shall hold in confidence, and shall not disclose to any person outside its organization, any Proprietary Information. The Recipient shall use such Proprietary Information only for the purpose for which it was disclosed and shall not use or exploit such Proprietary Information for its own benefit or the benefit of another without the prior written consent of the Disclosing Party. The Recipient shall disclose Proprietary Information received by

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it under this Agreement only to persons within its organization who have a need to know such Proprietary Information in the course of the performance of their duties and who are bound to protect the confidentiality of such Proprietary Information.

4. <u>Limitation on Obligations</u>. The obligations of the Recipient specified in Section 3 above shall not apply, and the Recipient shall have no further obligations, with respect to any Proprietary Information to the extent that such Proprietary Information:

(a) is generally known to the public at the time of disclosure or becomes generally known through no wrongful act on the part of the Recipient;

(b) is in the Recipient's possession at the time of disclosure otherwise than as a result of Recipient's breach of any legal obligation;

(c) becomes known to the Recipient through disclosure by sources other than the Disclosing Party having the legal right to disclose such Proprietary Information;

(d) is independently developed by the Recipient without reference to or reliance upon the Proprietary Information; or

(e) is required to be disclosed by the Recipient to comply with applicable laws or governmental regulations, <u>provided that</u> the Recipient provides prior written notice of such disclosure to the Disclosing Party and takes reasonable and lawful actions to avoid and/or minimize the extent of such disclosure.

5. <u>Ownership of Proprietary Information</u>. The Recipient agrees that the Disclosing Party is and shall remain the exclusive owner of Proprietary Information and all patent, copyright, trade secret, trademark and other intellectual property rights therein. No license or conveyance of any such rights to the Recipient is granted or implied under this Agreement.

6. <u>Return of Documents</u>. The Recipient shall, upon the request of the Disclosing Party, return to the Disclosing Party all drawings, documents and other tangible manifestations of Proprietary Information received by the Recipient pursuant to this Agreement (and all copies and reproductions thereof).

7. <u>Miscellaneous</u>.

(a) All prior confidentiality agreements between the parties remain in full force in effect and are incorporated herein by reference. This Agreement supersedes all such prior agreements, written or oral, between the Disclosing Party and the Recipient relating to the subject matter of this Agreement. This

GTB

Agreement may not be modified, changed or discharged, in whole or in part, except by an agreement in writing signed by the Disclosing Party and the Recipient.

(b) This Agreement will be binding upon and inure to the benefit of the parties hereto and their respective heirs, successors and assigns.

(c) This Agreement shall be construed and interpreted in accordance with the laws of the State of Michigan.

(d) The provisions of this Agreement are necessary for the protection of the business and goodwill of the parties and are considered by the parties to be reasonable for such purpose. The Recipient agrees that any breach of this Agreement will cause the Disclosing Party substantial and irreparable damages and, therefore, in the event of any such breach, in addition to other remedies which may be available, the Disclosing Party shall have the right to seek specific performance and other injunctive and equitable relief.

EXECUTED as a sealed instrument as of the day and year first set forth above.

Polar Molecular Corporation

By: [signature]

Title: Chairman & CEO

Elf France, S.A.

By: G. BAUDOUIN [signature]

Title: Director of the Research Centre

This agreement shall continue for a period of 10 years from the execution date

EVALUATION OF DURALT FC ADDITIVE

ELF - PMC Meeting

SOLAIZE, May 23 1996

EVALUATION OF DURALT FC ADDITIVE

- **Previous Tests (1993) :**

  – <u>ORI contol and combustion chamber cleanliness</u>

  The effect of the additive packages regarding the ORI control and the cleanliness of the combustion chamber have been evaluated by running the CEC PF28 procedure known as Renault 22700 procedure :

  – Renault F3N engine,

  – keep-clean / 400 hrs test,

  – visual rating of the deposits formed on the cylinder heads and

  – piston heads according to a demerit scale :

    » 0 = clean   3 = heavy deposits

  – measurements of Knock Limit Spark Advance in cranckshaft degrees and determination of the Δ KLSA° during the test and through an engine speed of 1500 to 4500 rpm.

4. ORI control - (technical reports = appendix III)

The effect of the additives package DE1248 regarding the Octane Requirement Increase Control as well as the cleanliness of combustion chambers and piston heads has been evaluated by running the CEC PF28 procedure known as Renault 22700 procedure :

- Renault F3N engine,
- keep clean / 400 hrs test,
- measurements of Knock Limit Spark Advance in crankshaft degrees and determination of the variations in KLSA (Δ KLSA°) throughout the test duration and through an engine speed range of 1500 rpm to 4500 rpm,
- visual ratings ot the deposits formed within the cylinder heads and piston heads according to a demerit scale : 0 = clean
  3 = heavy deposit

Δ KSLA° at end of test (400 hrs)
(2 consecutive determinations as required : # 1 & # 2)

rpm	Base fuel SP 98000 (08/92)		Base + DE1248	
	# 1	# 2	# 1	# 2
1500	8	7	5	5
2000	11	10	8	7
2500	13	11	9	8
3000	12	10	8	7
3500	10	8	6	5
4000	9	7	4	3
4500	9	7	5	4.5

Average visual ratings : demerit /3

	Base fuel SP98000 (08/92)	Base + DE 1248
Cylinder head	1.60	0.82
Piston heads	1.96	1.41

EVALUATION OF DURALT FC ADDITIVE

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  3 = heavy deposit

Δ KSLA° at end of test (400 hrs)
(2 consecutive determinations as required : # 1 & # 2)

rpm	Base fuel SP 98000 (08/92)		Base + DE1248	
	# 1	# 2	# 1	# 2
1500	8	7	5	5
2000	11	10	8	7
2500	13	11	9	8
3000	12	10	8	7
3500	10	8	6	5
4000	9	7	4	3
4500	9	7	5	4.5

Average visual ratings : demerit /3

	Base fuel SP98000 (08/92)	Base + DE 1248
Cylinder head	1.60	0.82
Piston heads	1.96	1.41

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Presentation on:

Polar Molecular Corporation

September 1997

SMITH BARNEY

A Member of *TravelersGroup*

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POLAR MOLECULAR CORPORATION

SMITH BARNEY
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Polar Molecular Corporation

PMC's founders, also the inventors of many of the Company's products, hold a controlling interest in PMC. The Company has invested over $30 million in product development since its inception, and contracts with Grow Automotive, a division of Imperial Chemical Industries Plc. ("ICI"), under a license agreement for the manufacture and supply of its products.

- ▶ PMC has treated over 1 billion gallons of fuel
- ▶ Over 10 billion trouble-free miles have been driven in gasoline and diesel-powered engines running on fuel treated with PMC products
- ▶ PMC has 40 patents issued or pending worldwide
- ▶ PMC products have been proven or marketed by major engine manufacturers including:
  - Ford Motor Company
  - Harley Davidson Motorcycle
  - Mercury Marine
  - Amway Corporation
  - Elf High Technology Racing Fuels

Polar Molecular Corporation ("PMC"), founded in 1984 and headquartered in Denver, Colorado, is a privately-held technology company whose mission is to market new, leading-edge fuel additives to major petroleum refiners, fuel consumers and oil producers.

Polar Molecular Corporation Products: DurAlt FC

DURALT FC IS PMC'S FLAGSHIP PRODUCT

- DurAlt FC is a gasoline and diesel fuel conditioner
- DurAlt FC reduces combustion chamber deposits ("CCD") which form as a result of the normal combustion process in engines by 55-80%
- CCD results in an octane requirement increase ("ORI"), which is the tendency of a motor vehicle engine to require additional octane of 5-10 numbers as it accumulates 10-20 thousand kilometers
- By controlling CCD, DurAlt FC controls the ORI of the vehicle
- Tetraethyl lead ("TEL" or "lead") is an octane enhancer universally recognized for adverse health effects, particularly on children
- Lead has been banned in domestic fuels for many years and is also banned in Canada and most of Western Europe
- The major markets for lead remain developing economies where the cost of supplemental octane is prohibitively expensive
- Nonetheless, most developing countries have lead phase-out plans currently underway
- By controlling the ORI, DurAlt FC can assist developing countries in phasing lead out of their gasoline pools
- DurAlt CFC is a highly concentrated version of DurAlt FC designed for refinery usage with sophisticated blending equipment

DurAlt FC is a fuel additive used to control combustion chamber deposits and reduce octane requirements in leaded gasoline, unleaded gasoline and diesel fuels.

Polar Molecular Corporation Products

DURAFLO I

DuraFlo I is a concentrated, premier fuel additive which combines DurAlt FC with a wax crystal modifier for use with diesel fuels in cold climates. DuraFlo changes the "flowability" of the fuel in cold weather by modifying its temperature-viscosity profile. The product is intended for use with sophisticated refinery blending equipment.

DURAFLO II

DuraFlo II is a jobber, fleet or consumer version of DuraFlo I.

DURASTA

DuraSta is an additive which improves fuel stability by inhibiting oxidation. This phenomena typically occurs when reactive molecules within the fuel combine with atmospheric oxygen, resulting with a degradation of product quality.

DURAKLEEN

DuraKleen is a heavy fuel conditioner designed for use in bunker-type fuels or crude oils. DuraKleen keeps the heavier fuel components in suspension, thereby reducing or preventing tank stratification. DuraKleen also reduces the cleaning requirements of oil field pipelines and storage units.

PMC offers a well-rounded product portfolio.

Great Lakes Chemicals: Octel

OCTEL SUBSIDIARY

- ▶ Octel is the world's foremost producer of lead compound, the most cost effective and energy efficient means for delivering antiknock qualities to motor fuel
  - Great Lakes has met declining volume in worldwide demand for tetra ethyl lead compounds with higher prices, but prices are expected to remain flat in the future
  - Octel has been aggressively managing its costs and consolidated all of its operations into its highly efficient Ellesmere Port, UK facility
- ▶ Octel uses its expertise in motor fuel technology to develop and manufacture new petroleum specialties
  - Octel is focusing its petroleum enhancing transport fuel additives technologies to emerging markets in the Far East and South Africa
  - Octel's new OLI 9000 lubricity improver to protect engine fuel pumps has seen strong demand from U.S., European, and Japanese oil companies because of new European legislation that mandates reduced levels of sulfur in diesel fuels
- ▶ Octel also draws on Great Lakes' abundant supply of elemental bromine to manufacture bromine and sodium derivatives and chlor-alkali products
- ▶ Octel's business strategy is to counter constricting demand for its alkyl lead compounds with aggressive cost cutting and diversification strategies

Through its Octel subsidiary, Great Lakes is the global leader in the production and distribution of certain high-performance fuel additives and petroleum specialties.

GREAT LAKES CHEMICAL/OCTEL

Description

Great Lakes Chemical Corporation

- Performance Chemicals (37% of 1996 sales, 30% of operating income)
  - Polymer additives: flame retardants, antioxidants, UV absorbers or light stabilizers, and plasticizers used in the textile, electronics, construction, and transportation equipment industries
  - Functional intermediates and fine chemicals: bromine and furfural-based specialty chemicals for the foundry, pharmaceutical, agrochemical, electronics, and lube oil refining industries
  - Industrial specialty chemicals: bromine, sodium, chlorine, furfural and their derivatives are used for the telecommunication, military, pest control, photographic, and film and rubber industries
- Water Treatment Chemicals (19% of 1996 sales, 10% of operating income)
  - Recreational: water sanitizers, algaecides, oxidizers, and specialty chemicals are sold to pool and spa dealers, mass market retailers, and builders distributors
  - Industrial: specialty biocides and biocide dispensing equipment serving the industrial cooling water treatment, industrial and municipal wastewater treatment, pulp and paper and food processing markets
- Specialized Services and Manufacturing (16% of 1996 sales, 10% of operating income)
  - Custom manufacturing; enviro-energy performance; oil field services, waste management, toxicological services, engineered surface treatments; and international trading
  - Markets served by these different groups range from aerospace and automotive to pharmaceutical and medical and agricultural
- Petroleum Additives (Octel subsidiary; 28% of 1996 sales, 50% of operating income)
  - Antiknock (TEL) octane boosters for leaded gasoline, cetane improvers for diesel, multi-functional fuel additives, detergents, petroleum oxidants, stabilizers and corrosion inhibitors are produced by this segment. Their principal markets are major oil refineries and fuel blenders across the world

Breakout of operating income is estimated

Great Lakes Chemical produces and sells performance chemicals, water treatment chemicals, specialized services and petroleum additives.

Great Lakes Chemical: Summary Financial Information

LTM FINANCIAL OVERVIEW

(All Amounts in Millions, Except Per Share Figures)

Income Statement [1]	
Sales	$2,123.2
EBITDA	537.8
EBIT	409.4
Net income	221.4
EPS	$3.57
LTM P/E	13.0x
Price/cash flow	7.7x
Indicative dividend	$0.64
Payout ratio	0.2x
Yield	1.4%

[1] *Excludes extraordinaries*

Equity Information	
Stock price	$46.31
LTM High	59.38
LTM Low	41.50
Shares outstanding	59.8
1997E EPS	$3.92
1998E EPS	4.25
1997E P/E	11.8x
1998E P/E	10.9
LTM TEV / EBITDA	5.9
LTM TEV / EBIT	7.7

Capitalization	Book Capitalization		Market Capitalization	
	Amount	Percent	Amount	Percent
Short-term debt	$5.7	0.3%	$5.7	0.2%
Long-term debt	569.9	27.7	569.9	16.8
Minority Interest	39.7	1.9	39.7	1.2
Preferred stock	0.0	0.0	0.0	0.0
Common equity	1,442.6	70.1	2,771.7	81.8
Total capitalization	**$2,057.9**	**100.0%**	**$3,387.0**	**100.0%**
Cash and equivalents			228.3	
Enterprise value			**$3,158.7**	
Market/Book		192.1%		

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Announced Spin-Off of Octel Co.

Great Lakes Chemical: *Spin-Off of Octel*

DEAL STRUCTURE

The transaction is as follows:

- Prior to the spin-off, GLK will acquire Chevron's 10.65% interest in Octel
- The Bromine operations, currently grouped with Octel, will be transferred to GLK along with a fine chemical research operation
- Prior to the spin-off, Octel will raise approximately $450 million through borrowings in the public and private sector
- A portion of the proceeds will be used to repay the loan expected to be incurred in connection with the Chevron transaction
- Borrowings will have a maturity up to eight years and an average annual interest rate of approximately 9.5%
- The remainder of the proceeds, plus available cash from Octel, less taxes and transaction costs, will be distributed to Great Lakes Chemical in the form of a special distribution of about $300 million prior to the completion of the spin-off
- Great Lakes intends to use these funds to complete strategic acquisitions
- The Company's Board also authorized the buyback of up to 4 million shares

On July 17, 1997, Great Lakes Chemical announced that its board has approved a plan to spin-off its petroleum-additives unit creating a new, independent publicly traded company, Octel.

Rationale for Octel Spin-Off from Great Lakes

GLK's management had previously telegraphed its intent to somehow eliminate Octel from its business portfolio. The following are the reasons most often cited for selling or spinning off Octel:

- ▶ Valuation Clarity
  - Management believes that its other businesses are not being afforded full-value by the market due to the presence of Octel and its declining earnings stream
    - The Specialty Chemicals Group is currently trading at 15.6x 1998 earnings estimates
    - Great Lakes is currently trading at 10.9x 1998 earnings estimates
- ▶ Management Focus
  - Management will be free to devote its attention to the growth businesses that comprise Great Lakes' future
- ▶ Environmental Liability
  - Great Lakes will be free from the specter of clean-up costs associated with TEL manufacture as well as potential health-related lead liabilities with could hamper the Company's ability to grow its other businesses
- ▶ Shareholders
  - Management believes that its shareholders own Great Lakes because of its specialty chemicals portfolio, not because of Octel

A separation of Octel from Great Lakes has been sought for several years by analysts who follow the stock.

Why is the Announced Transaction Disappointing?

MARKET REACTION

- Upon announcement of the transaction, the market bid GLK down from 53 5/8 to 48, a 10.5% decline (see indexed price graph)
- The stock recovered temporarily but has since declined further (GLK closed at 46 5/16 on 09/12/97)

Given the apparently valid rationale for the transaction, it is natural to wonder why the market reacted so negatively:

FACTORS IMPACTING MARKET REACTION

- Perceived low market valuation of public lead company
- Concern that Great Lakes overpaid Chevron for its minority stake in the business
- Concern regarding reinvestment risk of the net proceeds of the dividend
- Lack of commitment to a more significant share buyback
- Great Lakes shareholders are not rid of the specter of lead because they will now own shares in a lead company

CONCLUSION

Management must consider an alternate transaction that affords greater value to Great Lakes' shareholders. The PMC opportunity provides incremental value that justifies paying a premium to the transaction value afforded to Great Lakes under the proposed spin-off structure.

The market's reaction to the announcement of the transaction was decidedly negative - the stock was bid down over 10%.

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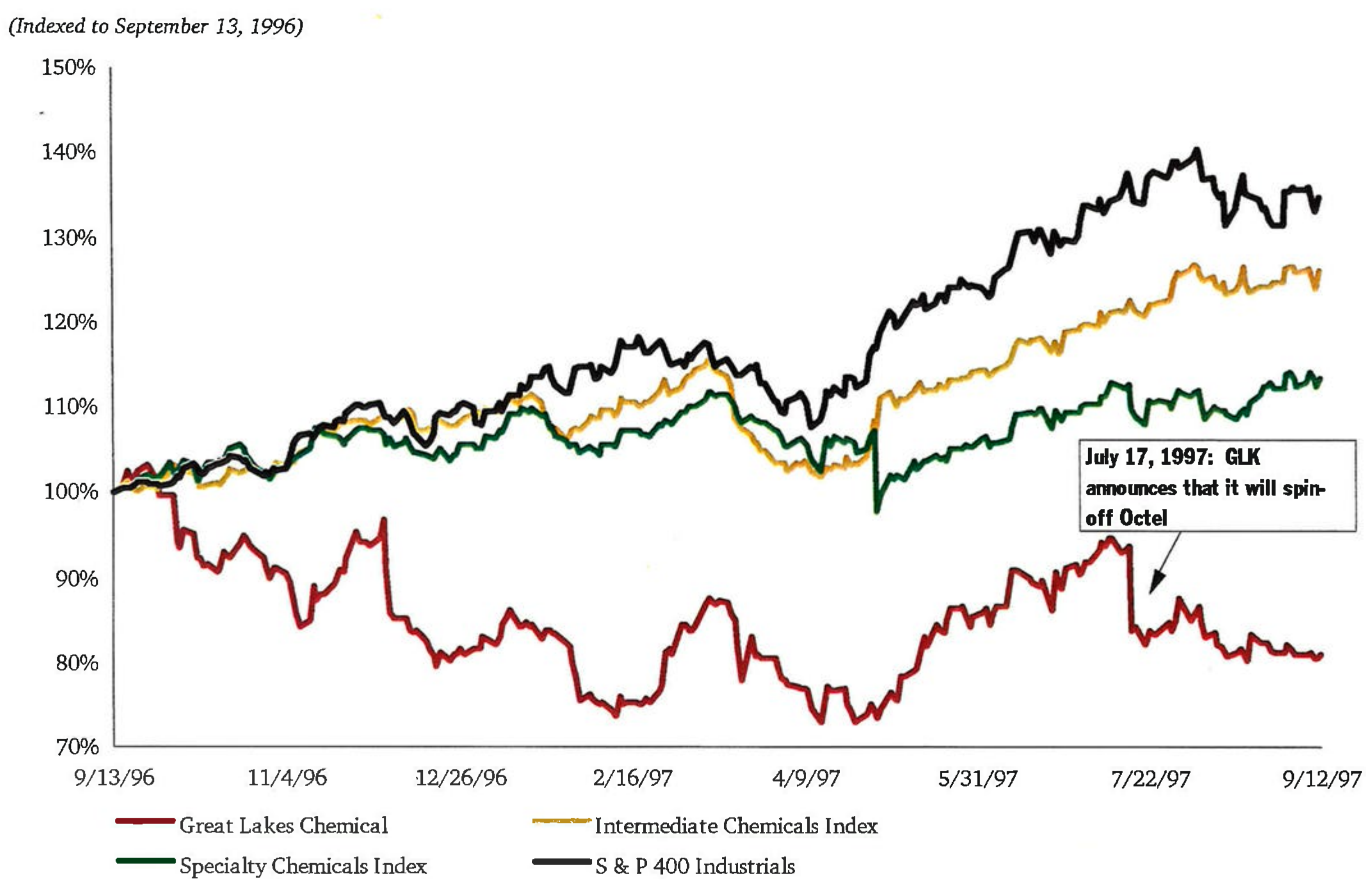
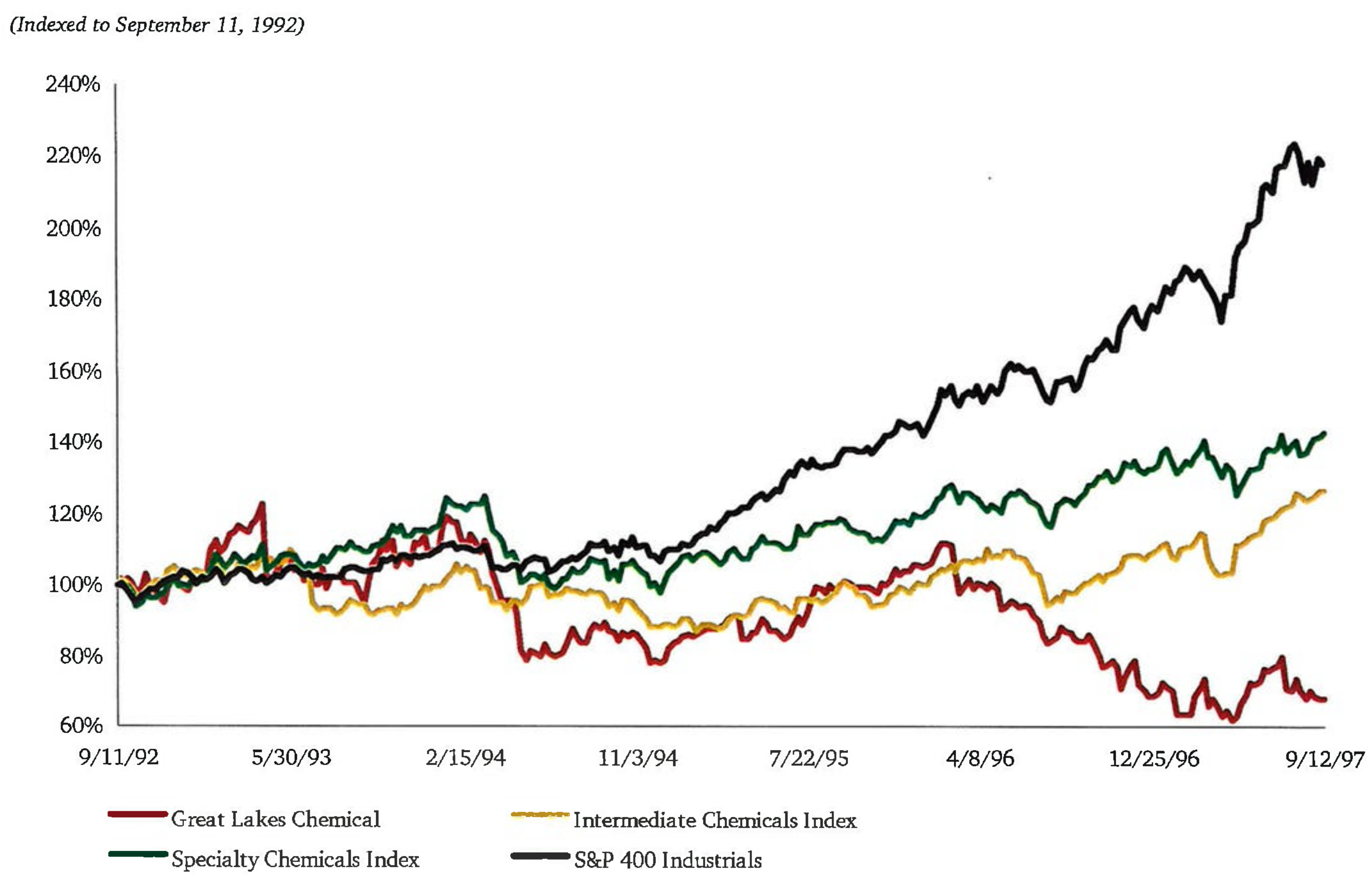
Great Lakes Chemical vs. Specialty & Intermediate Chemicals Indices & S&P 400 Industrials



Note: Intermediate Chemicals Index is a composite of: ALB, CNK, DEX, EY, MAH, ROH, RCM, WIT
Specialty Chemicals Index is a composite of: BTL, CEM, CYT, ECL, FOE, FULL, GLK, LZ, MII, NLC

Great Lakes Chemical vs. Specialty & Intermediate Chemicals Indices & S&P 400 Industrials



Note: Intermediate Chemicals Index is a composite of: ALB, CNK, DEX, EY, MAH, ROH, RCM, WIT
Specialty Chemicals Index is a composite of: BTL, CEM, CYT, ECL, FOE, FULL, GLK, LZ, MII, NLC

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Valuation of Stand-Alone Octel Co.

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Octel Income Statement

($ in thousands)

	Actual		Projected							
	Dec. 31,		Dec. 31,							
	1995	1996	1997	1998	1999	2000	2001	2002	2003	CGR
Revenue	$ 623,000	$ 590,000	$ 536,900	$ 488,579	$ 444,607	$ 404,592	$ 368,179	$ 335,043	$ 304,889	(9.0%)
Cost of Goods Sold			138,520	128,252	116,709	106,205	96,647	87,949	80,033	
Gross Margin			$398,380	$360,327	$327,898	$298,387	$271,532	$247,094	$224,856	
Operating Expenses			161,070	146,574	133,382	121,378	110,454	100,513	91,467	
EBITDA	287,000	264,000	$237,310	$213,753	$194,516	$177,009	$161,078	$146,581	$133,389	(9.2%)
Depreciation & Amortization	33,000	42,000	37,700	34,660	32,153	30,114	28,389	26,926	25,783	
EBIT	254,000	222,000	$199,610	$179,093	$162,363	$146,895	$132,690	$119,655	$107,606	(9.8%)
Interest expense			42,750	42,750	42,750	42,750	42,750	42,750	42,750	
Earnings before taxes			$156,860	$136,343	$119,613	$104,145	$89,940	$76,905	$64,856	(13.7%)
Income Taxes			53,332	46,357	40,668	35,409	30,579	26,148	22,051	
Net Income			$103,527	$89,987	$78,944	$68,735	$59,360	$50,757	$42,805	(13.7%)

Octel Company: Summary of Valuation Techniques

($ in millions)

Octel's value is approximately $900 million based on 5x 1998E earnings. A purchase price of $900 is used in this analysis:

1998 Earnings Multiple	4.0x	5.0x	6.0x
Total capitalization	$810	$900	$990

Discounted Cash Flow @ 10%			
Terminal EBITDA multiple	3.5x	4.0x	4.5x
Total capitalization	$753	$791	$829

Valuation Implied by GLK Post Spin-off	
Total capitalization	$728

Lowest valuation:	$728
Highest valuation:	$990
Median valuation:	$810

Octel Company: Multiple Valuation

($ in millions)

The market value of equity is estimated based on a P/E of 5x 1998E earnings. This valuation multiple, low relative to specialty chemical companies, is appropriate given the declining nature of Octel's operating cash flow.

PRO FORMA FINANCIALS AND VALUATION

	Octel Petroleum Additives		
	1996	**1997E**	**1998E**
Sales	$590	$537	$489
EBITDA	$264	$237	$214
EBIT	$222	$200	$179
Interest		43	43
EBT	$222	$157	$136
Taxes	75	53	46
Net Income	$147	$104	$90

Note: Smith Barney estimates

	Octel Market Capitalization (P/98E Multiple)		
	4.0x	5.0x	6.0x
Equity	$360	$450	$540
Debt	450	450	450
Total capitalization	**$810**	**$900**	**$990**

VALUATION CROSS-CHECK

Specialty Chemical Companies		
Cost of equity	11%	15%
Group P/98E multiple	15.6x	15.6x
Implied long-term growth	4.6%	8.6%
Octel long-term growth rate	(9.0%)	(9.0%)
Octel cost of equity	12%	16%
Implied P/98E multiple[1]	4.8x	4.0x

(1) *Model: P.E = 1/[r(e) - g]*

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Octel Company: Valuation Implied by GLK

($ in millions)

GREAT LAKES CHEMICAL (POST-OCTEL SPINOFF)

	1996 pf	1997E pf	1998E pf
Sales	1,631	1,669	1,769
EBITDA	276	266	280
EBIT	194	193	212
Interest	83	69	69
Other income	47	28	28
EBT	158	153	172
Taxes at 35%	55	53	60
Net income	103	99	112
Share currently outstanding			59.8
Shares repurchased			(4.0)
Pro forma shares outstanding			55.8
EPS			2.00

	Per Share	Market value
GLK, current (59.8 million shares outstanding)	$46.31 [1]	$2,771
GLK post-spinoff at 15.6x 98E (55.8 million shares outstanding)	36.59	2,043 [2]
		$728
Implied value of Octel (59.1 million shares outstanding)	**$12.16** [3]	

[1] Closing price as of 09/12/97

[2] Includes $300 million in special dividend back to GLK

[3] $728 market value divided by 59.8 million shares

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Octel Company: Discounted Cash Flow Valuation

($ in millions)

	Projected, Dec. 31,					
	1998	1999	2000	2001	2002	2003
Revenues	$489	$445	$405	$368	$335	$305
EBITDA	214	195	177	161	147	133
EBIT	179	162	147	133	120	108
Tax Effect	(61)	(55)	(50)	(45)	(41)	(37)
Unlevered net income	$118	$107	$97	$88	$79	$71
Plus: Depreciation & Amortization	$35	$32	$30	$28	$27	$26
Less: Capital Expenditure	(14)	(14)	(14)	(12)	(12)	(12)
Plus: Changes in Working Capital	(1)	(1)	(1)	(1)	(1)	(1)
Free Cash Flow	$138	$125	$113	$103	$93	$84

	Discounted Terminal Value, 2003 EBITDA Multiple				Present Value
Discount Rate	3.0x	3.5x	4.0x	4.5x	of Cash Flow
10.0%	$226	$264	$301	$339	$490
11.0%	214	250	285	321	477
12.0%	203	237	270	304	465
13.0%	192	224	256	288	453

	Net Present Value, 2003 EBITDA Multiple			
Discount Rate	3.0x	3.5x	4.0x	4.5x
10.0%	$716	$753	$791	$829
11.0%	703	740	778	816
12.0%	691	728	766	803
13.0%	679	716	754	792

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APPENDIX

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Octel Purchase Transaction Summary

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Octel Purchase Transaction Summary

($ in millions)

Octel could be acquired in a highly leveraged transaction valued at $925 million:

Sources of Funds	
Equity contribution - financial sponsor	$50
Debt refinanced at Octel	451
New bank debt	411
Balance sheet cash	13
Total	**$925**

Uses of Funds	
Purchase Octel equity	$450
Assumed Octel debt	451
Transaction costs	20
Working capital	4
Total	**$925**

Acquisition Multiples	
1997E EBITDA	4.0x
1998E EBITDA	4.3x
1999E EBITDA	4.8x

Octel Income Statement: Leveraged Acquisition

($ in thousands)

	Projected, Dec. 31,						
	1998	1999	2000	2001	2002	2003	CGR
Revenue	$488,579	$444,607	$404,592	$368,179	$335,043	$304,889	(9.0%)
Cost of Goods Sold	128,252	116,709	106,205	96,647	87,949	80,033	
Gross Margin	$360,327	$327,898	$298,387	$271,532	$247,094	$224,856	
Operating Expenses	146,574	133,382	121,378	110,454	100,513	91,467	
EBITDA	$213,753	$194,516	$177,009	$161,078	$146,581	$133,389	(9.2%)
Depreciation & Amortization	43,275	40,694	38,590	36,807	35,294	34,107	
Transaction Goodwill Amortization	10,665	10,665	10,665	10,665	10,665	10,665	
Transaction Cost Amortization	2,000	2,000	2,000	2,000	2,000	2,000	
EBIT	$170,479	$153,822	$138,419	$124,271	$111,287	$99,282	(9.3%)
Interest expense (on avg. balance)	77,158	68,160	59,847	52,045	44,680	37,779	
Earnings before taxes	$93,321	$85,662	$78,572	$72,226	$66,607	$61,503	
Income Taxes	31,729	29,125	26,714	24,557	22,646	20,911	
Net Income	$61,592	$56,537	$51,857	$47,669	$43,961	$40,592	(12.3%)
Cash Flow and Debt Service							
Net income	$61,592	$56,537	$51,857	$47,669	$43,961	$40,592	
D&A	43,275	40,694	38,590	36,807	35,294	34,107	
Goodwill Amortization	10,665	10,665	10,665	10,665	10,665	10,665	
Transaction Cost Amortization	2,000	2,000	2,000	2,000	2,000	2,000	
Capital expenditures	(14,000)	(14,000)	(14,000)	(12,000)	(12,000)	(12,000)	
Provision for clean-up sinking fund	(5,000)	(5,000)	(5,000)	(5,000)	(5,000)	(5,000)	
Free Cash Flow	$98,531	$90,895	$84,112	$80,141	$74,920	$70,364	
BOY Debt Balance	$861,455	$762,924	$672,029	$587,916	$507,775	$432,856	
Principal payment	98,531	90,895	84,112	80,141	74,920	70,364	
EOY Debt Balance	$762,924	$672,029	$587,916	$507,775	$432,856	$362,492	

Leverage Ratios, Coverage Ratios & Financial Returns

($ in millions)

Coverage ratios are reasonable even with greater than 90% leverage:

	1998 Octel Pro Forma for Acquisition
Leverage Ratios	
Total debt / capitalization	93.2%
Total debt / EBITDA	4.0x
Net Debt / EBITDA	4.0x
Coverage Ratios	
EBITDA / Interest expense	2.8x
EBITDA / Net interest expense	2.8x
(EBITDA-Capex) / Interest expense	2.6x
(EBITDA-Capex) / Net interest expense	2.6x
EBIT / Interest expense	2.2x
EBIT / Net interest expense	2.2x

Financial Sponsor Returns (Octel)	**Sale at end of 2002 at LTM EBITDA Multiple**		
	3.75x	4.00x	4.25x
Sale value of assets	$550	$586	$623
Terminal costs	(75)	(75)	(75)
Remaining debt	(433)	(433)	(433)
Balance sheet cash	4	4	4
Total value to financial buyer	$46	$82	$119
Equity investment at purchase	50	50	50
Annualized rate of return on equity investment	-2%	11%	19%

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COMBINATION OF PMC AND OCTEL

Motivation

Combination of PMC and GLK Tetra Ethyl Lead

POLAR MOLECULAR CORP	GLK TETRA ETHYL LEAD	COMBINATION
▲ Projected increase in EBITDA	▼ Projected decrease in EBITDA	▲ Use early year EBITDA cash flow proceeds from TEL to fund marketing and expansion of DurAlt and other additives
▲ Environmentally friendly lead additive substitute	▼ Lead additives	▲ Potential to introduce DurAlt to developing countries through existing TEL customer base; potential for continued growth from TEL
▼ Need for market access	▲ Wide customer base in Africa, Far East, and other developing regions	▲ Increased global presence; use existing offices and contacts to leverage marketing strengths
▲ Global growth potential	▼ Global market decline, although still strong growth potential in developing countries	▲ Strong, steady earnings in early years; later years still to enjoy robust growth from PMC additives and Octel detergents
▼ Need for cash inflow	▲ Strong current cash flow	▲ TEL provides for near term cash needs; potential for higher IPO proceeds in a delayed offering

The combination of the two companies provides the sales and distribution channels necessary to launch PMC's products into use globally.

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Valuation of Octel – PMC

Octel & PMC: Combined Income Statement

($ in thousands)

	Projected, Dec. 31,						
	1998	1999	2000	2001	2002	2003	CGR
Revenue	$515,796	$571,085	$591,969	$573,488	$546,706	$523,242	(0.5%)
Cost of Goods Sold	146,387	200,983	231,057	233,447	228,983	225,525	
Gross Margin	$369,409	$370,102	$360,912	$340,041	$317,724	$297,717	
Operating Expenses	147,935	137,176	126,999	116,613	106,863	98,017	
EBITDA	$221,474	$232,925	$233,913	$223,428	$210,861	$199,700	(2.9%)
Base Octel EBITDA	*$213,753*	*$194,516*	*$177,009*	*$161,078*	*$146,581*	*$133,389*	
Incremental EBITDA via PMC	*$7,721*	*$38,410*	*$56,904*	*$62,350*	*$64,280*	*$66,311*	
Depreciation & Amortization	44,917	43,587	42,480	41,503	40,638	39,947	
Transaction Goodwill Amortization	10,665	10,665	10,665	10,665	10,665	10,665	
Transaction Cost Amortization	2,000	2,000	2,000	2,000	2,000	2,000	
EBIT	$163,893	$176,673	$178,768	$169,261	$157,558	$147,088	(3.2%)
Interest expense (on avg. balance)	77,315	67,628	56,951	45,852	34,738	23,699	
Earnings before taxes	$86,578	$109,046	$121,817	$123,408	$122,819	$123,389	
Income Taxes	29,436	37,076	41,418	41,959	41,759	41,952	
Net Income	$57,141	$71,970	$80,399	$81,449	$81,061	$81,437	4.1 %
Cash flow							
Net income	$57,141	$71,970	$80,399	$81,449	$81,061	$81,437	
D&A	44,917	43,587	42,480	41,503	40,638	39,947	
Goodwill Amortization	10,665	10,665	10,665	10,665	10,665	10,665	
Transaction Cost Amortization	2,000	2,000	2,000	2,000	2,000	2,000	
Capital expenditures	(14,500)	(14,500)	(14,500)	(13,000)	(13,000)	(13,000)	
Provision for clean-up sinking fund	(5,000)	(5,000)	(5,000)	(5,000)	(5,000)	(5,000)	
Free Cash Flow	$95,223	$108,722	$116,044	$117,617	$116,364	$116,049	
BOY Debt balance	$861,455	$766,232	$657,510	$541,466	$423,849	$307,485	
Principal payment	95,223	108,722	116,044	117,617	116,364	116,049	
EOY Debt balance	$766,232	$657,510	$541,466	$423,849	$307,485	$191,436	

Octel & PMC: Summary of Valuation Techniques

($ in millions)

The combined entity is worth an estimated $1261 million based on 7x 1998E earnings

1998 Earnings Multiple	6.0x	7.0x	8.0x
Total capitalization	$1,204	$1,261	$1,319

Discounted Cash Flow @ 10%			
Terminal EBITDA multiple	4.5x	5.0x	5.5x
Total capitalization	$1,115	$1,171	$1,228

Octel & PMC: Discounted Cash Flow

($ in millions)

	Projected, Dec. 31,					
	1998	1999	2000	2001	2002	2003
Revenues	$516	$571	$592	$573	$547	$523
EBITDA	221	233	234	223	211	200
EBIT	164	177	179	169	158	147
Tax Effect	(56)	(60)	(61)	(58)	(54)	(50)
Unlevered net income	$108	$117	$118	$112	$104	$97
Plus: Depreciation & Amortization	$45	$44	$42	$42	$41	$40
Less: Capital Expenditure	(15)	(15)	(13)	(13)	(13)	-
Plus: Changes in Working Capital	(1)	(1)	(1)	(1)	(1)	(1)
Free Cash Flow	$138	$145	$146	$139	$131	$136

	Discounted Terminal Value, 2003 EBITDA Multiple				Present Value
Discount Rate	4.0x	4.5x	5.0x	5.5x	of Cash Flow
10.0%	$451	$507	$564	$620	$608
11.0%	427	480	534	587	590
12.0%	405	455	506	556	574
13.0%	384	432	480	528	558

	Net Present Value, 2003 EBITDA Multiple			
Discount Rate	4.0x	4.5x	5.0x	5.5x
10.0%	$1,059	$1,115	$1,171	$1,228
11.0%	1,018	1,071	1,124	1,178
12.0%	979	1,029	1,080	1,130
13.0%	942	990	1,038	1,086

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Financial Sponsor Returns

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Financial Sponsor Returns

($ in millions)

INCREMENTAL VALUE ADDED BY PMC	
Capitalization of combined entity at 7x 1998 earnings	$1,261
Purchase of Octel at 5x 1998 earnings	900
Transaction costs	20
Incremental value added by PMC	**$342**
DCF of combined entity, 5x EBITDA terminal multiple	$1,171
DCF of Octel, 4x EBITDA terminal multiple	791
Transaction costs	20
Incremental value added by PMC	**$360**

FINANCIAL SPONSOR RETURNS		Sale at end of 2002 at LTM EBITDA Multiple		
		5.0x	5.5x	6.0x
Sale value of assets		$1,054	$1,160	$1,265
Terminal costs		(75)	(75)	(75)
Remaining debt		(307)	(307)	(307)
Balance sheet cash		4	4	4
Total value to financial buyer		$676	$781	$887
Equity investment at purchase		50	50	50
Annualized return on equity with share to PMC:	0%	68%	73%	78%
	25%	59%	64%	68%
	50%	47%	51%	55%

SMITH BARNEY

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APPENDICES

SALOMON SMITH BARNEY

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PMC Revenue/COGS Schedule

PMC Revenue and Cost of Sales Assumptions by Country

Octel's cost for DurAlt per gallon (price sold)	$9.41	
PMC's manufacturing cost of DurAlt, per gallon	$6.27	500 gallons of DurAlt per 1,000,000 gallons of gasoline
Gross Margin per gallon	$3.14	1,000 gallons of DurAlt per 1,000,000 gallons of diesel

INDONESIA	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
GASOLINE								
Gasoline barrels per day	196,138	210,905	226,784	243,859	262,219	281,961	303,190	326,017
Growth	7.5%	7.5%	7.5%	7.5%	7.5%	7.5%	7.5%	7.5%
Gallons of gasoline per day	8,237,787	8,858,010	9,524,929	10,242,061	11,013,186	11,842,369	12,733,981	13,692,722
% of Market	10.0%	15.0%	20.0%	20.0%	20.0%	20.0%	20.0%	20.0%
Market share of gallons of gas per day	823,779	1,328,701	1,904,986	2,048,412	2,202,637	2,368,474	2,546,796	2,738,544
Gallons of DurAlt required, per day	412	664	952	1,024	1,101	1,184	1,273	1,369
Gallons of DurAlt required, per year	150,340	242,488	347,660	373,835	401,981	432,246	464,790	499,784
Revenue, per year	$1,414,696	$2,281,812	$3,271,480	$3,517,790	$3,782,644	$4,067,439	$4,373,677	$4,702,971
Cost of Sales	942,629	1,520,400	2,179,828	2,343,947	2,520,423	2,710,185	2,914,235	3,133,648
GROSS MARGIN	$472,066	$761,412	$1,091,652	$1,173,843	$1,262,221	$1,357,254	$1,459,442	$1,569,323
DIESEL								
Diesel barrels per day	387,494	412,294	438,681	466,756	496,628	528,413	562,231	598,214
Growth	6.4%	6.4%	6.4%	6.4%	6.4%	6.4%	6.4%	6.4%
Gallons of diesel per day	16,274,753	17,316,337	18,424,583	19,603,756	20,858,397	22,193,334	23,613,707	25,124,985
% of Market	0.0%	10.0%	15.0%	20.0%	20.0%	20.0%	20.0%	20.0%
Market share of gallons of gas per day	–	1,731,634	2,763,687	3,920,751	4,171,679	4,438,667	4,722,741	5,024,997
Gallons of DurAlt required, per day	–	1,732	2,764	3,921	4,172	4,439	4,723	5,025
Gallons of DurAlt required, per year	–	632,046	1,008,746	1,431,074	1,522,663	1,620,113	1,723,801	1,834,124
Revenue, per year	–	$5,947,556	$9,492,299	$13,466,408	$14,328,258	$15,245,267	$6,220,964	$17,259,106
Cost of Sales	–	3,962,930	6,324,837	8,972,835	9,547,097	10,158,111	10,808,230	11,499,957
GROSS MARGIN	–	$1,984,625	$3,167,462	$4,493,573	$4,781,162	$5,087,156	$5,412,734	$5,759,149
INDONESIA – TOTAL GROSS MARGIN	**$472,066**	**$2,746,038**	**$4,259,114**	**$5,667,416**	**$6,043,383**	**$6,444,410**	**$6,872,176**	**$7,328,472**

PMC Revenue and Cost of Sales Assumptions by Country

Octel's cost for DurAlt per gallon (price sold)	$9.41	
PMC's manufacturing cost of DurAlt, per gallon	$6.27	500 gallons of DurAlt per 1,000,000 gallons of gasoline
Gross Margin per gallon	$3.14	1,000 gallons of DurAlt per 1,000,000 gallons of diesel

THAILAND	1998	1999	2000	2001	2002	2003	2004	2005
GASOLINE								
Gasoline barrels per day	124,060	135,474	147,938	161,548	173,502	186,342	200,131	214,941
Growth	9.2%	9.2%	9.2%	9.2%	7.4%	7.4%	7.4%	7.4%
Gallons of gasoline per day	5,210,538	5,689,907	6,213,379	6,785,010	7,287,100	7,826,346	8,405,496	9,027,502
% of Market	10.0%	15.0%	20.0%	20.0%	20.0%	20.0%	20.0%	20.0%
Market share of gallons of gas per day	521,054	853,486	1,242,676	1,357,002	1,457,420	1,565,269	1,681,099	1,805,500
Gallons of DurAlt required, per day	261	427	621	679	729	783	841	903
Gallons of DurAlt required, per year	95,092	155,761	226,788	247,653	265,979	285,662	306,801	329,504
Revenue, per year	$894,819	$1,465,713	$2,134,078	$2,330,413	$2,502,864	$2,688,076	$2,886,994	$3,100,631
Cost of Sales	596,229	976,623	1,421,963	1,552,783	1,667,689	1,791,098	1,923,640	2,065,989
GROSS MARGIN	$298,590	$489,090	$712,115	$777,630	$835,175	$896,978	$963,354	$1,034,642
DIESEL								
Diesel barrels per day	287	309	333	352	372	394	417	441
Growth	7.6%	7.6%	5.8%	5.8%	5.8%	5.8%	5.8%	5.8%
Gallons of diesel per day	12,063	12,980	13,967	14,777	15,634	16,540	17,500	18,515
% of Market	0.0%	10.0%	15.0%	20.0%	20.0%	20.0%	20.0%	20.0%
Market share of gallons of gas per day	–	1,298	2,095	2,955	3,127	3,308	3,500	3,703
Gallons of DurAlt required, per day	–	1	2	3	3	3	3	4
Gallons of DurAlt required, per year	–	474	765	1,079	1,141	1,207	1,277	1,352
Revenue, per year	–	$4,458	$7,196	$10,150	$10,739	$11,362	$12,021	$12,718
Cost of Sales	–	2,971	4,794	6,763	7,156	7,571	8,010	8,474
GROSS MARGIN	–	$1,488	$2,401	$3,387	$3,584	$3,791	$4,011	$4,244
THAILAND – TOTAL GROSS MARGIN	**$298,590**	**$490,578**	**$14,516**	**$781,017**	**$838,758**	**$900,769**	**$967,365**	**$1,038,886**

PMC Revenue and Cost of Sales Assumptions by Country

Octel's cost for DurAlt per gallon (price sold)	$9.41	
PMC's manufacturing cost of DurAlt, per gallon	$6.27	500 gallons of DurAlt per 1,000,000 gallons of gasoline
Gross Margin per gallon	$3.14	1,000 gallons of DurAlt per 1,000,000 gallons of diesel

KUWAIT	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
GASOLINE								
Gasoline barrels per day	18,700	19,299	19,916	20,554	21,211	21,890	22,591	23,313
Growth	3.2%	3.2%	3.2%	3.2%	3.2%	3.2%	3.2%	3.2%
Gallons of gasoline per day	785,414	810,547	836,484	863,252	890,876	919,384	948,804	979,166
% of Market	10.0%	15.0%	20.0%	20.0%	20.0%	20.0%	20.0%	20.0%
Market share of gallons of gas per day	78,541	121,582	167,297	172,650	178,175	183,877	189,761	195,833
Gallons of DurAlt required, per day	39	61	84	86	89	92	95	98
Gallons of DurAlt required, per year	14,334	22,189	30,532	31,509	32,517	33,558	34,631	35,740
Revenue, per year	$134,881	$208,796	$287,303	$296,497	$305,985	$315,776	$325,881	$336,309
Cost of Sales	89,873	139,123	191,434	197,560	203,881	210,406	217,139	224,087
GROSS MARGIN	$45,008	$69,673	$95,869	$98,937	$102,103	$105,371	$108,742	$112,222
DIESEL								
Diesel barrels per day	27	28	30	31	33	35	36	38
Growth	5.1%	5.1%	5.1%	5.1%	5.1%	5.1%	5.1%	5.1%
Gallons of diesel per day	1,132	1,190	1,251	1,314	1,381	1,452	1,526	1,604
% of Market	0.0%	10.0%	15.0%	20.0%	20.0%	20.0%	20.0%	20.0%
Market share of gallons of gas per day	–	119	188	263	276	290	305	321
Gallons of DurAlt required, per day	–	–	–	–	–	–	–	–
Gallons of DurAlt required, per year	–	43	68	96	101	106	111	117
Revenue, per year	–	$409	$ 644	$903	$949	$997	$1,048	$1,102
Cost of Sales	–	272	429	602	632	665	698	734
GROSS MARGIN	–	$136	$215	$301	$317	$333	$350	$368
KUWAIT – TOTAL GROSS MARGIN	**$45,008**	**$69,809**	**$96,084**	**$ 99,239**	**$102,420**	**$105,703**	**$109,092**	**$112,590**

PMC Revenue and Cost of Sales Assumptions by Country

Octel's cost for DurAlt per gallon (price sold)	$9.41	
PMC's manufacturing cost of DurAlt, per gallon	$6.27	500 gallons of DurAlt per 1,000,000 gallons of gasoline
Gross Margin per gallon	$3.14	1,000 gallons of DurAlt per 1,000,000 gallons of diesel

MALAYSIA	1998	1999	2000	2001	2002	2003	2004	2005
GASOLINE								
Gasoline barrels per day	118,421	127,658	137,615	146,423	155,794	165,765	176,374	187,661
Growth	7.8%	7.8%	7.8%	6.4%	6.4%	6.4%	6.4%	6.4%
Gallons of gasoline per day	4,973,689	5,361,637	5,779,845	6,149,755	6,543,339	6,962,113	7,407,688	7,881,780
% of Market	10.0%	15.0%	20.0%	20.0%	20.0%	20.0%	20.0%	20.0%
Market share of gallons of gas per day	497,369	804,246	1,155,969	1,229,951	1,308,668	1,392,423	1,481,538	1,576,356
Gallons of DurAlt required, per day	249	402	578	615	654	696	741	788
Gallons of DurAlt required, per year	90,770	146,775	210,964	224,466	238,832	254,117	270,381	287,685
Revenue, per year	$ 854,144	$1,381,151	$1,985,174	$2,112,226	$2,247,408	$2,391,242	$2,544,282	$2,707,116
Cost of Sales	569,127	920,278	1,322,746	1,407,402	1,497,476	1,593,314	1,695,286	1,803,785
GROSS MARGIN	$285,017	$460,873	$662,428	$704,823	$749,932	$797,928	$848,995	$903,331
DIESEL								
Diesel barrels per day	144,461	152,695	161,399	170,599	180,323	190,601	201,466	212,949
Growth	5.7%	5.7%	5.7%	5.7%	5.7%	5.7%	5.7%	5.7%
Gallons of diesel per day	6,067,367	6,413,207	6,778,760	7,165,149	7,573,563	8,005,256	8,461,555	8,943,864
% of Market	0.0%	10.0%	15.0%	20.0%	20.0%	20.0%	20.0%	20.0%
Market share of gallons of gas per day	–	641,321	1,016,814	1,433,030	1,514,713	1,601,051	1,692,311	1,788,773
Gallons of DurAlt required, per day	–	641	1,017	1,433	1,515	1,601	1,692	1,789
Gallons of DurAlt required, per year	–	234,082	371,137	523,056	552,870	584,384	617,694	652,902
Revenue, per year	–	$2,202,712	$ 3,492,400	$4,921,956	$ 5,202,507	$5,499,050	$5,812,496	$6,143,809
Cost of Sales	–	1,467,695	2,327,030	3,279,560	3,466,495	3,664,086	3,872,939	4,093,696
GROSS MARGIN	–	$735,018	$1,165,371	$1,642,396	$1,736,012	$1,834,965	$1,939,558	$2,050,113
MALAYSIAN – TOTAL GROSS MARGIN	**$285,017**	**$1,195,891**	**$1,827,799**	**$2,347,219**	**$2,485,944**	**$2,632,892**	**$2,788,553**	**$2,953,443**

PMC Revenue and Cost of Sales Assumptions by Country

Octel's cost for DurAlt per gallon (price sold)	$9.41	
PMC's manufacturing cost of DurAlt, per gallon	$6.27	500 gallons of DurAlt per 1,000,000 gallons of gasoline
Gross Margin per gallon	$3.14	1,000 gallons of DurAlt per 1,000,000 gallons of diesel

PHILIPPINES	1998	1999	2000	2001	2002	2003	2004	2005
GASOLINE								
Gasoline barrels per day	49,293	52,201	55,281	58,874	62,701	66,777	71,117	75,740
Growth	5.9%	5.9%	5.9%	6.5%	6.5%	6.5%	6.5%	6.5%
Gallons of gasoline per day	2,070,308	2,192,456	2,321,811	2,472,729	2,633,456	2,804,631	2,986,932	3,181,082
% of Market	10.0%	15.0%	20.0%	20.0%	20.0%	20.0%	20.0%	20.0%
Market share of gallons of gas per day	207,031	328,868	464,362	494,546	526,691	560,926	597,386	636,216
Gallons of DurAlt required, per day	104	164	232	247	263	280	299	318
Gallons of DurAlt required, per year	37,783	60,018	84,746	90,255	96,121	102,369	109,023	116,110
Revenue, per year	$355,539	$564,774	$797,461	$849,296	$904,500	$963,293	$1,025,907	$1,092,590
Cost of Sales	236,900	376,316	531,358	565,896	602,680	641,854	683,574	728,007
GROSS MARGIN	$118,639	$188,458	$266,103	$283,399	$301,820	$321,439	$342,332	$364,584
DIESEL								
Diesel barrels per day	89	91	94	98	102	107	112	117
Growth	2.8%	2.8%	2.8%	4.6%	4.6%	4.6%	4.6%	4.6%
Gallons of diesel per day	3,720	3,824	3,931	4,112	4,301	4,499	4,706	4,922
% of Market	0.0%	10.0%	15.0%	20.0%	20.0%	20.0%	20.0%	20.0%
Market share of gallons of gas per day	–	382	590	822	860	900	941	984
Gallons of DurAlt required, per day	–	–	1	1	1	1	1	1
Gallons of DurAlt required, per year	–	140	215	300	314	328	344	359
Revenue, per year	–	$1,313	$2,025	2,825	$2,955	$3,090	$3,233	$3,381
Cost of Sales	–	875	1,349	1,882	1,969	2,059	2,154	2,253
GROSS MARGIN	–	$438	$676	$943	$986	$1,031	$1,079	$1,128
PHILIPPINES – TOTAL GROSS MARGIN	**$118,639**	**$188,896**	**$266,779**	**$284,342**	**$302,806**	**$322,470**	**$343,411**	**$365,712**

PMC Revenue and Cost of Sales Assumptions by Country

Octel's cost for DurAlt per gallon (price sold)	$9.41	
PMC's manufacturing cost of DurAlt, per gallon	$6.27	500 gallons of DurAlt per 1,000,000 gallons of gasoline
Gross Margin per gallon	$3.14	1,000 gallons of DurAlt per 1,000,000 gallons of diesel

CHINA	1998	1999	2000	2001	2002	2003	2004	2005
GASOLINE								
Gasoline barrels per day	807,708	864,248	924,745	1,001,499	1,084,623	1,174,647	1,272,143	1,377,730
Growth	7.0%	7.0%	7.0%	8.3%	8.3%	8.3%	8.3%	8.3%
Gallons of gasoline per day	33,923,739	36,298,401	38,839,289	42,062,950	45,554,175	49,335,172	53,429,991	57,864,680
% of Market	5.0%	5.0%	8.0%	8.0%	8.0%	8.0%	8.0%	8.0%
Market share of gallons of gas per day	1,696,187	1,814,920	3,107,143	3,365,036	3,644,334	3,946,814	4,274,399	4,629,174
Gallons of DurAlt required, per day	848	907	1,554	1,683	1,822	1,973	2,137	2,315
Gallons of DurAlt required, per year	309,554	331,223	567,054	614,119	665,091	720,294	780,078	844,824
Revenue, per year	$2,912,904	$ 3,116,808	$5,335,975	$5,778,860	$ 6,258,506	$6,777,962	$7,340,533	$7,949,797
Cost of Sales	1,940,904	2,076,768	3,555,426	3,850,527	4,170,120	4,516,240	4,891,088	5,297,049
GROSS MARGIN	$972,000	$1,040,040	$1,780,548	$1,928,334	$2,088,386	$2,261,722	$2,449,445	$2,652,748
DIESEL								
Diesel barrels per day	927,588	988,809	1,054,070	1,123,639	1,197,799	1,276,854	1,361,126	1,450,960
Growth	6.6%	6.6%	6.6%	6.6%	6.6%	6.6%	6.6%	6.6%
Gallons of diesel per day	38,958,696	41,529,970	44,270,948	47,192,831	50,307,558	53,627,857	57,167,295	60,940,337
% of Market	0.0%	5.0%	8.0%	8.0%	8.0%	8.0%	8.0%	8.0%
Market share of gallons of gas per day	–	2,076,499	3,541,676	3,775,426	4,024,605	4,290,229	4,573,384	4,875,227
Gallons of DurAlt required, per day	–	2,076	3,542	3,775	4,025	4,290	4,573	4,875
Gallons of DurAlt required, per year	–	757,922	1,292,712	1,378,031	1,468,981	1,565,933	1,669,285	1,779,458
Revenue, per year	–	$7,132,046	$12,164,417	$12,967,269	$13,823,108	$14,735,433	$15,707,972	$16,744,698
Cost of Sales	–	4,752,171	8,105,302	8,640,252	9,210,509	9,818,403	10,466,417	11,157,201
GROSS MARGIN	–	$2,379,875	$4,059,115	$4,327,016	$4,612,599	$4,917,031	$5,241,555	$5,587,498
CHINA – TOTAL GROSS MARGIN	**$972,000**	**$3,419,915**	**$5,839,663**	**$6,255,350**	**$6,700,985**	**$7,178,753**	**$7,690,999**	**$8,240,246**

PMC Revenue and Cost of Sales Assumptions by Country

Octel's cost for DurAlt per gallon (price sold)	$9.41	
PMC's manufacturing cost of DurAlt, per gallon	$6.27	500 gallons of DurAlt per 1,000,000 gallons of gasoline
Gross Margin per gallon	$3.14	1,000 gallons of DurAlt per 1,000,000 gallons of diesel

INDIA	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
GASOLINE								
Gasoline barrels per day	116,154	122,077	128,303	136,002	144,162	152,811	161,980	171,699
Growth	5.1%	5.1%	5.1%	6.0%	6.0%	6.0%	6.0%	6.0%
Gallons of gasoline per day	4,878,453	5,127,254	5,388,744	5,712,069	6,054,793	6,418,081	6,803,166	7,211,356
% of Market	5.0%	5.0%	8.0%	8.0%	8.0%	8.0%	8.0%	8.0%
Market share of gallons of gas per day	243,923	256,363	431,100	456,966	484,383	513,446	544,253	576,908
Gallons of DurAlt required, per day	122	128	216	228	242	257	272	288
Gallons of DurAlt required, per year	44,516	46,786	78,676	83,396	88,400	93,704	99,326	105,286
Revenue, per year	$418,894	$440,258	$740,338	$784,758	$831,844	$881,754	$934,660	$990,739
Cost of Sales	279,115	293,349	493,296	522,894	554,268	587,524	622,775	660,142
GROSS MARGIN	$139,780	$146,909	$247,042	$261,864	$277,576	$294,230	$ 311,884	$330,597
DIESEL								
Diesel barrels per day	709,296	750,435	793,961	840,010	888,731	940,277	994,813	1,052,512
Growth	5.8%	5.8%	5.8%	5.8%	5.8%	5.8%	5.8%	5.8%
Gallons of diesel per day	29,790,436	31,518,281	33,346,342	35,280,430	37,326,694	39,491,643	41,782,158	44,205,523
% of Market	0.0%	5.0%	8.0%	8.0%	8.0%	8.0%	8.0%	8.0%
Market share of gallons of gas per day	–	1,575,914	2,667,707	2,822,434	2,986,136	3,159,331	3,342,573	3,536,442
Gallons of DurAlt required, per day	–	1,576	2,668	2,822	2,986	3,159	3,343	3,536
Gallons of DurAlt required, per year	–	575,209	973,713	1,030,189	1,089,939	1,153,156	1,220,039	1,290,801
Revenue, per year	–	$5,412,713	$9,162,641	$9,694,074	$10,256,330	$10,851,198	$11,480,567	$12,146,440
Cost of Sales	–	3,606,558	6,105,182	6,459,282	6,833,921	7,230,288	7,649,645	8,093,324
GROSS MARGIN	–	$1,806,155	$3,057,459	$3,234,792	$3,422,410	$3,620,910	$3,830,923	$4,053,116
INDIA – TOTAL GROSS MARGIN	**$139,780**	**$1,953,064**	**$3,304,501**	**$3,496,656**	**$3,699,986**	**$3,915,140**	**$4,142,807**	**$4,383,713**

PMC Revenue and Cost of Sales Assumptions by Country

Octel's cost for DurAlt per gallon (price sold)	$9.41	
PMC's manufacturing cost of DurAlt, per gallon	$6.27	500 gallons of DurAlt per 1,000,000 gallons of gasoline
Gross Margin per gallon	$3.14	1,000 gallons of DurAlt per 1,000,000 gallons of diesel

JAPAN	1998	1999	2000	2001	2002	2003	2004	2005
GASOLINE								
Gasoline barrels per day	961,352	989,231	1,017,919	1,047,438	1,077,814	1,109,071	1,141,234	1,174,330
Growth	2.9%	2.9%	2.9%	2.9%	2.9%	2.9%	2.9%	2.9%
Gallons of gasoline per day	40,376,777	41,547,703	42,752,587	43,992,412	45,268,192	46,580,969	47,931,817	49,321,840
% of Market	5.0%	5.0%	8.0%	8.0%	8.0%	8.0%	8.0%	8.0%
Market share of gallons of gas per day	2,018,839	2,077,385	3,420,207	3,519,393	3,621,455	3,726,478	3,834,545	3,945,747
Gallons of DurAlt required, per day	1,009	1,039	1,710	1,760	1,811	1,863	1,917	1,973
Gallons of DurAlt required, per year	368,438	379,123	624,188	642,289	660,916	680,082	699,805	720,099
Revenue, per year	$3,467,002	$3,567,545	$5,873,607	$6,043,941	$ 6,219,216	$6,399,573	$6,585,161	$6,776,130
Cost of Sales	2,310,107	2,377,100	3,913,657	4,027,153	4,143,941	4,264,115	4,387,774	4,515,020
GROSS MARGIN	$1,156,896	$1,190,446	$1,959,950	$2,016,788	$2,075,275	$2,135,458	$2,197,386	$2,261,110
DIESEL								
Diesel barrels per day	1,362,497	1,393,834	1,425,893	1,458,688	1,492,238	1,526,559	1,561,670	1,597,589
Growth	2.3%	2.3%	2.3%	2.3%	2.3%	2.3%	2.3%	2.3%
Gallons of diesel per day	57,224,875	58,541,047	59,887,491	61,264,904	62,673,997	64,115,498	65,590,155	67,098,728
% of Market	0.0%	5.0%	8.0%	8.0%	8.0%	8.0%	8.0%	8.0%
Market share of gallons of gas per day	–	2,927,052	4,790,999	4,901,192	5,013,920	5,129,240	5,247,212	5,367,898
Gallons of DurAlt required, per day	–	2,927	4,791	4,901	5,014	5,129	5,247	5,368
Gallons of DurAlt required, per year	–	1,068,374	1,748,715	1,788,935	1,830,081	1,872,173	1,915,233	1,959,283
Revenue, per year	–	$10,053,400	$16,455,406	$16,833,880	$17,221,059	$17,617,144	$18,022,338	$18,436,852
Cost of Sales	–	6,698,706	10,964,441	11,216,624	11,474,606	11,738,522	12,008,508	12,284,704
GROSS MARGIN	–	$3,354,695	$5,490,964	$5,617,256	$5,746,453	$5,878,622	$6,013,830	$6,152,148
JAPAN – TOTAL GROSS MARGIN	**$1,156,896**	**$4,545,140**	**$7,450,914**	**$7,634,045**	**$7,821,728**	**$8,014,080**	**$8,211,216**	**$8,413,259**

PMC Revenue and Cost of Sales Assumptions by Country

Octel's cost for DurAlt per gallon (price sold)	$9.41	
PMC's manufacturing cost of DurAlt, per gallon	$6.27	500 gallons of DurAlt per 1,000,000 gallons of gasoline
Gross Margin per gallon	$3.14	1,000 gallons of DurAlt per 1,000,000 gallons of diesel

SAUDI ARABIA	1998	1999	2000	2001	2002	2003	2004	2005
GASOLINE								
Gasoline barrels per day	223,032	231,284	239,841	248,715	257,918	267,461	277,357	287,619
Growth	3.7%	3.7%	3.7%	3.7%	3.7%	3.7%	3.7%	3.7%
Gallons of gasoline per day	9,367,324	9,713,915	10,073,330	10,446,043	10,832,547	11,233,351	11,648,985	12,079,998
% of Market	5.0%	5.0%	8.0%	8.0%	8.0%	8.0%	8.0%	8.0%
Market share of gallons of gas per day	468,366	485,696	805,866	835,683	866,604	898,668	931,919	966,400
Gallons of DurAlt required, per day	234	243	403	418	433	449	466	483
Gallons of DurAlt required, per year	85,477	88,639	147,071	152,512	158,155	164,007	170,075	176,368
Revenue, per year	$804,337	$834,097	$1,383,935	$1,435,140	$1,488,240	$1,543,305	$1,600,407	$1,659,623
Cost of Sales	535,940	555,770	922,133	956,252	991,633	1,028,323	1,066,371	1,105,827
GROSS MARGIN	$268,397	$278,328	$461,802	$478,888	$496,607	$514,982	$534,036	$553,795
DIESEL								
Diesel barrels per day	377,867	391,092	404,781	418,948	433,611	448,787	464,495	480,752
Growth	3.5%	3.5%	3.5%	3.5%	3.5%	3.5%	3.5%	3.5%
Gallons of diesel per day	15,870,412	16,425,876	17,000,782	17,595,809	18,211,662	18,849,070	19,508,788	20,191,595
% of Market	0.0%	5.0%	8.0%	8.0%	8.0%	8.0%	8.0%	8.0%
Market share of gallons of gas per day	–	821,294	1,360,063	1,407,665	1,456,933	1,507,926	1,560,703	1,615,328
Gallons of DurAlt required, per day	–	821	1,360	1,408	1,457	1,508	1,561	1,615
Gallons of DurAlt required, per year	–	299,772	496,423	513,798	531,781	550,393	569,657	589,595
Revenue, per year	–	$2,820,857	$4,671,339	$4,834,836	$5,004,055	$5,179,197	$5,360,469	$5,548,085
Cost of Sales	–	1,879,572	3,112,571	3,221,511	3,334,264	3,450,963	3,571,747	3,696,758
GROSS MARGIN	–	$941,285	$1,558,768	$1,613,325	1,669,791	$1,728,234	$1,788,722	$1,851,327
SAUDI ARABIA – TOTAL GROSS MARGIN	**$268,397**	**$1,219,613**	**$2,020,569**	**$2,092,213**	**$2,166,398**	**$2,243,215**	**$2,322,758**	**$2,405,122**

PMC Revenue and Cost of Sales Assumptions by Country

Octel's cost for DurAlt per gallon (price sold)	$9.41	
PMC's manufacturing cost of DurAlt, per gallon	$6.27	500 gallons of DurAlt per 1,000,000 gallons of gasoline
Gross Margin per gallon	$3.14	1,000 gallons of DurAlt per 1,000,000 gallons of diesel

MEXICO (assumed growth rate)	1998	1999	2000	2001	2002	2003	2004	2005
GASOLINE								
Gasoline barrels per day	619,003	641,906	665,656	690,286	715,826	742,312	769,777	798,259
Growth	3.7%	3.7%	3.7%	3.7%	3.7%	3.7%	3.7%	3.7%
Gallons of gasoline per day	25,998,113	26,960,043	27,957,564	28,991,994	30,064,698	31,177,092	32,330,644	33,526,878
% of Market	5.0%	5.0%	8.0%	8.0%	8.0%	8.0%	8.0%	8.0%
Market share of gallons of gas per day	1,299,906	1,348,002	2,236,605	2,319,360	2,405,176	2,494,167	2,586,452	2,682,150
Gallons of DurAlt required, per day	650	674	1,118	1,160	1,203	1,247	1,293	1,341
Gallons of DurAlt required, per year	237,233	246,010	408,180	423,283	438,945	455,186	472,027	489,492
Revenue, per year	$2,232,360	$2,314,958	$3,840,978	$3,983,094	$4,130,469	$4,283,296	$4,441,778	$4,606,124
Cost of Sales	1,487,450	1,542,485	2,559,291	2,653,985	2,752,183	2,854,013	2,959,612	3,069,117
GROSS MARGIN	$744,911	$772,473	$1,281,687	$1,329,109	$1,378,286	$1,429,283	$1,482,166	$1,537,006
DIESEL								
Diesel barrels per day	287,535	297,599	308,015	318,795	329,953	341,502	353,454	365,825
Growth	3.5%	3.5%	3.5%	3.5%	3.5%	3.5%	3.5%	3.5%
Gallons of diesel per day	12,076,475	12,499,151	12,936,622	13,389,403	13,858,033	14,343,064	14,845,071	15,364,648
% of Market	0.0%	5.0%	8.0%	8.0%	8.0%	8.0%	8.0%	8.0%
Market share of gallons of gas per day	–	624,958	1,034,930	1,071,152	1,108,643	1,147,445	1,187,606	1,229,172
Gallons of DurAlt required, per day	–	625	1,035	1,071	1,109	1,147	1,188	1,229
Gallons of DurAlt required, per year	–	228,110	377,749	390,971	404,655	418,817	433,476	448,648
Revenue, per year	–	$2,146,511	$3,554,621	$3,679,033	$3,807,799	$3,941,072	$4,079,010	$4,221,775
Cost of Sales	–	1,430,247	2,368,488	2,451,386	2,537,184	2,625,985	2,717,895	2,813,021
GROSS MARGIN	–	$716,264	$1,186,133	$1,227,648	$1,270,615	$1,315,087	$1,361,115	$1,408,754
MEXICO – TOTAL GROSS MARGIN	**$744,911**	**$1,488,736**	**$2,467,820**	**$2,556,757**	**$2,648,901**	**$2,744,369**	**$2,843,281**	**$2,945,760**

PMC Revenue and Cost of Sales Assumptions by Country

Octel's cost for DurAlt per gallon (price sold)	$9.41	
PMC's manufacturing cost of DurAlt, per gallon	$6.27	500 gallons of DurAlt per 1,000,000 gallons of gasoline
Gross Margin per gallon	$3.14	1,000 gallons of DurAlt per 1,000,000 gallons of diesel

Former USSR (assumed growth rates)	1998	1999	2000	2001	2002	2003	2004	2005
GASOLINE								
Gasoline barrels per day	2,147,166	2,226,611	2,308,995	2,394,428	2,483,022	2,574,894	2,670,165	2,768,961
Growth	3.7%	3.7%	3.7%	3.7%	3.7%	3.7%	3.7%	3.7%
Gallons of gasoline per day	90,180,954	93,517,649	96,977,802	100,565,980	104,286,922	108,145,538	112,146,923	116,296,359
% of Market	5.0%	5.0%	8.0%	8.0%	8.0%	8.0%	8.0%	8.0%
Market share of gallons of gas per day	4,509,048	4,675,882	7,758,224	8,045,278	8,342,954	8,651,643	8,971,754	9,303,709
Gallons of DurAlt required, per day	2,255	2,338	3,879	4,023	4,171	4,326	4,486	4,652
Gallons of DurAlt required, per year	822,901	853,349	1,415,876	1,468,263	1,522,589	1,578,925	1,637,345	1,697,927
Revenue, per year	$7,743,500	$8,030,010	$13,323,392	$13,816,358	$14,327,563	$14,857,683	$15,407,417	$15,977,492
Cost of Sales	5,159,591	5,350,495	8,877,542	9,206,011	9,546,633	9,899,859	10,266,154	10,646,001
GROSS MARGIN	$2,583,910	$2,679,514	$4,445,850	$ 4,610,347	$4,780,930	$4,957,824	$5,141,264	$5,331,490
DIESEL								
Diesel barrels per day	2,360,078	2,442,681	2,528,175	2,616,661	2,708,244	2,803,032	2,901,138	3,002,678
Growth	3.5%	3.5%	3.5%	3.5%	3.5%	3.5%	3.5%	3.5%
Gallons of diesel per day	99,123,277	102,592,592	106,183,333	109,899,749	113,746,241	117,727,359	121,847,817	126,112,490
% of Market	0.0%	5.0%	8.0%	8.0%	8.0%	8.0%	8.0%	8.0%
Market share of gallons of gas per day	–	5,129,630	8,494,667	8,791,980	9,099,699	9,418,189	9,747,825	10,088,999
Gallons of DurAlt required, per day	–	5,130	8,495	8,792	9,100	9,418	9,748	10,089
Gallons of DurAlt required, per year	–	1,872,315	3,100,553	3,209,073	3,321,390	3,437,639	3,557,956	3,682,485
Revenue, per year	–	$17,618,482	$29,176,207	$30,197,374	$31,254,282	$32,348,182	$33,480,368	$34,652,181
Cost of Sales	–	11,739,414	19,440,469	20,120,886	20,825,117	21,553,996	22,308,386	23,089,179
GROSS MARGIN	–	$5,879,068	$9,735,737	$10,076,488	$10,429,165	$10,794,186	$11,171,983	$11,563,002
Former USSR – TOTAL GROSS MARGIN	**$2,583,910**	**$8,558,583**	**14,181,588**	**14,686,835**	**15,210,095**	**15,752,010**	**16,313,246**	**16,894,492**

PMC Revenue and Cost of Sales Assumptions by Country

Octel's cost for DurAlt per gallon (price sold)	$9.41	
PMC's manufacturing cost of DurAlt, per gallon	$6.27	500 gallons of DurAlt per 1,000,000 gallons of gasoline
Gross Margin per gallon	$3.14	1,000 gallons of DurAlt per 1,000,000 gallons of diesel

Canada – Oil Company	1998	1999	2000	2001	2002	2003	2004
Gallons of DurAlt required, per year for gasoline	500,000	500,000	500,000	500,000	500,000	500,000	500,000
% realized in sales	20.0%	25.0%	30.0%	30.0%	30.0%	30.0%	30.0%
Total gallons of DurAlt sold	100,000	125,000	150,000	150,000	150,000	150,000	150,000
Revenue, per year	$941,000	$1,176,250	$1,411,500	$1,411,500	$1,411,500	$1,411,500	$1,411,500
Cost of Sales	627,000	783,750	940,500	940,500	940,500	940,500	940,500
GROSS MARGIN	$314,000	$392,500	$471,000	$471,000	$471,000	$471,000	$471,000
Gallons of DurAlt required, per year for diesel	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000
% realized in sales	0.0%	20.0%	25.0%	30.0%	30.0%	30.0%	30.0%
Total gallons of DurAlt sold	–	200,000	250,000	300,000	300,000	300,000	300,000
Revenue, per year	–	$1,882,000	$2,352,500	$2,823,000	$2,823,000	$2,823,000	$2,823,000
Cost of Sales	–	1,254,000	1,567,500	1,881,000	1,881,000	1,881,000	1,881,000
GROSS MARGIN	–	$628,000	$785,000	$942,000	$942,000	$942,000	$942,000
TOTAL GROSS MARGIN	**$314,000**	**$1,020,500**	**$1,256,000**	**$1,413,000**	**$1,413,000**	**$1,413,000**	**$1,413,000**

Europe – Oil Company	1998	1999	2000	2001	2002	2003	2004
Gallons of DurAlt required, per year for gasoline	2,500,000	2,500,000	2,500,000	2,500,000	2,500,000	2,500,000	2,500,000
% realized in sales	20.0%	25.0%	30.0%	30.0%	30.0%	30.0%	30.0%
Total gallons of DurAlt sold	500,000	625,000	750,000	750,000	750,000	750,000	750,000
Revenue, per year	$4,705,000	$5,881,250	$7,057,500	$7,057,500	$7,057,500	$7,057,500	$7,057,500
Cost of Sales	3,135,000	3,918,750	4,702,500	4,702,500	4,702,500	4,702,500	4,702,500
GROSS MARGIN	$1,570,000	$1,962,500	$2,355,000	$2,355,000	$2,355,000	$2,355,000	$2,355,000
Gallons of DurAlt required, per year for diesel	5,000,000	5,000,000	5,000,000	5,000,000	5,000,000	5,000,000	5,000,000
% realized in sales	0.0%	20.0%	25.0%	30.0%	30.0%	30.0%	30.0%
Total gallons of DurAlt sold	–	1,000,000	1,250,000	1,500,000	1,500,000	1,500,000	1,500,000
Revenue, per year	–	$9,410,000	$11,762,500	$14,115,000	$14,115,000	$14,115,000	$14,115,000
Cost of Sales	–	6,270,000	7,837,500	9,405,000	9,405,000	9,405,000	9,405,000
GROSS MARGIN	–	$3,140,000	$3,925,000	$4,710,000	$4,710,000	$4,710,000	$4,710,000
TOTAL GROSS MARGIN	**$1,570,000**	**$5,102,500**	**$6,280,000**	**$7,065,000**	**$7,065,000**	**$7,065,000**	**$7,065,000**

PMC Revenue and Cost of Sales Assumptions by Country

Octel's cost for DurAlt per gallon (price sold)	$9.41	
PMC's manufacturing cost of DurAlt, per gallon	$6.27	500 gallons of DurAlt per 1,000,000 gallons of gasoline
Gross Margin per gallon	$3.14	1,000 gallons of DurAlt per 1,000,000 gallons of diesel

US – Oil Company	1998	1999	2000	2001	2002	2003	2004
Gallons of DurAlt required, per year for gasoline	5,000,000	5,000,000	5,000,000	5,000,000	5,000,000	5,000,000	5,000,000
% realized in sales	20.0%	25.0%	30.0%	30.0%	30.0%	30.0%	30.0%
Total gallons of DurAlt sold	1,000,000	1,250,000	1,500,000	1,500,000	1,500,000	1,500,000	1,500,000
Revenue, per year	$9,410,000	$11,176,500	$14,115,000	$14,115,000	$14,115,000	$14,115,000	$14,115,000
Cost of Sales	6,270,000	7,837,500	9,405,000	9,405,000	9,405,000	9,405,000	9,405,000
GROSS MARGIN	$3,140,000	$3,925,000	$4,710,000	$4,710,000	$4,710,000	$4,710,000	$4,710,000
Gallons of DurAlt required, per year for diesel	10,000,000	10,000,000	10,000,000	10,000,000	10,000,000	10,000,000	10,000,000
% realized in sales	0.0%	20.0%	25.0%	30.0%	30.0%	30.0%	30.0%
Total gallons of DurAlt sold	–	2,000,000	2,500,000	3,000,000	3,000,000	3,000,000	3,000,000
Revenue, per year	–	$18,820,000	$23,525,000	$28,230,000	$28,230,000	$28,230,000	$28,230,000
Cost of Sales	–	12,540,000	15,675,000	18,810,000	18,810,000	18,810,000	18,810,000
GROSS MARGIN	–	$6,280,000	$7,850,000	$9,420,000	$9,420,000	$9,420,000	$9,420,000
TOTAL GROSS MARGIN	**$3,140,000**	**$10,205,000**	**$12,560,000**	**$14,13,000**	**$14,13,000**	**$14,13,000**	**$14,13,000**

ASSUMES PURCHASE COMPLETED 03/98

	1998	1999	2000	2001	2002	2003	2004
Total Revenue	$27,216,800	$126,478,370	$187,376,916	$205,309,081	$211,663,281	$218,353,392	$225,399,181
Total Cost of Sales	18,134,898	84,274,117	124,851,569	136,799,993	141,033,876	145,491,580	150,186,277
TOTAL GROSS MARGIN	**$9,081,911**	**$42,204,263**	**$62,525,347**	**$68,509,088**	**$70,629,405**	**$72,861,812**	**$75,212,904**

SALOMON SMITH BARNEY

A Member of TravelersGroup

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PMC Patent and Trademark Information

Polar Molecular Corporation

U.S. PATENTS

Title	Inventor	Patent Number	Issue Date
Residual Oil Sludge Dispersant	Nelson, Jr., et al.	4,516,981	05/14/85
Residual Oil Sludge Dispersant	Nelson, Jr., et al	4,613,340	09/23/85
Anti-Gel Fuel Additive	Nelson, et al	4,673,411	06/16/87
Fuel Conditioner	Nelson, et al	4,753,661	06/28/88
Anti-Gel Fuel Composition	Nelson, et al	4,848,847	07/11/89

U.S. PATENT APPLICATIONS

Title	Inventor	Serial Number
Motor Fuel Additive Composition and Method for Preparation Thereof	Nelson, et al	08,472,179

Polar Molecular Corporation

FOREIGN PATENTS

Title	Country	Serial/Patent Number	Issue Date
Motor Fuel Additive Composition and Method for Preparation Thereof	Australia	660,608	03/05/91
	Brazil	PI9106137	Pending
	Canada	2,077,666	Pending
	Japan	3-506077	Pending
	South Korea	92-702149	Pending
	EPC[1]	0 518 966	12/27/95
Residual Oil Sludge Dispersant	Canada	1,262,855	11/14/89
	Britain	2,174,984	10/25/89
	Israel	78742	10/14/90
	France	2,581,563	05/09/90
	Venezuela	49761	05/09/86
Fuel Conditioner	Brazil	PI8603711-0	06/28/94
	Canada	1,331,093	08/02/94
	France	2,602,240	07/05/91
	Israel	79662	02/06/91
	Italy	1,196,571	11/16/88
	Mexico	168875	06/14/93
	South Korea	34765	07/30/90
	Taiwan	42057	10/11/90
	Venezuela	49691	08/15/86

[1] Includes Britain, Austria, Belgium, Switzerland, Germany, Denmark, Spain, France, Italy, Luxembourg, Netherlands, Sweden and Greece.

Polar Molecular Corporation

U.S. TRADEMARKS

Title	Serial Number	Filing Date
DuraFlo	74/674,029	05/15/95
DurAlt	74/673,451	05/12/95
DuraSta	74/673,000	05/12/95

FOREIGN TRADEMARKS

Title	Country	Serial Number	Filing Date
DurAlt	Indonesia	HC.01-01-1090	09/09/91
	Venezuela	7073/86	05/30/86

Title	Country	Registration Number	Registration Date
DuraAlt	Canada	330,690	07/31/87
	France	1,335,576	05/21/86
	Britain (CL. 1)	1,266,770	05/08/86
	Britain (CL. 2)	1,300,476	02/10/87
	Italy	475,056	03/30/87
	Italy	600,326	07/12/93
	Japan	2,032,111	03/30/88
	Mexico	426,746	11/30/92
	Germany	1,131,163	11/28/88

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Management Biographies

Polar Molecular Corporation Management Profiles

Mark L. Nelson – *Chairman, President and Chief Executive Officer*

Mr. Nelson was one of the co-founders of PMC and has been associated with developing and marketing PMC products throughout his entire professional career. Mr. Nelson was the principal management force behind the development of the organization from conception of PMC to the present, including development of the product, key business relationships, distribution system, marketing activities, research which confirmed performance of the product, acquisition of patents, and the negotiation of the Company through a hostile takeover and eventual recovery and restructuring.

Mr. Jerry R. Allsup – *Vice President for Research and Technology*

Mr. Allsup joined PMC in June 1995 following extensive research experience in commercial and government engine laboratories. Mr. Allsup has published many technical papers describing the relationships of fuels and fuel components on specific engine parameters. He began his research career in fuels research at a U.S. Department of Energy ("DOE") field laboratory in the late 1960's and in the 1980's was appointed Director of the DOE's Office of Alternative Fuels in Washington, D.C. Mr. Allsup was responsible for the concept and initiation of the Clean Cities Program which builds alliances between federal and local government and industry to promote alternative fuels.

Mr. Allsup also served as chief scientist on evaluations of other major fuel additive suppliers including directing a joint EPS/USDA study on the impact of lead phasedown in the U.S. gasoline engine market, which was published as a special report to the President and Congress. Jerry's research while employed by the National Institute for Petroleum Energy Research quantified the performance claims of DurAlt in controlling combustion chamber deposit formation. He also serves on the Board of Advisors for Information Resources, Inc., an organization which coordinates industry issues involving oil refiners, engine manufacturers and governmental agencies.

Mr. Nelson was one of the co-founders of PMC and has been associated with developing and marketing PMC products throughout his entire professional career.

Polar Molecular Corporation Management Profiles

M. A. Richard Nelson – *Consultant*

Mr. Richard Nelson is one of the co-founders of PMC and is currently President of Polar Research in Michigan and a consultant to PMC. Polar Research is independent of PMC. Richard manages the technical related patent activities and oversees production and quality control of PMC products at Grow Chemical.

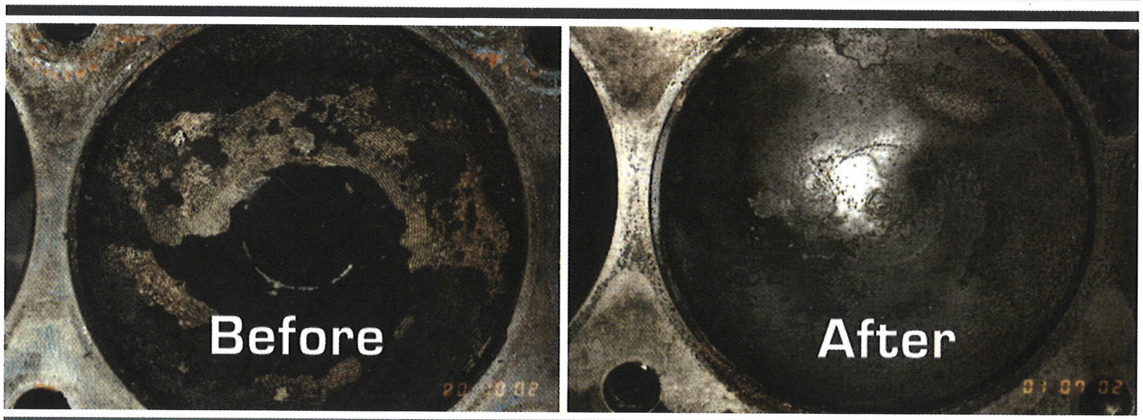
Dr. Chandra Prakash – *Consultant*

Dr. Prakash is a scientist who is responsible for marketing DurAlt FC in India as a technology for the replacement of lead. Dr. Prakash attended a University in India and received a B.S. with majors in Physics, Chemistry and Mathematics and a M.S. degree in Mathematics. He also received a B.S. in Chemical Engineering from a second University in India and his Ph.D. in Chemical Engineering from the University of British Columbia. Dr. Prakash was previously the head of a major Canadian governmental operation involving environmental transportation issues. He provided technical expertise and guidance related to various transportation fuels in motor vehicles and the technology interactions of emissions, engines and fuels. Dr. Prakash has authored over 50 technical papers and presentations worldwide.

Dr. Prakash will spearhead entry into India, a major market for TEL and therefore for PMC products.

SELECT TEST DATA

DURALT®



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POLAR MOLECULAR CORPORATION

Select Test Data

Table of Contents

Advanced Fuel Additive Technology for Cost Effective Gasoline Lead Phaseout by Control of Octane Requirement Increase

By

Jerry R. Allsup

Polar Molecular Corporation

For Distribution at the
UN Special Session on Environment and Development
New York, NY
June 1997

ABSTRACT

Data shows that a new generation of gasoline additive developed by Polar Molecular Corporation, known as DurAlt Fuel Conditioner (DurAlt FC), controls octane requirement increase (ORI) by inhibiting and reversing the build up of combustion chamber deposits (CCD). The additive can effectively eliminate the use of tetraethyl lead (TEL) which is universally recognized for its harmful health effects, but is still being used in many parts of the world as a gasoline octane enhancer.

ORI is the tendency of a motor vehicle engine to require additional octane ranging from about 5 to 10 octane numbers as the vehicles accumulates 10,000 to 20,000 kilometers. The data shows that DurAlt FC limits the ORI to about 2 octane numbers as compared to the normal increase of 5 to 10 numbers. Thus, the use of this additive can result in reducing the octane demand by 3 or more octane numbers. Typically the use of TEL at 0.15 gram of lead per liter of gasoline increases the octane of fuel by about 3 numbers. Thus in a simple scenario, a country using 0.15 gm/liter of lead could completely eliminate the use of TEL in its gasoline by introducing DurAlt FC additive. The result will be a reduction in the octane value of fuel by about 3 numbers which will be offset by the reduction in octane requirement of the engine by 3 or more numbers.

The use of the additive will not only eliminate or reduce extremely hazardous TEL in gasoline, but also will avoid the need for major and costly refinery modifications to produce high octane components such as benzene and other aromatics which contribute to carcinogenic emissions.

Many countries which use TEL or other harmful octane enhancers, clearly recognize the adverse health implications, but believe they must continue along this path because of the high economic cost of importing unleaded fuel components or building new refinery capability in order to produce high octane unleaded fuel. Economic data is presented that shows the use of DurAlt FC additive is more cost effective than refinery modification and other options.

Introduction

Octane Requirement Increase (ORI) is a phenomenon that occurs in gasoline powered vehicles in which engines experience an increase in the octane requirement as new vehicles accumulate 10,000 or 20,000 kilometers. Typically, the ORI ranges between 5 to 10 octane numbers. The ORI is dependent upon several factors including the vehicle operation mode, fuel composition and engine design. The anticipated ORI and the octane quality of gasoline available in the marketplace are principal elements included in the design of the engine.

Deposits resulting from incomplete combustion inside the combustion chambers of the engine are responsible for the increased octane requirement of the engine. Thus, removing combustion chamber deposits (CCD), or preventing CCD from forming reduces the octane demand of the engine and allows the use of lower octane fuel without adversely affecting the engine performance or incurring engine damage.

A new generation of fuel additive technology is currently available in the marketplace which controls the buildup of CCD and the resultant ORI. Thus the historical assumption that a ORI of up to 10 numbers is unavoidable and must be accommodated by higher octane fuel, is no longer valid. The reduction in octane demand of the engine due to the new fuel additive technology allows the use of lower octane fuel with possible elimination of tetraethyl lead needed to accommodate the historical ORI.

Additives that control ORI are important for future operations that will optimize the new engine octane demand to the octane of the fuel. However, during the transition period while phasing lead out of gasoline, it is desirable that the fuel additives also reduce the octane requirement of the current population of vehicles by reducing the deposits. This is clearly a more difficult performance requirement. Data obtained from large scale fleet operations confirm the ability of the additive to reduce not only the octane requirement increase of new vehicles, but also reduces the octane requirement of used vehicles.

Application of CCD additives - a new way to reduce or eliminate tetraethyl lead

A review of test data generated at a US Department of Energy test facility (National Institute for Petroleum Energy Research) confirm the ORI from normal operations without the DurAlt FC average about 7 octane numbers and the ORI with the additive was only about 2 octane numbers (Ref. 2). Further, the test data show that after the first data point at 2,500 miles, the ORI remained essentially unchanged throughout the rest of the mileage accumulation.

The test procedure involved procuring vehicles with approximately 30,000 miles of normal use and disassembling the engines and removing all deposits before initiating the tests. Mileage accumulation was highly controlled to insure all vehicles received the same operational parameters and included the use of professional drivers and instrumented vehicles. Other test operations including monitoring octane rating of the vehicles were conducted using industry approved test protocols.

FIG. 2 ORI With and Without DurAlt FC Technology
Ford 2.3 liter engine

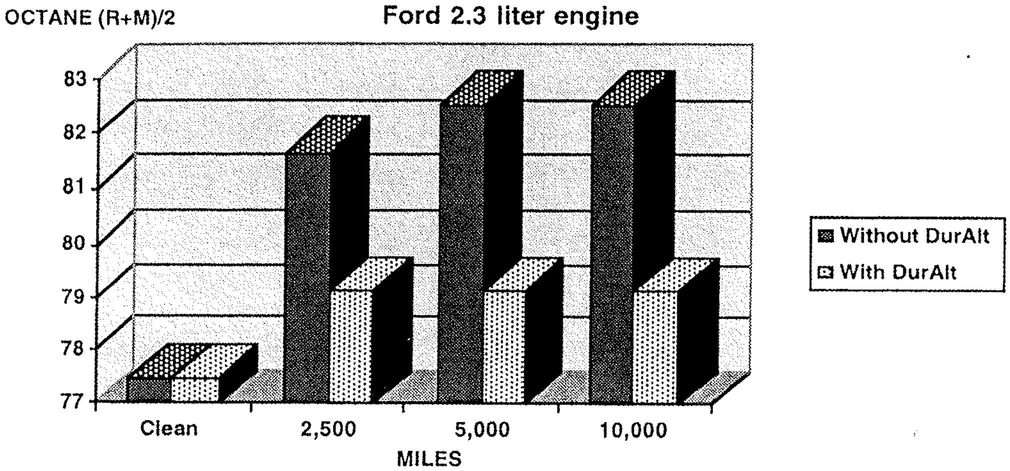
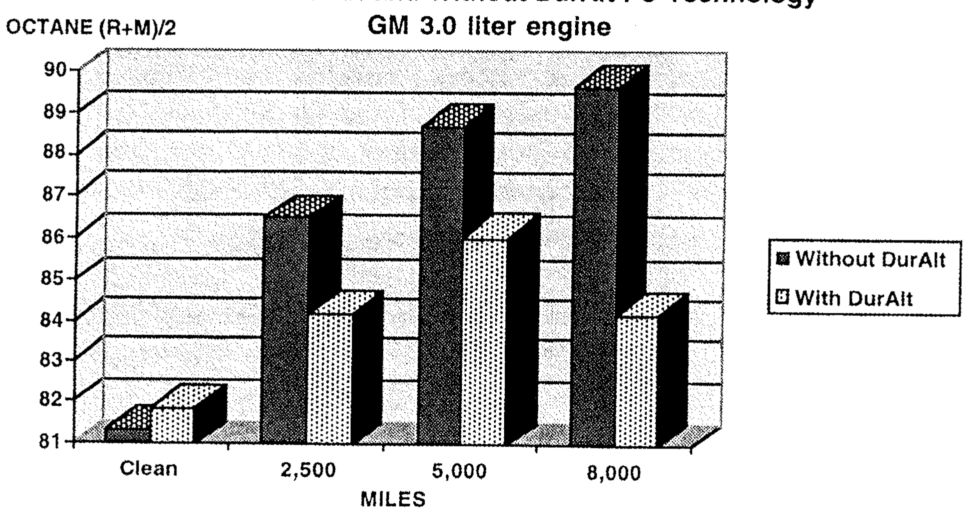


Figure 2 presents data from a fleet of Ford vehicles with 2.3 liter engines showing an ORI of 5 numbers without the additive compared to an ORI of only 2 with the additive. It is also important to note that after the first 2,500 miles the octane requirement remained constant with the DurAlt FC additive, but continued to increase without the additive (Ref. 2).

Figure 3 presents similar data from a fleet of GM vehicles with 3.0 liter engines showing a ORI of 8 numbers without the additive and an ORI of only 2 numbers with the DurAlt FC additive (Ref. 2).

FIG. 3 ORI With and Without DurAlt FC Technology
GM 3.0 liter engine



Technology confirmed in large scale fleet tests

Two public utility companies in the US participated in a large scale fleet test to determine the feasibility of phasing lead from their gasoline and substituting DurAlt FC technology. The vehicles used by both fleets consisted of large trucks with large displacement engines designed for heavy duty operations (Ref. 6).

One of the fleets changed the fuel for their fleet of 34 heavy duty vehicles from the regular leaded fuel 89 octane) to regular unleaded fuel (87 octane). This utility company reported significant engine knocking and related problems. The fleet eventually began using premium unleaded fuel which still did not resolve all of the problems, and finally elected to change back to leaded fuels for satisfactory operation.

The other utility company changed the fuel for their fleet of 139 heavy duty vehicles from the regular leaded fuel to unleaded regular fuel with the DurAlt FC. This fleet reported no problems with knocking and was successful in making the transition from regular octane leaded fuel (89) to the regular grade unleaded fuel (87 octane) with the DurAlt FC, with no related engine problems or driver complaints.

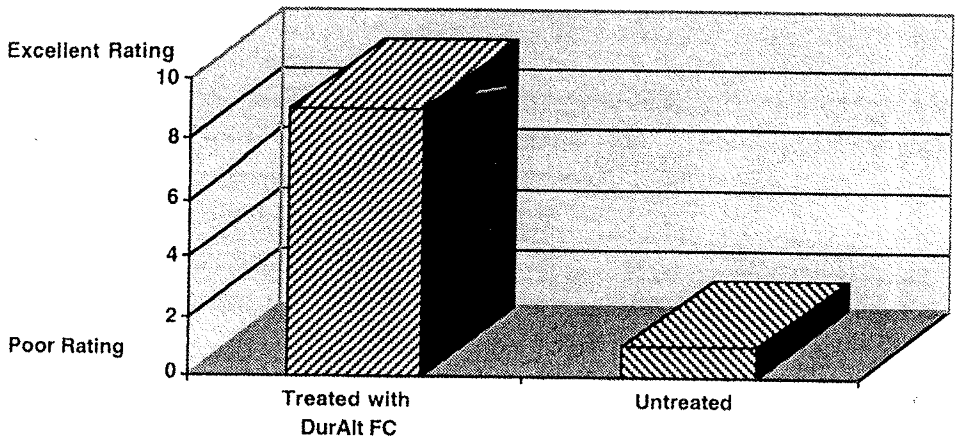
This experience mirrors results from several experiences which document the ORI reduction observed in highly controlled laboratory studies are consistent with the ORI reduction observed in real world fleet tests.

Opportunity in 2 cycle engines

The use of small motorcycles employing 2 cycle engines represents the major mode of motorized transportation in many countries. For example, it is reported that 60 % of the gasoline consumed in India, is used for this transportation sector. The engine technology for these engines typically requires the addition of lubricating oil to the gasoline. In all engines one of the major sources of CCD formation is due to lubricating oil which makes its way by various means into the combustion chamber. Therefore adding lubricating oil directly to the fuel, makes these engines particularly susceptible to the build up of excessive CCD adversely affecting engine life, efficiency and emissions.

Test data published in Mercury Marine advertisements (Ref. 7) confirm the use of the DurAlt FC results in improved cleanliness of the engine combustion chamber using standard industry test methodology and several test engines (Figure 7). Reduction of the CCD in the 2 cycle engine application is particularly significant and confirms the performance of the additive in all engine applications.

Figure 7 Engine Cleanliness Rating (2 cycle engines
(10 = Clean, 0 = Dirty)



National Marine Manufacturers Association (NMMA) Test Protocol
(Tests conducted by Mercury Marine)

Significance of CCD/ORI fuel additive technology

The use of fuel additive technology to control CCD is strongly supported by the automotive manufacturers worldwide. The basic reason is that currently, the engine combustion chamber is not designed to be optimum for a fuel when the engine is new or clean of deposits, but is expected to become "more or less optimized" as the deposits are formed. The deposit formation is influenced by many factors including the engine design, fuel composition, and driving patters, making the task of the engine designer difficult. It would be preferable in the engine designers were allowed to design a specific combustion chamber geometry for a specific fuel when new or clean, and be assured the design would not be perturbed by deposits. The buildup of deposits in a combustion chamber is not a small change, but affects octane requirement by up to 10 octane numbers. When the engine manufacturers are assured that effective technology is in place to control CCD, the engines will be designed for optimum emissions, performance, and economy for a specific fuel throughout the useful life of the vehicle.

Summary and Conclusions

- Technical data generated at several laboratories throughout the world have demonstrated that the DurAlt FC is effective in reducing the normal ORI of engines by about 70% in a wide range of engines, fuels and applications.
- Application of this additive would reduce or eliminate the need for tetraethyl lead in many countries which are currently using about 0.3 gm/liter lead or less.
- The DurAlt FC is demonstrated by independent studies to be the least costly option to reduce or eliminate lead compared to using other high octane blending components or modifying refineries.
- The DurAlt FC has no associated environmental liabilities such as TEL and high aromatic blending components such as benzene. DurAlt FC has received approval by the US EPA for bulk treatment of motor fuels.

The availability of the DurAlt FC technology presents governmental and oil company officials a cost effective option that can eliminate or reduce the lead poisoning of its citizens. Its use is simple and can be implemented immediately.

DURALT® FUEL CONDITIONER

BROAD-SPECTRUM, NON-METALLIC ADDITIVE FOR DIESEL FUELS

ABSTRACT

This report describes the performance of a single, multifunctional fuel additive, DurAlt® Fuel Conditioner, that alleviates many of the common Diesel fuel problems.

Test data obtained from several independent laboratories are presented. The results show that the Additive increased cetane number by an average of 2.5 in a variety of Diesel fuels and reduced hydrocarbon emissions by the order of 20% or more in Diesel Compression-Ignition (CI) engines. Data also show a reduction in particulate and smoke emissions in CI-engines.

The additive improved fuel economy by at least 2-3% - and often much more - in a variety of CI-engines. Further, it reduced both Diesel injector deposits and combustion noise. The Additive also enhances storage stability of Diesel fuels.

Finally, the report suggests that the Additive achieves its multifunctional behavior by modifying the hydrocarbon oxidation (combustion) process in CI-engines.

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INTRODUCTION

Compliance with environmentally based mandates requires Diesel engine manufacturers to produce engines that operate efficiently while reducing exhaust emissions. These engine performance constraints are being met by using increasingly sophisticated fuel injection systems, piston/combustion chamber designs, and exhaust system traps. Proper performance of the engine and its control systems requires continual maintenance of these systems. This has placed demands on Diesel fuel quality which are being met by bulk treatment with special purpose detergent, dispersant and cetane improving additives.

Refiners, as a consequence of the gasoline lead phasedown and greater octane requirement of unleaded gasoline, have been experiencing growing difficulty in meeting the demand for increased octane level. This demand has led to: (1) increasingly severe catalytic cracking, which produces more aromatic and olefinic gas oil for Diesel fuel and heating oils, and (2), the expanded use of octane enhancing oxygenates (methyltertiary butyl ether and alcohols) in gasoline.

The quality of both Diesel fuel and heating oil have gradually deteriorated. The use of heavier, higher sulfur crude oils along with more severe catalytic cracking has raised aromatic, olefinic and sulfur contents. The aromatics and olefins have lowered cetane number, while the aromatics and sulfur have increased exhaust particulates and smoke from Diesel (CI) engines, gas turbines and furnaces.

Multiple special-purpose additives are used in Diesel fuel to raise the cetane number, reduce the cloud and pour points, prevent oxidative and bacterial deterioration in storage, and reduce exhaust smoke.

In contrast, DurAlt FC is a patented single, multifunctional concentrate, that can be used in Diesel fuels (including gas turbine fuels and heating oil) to reduce many of the problems mentioned above.

This report presents the results of evaluations by several, independent laboratories. These laboratories are identified and listed in Appendix A. A summary of extensive fleet tests is also included for reference purposes. A mechanism is suggested to explain the multifunctional performance of DurAlt FC in both gasoline and Diesel engines.

DurAlt FC was initially developed because of concern for energy conservation and the control of exhaust emissions. Its main function was intended to improve fuel economy of internal combustion engines without degradation of exhaust emission control. However, it was subsequently observed that it had a cetane improvement effect in CI-engines. This behavior suggested that it might have an important effect in modifying the combustion process and in controlling combustion chamber deposits.

This patented Additive is a several-component mixture of materials containing only carbon, hydrogen and oxygen (*); Patent No. 4,753,661, June 28, 1988. It is a blend of oxygenated aliphatic hydrocarbon liquids, Glycol Ethers, and mixed aromatic and paraffinic fuel solubilizers. The active components are a polar material, compatibilizers for the polar material and hydrocarbons, and a compound for enhancing water tolerance.

Typical physical properties of DurAlt FC are:

Appearance	Clear Amber Liquid
Odor	Sweetish, Distinctive
Specific Gravity at	0.875 @ 60° F
Density	7.33 @ 60°F
Flashpoint (t.c.c)	110° F
Boiling Range	220° - 600° F
Water Content	< 0.5%

COMPRESSION IGNITION ENGINE LABORATORY AND ROAD TESTS

INJECTOR DEPOSITS

Injector coke deposits (nozzle coking) were assessed at Laboratory L-4 by flow testing before and after a 50-hour full-load/maximum speed durability test in a 1.6 liter 4-stroke cycle IDI, CI-engine. Nozzle coking is where deposits accumulate in the tip of the pintle nozzle in an IDI engine. These can cause increased hydrocarbon emissions and increased engine noise, particularly a noticeable "crackle" or irregularity in the combustion. In order to insure consistency of the results, a new set of injector nozzles was used for each test.

Table 1 shows the substantial flow improvement at low injector lifts with 500 ppm and 1000 ppm of DurAlt FC. Low injector lifts correspond to the light loads and relatively low speeds typical of passenger car operation.

TABLE 1

DIESEL INJECTOR FLOW PERFORMANCE

	Percent Flow Loss			Flow Improvement Factor	
LIFT.mm	Untreated	Additive 500 ppm(m)	Additive 1000 ppm(m)	500 ppm(m)	1000 ppm(m)
0.05	90.79	72.42	65.25	2.99	3.77
0.1	90.52	70.46	61.48	3.12	4.06
0.2	86.10	66.64	54.08	2.40	3.30
0.3	75.40	56.94	49.55	1.75	2.05
0.4	59.60	44.09	47.49	1.38	1.30
0.5	38.64	23.16	35.96	1.25	1.04
0.6	20.86	20.79	24.58	1.00	0.95
0.7	14.21	14.71	18.53	0.99	0.95
0.8	5.82	5.89	8.67	1.00	0.97

ENGINE EMISSIONS

CI-engine emissions were determined for two engines on test stands. The first engine was a 4-cylinder, 1.6 liter four-stroke cycle IDI engine in Laboratory L-4. It was tested using a simulated ECE-15 procedure. The fuel was a European, consumer-type, low sulfur fuel. For both the untreated and treated fuel, emission tests were run after a 1-hour break-in following a combustion chamber cleaning and replacement of injectors and valve seats.

The second engine was a four-cylinder, 4.7 liter (281 in^3) 2-stroke cycle DI engine in Laboratory L-3. It was tested using the SAE J1003, 13-mode test cycle. D-2 Reference Fuel was used untreated for the initial testing after installation of new injectors. Twenty hours of running then was accumulated using DurAlt FC treated D-2 Reference Fuel. The 20-hour accumulation cycle consisted of 5 minutes of idle, 40 minutes of 50% load at 26.7Hz (1,600 rpm), 40 minutes of 90% load at 35Hz (2,100 rpm), and 35 minutes of 25% load at 35Hz (2,100 rpm).

Results from both laboratories are described in Appendix C, Table C-1 and C-2. Table 3 shows that the Additive substantially reduced hydrocarbon emissions and either particulate matter or smoke. The absence of particulate reduction in the 4.7L 2-stroke engine probably reflects 1) the fact that a majority of the 2-stroke particulate matter emissions come from oil consumption and 2) the test procedure. The procedure at Laboratory L-3 did not test the untreated fuel after accumulation of injector deposits.

TABLE 3

PERCENT REDUCTION IN COMPRESSION IGNITION EXHAUST EMISSIONS

	Lab L-4		Lab L-3		
TEST PROCEDURE	1.6 L, 4-Stroke IDI ECE-15 SIMULATION		4.7 L, 2-Stroke DI 13-MODE		
			OVERALL	MAX TORQUE SPEED	MAX LOAD RATED SPEED
Treatment, ppm	500(m)	1000(m)	667(v)	667 (v)	667(v)
NO_x	7 *	-6 *	-7 *	-5 *	-9 *
Particulates	22	39	-3 *	11*	-14 *
Smoke	--	--	--	61	25
HC	13	43	22	23	17
CO	6	22	17	10	27
BSFC	2.6	2.8	0	0	0

FUEL ECONOMY

Fuel economy improvements using DurAlt FC in CI-engines are shown in Figure 1. Results for identifications 1 through 5 are from dynamometer tests using engines reconditioned prior to testing. Test identifications 6 through 12 are from road or field tests.

The data for test identification 1 was obtained with the simulated ECE-15 cycle, the official European legislative procedure used for emission evaluations. This engine was the only indirect injection type in the group. All of the identifications are listed in Appendix B. The majority of the additive concentrations for these 11 tests were about 1000 ppm(v).

Results, as with SI-engine fuel economy, vary over a considerable range. However, for the CI-engines there does not appear to be any correlation of the magnitude of the improvement with the engine's previous condition.

CETANE NUMBER

The additive improves the ASTM D-613 cetane number of CI fuels. The test uses a CFR engine. Table 4 shows cetane number increases ranging to a maximum of about 5 CN at a 1000 ppm treatment level.

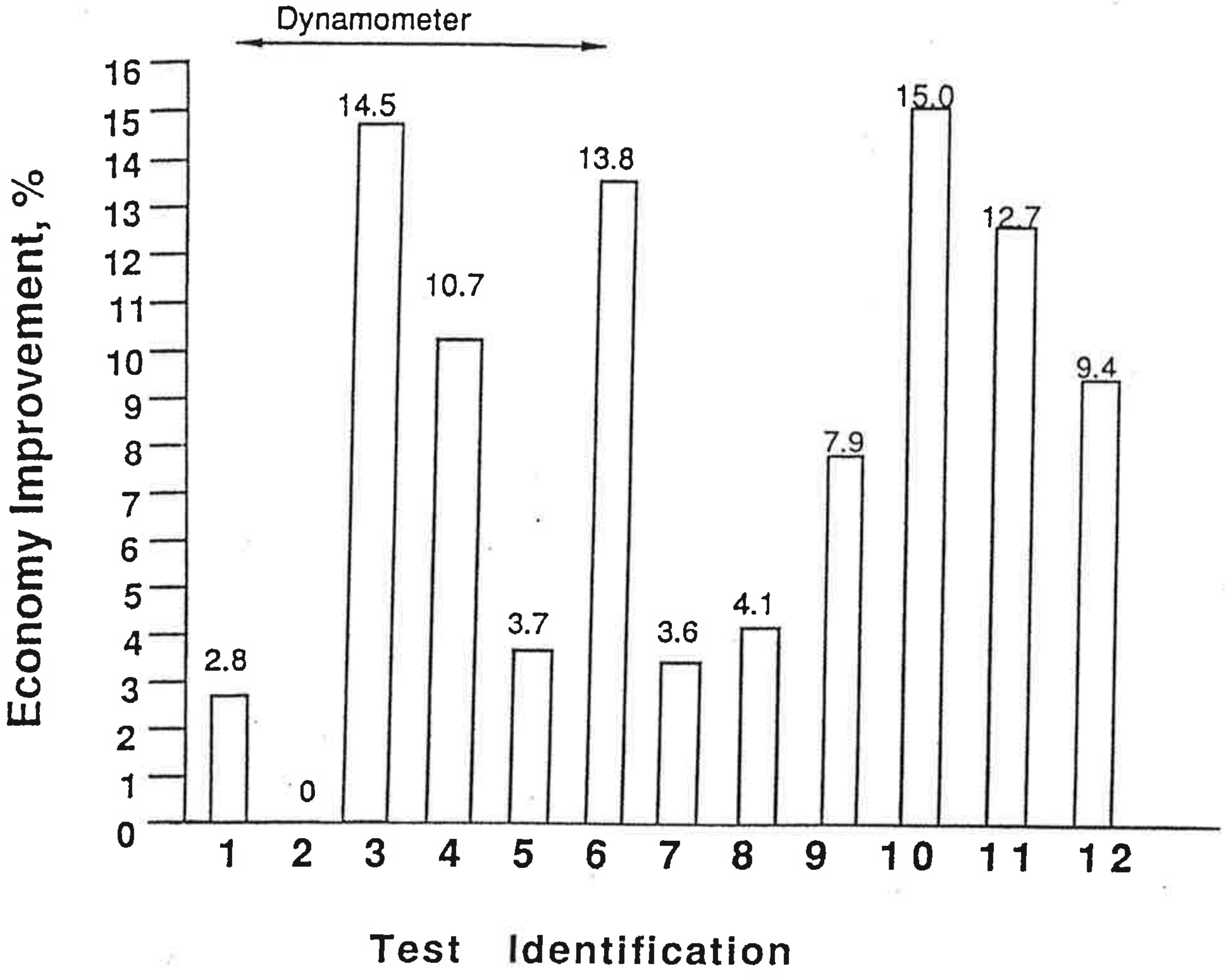
TABLE 4

CETANE NUMBER IMPROVEMENT
ASTM D-613
(average change)

Fuel	Untreated Fuel		Treated Fuel 500 ppm			1000 ppm			2000 ppm			Lab
LC	37.0	37.0	37.3	37.5	(0.4)	39.0	38.7	(1.9)	39.0	38.7	(1.9)	L2
D2-1	42.2	42.3	45.1	45.4	(3.0)	46.3	46.4	(4.1)	--	--	--	L2
D2-2	44.9	--	--	--	--	46.8		(1.9)	--	--		L2
PRE	45.0	45.0	--	--		49.6	50.3	(5.0)	50.1	47.2	(3.7)	L2
2D	46.1	48.2	--	--	--	46.6	46.6	(-0.7)	47.1	47.6	(0.2)	L2
LS	52.7					55.2		(2.5)				L4*
Mean Increase					(1.7)			(2.5)			(1.9)	

Figure 1

Fuel Economy Improvement With The Additive, C. I. Engines



SUMMARY OF FLEET EXPERIENCES

Fuel economy data obtained in the earlier period of Additive development convinced two fleet operators to run their own extensive tests. These tests, now extending over several years, confirmed the economic value of DurAlt FC. The experience gained from these fleet tests, although qualitative and not subject to statistical analysis, did provide information on other aspects of the performance of the Additive. These have subsequently been confirmed by controlled laboratory and road tests. Many of these tests are continuing.

UTILITY AND INDUSTRIAL PLANT FLEETS

This is a very brief summary of the experiences of a specific electric utility gathered over several years while operating some 654 vehicles ranging from passenger cars to large Diesel trucks. The voluminous records, obtained by the operating department, are on file and available. As of late 1990, the utility fleet has treated over 3,000,000 gallons of gasoline.

Generally, the utility vehicle fleet spends a major fraction of the time idling. This is interspersed, with runs of about one hour at interstate highway speeds. Such operation is conducive to the development of combustion chamber deposits with consequent knocking and burning of exhaust valves. Introduction of DurAlt FC eliminated valve burning problems within a year and also essentially eliminated reports of knocking and pinging.

MANUFACTURING FLEET

This fleet consists of approximately 1200 vehicles, including about 1000 gasoline-powered cars and light trucks. The remainder consists of Diesel-powered heavy trucks and construction equipment. The fleet operators primarily within the confines of a large industrial plant, hence almost all operation is at low speed.

About five years ago, by using DurAlt FC, this company was able to change their gasoline fuel from 89 (R+M)/2 leaded gasoline to 87 (R+M)/2 unleaded gasoline. A fuel economy improvement was recorded and no problems with knocking/surface ignition or exhaust valve recession were observed.

STATIONARY GAS TURBINES

Evaluations were conducted on two utility-owned gas turbines to assess improvements in fuel economy between the normal, untreated base fuel, the fuel treated with an iron-based additive, and fuel treated with DurAlt FC. Fuel consumption data in gallons per Megawatt hour were obtained using a standard OEM monitoring procedure.

Use of DurAlt FC yielded a 1.1% reduction in fuel consumption compared with untreated fuel and a 3.6% reduction compared with fuel treated with the iron-based additive. Additional fuel stabilization benefits were reported.

ADDITIVE CONCENTRATION

The DurAlt FC concentrations in the fuel used in these many tests has not been a fixed quantity. The range of additive concentrations used has ranged from 500 to 2000 ppm. The wider range of concentrations are more typical of recent tests exploring the possibility of optimum performance. Earlier testing was usually performed using only one concentration. For example, the Electric Utility fleet used 556 ppm while the stationary gas turbine testing was conducted at 667 ppm.

Laboratory L-2 evaluated cetane number improvement for Diesel fuel. An optimum concentration was indicated at about 1000 ppm. This concentration also provided appreciable Diesel fuel storage stability improvement.

CONCLUSIONS

The results reported show that our new Additive technology successfully treats a broad spectrum of important middle distillate fuel-related problems.

In Diesel fuel DurAlt Fuel Conditioner:

1. Reduces injector coking.
2. Reduces engine noise.
3. Reduces exhaust hydrocarbons, carbon monoxide, and particulates/smoke emissions.
4. Reduces fuel consumption.
5. Increases cetane number.
6. Improves fuel stability in storage.

A hypothesis that DurAlt FC primarily functions by affecting hydrocarbon oxidation processes appears consistent with actual performance.

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A Broad-Spectrum, Non-Metallic Additive for Gasoline and Diesel Fuels: Performance in Gasoline Engines

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Polar Molecular Corp.
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Scientific Advisor to Polar Molecular Corp.
R. W. Krumm and G. E. Ducker
Pfizer, Inc.

International Congress
and Exposition
Detroit, Michigan
February 27–March 3, 1989

ABSTRACT

This paper describes the performance of a single, multifunctional additive that alleviates many of the common gasoline and Diesel fuel problems. The additive has been deemed "substantially similar" by the EPA and thus may be used for bulk treatment of unleaded gasoline.

Test data obtained from several independent laboratories are presented. The results show that the additive limits octane requirement increase (ORI) to an average of about 30% of that experienced when using untreated gasolines; reduces hydrocarbon emissions by the order of 10% or more; improves fuel economy approximately 1.5% - and often much more - in a variety of engines; and also reduces exhaust valve recession and combustion chamber deposits.

The additive effects on Diesel engine performance and on combustion modification in both gasoline and Diesel engines will be reported later.

RECENT DEMANDS ON ENGINE PERFORMANCE AND FUELS

Compliance with environmentally based mandates has forced automobile manufacturers to produce spark-ignition (SI) engines that operate reliably with curtailed evaporative and exhaust emissions and improved fuel economy while using unleaded gasoline.

These engine performance constraints have been met by using increasingly sophisticated induction, piston/combustion-chamber, exhaust, and control systems. Maintenance and performance of these systems has placed demands on gasoline quality which are being met by bulk treatment with special purpose, detergent and dispersant additives, and by using higher octane gasoline.

Detergent and dispersant additives quite effectively deal with induction system deposits, but have not been very effective in preventing Octane Requirement Increase (ORI), presumably from combustion chamber deposits associated with extended use.

Refiners, as a consequence of lead phasedown and greater octane requirement of unleaded gasoline, have been experiencing growing difficulty in meeting the demand for increased octane levels. This demand has led to: (1) increasingly severe catalytic cracking, and (2), the expanded use of octane enhancing oxygenates (methyl t-butyl ether and alcohols) in gasoline.

Heavier, higher sulfur crude oils along with the more severe catalytic cracking have raised aromatic, olefinic and sulfur contents. Consequently, the quality of both Diesel fuel and heating oil has gradually deteriorated. The aromatics and olefins have lowered cetane number and the aromatics and sulfur have increased exhaust particulates and smoke from Diesel (CI) engines, gas turbines and furnaces.

Several single-purpose additives have been used in Diesel fuel to raise the cetane number, reduce the cloud and pour points, prevent oxidative and bacterial deterioration in storage, and reduce exhaust smoke.

In contrast, the additive described in this paper is a single, multifunctional concentrate, for use in both gasoline and Diesel fuels (including gas turbine fuels and heating oil) to reduce many of the problems mentioned above.

The paper presents the results of SI-engine evaluations by several, independent laboratories, identified in Appendix A.

Topics addressed are ORI, passenger car exhaust emissions, fuel economy, octane number and octane related engine performance, and valve seat recession. Results showing that the additive affects CI-engine injector deposits, engine combustion noise, exhaust emissions, fuel economy, cetane number, cold fuel flow, and fuel storage stability will be published subsequently.

A summary of several fleet tests is also included at the end of the paper as evidence of acceptable field performance.

ADDITIVE HISTORY — The additive discussed in this paper was initially developed to improve fuel economy of internal combustion engines without degradation of exhaust emission control systems. It was subsequently observed that the additive had a knock-reduction effect in SI-engines and a cetane improvement effect in CI-engines, and reduced hydrocarbon and smoke emissions. This behavior suggested that the additive might have an important effect in modifying the combustion process and in controlling combustion chamber deposits.

ADDITIVE DESCRIPTION — The additive is a several-component mixture of materials containing only carbon, hydrogen and oxygen; U.S. Patent No. 4,753,661, June 28, 1988. It is a blend of oxygenated aliphatic hydrocarbon liquids, glycol ethers, and hydrocarbon fuel solubilizers. The active components are a polar material, compatibilizers for the polar material and hydrocarbons, and a compound for enhancing the water tolerance of the additive.

SPARK-IGNITION ENGINE LABORATORY AND ROAD TESTS

OCTANE REQUIREMENT INCREASE — Octane requirement increase is observed with extended operation of gasoline engines. In order to maintain normal engine performance, under these conditions, a higher octane fuel is often required. Although a number of factors may be involved in the phenomenon of ORI, combustion chamber deposits are recognized as being a major contributor to the problem. The effect of the additive on ORI was determined by Laboratories L-3, L-4, and L-6 using three different test procedures and five engine/base fuel combinations.

10 Car Road Test — Laboratory L-3 tested six 1985 cars manufactured by Company A and four 1984 cars manufactured by Company B. The Group A cars were equipped with 3.0 liter V-6 port-injected engines and automatic transmissions; the Group B cars were equipped with 2.3 liter 4-cylinder carburetted engines and automatic transmissions. Cars within Group A consisted of three each of two body styles of the same size. All cars in Group B had the same body style.

In preparation for testing, the cylinder heads of each of the cars were removed and the combustion chambers cleaned. The valve train assembly (especially the valve guide clearances) were inspected to insure that undue amounts of lubricating oil would not enter the combustion area and thus affect the test results. Crankcase oil was changed and oil, air and fuel filters were replaced, together with spark plugs, EGR and PCV valves. Each of the engines was then tuned to manufacturer's specifications.

The gas tanks were drained and filled with a commercially available unleaded regular fuel obtained from a single batch. The cars were then driven for approximately 100 miles, under identical conditions in an attempt to equalize combustion chamber deposits. At this point, octane requirement evaluations were made with a chassis dynamometer, using the CRC designated E-15-87 test procedure. The initial octane requirements for each of the ten cars was thus established.

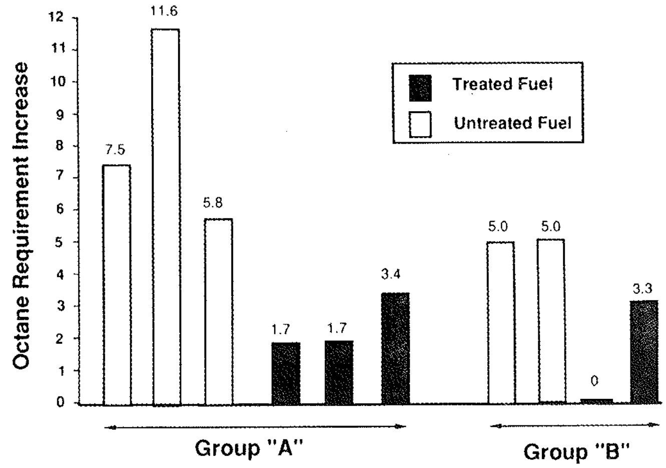
Fuel for half of each of the Group A and B cars was treated with the additive at a concentration level of 667 ppm. A closed route representing both city and country driving conditions was followed with all of the vehicles traveling in line. The 100-mile route was traversed at an average speed of about 64 km/hr (40 mph), with the maximum speed limited to 97 km/hr (60 mph). Vehicle order in the line and vehicle-driver combinations were rotated.

Octane requirement levels were determined for each of the cars after 2,500 and 5,000 miles. Based on the trends of the results, the Group A cars were subsequently run to 8,000 miles. The Group A car tests were then terminated, since the laboratory judged that the octane requirements had essentially stabilized.

The octane requirements among the Group B vehicles were smaller than the Group A vehicles. Therefore, Group B test duration was extended to 10,000 miles to assure that equilibrium had been attained. The octane requirement results are shown in Table 1 and the ORI's are summarized in Figure 1. Mean ORI with the additive treated fuel was 6.0 octane numbers lower than with untreated fuel for Group A cars and 3.3. lower with Group B cars.

Figure 1

Octane Requirement Increase Over Test Duration (R+M)/2



1.6 L Engine Test — An additional ORI evaluation was made by Laboratory L-4, with a European 1.6 L, 4-cylinder, crossflow 4-stroke engine with a compression ratio of 9:1. The twin choke carburetor was modified to permit air/fuel ratio adjustment by control of float chamber pressure.

The engine was initially run-in for 20 hours over a range of speeds and loads. The test schedule in this case took the form of a 200 hour mixed-cycle run, with octane requirement, part-load exhaust emissions and fuel consumption being determined at 50 hour intervals. Octane requirement was determined from the spark advance producing borderline knock. The cycle used in this test program is listed in Table 2. It is representative of a typical European engine duty cycle.

The 200 hour test was completed twice, first with the baseline fuel and then with 424 ppm of the additive. Prior to each test the engine was stripped, cleaned and measured.

The initial octane requirement of the engine at the start of the baseline fuel test was 93.5 RON. After the 200 hour run, this increased by 2.8 to 96.3, as shown in Figure 2.

After rebuilding the engine, the initial octane requirement was 94 instead of 93.5. After the 200 hour run, the octane requirement with the additive, had increased by 1.2 to 95.2. Thus, ORI with the additive was reduced 1.6 RON from that for the baseline gasoline, or a 57% reduction in ORI requirement.

TABLE 1
OCTANE REQUIREMENT
(R + M)/2

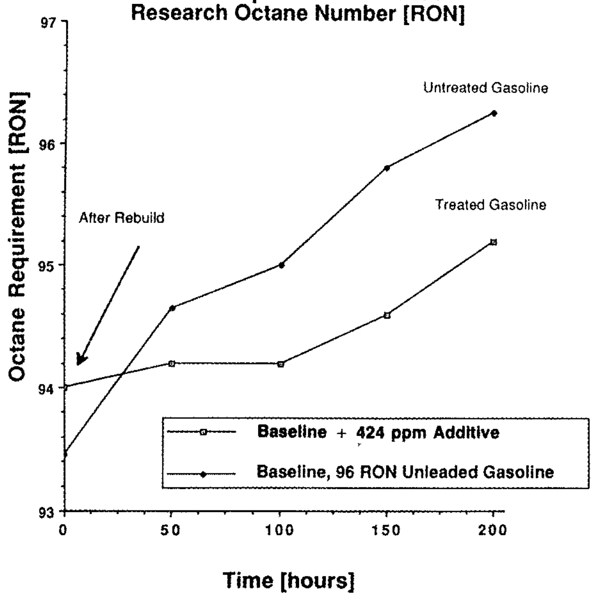
Group A Car No.	Concn. ppm	MILES ACCUMULATED 0	2500	5000	8000	10,000	FINAL ORI
1	0	80.8	87	87	88.3	-	7.5
2	0	80.8	84.2	90.8	92.4	-	11.6
4	0	82.5	88.3	88.3	88.3	-	5.8
3	667	82.5	84.2	84.2	84.2	-	1.7
5	667	82.5	84.2	87*	84.2	-	1.7
6	667	80.8	84.2	87*	84.2	-	3.4
Group B							
8	0	77.5	82.5	82.5	-	82.5	5.0
10	0	77.5	80.8	82.5	-	82.5	5.0
7	667	77.5	77.5	77.5	-	77.5	0
9	667	77.5	80.8	80.8	-	80.8	3.3

* Erroneous data because of procedural problems discovered after testing

TABLE 2
TEST SCHEDULE
1.6 L, 4-Cylinder Engine

Condition	Engine Speed rev/min	Engine Load BMEP	Time Minutes
1	2400	2.5 bar	20
2	3600	4 bar	20
3	3000	Full Load	5
4	2400	5.5 bar	20
5	1200	5.5 bar	20
6	1200	1.5 bar	20
7	850	Idle	15

Figure 2
Fuel Additive Tests
Octane Requirement Increase
Research Octane Number [RON]



10,000 km Road Tests — Laboratory L-6, a major European petroleum company, also ran some extended road tests on a car equipped with a 4-cylinder gasoline engine. These were four, 10,000 km tests run in series with a different fuel in each test. The combustion chamber was cleaned between tests. Octane requirement for each cylinder was determined from the spark advance producing borderline knock. The knock and octane requirement characteristics of this engine were very well known to this laboratory. Based on this experience, the ORI reductions by the additive that are shown in Table 3 were "considered to be very significant".

TABLE 3
OCTANE REQUIREMENT INCREASE*

	Untreated	Treated	ORI Reduction	Percent Reduction
Leaded Gas	4.6	0.8	3.8	82%
Unleaded Gas	1.5	0.3	1.2	80%

* Average Values of the 4-cylinders

GASOLINE ENGINE EMISSIONS — FTP Tests — Laboratory L-1 tested two pairs of 1986 cars using the 1975 Federal Test Procedure. Appendix B describes the work, summarizes the results and the statistical analyses. Table 4 presents the hydrocarbon and fuel economy results analyzed in terms of percent improvement when using the additive. Results are shown for the full three-bag FTP tests and for the hot transient (HT) third bag portion of the test.

Table 4 shows that additive use consistently reduces hydrocarbon emissions and increases fuel economy by the order of 5-15% and 1.5-2.5%, respectively. Results in Appendix B Table B-2 show that carbon monoxide and NOx emissions are not consistently nor, in most cases, significantly affected by additive use.

TABLE 4
EFFECT OF ADDITIVE ON
HYDROCARBON EMISSIONS AND FUEL ECONOMY
Two Car Pairs, 3 Replicates, 333 ppm**

HYDROCARBON EMISSIONS

Additive Use	Percent Reduction from Untreated		
	0 mi	500 mi	1000 mi
FTP			
Car Pair C		13.7 #	
Car Pair D	5.2 &	3.2	4.6
HT			
Car Pair C		16.1 #	
Car Pair D	10.0 @	11.4 #	14.3 &

FUEL ECONOMY
Carbon Balance

Additive Use	Percent Increase from Untreated		
	0 mi	500 mi	1000 mi
FTP			
Car Pair C		2.0 #	
Car Pair D	-0.1	1.5 #	1.4 #
HT			
Car Pair C		2.4 #	
Car Pair D	0.1	1.5 #	1.7 *

# $p < .01$ by two tail t-test
* $p < .05$ by two tail t-test
@ $p < .1$ by two tail t-test
& $p < .2$ by two tail t-test

**500 ppm used in one Pair D car after 500 miles FTP testing

Inspection-Type Emission Tests — In addition to the FTP testing, service-station, emission-control, inspection-type test data on hydrocarbon and carbon monoxide emissions were obtained on twenty-one cars. Additive concentrations were nominally 500 ppm and 1000 ppm. Data are tabulated in Appendix C and Table C-1. Duration of additive treatment varied from a flush through the fuel system by driving the car "around the block," to a more usual consumption of a full tank of treated fuel.

Table 5, summarizes the hydrocarbon emission results which show that the additive consistently reduced hydrocarbon emissions.

TABLE 5
EMISSION INSPECTION TEST SUMMARY

Concentration ppm	Number of Cars	HYDROCARBONS, % REDUCTION Minimum	Average	Maximum
500	16	10	62	100**
1000	5	2	70	100**

** 100% indicates additive reduced emissions below instrument detection limit.

1.6 L, 4-Cylinder Carburetted Engine — The emissions and fuel efficiency of the 1.6 L, 4-cylinder engine used in the ORI testing (Laboratory L-4) were also evaluated when the octane requirement was determined at 50 hour intervals. The data at equivalence ratios of 1.1, 1.0, 0.9 and 0.8 (13 to 18 A/F) with untreated and 424 ppm treated fuels are shown in Appendix D, Table D-1. Ignition timing was set at the minimum advance which gave best (highest) torque (MBT) at 40 Hz (2400 rpm) and 2.5 bar BMEP. Despite the fact that the engine was previously run-in for 20 hours over a range of speeds and loads, emissions and fuel efficiency evidenced an appreciable further break-in in the first 50 hours of the ORI test. Consequently, the Appendix Table D-1 and the following Table 6 summarize only the 50-200 hour steady state data.

TABLE 6
AVERAGE PERCENT DECREASE IN
FUEL CONSUMPTION AND EMISSIONS
424 ppm
1.6 L, 4-Cylinder Carburetted Engine
40 Hz, 2.5 Bar BMEP
MBT Timing, 50-200 Hour Average

Equivalence Ratio*	Fuel Consumption	HC	NOx	CO
1.1	0.3	-2.3**	15.9	-3.3
1.0	4.3	0.4	6.1	3.9
0.9	3.7	5.0	6.0	-3.3
0.8	1.2	-2.9	10.3	-1.5

* Equivalence ratio = $(A/F)_{stoich}$ / (A/F)
** Negative decreases indicate increases

Table 6 shows that fuel consumption and NOx were both consistently reduced over the entire range of equivalence ratios. Hydrocarbon and carbon monoxide emissions both tend to be decreased near stoichiometric, but increased at the mixture extremes.

0.496 L Single-Cylinder Engine — Laboratory L-4 obtained additional emissions and fuel efficiency data in a 0.496 liter, single-cylinder engine, with a "bathtub" combustion chamber representative of many modern engine designs. The laboratory finds that the engine gives levels of performance representative of current gasoline engines. Data are given in Appendix D, Tables D-2 and D-3. Table 7 data cover a range of speeds and loads and treatment levels with MBT ignition-timing. Table 8 data are for five ignition settings with untreated fuel and fuel treated with 424 ppm. The 40 Hz and 2.5 bar BMEP condition for these tests was found to give the largest difference between treated and untreated fuel in spark advance for maximum torque.

TABLE 7
EFFECT OF OPERATING CONDITIONS ON PERCENT
DECREASE FROM UNTREATED FUEL
MBT Timing
0.496 L Single-Cylinder Engine
424 ppm, Stoichiometric A/F

Speed, Hz	BMEP, Bar	Fuel Consumption	HC	NOx	CO
40	2.5	-1.5	11.8	9.1	-1.7
40	5.5	0.1	2.0	-3.2	-0.1
20	5.5	0.4	1.9	5.6	-12.7
20	1.5	-0.3	7.9	-14.8	-0.5
15	0	-0.2	9.0	0.0	0.0

TABLE 8
TIMING EFFECT ON PERCENT DECREASE
IN FUEL CONSUMPTION AND EMISSIONS
0.496 L Single-Cylinder Engine
40 Hz, 2.5 bar BMEP
424 ppm, Stoichiometric A/F (14.5)

Timing, °BTDC	Fuel Consumption	HC	NOx	CO
25	2.4	4.7	7.0	3.0
30	1.6	14.0	5.1	13.2
35	-0.1	11.1	-0.3	-0.3
40	-1.3	6.0	-1.3	-26.7
45	-2.7	11.0	-8.8	-14.4

Table 7, with best torque ignition timing, indicates that 424 ppm treatment consistently decreases hydrocarbon emissions. Nitrogen oxide emissions may be either increased or decreased, depending on operating conditions. Carbon monoxide emissions are unaffected except at the high load of 5.5 bar at 20 Hz (1200 rpm). Data in the Appendix D, Table D-2 indicate that treatment with 848 ppm provides smaller and less consistent effects.

Increasing ignition advance is shown in Table 8 to have no systematic effect on percent decrease in hydrocarbon emissions. Fuel consumption, nitrogen oxide and carbon monoxide emissions increase when timing is advanced beyond the optimum for highest torque (about 35° BTDC for untreated fuel and 32° BTDC for treated fuel). Most engines have timing retarded from MBT to allow for manufacturing variations and to reduce exhaust emissions. With ignition retarded to 30° BTDC, Table 8 indicates that additive treatment would reduce fuel consumption by 1.6%, hydrocarbon emissions by 14%, NOx emissions by 5% and CO emissions by 13%.

FUEL ECONOMY — Significant improvements in fuel economy are realized with use of the additive in a variety of SI-engines with the engines tuned normally (i.e., not with gross variations in mixture ratio or spark-timing from manufacturer's recommendations). This is illustrated by the data shown in Figure 3. Tests are described in Appendix E, Table E-1.

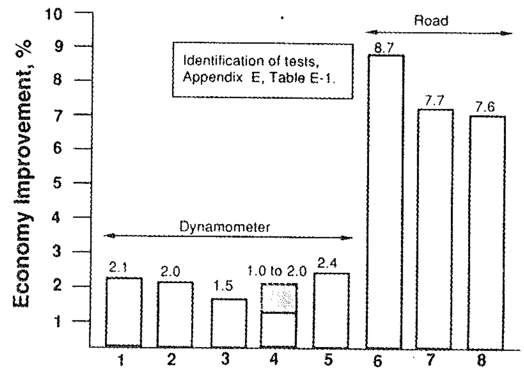
In Figure 3 the economy improvements for dynamometer evaluations 1 through 5 were obtained using engines which were relatively clean and/or had little accumulated mileage since manufacture or rebuilding. Conversely, the engines in 6, 7, and 8 were in over-the-road vehicles with considerable mileage. These would be expected to have deteriorated appreciably from a well-tuned state. The additive improved the fuel economy of the latter vehicles by significantly greater amounts than for the "nearly new" engines. Presumably, none of these engines had deteriorated sufficiently from normal mixture ratios or spark-timing to show the inconsistent effects illustrated in Table 5, 6, 7, and 8.

OCTANE NUMBER AND OCTANE RELATED ENGINE PERFORMANCE — The additive when incorporated in primary reference fuels and commercial gasoline has shown no significant effect on Research or Motor Octane Number, in limited testing by Laboratory L-2.

Laboratory L-4 measured octane number in the 0.496 L, single-cylinder engine used to obtain emissions and fuel economy data. Octane number at 1800 RPM and full-load was determined from the spark advance required to produce borderline knock. Additive concentrations of 424, 848 and 1700 ppm all produced borderline knock at 1 degree greater spark advance than for the untreated 91.5 RON gasoline. This corresponds to a 0.5 higher RON for the additive treated fuels.

Figure 3

Fuel Economy Improvement With the Additive, S.I. Engines



User reports suggest that in-service increases in effective octane number are greater than this slight increase.

VALVE SEAT RECESSION — Two exhaust valve seat recession tests were run by Laboratory L-4. The first was on a 1.2 L, European type, four cylinder, gasoline engine. The engine was run at wide-open throttle at a speed of 4500 rpm, for 55 hours. Every 5 hours the valve recession was measured. The cool-down time was kept constant to minimize temperature effects on these measurements.

Runs were made with untreated unleaded gasoline and with the gasoline trated with 848 and 424 ppm of the additive. The data are tabulated in Appendix Table F-1 and summarized in terms of average wear rates in Table 9. Untreated leaded gasoline data are also shown for comparison.

Data on the unleaded gasolines were analyzed by computation of the average recession rate for each valve for each five hour period. Paired untreated and treated recession rates for corresponding 5-hour time periods for each valve were examined statistically at both concentrations. Both the two-tailed binomial signs tests and the t-test indicate statistical significance at both concentrations ($p < 0.002$ and < 0.001, respectively at 424 ppm and $p < 0.008$ and < 0.01 at 848 ppm).

Table 9 averages indicate that additive treatment produces a 1.6 to 1.7-fold increase in average valve life and a 1.2-fold increase in worst valve life. It also indicates that leaded gasoline virtually eliminates wear.

TABLE 9
VALVE SEAT RECESSION RATES
1.2 L, 4-Cylinder

FUEL	NUMBER OF TESTS	AVERAGE VALVE μm/h	WORST VALVE μm/h
UNTREATED[1]	2	37.6	42.9
TREATED			
424 ppm(v)[1]	1	23.1	35.6
848 ppm(v)[2]	1	21.8	35.9
LEADED			
(150 mg/L)[1]	1	0.0	1.3

[1] 20-hr. test [2] 35-hr. test

An extensive series of valve recession tests, using unleaded gasoline, was also conducted by an engine manufacturer. These tests extended over a period of two years. The accumulated total running time on the engines reported here was 7108 hours, of which 4829 were run using the additive in the gasoline, and 2280 hours were run without.

The following engines were run both with and without the additive.

Engine Number	Configuration	Rated Power(kW)
1	4 cyl in-line	104
2	4 cyl in-line	142
3	V-8	194
4	V-8	205
5	V-6	153

All engines had induction-hardened valve seats.

The manufacturer used his standard durability test procedure, consisting of 55-minutes at full throttle and maximum load, followed by a 5-minutes idle period. The cycle was then repeated.

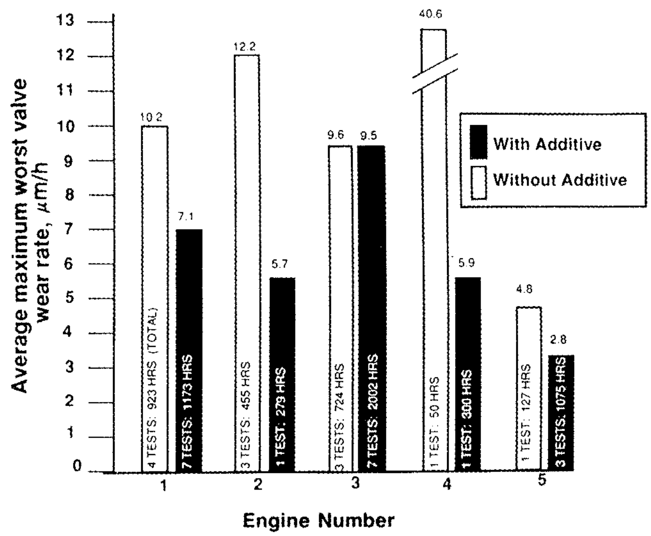
The tests were not formulated with paired tests of untreated and treated fuel or with frequent reference runs. Consequently, it is not possible to discount fluctuating variables of air/fuel ratio, fuel volatility, ambient test conditions, and the length of individual tests over the protracted period of testing. However, the data on 31 total tests in Appendix F, Table F-2 imply that the results were not influenced by such fluctuating variables. For comparative purposes, the manufacturer's raw data from the tests of different duration were analyzed by the authors and the author's conclusions were expressed as average wear rates over the test duration, even though it is known that rates vary with time during a test.

Nevertheless, the rather formidable collection of data, gathered over a prolonged period of time, through thousands of hours of testing, and with all of the variables present, does provide a consistent conclusion. The authors' conclusion from their analysis of the manufacturer's raw data is that valve seat wear rate reduction is significant when using the additive.

The data for each run are summarized in Appendix F, Table F-2 and average data for each engine model are in Table 10 and Figure 4. Data on any one engine model is too limited for statistical significance. However, combining the data from all five engines is adequate. The two-tailed t-test indicates that the mean recession rates are not the same with $p \vee 0.05$ and $p \vee 0.01$ for the worst valve and the average valve data, respectively. Thus, recession rates with treated fuel are significantly different from those with untreated fuel, provided that the usual assumptions for use of the t-test are satisfied.

Additional tests were run on six other engines using the additive. However, the engine manufacturer did not run comparative tests using untreated fuel. Therefore, although the data are available, they are not presented in this paper.

Figure 4
Four Cycle S.I. Engine Valve Recession Test Data



SUMMARY OF FLEET EXPERIENCES

Most of the foregoing text is based upon test results that characterize the behavior of the additive over short periods of time, under carefully controlled conditions.

The additive has also been evaluated for extended test periods, usually several years in duration, with a number of motor fleets. The nature of these data, although judged credible by the fleet manager, generally would not survive critical review and so are not tabulated in this paper. Highlights of these results from representative fleets, however, are included to demonstrate satisfactory field performance:

The types of fleets in which the additive was tested were 1) a large electric utility fleet of 654 vehicles, comprised of gasoline passenger cars and trucks, Diesel trucks, and miscellaneous machines; 2) a manufacturing plant fleet of approximately 1000 gasoline powered vehicles and 200 large Diesel trucks and construction vehicles; 3) a fleet of six police motorcycles; and 4), a utility which tested the additive in two aircraft-type, stationary gas

TABLE 10
AVERAGE VALVE SEAT RECESSION RATES
FOR EACH ENGINE MODEL
556 & 1000 ppm Treatment

Engine Number	Worst Valve, µm/h		Average Valve, µm/h		Total Test Hours	
	Untreated	Treated	Untreated	Treated	Untreated	Treated
1	10.2	7.1	4.4	3.1	923	1173
2	12.2	5.7	6.9	4.8	455	279
3	9.6	9.5	3.7	4.1	724	2002
4	40.6	5.9	8.1	1.4	50	300
5	4.8	2.8	3.2	1.3	127	1075
Mean*	12.61	7.19	5.07	3.18		

* Mean calculated from average rate before rounding.

turbines. About five years of experience with the additive has been accumulated by the utility and plant fleets, and three years by the motorcycle fleet and gas turbines without observation of any adverse treatment effects.

The utility fleet reported that a troublesome valve burning problem had been eliminated by use of the additive, and that knocking and pinging problems also had been eliminated. They have treated in excess of 9,100 m^3 (2,400,000 gallons) of fuel with the additive.

Both fleets 1 and 2 noted improvements in fuel economy. Moreover, they together with fleet 3 were able to switch from 89 octane leaded gasoline to 87 octane unleaded without adverse effects.

A six-month comparative test was run with the motorcycle fleet. Three motorcycles used a base fuel; three used the same fuel but treated with the additive. Qualitative evaluations indicated both better throttle response and reductions in knock and pinging. The knock/pinging reduction is supported by Figure 5 which shows much smaller amounts of piston top deposits associated with use of the additive.

Lastly, in the gas turbine group 4, a 1% reduction in fuel consumption was noted.

ADDITIVE CONCENTRATION

At present, additive concentration has not been systematically investigated. However, consideration of the several concentrations tested for the various types of performance suggests an approximate optimum for gasoline to be in the vicinity of 500 ppm (i.e., between 300-700 ppm).

DISCUSSION

The additive performance suggests that it acts as a combustion modifier in engines. Further support for combustion modification is suggested by SI-engine work at Laboratory L-4. The single-cylinder 0.496 L engine and the 4-cylinder 1.6 L engine emission data were both obtained with ignition timing set to the minimum value giving the highest torque. Generally, the timing for the additive treated fuels was 1 to 3 or 4° BTDC less advanced than the untreated fuel (usually 1 to 2°). This is consistent with expectations if the additive treated fuels ignite and/or burn faster than untreated fuel.

More direct confirmation of combustion effects has been obtained by Laboratory L-4. Pressure signature data were obtained on the 0.496 L, single-cylinder SI-engine for which data are shown in Table 7 and on a 1.6 L IDI CI-engine. The pressure signature data were analyzed in terms of energy release. Results on the SI-engine show that the delay from ignition to 10% energy release and the time for 10% to 50% energy release are reduced, while peak pressure generally is not changed. Results in the IDI CI-engine similarly show that the ignition delay and the time to release 10-to-90% of the heat are both reduced. These SI- and CI-engine results will be detailed in a separate paper.

CONCLUSIONS

The results reported above show that the additive treats a broad spectrum of important gasoline related problems. The additive at 333-848 ppm:

1. Reduces the need for higher (R + M)/2 octane fuel by reducing octane requirement increase by about 70%.
2. Reduces exhaust hydrocarbon emissions by the order of 10% or more.
3. Reduces fuel consumption, by about 1.5% and often much more.
4. Reduces valve seat recession.

These additive effects appear to be the result of combustion modification.

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We also thank the other members of the office staff who helped us in the preparation of this paper.

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Polar Molecular Corporation

Exhibit # 5

SAE TECHNICAL PAPER SERIES

911739

Octane Requirement Increase Control - A New Way of Saving

Mark L. Nelson, James E. Larson, and Mark S. Carruthers
Polar Molecular Corp.

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ABSTRACT

Due to the accumulation of deposits in the combustion chamber, the "appetite" of an engine for octane increases with mileage. Depending on the type of engine, driving conditions, and gasoline, this octane requirement increase (ORI) ranges from 3 to 10 octane numbers.

Because of ORI, national specifications for octane number of gasoline must be based on engines' octane requirement at equilibrium. Applying the incremental analysis technique to refining economics, F. Bernasconi calculated that the incremental cost of producing each extra octane number by refining ranges from $2 to $6 per ton. It is generally well accepted that an increase of one octane number will lead to a loss in refinery yield of 4 to 6%.

Octane requirement increase can be controlled with a new type of ashless, non-metallic additive. An ORI reduction of 50 to 80% has been observed, opening the route to decreasing national gasoline octane specifications. Savings of millions of dollars and up to 20% of crude are possible. Emissions are reduced.

DISCUSSION

In terms of combustion, a fuel for spark ignited engines is commonly characterized by its resistance to knock.

Toward the end of the 1920's, an experimental engine was designed in the USA to determine resistance to knock. It was called the CFR engine. The first method for classifying knock resistance was developed in 1931; it was very similar to the current method for research octane number (RON). A little later in the 1930's, a second procedure was developed which gave rise to the motor octane number (MON). Both methods are still used worldwide; all specifications of gasolines in every country include one or both of these numbers.

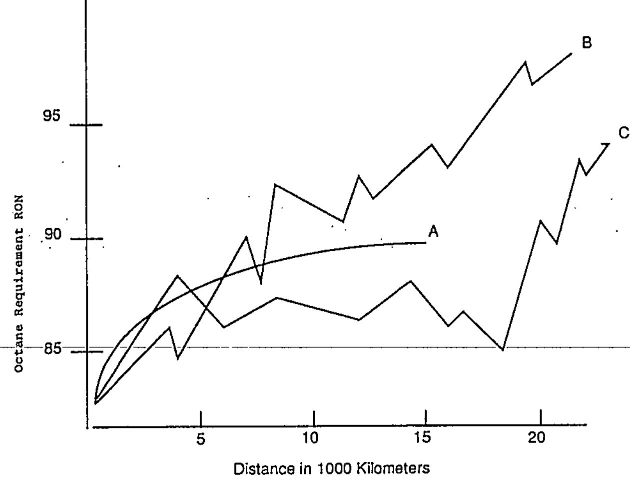
A spark ignited engine is well characterized by its octane requirement, which is the lowest octane of a fuel necessary for the engine to avoid any knock. At the minimum, the octane of a gasoline must satisfy the octane requirement of the engine, over the range of the running conditions of the vehicle.

The octane requirement increase of an engine over time was investigated as early as the mid 1920's (1)* and has been studied extensively over the years (2) (3). In an excellent recent literature review on deposits in gasoline engines (4), Kalghatgi reported variation of octane requirement with distance or engine operating time.

Basically, this increase can be very sharp right from the beginning (Figure 1, curve A), more continuous (curve B), or in a Z shape (curve C). An equilibrium is generally reached even if a plateau is not obvious. Depending upon the type of engine (compression ratio, shape of the combustion chamber, etc. . .), the driving conditions, weather, and the type of gasoline used (leaded, unleaded), the equilibrium octane requirement increase can range from 3 to 15 numbers. (5) (6) (7) (8).

*Numbers in parentheses designate references at end of paper.

Figure 1
Change in Octane Requirements
with distance



The main contributors to ORI are the combustion chamber deposits, even if, in the same engines, intake system deposits also contribute to ORI (4). In the combustion chamber, the deposits involved in ORI are those on the piston top, on the intake and exhaust valve surface, and in the end gas region. These deposits are related to both fuel and lubricating oil.

The nature of the fuel has a direct effect on the physical properties of the deposits: high boiling point components, for instance, are detrimental (9). Another large contribution to ORI is related to the type of gasoline detergents and carrier oils associated with the detergent to improve inlet valve cleanliness (11). These either add to the ORI problem or, in the best case, have no effect at all on ORI.

Lubricating oil also contributes to combustion chamber deposit levels. Large percentages of high molecular weight ingredients (bright stock, for instance) or high levels of sulphated ash increase deposit accumulation (4).

Three possible mechanisms through which combustion chamber deposits could effect octane requirement have been considered (2):

- Volume effect - the space occupied by the deposits increases compression ratio. This effect would be small (about 10%)
- Chemical/catalytic effect - deposits may change the combustion chemistry during flame propagation. There is some evidence against this mechanism (2).
- Thermal effect - deposits store heat in one cycle and give it up to the fresh charge in the next cycle. This is the most likely mechanism.

The control of octane requirement increase while maintaining induction system cleanliness is the real challenge of the 90's.

RECENT DEMANDS ON ENGINE PERFORMANCE AND FUELS

Environmental concerns and public pressure have forced automobile manufacturers to produce spark-ignition (SI) engines that operate reliably with reduced evaporative and exhaust emissions and improved fuel economy while using low lead or unleaded gasoline. These needs have been met by using increasingly sophisticated intake, piston/combustion chamber, exhaust, and control systems.

Performance of these systems has placed demands on gasoline quality which are being met by bulk treatment with special purpose detergent and dispersant additives and by using higher octane gasoline.

Detergent and dispersant additives quite effectively deal with intake system deposits, but have not been effective in preventing octane requirement increase. In fact, the reverse is frequently true - these additives often are contributors to ORI through increased combustion chamber deposits.

Refiners are experiencing growing difficulty in meeting octane demand. The rapid elimination of tetraethyl lead, changes in crude supply and availability, and environmental demands for reduction in aromatic components are forcing substantial reformulations of gasoline. To meet the demand for increasing octane levels, refiners have resorted to (a) increasingly severe catalytic cracking and (b) expanded use of octane enhancing oxygenates. Both approaches are expensive, and the use of oxygenates reduces the energy potential of the fuel, thus increasing overall fuel consumption.

The additive described in this paper is a multifunctional concentrate for use in gasoline. It has been shown to reduce ORI from 50% to 80%, which allows use of lower octane gasoline (8). Extensive testing shows improved fuel mileage (4.5% average increase) and substantially reduced exhaust emissions (10% average hydrocarbon emission reduction). This testing includes both laboratory and fleet use, with over 70,000,000 gallons (262,500,000 litres) of fuel treated since introduction of the additive. No deleterious effects have been noted with recommended use levels.

ADDITIVE HISTORY The additive discussed herein was initially developed to improve fuel economy of internal combustion engines without degradation of exhaust emission control systems. It was subsequently observed that the additive had a knock-reduction effect in SI engines. Hydrocarbon emissions were reduced. This behavior suggested the additive might have an important effect in modifying the combustion process and in controlling combustion chamber deposits.

ADDITIVE DESCRIPTION The additive is a patented multi-component mixture of materials containing only carbon, hydrogen, and oxygen. It is a blend of oxygenated aliphatic hydrocarbon liquids, glycol ethers, and hydrocarbon fuel stabilizers, with specific gravity and fuel value similar to gasoline.. The active materials include a polar material, compatibilizers for the polar material and hydrocarbon fuels, and a compound for enhancing the water tolerance of the additive. The additive has been designated "substantially similar" by the US Environmental Protection Agency, and may therefore be used for bulk treatment of unleaded gasoline.

Table 1

Typical Properties of the Additive

Appearance	Clear Liquid
Color	Amber
Specific Gravity	0.875 15/15° C (60/60° F)
Vapor Pressure	0.86 kPa (6.5torr) @ 22° C (72°F)
Flashpoint (TCC)	43.3° C (110°F)
Boiling Range	104-316° C (220-600° F)
Water Content	< 0.5% by Wt.
Viscosity	4.1 cSt @ 15.6° C (60° F)
Heat of Combustion	45.00 MJ/kg (19,350 BTU/lb)

The additive has been tested in the laboratory and through fleet use in commercial fuels with most currently commerically available detergents and carrier oils. Representative classes of such detergents include polybutene succinimides, polybutene amines, polyether amines, and polyisobutylene amines. There is no degradation in the effectiveness of these detergents in controlling intake system cleanliness.

SPARK-IGNITION ENGINE LABORATORY AND ROAD TESTS

OCTANE REQUIREMENT INCREASE - Octane requirement increase is observed with extended operation of gasoline engines. In order to maintain normal engine performance under these conditions, a higher octane fuel is often required. Although a number of factors may be involved in ORI, combustion chamber deposits are recognized as a major contributor to the problem. The effect of the addtive on ORI was determined by Laboratories L-3, L-4, and L-6 using three different test procedures and five engine/base fuel combinations.

10 Car Road Test - Laboratory L-3 tested six (6) 1985 cars manufactured by Company A and four (4) 1984 cars manufactured by Company B. The Group A cars were equipped with 3.0 litre V-6 port injected engines and automatic transmissions. The Group B cars were equipped with 2.3 litre 4-cylinder carbureted engines and automatic transmissions. Cars within Group A consisted of three each of two body styles of the same size. All cars in Group B had the same body style.

In preparation for testing, the cylinder heads of each of the cars were removed and the combustion chambers cleaned. The valve train assemblies (especially the valve guide clearances) were inspected to insure that undue amounts of lubricating oil would not enter the combustion area and thus effect the test results. Crankcase oil was changed and oil, air, and fuel filters were replaced, together with spark plugs, EGR and PCV valves. Each of the engines was then tuned to the manufacturer's specifications.

The gas tanks were drained and filled with a commercially available unleaded regular fuel obtained from a single batch. The cars were driven for approximately 100 miles, under identical conditions, in an attempt to equalize combustion chamber deposits. At this point, octane requirement evaluations were made with a chassis dynamometer, using the CRC designated E-15-87 test procedure. The initial octane requirements for each of the ten cars was thus established.

Fuel for half of each of the Group A and B cars was treated with the additive at a concentration level of 667 ppm. A closed route representing both city and country driving conditions was followed with all of the vehicles traveling in line. The 100 mile route was traversed at an average speed of about 64 kph (40 mph), with maximum speed limited to 97 kph (60 mph). Vehicle order in the line and vehicle-driver combinations were rotated.

Octane requirement levels were determined for each of the cars after 2,500 and 5,000 miles. Based on the trends for the results, the Group A cars were subsequently run to 8,000 miles. The Group A tests were then terminated, since the laboratory judged that the octane requirements had essentially stabilized.

The octane requirement increases among the Group B vehicles were smaller than the Group A vehicles. Therefore, Group B test duration was extended to 10,000 miles to assure that equilibrium had been reached.

The octane requirement results are shown in Table 2 and the ORI's are summarized in Figure 2. Mean ORI with the additive treated fuel was 6.0 octane numbers lower than with untreated fuel for Group A cars and 3.3 octane numbers lower with Group B cars. The photographs are from Group B.

TABLE 2
OCTANE REQUIREMENT
(R+M)/2

Car No.	Concn.	Miles Accumulated					Final
Group A	ppm	0	2,500	5,000	8,000	10,000	ORI
1	0	81	87	87	88	—	7
2	0	81	84	91	92	—	11
3	667	83	84	84	84	—	1
4	0	83	88	88	88	—	5
5	667	83	84	—	84	—	1
6	667	81	84	—	84	—	3
Group B							
7	667	78	78	78	—	78	0
8	0	78	83	83	—	83	5
9	667	78	81	81	—	81	3
10	0	78	81	83	—	83	5

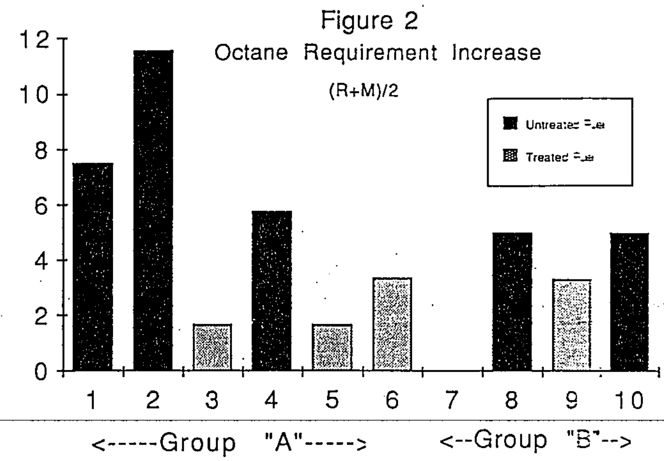


Figure 2
Octane Requirement Increase
(R+M)/2

1.6 Litre Engine Test — An additional ORI evaluation was made by Laboratory L-4, using a Europeon 1.6 litre, 4-cylinder, crossflow 4-stroke engine with a compression ratio of 9:1. The twin choke carburetor was modified to permit air/fuel ratio adjustment by control of float chamber pressure.

The engine was initially run in for 20 hours over a range of speeds and loads. The test schedule in this case took the form of a 200 hour mixed-cycle run, with octane requirement, part-load exhaust emissions, and fuel consumption determined at 50 hour intervals. Octane requirement was determined from the spark advance producing borderline knock. The cycle used in this test program is listed in Table 3. It is representative of a typical European duty cycle.

TABLE 3
TEST SCHEDULE
1.6 L 4-Cylinder Engine

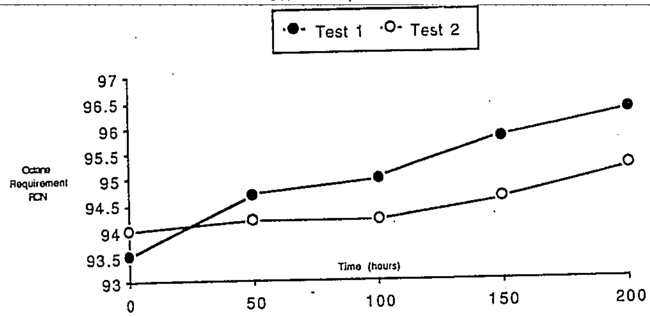
Condition	Engine Speed rev/min	Engine Load BMEP	Time Minutes
1	2400	2.5 bar	20
2	3600	4.0 bar	20
3	3000	Full Load	5
4	2400	5.5 bar	20
5	1200	5.5 bar	20
6	1200	1.5 bar	20
7	850	Idle	15

The 200 hour test was completed twice, first with the baseline fuel and then with 424 ppm of the additive. Prior to each test the engine was stripped, cleaned, and measured.

The initial octane requirement of the engine at the start of the baseline fuel test was 93.5 RON. After the 200 hour run, this increased by 2.8 to 96.3, as shown in Figure 3.

After rebuilding the engine, the initial octane requirement was 94 instead of 93.5. After the 200 hour run with the additive, the octane requirement had increased by 1.2 to 95.2. Thus, ORI with the addtive was reduced 1.6 RON from that for the baseline gasoline, or a 57% reduction in ORI.

Figure 3
Additive Tests
Octane Requirement Increase



Test 1: Baseline 96 RON Unleaded gasoline
Test 2: + 500 ppm Additive

10,000 km Road Tests — Laboratory L-6, a major European petroleum company, also ran some extended road tests on a car equipped with a 4-cylinder gasoline engine. These were four 10,000 km tests run in series with a different fuel in each test. The combustion chamber was cleaned between tests. Octane requirement for each cylinder was determined from the spark advance producing borderline knock. The knock and octane requirement characteristics of this engine were very well known to this laboratory. Based on this experience, the ORI reductions due to the additive as shown in Table 4 were "considered very significant."

TABLE 4

OCTANE REQUIREMENT INCREASE +
1.6L 4-CYLINDER ENGINE

	Untreated	Treated	ORI Reduction	Percent Reduction
Leaded gas	4.6	0.8	3.8	82%
Unleaded gas	1.5	0.3	1.2	80%

+ Average values of the 4 cylinders

ECONOMY AND SAVINGS

With the lead phase down in the United States and Japan, production of gasoline has become more and more sophisticated. It will do so in Western Europe and other areas in the very near future.

To produce gasoline, a refiner can mix different types of major blending stocks, representing more and more complete types of refining:

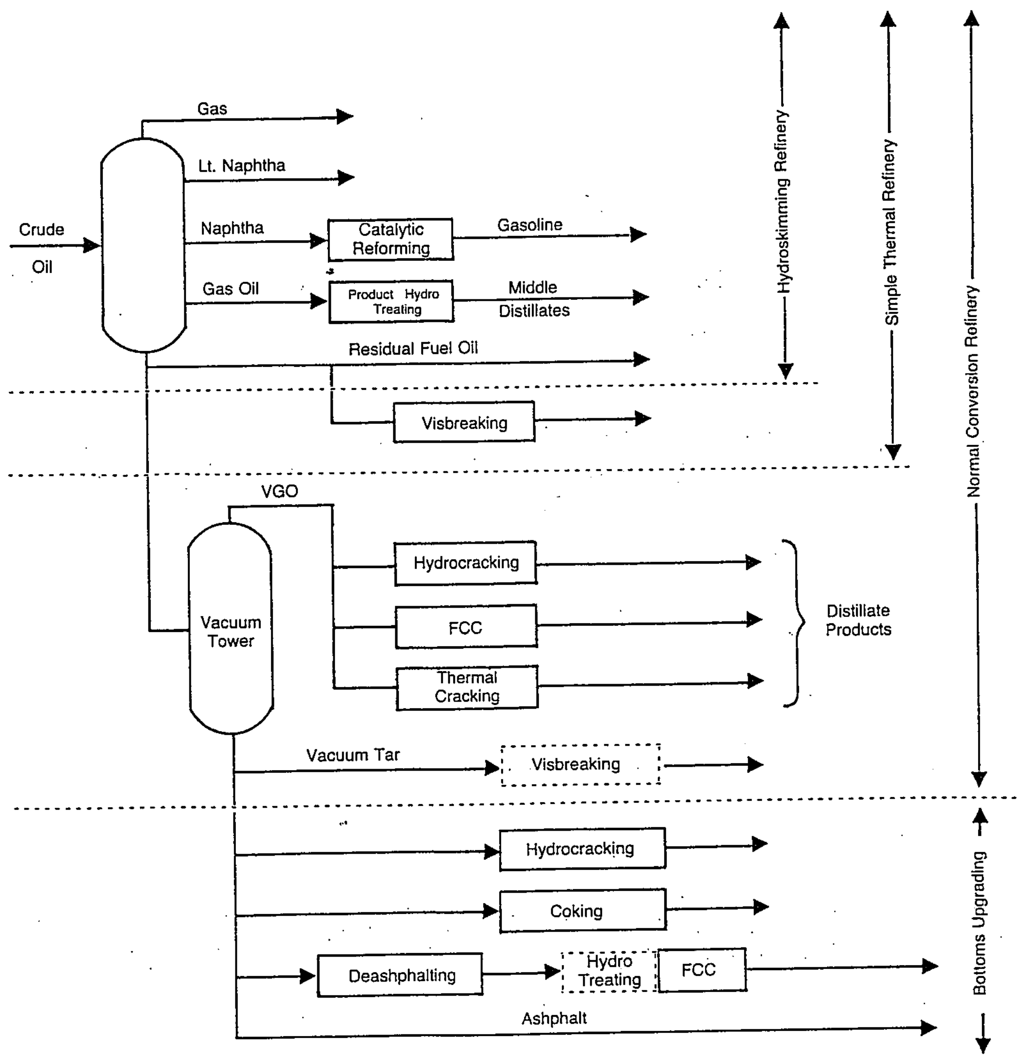
- Light napthas — these have a rather low octane. This octane can be increased significantly by isomerization.
- Reformates — while reformate octanes can be high, they are very dependent on the severity of refinery operation. The highest practical clear RON level (no additive) is around 100.
- Alkylates - good blending stocks, with a reasonably high clear RON level and very low sensitivity. Alkylates show a very small difference between RON and MON.
- Fluid Catalytic Cracked (FCC) gasoline — again, a relatively low octane product. FCC gasolines exhibit high sensitivity, with a big difference between RON and MON.
- Oxygenates — provide flexibility through their high RON, but are available only in limited quantities. MTBE and ETBE can contribute to front end octane number (FEON) while benefiting volatile organic compound emissions control.

COST OF PRODUCING EXTRA OCTANE — The challenge is to produce extra octane numbers at the lowest cost. By applying the incremental analysis technique to refining economics, F. Bernasconi has been able to calculate the incremental cost of producing gasoline with one extra octane number. (12). The gasoline production cost is assessed by incremental analysis as a function of the refinery feedstock (crude oil) and the main byproduct associated with gasoline production (residual fuel oil) for different refinery configurations. He identifies two general classifications for this analysis:

- "Leader" — a refinery equipped with residue upgrading facilities, such as hydrocracking, fluid catalytic cracking and thermal cracking or visbreaking.
- "Laggard" — a simple hydroskimming refinery

A typical schematic for these types of refineries is shown in Figure 4 (13).

Figure 4: Upgrading Stages



Depending on the type of refinery and the type of gasoline produced (leaded or unleaded), and using a crude oil price of $20 per barrel and a residual fuel oil price of $11 per barrel, the cost of a single extra octane number can range anywhere from $2 to $6 per metric ton (Figure 5).

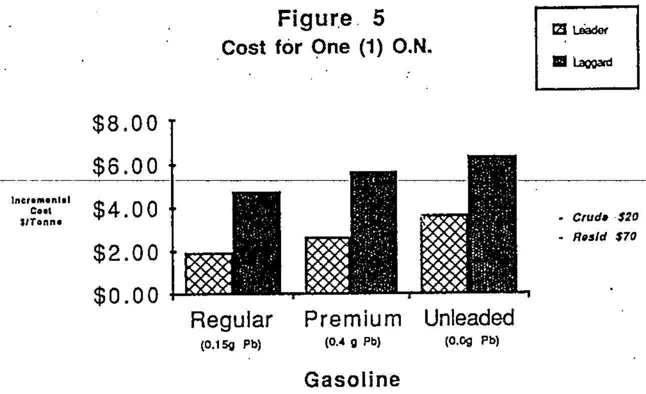


Figure 5
Cost for One (1) O.N.

This is very consistent with the numbers published by Turner, Mason, and Company in their report US Gasoline Outlook 1989-96 summarized in reference (14), where numbers of $.30 to $.60 per incremental octane number per barrel (ION.B) are reported. This equates to $2.5 to $5 per incremental octane number per metric ton ($2.5 to $5 per ION.T).

Generating this single extra octane number will also reduce yield. This results in increased consumption of crude for a given amount of gasoline production.

It is generally well accepted that in a semi-complex type refinery, if everything remains constant (type of crude feedstock, general process settings, etc. . .) an increase of one octane number over normally attainable octane will lead to a reduction in yield of gasoline per barrel of crude oil of about 5%. For example, if the basic yield is 30%, increasing refining severity to get one more octane number will reduce the yield to 25%. In order to provide the same total quantity of gasoline, you will consume 20% more crude oil.

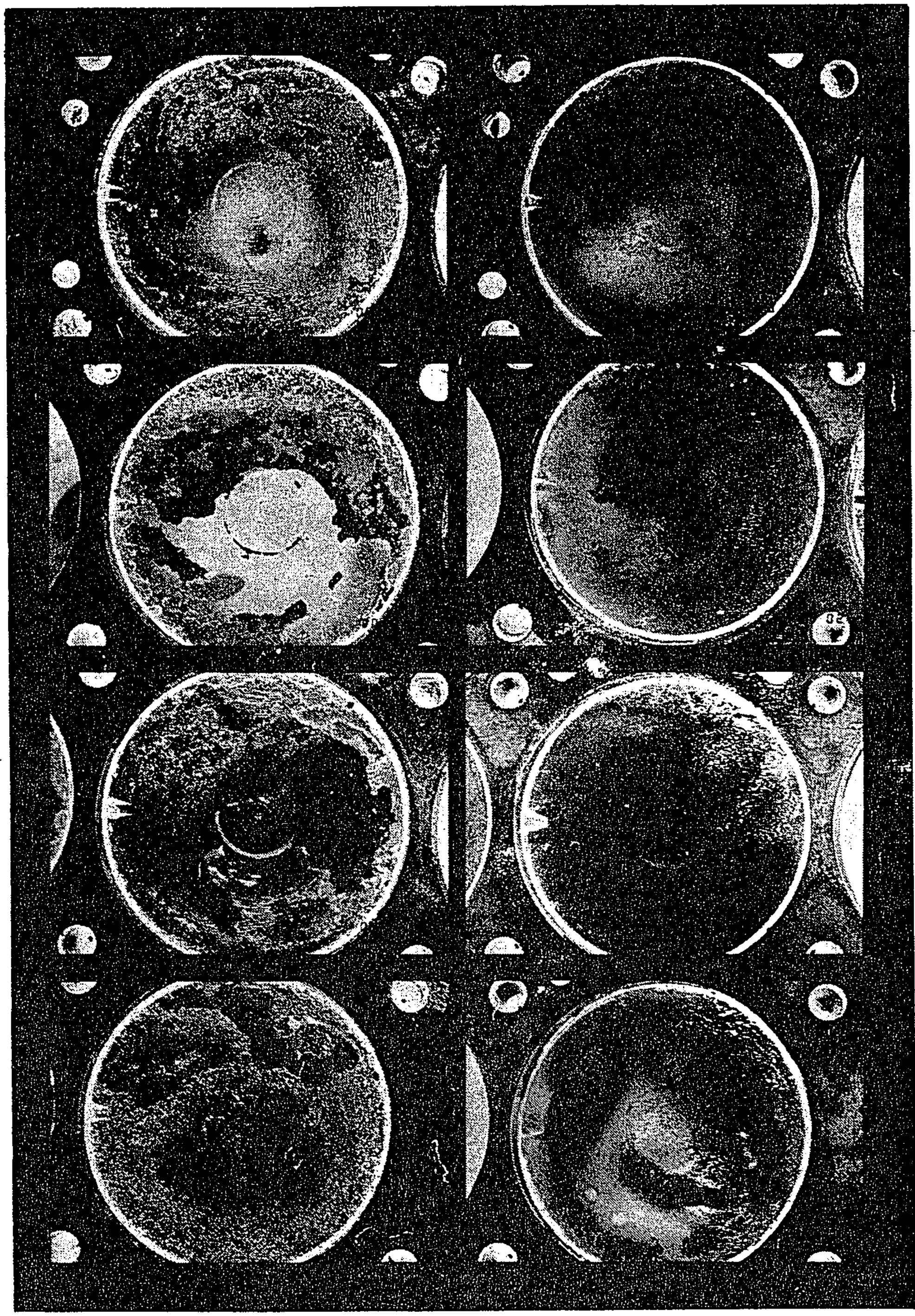
On the other hand, if someone can satisfy the octane requirement of engines while decreasing the octane level of the gasoline by one octane number, he can potentially save:

- $2 to $6 per metric ton of gasoline produced, and
- 20% of his crude oil consumption.

SAVINGS THROUGH ORI CONTROL — As we have seen previously, it is now possible to control the octane requirement increase of engines with ashless non-metallic additives comprised solely of carbon, hydrogen, and oxygen. A dramatic reduction of 50% to 80% of ORI has been observed (8), in current mass-produced engines. This opens the route to a decrease in national gasoline octane specifications, with no degradation in engine performance. Additional benefits also accrue, as reported in the referenced paper (Table 5).

TABLE 5
ADDITIONAL BENEFITS

- Intake system cleanliness - neutral (CEC procedures)
- Corrosion protection
  fuel systems - improved
- Spark plug cleanliness - improved
- Gasoline consumption - reduced 4.5% (average)
- Emissions reduced
  hydrocarbons 10% (average)
  carbon monoxide neutral
  nitrogen oxides neutral
- Valve recession reduced 40% to 60%



Untreated Treated

Piston Tops

Group B

If one applies a national octane decrease specifications policy, huge savings can be achieved. For example, reducing the national gasoline octane specification by one octane numbers in various countries could produce the following savings (Table 6):

TABLE 6

POTENTIAL SAVINGS
Reduction of ONE Octane Number

	Annual Production Metric Tons/Year (000,000)	Annual Saving Potential @ $(000,000)
Argentina	3	12
Brazil	7	28
Mexico	15	60
Venezuela	7	28

@ Based on $4 per metric ton average saving

CONCLUSION

The octane requirement of an engine is known to increase with mileage by 3 to 15 octane numbers, averaging 6 to 7. For that reason the national specifications in octane number of gasolines have to be based not on the original octane requirement of the engine, but on its octane requirement when, after mileage is accumulated, an equilibrium octane requirement is established.

By using a new generation of ashless additive, it is possible to reduce that octane requirement increase by 50% to 80%, opening a new route to control waste of octane with no performance penalty. The savings in both money and crude oil are substantial:

- Decreasing the octane number by ONE units saves $2 to $6 per metric ton of gasoline produced.
- Decreasing the octane number by ONE units saves up to 20% of the crude oil feedstock requirement.

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APPENDIX A
LABORATORY KEY

National Institute for Petroleum and Energy Research (USA) L-3

RICARDO Consulting Engineers (UK) L-4

A Major European Petroleum Company . . L-5

UNITED STATES BANKRUPTCY COURT
FOR THE DISTRICT OF MASSACHUSETTS
(EASTERN DIVISION)

In re: POLAR MOLECULAR CORPORATION, Debtor	Chapter 11 Case No. 93-10960-JNF
STEPHEN S. GRAY, AS CHAPTER 11 TRUSTEE OF THE ESTATE OF POLAR MOLECULAR CORPORATION, Plaintiff v. CHARLES C. JOHNSTON, ELLIOT FEINER, K. KEITH MOON, RUDOLPH J. THOMAS, ROBINS, KAPLAN, MILLER & CIRESI, P.C., J&C RESOURCES, INC., REGAN & ASSOCIATES, INC., BRIAN W. TAYLOR, NEW AGE FUEL ADDITIVES CORPORATION, ROBERT T. MONTAGUE, RICHARD J. OGDEN, JR., JOHN A. BARRY, MARK J. McKINLEY, and GEORGE HENRY, Defendants	Adversary Proceeding No. 93-________

COMPLAINT

Stephen S. Gray (the "Trustee"), duly appointed Chapter 11 trustee of the estate of Polar Molecular Corporation (the "Debtor"), hereby commences this action against Charles C. Johnston ("Johnston"), Elliot Feiner ("Feiner"), K. Keith Moon

("Moon"), Rudolph J. Thomas ("Thomas"), the law firm of Robins, Kaplan, Miller & Ciresi, P.C. ("Robins Kaplan"), J&C Resources, Inc. ("J&C Resources"), Regan & Associates, Inc. ("Regan"), Brian W. Taylor ("Taylor"), New Age Fuel Additives Corporation ("NAFA"), Robert T. Montague ("Montague"), Richard J. Ogden, Jr. ("Ogden"), John A. Barry ("Barry"), Mark J. McKinley ("McKinley") and George Henry ("Henry"). The Trustee seeks to avoid preferential payments, to recover damages for usurpation of corporate opportunity, waste of corporate assets, breach of fiduciary duty, to equitably subordinate debt allegedly owed to Johnston or, in the alternative, to have that debt reclassified as a capital investment.

In support of this Complaint, the Trustee states as follows:

PARTIES

1. The Debtor is a corporation organized under the laws of the State of Utah. It commenced this case by filing a voluntary petition under Chapter 11 of the United States Bankruptcy Code (the "Code") on or about February 2, 1993.

2. The Trustee was duly appointed Chapter 11 trustee of the estate of the Debtor by order of this Court entered on or about May 14, 1993, and has continued to serve in that capacity since that date.

3. Defendant Johnston is an individual residing at 706 Ocean Drive, Juno, Florida. At all relevant times hereto, Johnston has been a director of the Debtor and, for the period

after June 30, 1992, has been its president and chief executive officer.

4. Defendant Feiner is an individual residing at 10 Rogers Street, Unit #1102, Cambridge, Massachusetts. At all relevant times hereto, Feiner has been a member of the Polar Molecular Dissident Shareholder Committee, as that term is defined below.

5. Defendant Moon is an individual residing at 4901 Towne Centre Road, Saginaw, Michigan. At all relevant times hereto, Moon has been a member of the Polar Molecular Dissident Shareholder Committee, as that term is defined below. Moon was also, at all times from June 30, 1992 through and including May 14, 1993, a director and the vice president of the Debtor.

6. Defendant Thomas is an individual residing at 12,366 Windsor Beach Drive, Fenton, Michigan. At all relevant times hereto, Thomas has been a member of the Polar Molecular Dissident Shareholder Committee, as that term is defined below.

7. Defendant Robins Kaplan is a Minnesota professional corporation having its principal place of business at 2800 LaSalle Plaza, 800 LaSalle Avenue, Minneapolis, Minnesota. Prior to June 30, 1992, Robins Kaplan was a law firm retained by the Polar Molecular Dissident Shareholder Committee, as that term is defined below. From June 30, 1992, through and including February 2, 1993, Robins Kaplan served as general counsel to the Debtor.

8. Defendant J&C Resources is a New Hampshire corporation having its principal place of business at 96 Walden Pond Drive, Nashua, New Hampshire. At all relevant times hereto, J&C Resources was a consulting firm, of which the defendant Johnston was the principal, and which was employed by the Debtor.

9. Defendant Regan & Associates, Inc. ("Regan") is, upon information and belief, a Delaware corporation with a principal place of business at 1013 Centre Road, Wilmington, Delaware.

10. Defendant Taylor is an individual who, upon information and belief, resides in Stanardsville, Virginia. At all relevant times hereto, Taylor served as chief technical officer of the Debtor. Since some time in the spring of 1993, Taylor has also served as chief technical officer of NAFA.

11. Defendant NAFA is a Florida corporation having its principal place of business at Suite 1940, S.E. 3rd Avenue, Miami, Florida.

12. Defendant Montague is an individual residing at 180 Lakeview Lane, Mayzata, Minnesota. From June 30, 1992 through and including February 2, 1993, Montague served as secretary of the Debtor. At all relevant times hereto, Montague also was a partner at Robins Kaplan.

13. Defendant Ogden is an individual residing at 14 Allen Park Drive, Wilmington, Massachusetts. From June 30, 1992 through and including May 17, 1993, Ogden served as treasurer of the Debtor.

14. Defendant Barry is an individual with a business address at c/o NAFA, Suite 1940, S.E. 3rd Avenue, Miami, Florida. From June 30, 1992 through and including May 17, 1993, Barry served as a director of the Debtor.

15. Defendant McKinley is an individual residing at 1109 Brissette Beach Road, Kawkawlin, Michigan. From June 30, 1992 through and including May 14, 1993, McKinley served as a director of the Debtor.

16. Defendant Henry is an individual with a business address at c/o NAFA, Suite 1940, S.E. 3rd Avenue, Miami, Florida. From June 30, 1992 through and including May 17, 1993, Henry served as a director of the Debtor.

JURISDICTION

17. This matter is a core proceeding brought under, among other things, Sections 547 and 550 of the Code, over which this Court has subject-matter jurisdiction under the provisions of 28 U.S.C. §1334(a) and §§157(b)(2)(A), 157(b)(2)(E), 157(b)(2)(F), 157(b)(2)(G), 157(b)(2)(H), and 157(b)(2)(O).

18. Venue of this proceeding lies in this District under the provisions of 28 U.S.C. §1409(a).

FACTS RELEVANT TO ALL COUNTS

19. At all relevant times hereto, The Debtor has been engaged in the business of manufacturing and selling various fuel additives to both consumer and industrial end-users. At all relevant times, the most valuable assets of the Debtor's estate have been various patents, both foreign and domestic, protecting

the technologies necessary for the design and manufacture of these additive products.

20. Prior to June 30, 1992, the Debtor was managed by a team headed by Mark L. Nelson ("Nelson"), who served in the capacities of president and a director of the Debtor. (Nelson and the other members of his management team will hereinafter be referred to as the "Nelson Group").

21. Before and during the spring of 1992, Johnston was a minority shareholder of the Debtor. During the spring of 1992, a committee comprised of Johnston, Feiner, Moon, and Thomas (the "PMC Dissident Shareholder Committee"), waged a proxy contest (the "Proxy Fight") against the Nelson Group for control of the Debtor.

22. The PMC Dissident Shareholder Committee's Proxy Fight was successful, in that such Committee obtained control of the Debtor's board of directors in June, 1992. On or about June 30, 1992, Johnston was named chief executive officer of the Debtor and became a director of the Debtor.

23. On or about February 2, 1993 (the "Petition Date"), the Debtor filed for protection under Chapter 11 of the Code.

24. Existing management, including Johnston, continued to operate the Debtor as a debtor-in-possession through May 14, 1993, on which date the Trustee was appointed as Chapter 11 trustee.

25. At all relevant times hereto, the Debtor was insolvent.

COUNT I
(Avoidable Preferential Transfers -- Charles Johnston and the Members of the PMC Dissident Shareholder Committee)

26. The Trustee restates, realleges and reavers the contents of paragraphs 1 through 25 above as though restated here in full.

27. During the one-year period preceding the Petition Date, the Debtor made the following payments, on the following dates, to the following individuals and entities:

PAYMENT NO.	TRANSFEREE	DATE OF TRANSFER	AMOUNT
1	Charles C. Johnston	September 30, 1992	45,000.00
2	Polar Molecular Shareholders Committee	August 28, 1992	100,000.00
3	Robins, Kaplan	October 21, 1992	157,042.48
4	Regan & Associates, Inc.	September 25, 1992	5,568.18

28. The Debtor derived no benefit from the payments listed in paragraph 27 above. Rather, each of those payments was made either to Johnston himself, to the PMC Dissident Shareholder Committee, or to an individual or entity retained by and for the Dissident Shareholder Committee for services rendered during the course of, and in connection with, the Proxy Fight.

29. The $157,042.48 payment to Robins Kaplan made on October 21, 1992 (the "October 21, 1992 Robins Kaplan Payment") and the $100,000.00 payment to Polar Molecular Shareholders Committee were for legal fees incurred with respect to the proxy battle for control of the Debtor and related litigation. Both

the PMC Dissident Shareholder Committee and Johnston, in his individual capacity, were liable for payment of the underlying debt to Robins, Kaplan. On or about March 20, 1992, Johnston, as representative of the PMC Dissident Shareholder Committee, entered into a letter agreement (the "Engagement Agreement") with Robins Kaplan, whereby the PMC Dissident Shareholder Committee agreed to pay Robins Kaplan for legal services to be rendered i. connection with the Proxy Fight. The Engagement Agreement further stated that Johnston, in his individual capacity, agreed to accept "initial financial responsibility" for "reasonable legal fees incurred by the [PMC Dissident Shareholder] Committee." A true and accurate copy of the Engagement Agreement is attached to this Complaint as Exhibit A.

30. The Debtor's check which constituted payment of the October 21, 1992 Robins Kaplan Payment was accompanied by a letter from Ogden, in his capacity as acting chief financial officer of the Debtor, to Montague, in his capacity as a partner at Robins Kaplan (the "Ogden Letter"). The Ogden Letter states, in effect, that the enclosed check constitutes payment in full of the Debtor's outstanding obligation to Robins Kaplan of $233,153.16, as reflected on the attached invoice (the "July 9, 1992 Invoice"), reduced by an arithmetic error in the amount of $1,110.68. The Ogden Letter further states that the total on the July 9, 1992 Invoice had been further reduced by $75,000.00, to reflect a payment in that amount made to Robins Kaplan by J&C Resources on or about August 7, 1992. Thus, the October 21, 1992

Robins Kaplan Payment, according to the Ogden Letter, was to retire the remaining balance of $157,042.48 still outstanding on the July 9, 1992 Invoice. True and accurate copies of the Ogden Letter and the July 9, 1992 Invoice are attached to this Complaint as Exhibits B and C, respectively.

31. Of the $233,153.16 due under the July 9, 1992 Invoice, $57,949.54 was incurred in connection with Robins Kaplan file number 026546-0000, titled "The Proxy and Related Materials." The remaining balance of $175,203.62 was incurred in connection with Robins Kaplan file number 030407-0000, titled "Litigation and Related Matters."

32. According to Robins Kaplan's records, this balance of $175,203.62 -- which was retired by the Debtor's October 21, 1992 Robins Kaplan Payment -- was comprised of four separate invoices. These invoices are detailed as follows:

	INVOICE NUMBER	INVOICE AMOUNT	INVOICE DATE
	162244	$46,934.92	April 29, 1992
	163392	$39,861.52	May 19, 1992
	165336	$21,541.12	June 26, 1992
	165728	$66,866.06	July 8, 1992
TOTAL		$175,203.62	

33. As described in paragraph 32 above, each of the invoices paid by the October 21, 1992 Robins Kaplan Payment covers periods prior to June 30, 1992 -- a period when, upon

information and belief, the law firm of Berry, Moorman, King & Hudson, P.C. ("Berry Moorman"), and not Robins Kaplan, served as the Debtor's counsel. As a result, the obligations paid by the October 21, 1992 Robins Kaplan Payment could only have been obligations of Johnston and/or the PMC Dissident Shareholder Committee, not of the Debtor. Upon information and belief, the obligations paid by the October 21, 1992 Robins Kaplan Payment derived from Robins Kaplan's representation of Johnston in connection with civil litigation between Johnston and Nelson. Therefore, the Debtor derived no value on account of the October 21, 1992 Robins Kaplan Payment.

34. On or about September 25, 1992, the Debtor paid $5,568.18 to Regan. Upon information and belief, Regan was engaged by the PMC Dissident Shareholder Committee for proxy solicitation services. Upon information and belief, Johnston and the PMC Dissident Shareholder Committee were each contingently liable for the payment of Regan's fees in connection with the Proxy Fight.

35. On or about August 28, 1992, the Debtor paid $100,000.00 to the PMC Dissident Shareholder Committee. This payment was made as a reimbursement of expenses incurred by the PMC Dissident Shareholder Committee during the Proxy Fight.

36. At all relevant times hereto, Johnston and each member of the PMC Dissident Shareholder Committee were insider creditors of the Debtor.

37. Each payment listed in paragraph 27 above was made on account of an antecedent debt owed by the Debtor to the transferee before each payment was made.

38. Each payment listed in paragraph 27 above enabled Johnston and each member of the PMC Dissident Shareholder Committee each to receive more than each such person would have received if:

A. the case were a case under Chapter 7;

B. the transfer had not been made; and

C. each such transferee received payment of such debt to the extent provided by the Code.

39. With respect to the payment listed in paragraph 27 above to Johnston, Johnston benefitted from the payments by virtue of his status as initial transferee. With respect to the payment listed in paragraph 27 above made to the PMC Dissident Shareholder Committee, each member of the PMC Dissident Shareholder Committee benefitted from the payments by virtue of the PMC Dissident Shareholder Committee's status as initial transferee. With respect to the payments listed in paragraph 27 above made to Robins Kaplan and to Regan, Johnston and each of the other members of the PMC Dissident Shareholder Committee benefitted from such payments because Johnston and each member of the PMC Dissident Shareholder Committee were each liable for the underlying debts to Robins Kaplan and Regan satisfied by such transfers.

40. Based on the foregoing, the Trustee may avoid each of the payments listed in paragraph 27 above under Section 547(b) of the Code.

41. Pursuant to Section 550(a) of the Code, the Trustee may recover the total amount of the payments listed in paragraph 27 above, plus interest from the dates such payments were made, from Johnston and each of the other members of the PMC Dissident Shareholder Committee.

WHEREFORE, the Trustee requests relief against Johnston, Feiner, Moon and Thomas as more fully set forth below.

COUNT II
(Avoidable Preferential Transfers -- Robins Kaplan)

42. The Trustee restates, realleges and reavers the contents of paragraphs 1 through 41 as though restated here in full.

43. As more fully described above, on or about October 21, 1992, the Debtor made the October 21, 1992 Robins Kaplan Payment, in the amount of $157,042.48, to Robins Kaplan.

44. As more fully described above, the Debtor derived no benefit from the October 21, 1992 Robins Kaplan Payment. Rather, the October 21, 1992 Robins Kaplan Payment constituted payment for legal services rendered prior to the time when Robins Kaplan was retained by the Debtor, and for which Johnston and each member of the PMC Dissident Shareholder Committee were personally liable.

45. The October 21, 1992 Robins Kaplan Payment was made on account of an antecedent debt owed by Johnston and each member of the PMC Dissident Shareholder Committee to Robins Kaplan before each payment was made.

46. The October 21, 1992 Robins Kaplan Payment enabled Robins Kaplan to receive more than it would have received if:

A. the case were a case under Chapter 7;

B. the transfer had not been made; and

C. Robins Kaplan received payment of such debt to the extent provided by the Code.

47. At all relevant times hereto, Robins Kaplan was an insider creditor of the Debtor. Robins Kaplan was an insider both because it served as general counsel to the corporation from June 30, 1992 through and including the Petition Date, and because Montague -- the partner at Robins Kaplan in charge of billing the Debtor's account -- served as secretary of the Debtor at all relevant times hereto. In addition, the October 21, 1992 Robins Kaplan Payment benefitted other insiders of the Debtor.

48. Based on the foregoing, the Trustee may avoid the October 21, 1992 Robins Kaplan Payment under Section 547(b) of the Code.

49. Pursuant to Section 550(a) of the Code, the Trustee may recover the total amount of the October 21, 1992 Robins Kaplan Payment, plus interest from the dates such payments were made, from Robins Kaplan because Robins Kaplan is the initial transferee of such payments.

WHEREFORE, the Trustee requests relief against Robins Kaplan as more fully set forth below.

COUNT III
(Avoidable Preferential Transfers -- J&C Resources)

50. The Trustee restates, realleges, and reavers the contents of paragraphs 1 through 49 as though restated here in full.

51. The Debtor's October 21, 1992 Robins Kaplan Payment, in the amount of $157,042.48, was made during the one-year period preceding the Petition Date.

52. As set forth more fully above, the Debtor derived no benefit from the October 21, 1992 Robins Kaplan Payment.

53. The Defendant, J&C Resources, was contingently liable for the cost of legal services performed by Robins Kaplan in connection with the Proxy Fight. Upon information and belief, J&C Resources guaranteed the PMC Dissident Shareholder Committee's obligations to Robins Kaplan in connection with such legal services. In the October 21, 1992 Ogden Letter, Ogden informed Montague that ". . . based on my conversation with [Johnston] this week, it is my understanding that J&C Resources has guaranteed the 'proxy' portion of the invoice but not the 'related litigation' portion of the bill."

54. Notwithstanding the assertion of the Ogden Letter, the course of dealing among the Debtor, Robins Kaplan and J&C Resources shows that Robins Kaplan customarily looked to J&C

Resources for payment of all of Robins Kaplan's legal bills, whether the underlying legal services pertained to the Proxy Fight or not. By way of example only, on or about September 8, 1992, Robins Kaplan sent a statement of account (the "September 8, 1992 Bill") directly to J&C Resources, at the latter's Nashua, New Hampshire address, seeking payment in the amount of $175,203.62 for legal services rendered through August 31, 1992. The September 8, 1992 Bill covered Robins Kaplan invoice numbers 162244, 163392, 165336 and 165728. According to Robins Kaplan's records, each of these invoices concerned legal work performed in connection with Robins Kaplan file number 030407-0000, titled "Polar Molecular -- Litigation." Thus, while the Ogden Letter asserted that J&C Resources had guaranteed payment only for charges arising from the Proxy Fight, the September 8, 1992 Bill for general litigation was also sent to J&C Resources for payment.

55. The September 8, 1992 Bill was paid by the Debtor, by check number 1173, as the October 21, 1992 Robins Kaplan Payment.

56. As a result of its apparent guaranty of all payments to Robins Kaplan, J&C Resources benefitted from the Debtor's payment of the October 21, 1992 Robins Kaplan Payment.

57. At all relevant times hereto, J&C Resources was an insider creditor of the Debtor. J&C Resources was an insider because its principal and sole stockholder was Johnston, who was also the chief executive officer, director and controlling shareholder of the Debtor.

58. The October 21, 1992 Robins Kaplan Payment was made on account of an antecedent debt owed to Robins Kaplan before the October 21, 1992 Robins Kaplan Payment was made.

59. The October 21, 1992 Robins Kaplan Payment enabled J&C Resources to receive more then it would have received if:

A. the case were a case under Chapter 7;

B. the transfer had not been made; and

C. it received payment of such debt to the extent provided by the Code.

60. Based on the foregoing, the Trustee may avoid the October 21, 1992 Robins Kaplan Payment under Section 547(b) of the Code.

61. Pursuant to Section 550(a) of the Code, the Trustee may recover the total amount of the October 21, 1992 Robins Kaplan Payment, plus interest from the dates such payments were made, from J&C Resources.

WHEREFORE, the Trustee requests relief against J&C Resource as set forth more fully below.

COUNT IV
(Avoidable Preferential Transfer -- Regan Associates)

62. The Trustee restates, realleges and reavers the contents of paragraphs 1 through 61 above as though restated here in full.

63. As set forth more fully above, the Debtor made a payment in the amount of $5,568.18 to Regan on or about September

25, 1992 (the "Regan Payment"). The Debtor derived no benefit from the Regan Payment. Rather, upon information and belief, the Regan Payment was made in consideration of services provided by Regan to Johnston and the PMC Dissident Shareholder Committee in connection with the Proxy Fight.

64. Upon information and belief, Johnston and each member of the PMC Dissident Shareholder Committee were each contingently liable for the payment of Regan's fees in connection with the Proxy Fight.

65. The Regan Payment was made on account of an antecedent debt owed by Johnston and each member of the PMC Dissident Shareholder Committee, jointly and severally, to Regan before the date of the Regan Payment.

66. The Regan Payment enabled Regan to receive more than it would have retained if:

A. the case were a case under Chapter 7;

B. the transfer had not been made; and

C. Regan received payment of such debt to the extent provided by the Code.

67. The Regan Payment benefitted Johnston and each member of the PMC Dissident Shareholder Committee who, in turn, were insiders of the Debtor at all relevant times hereto.

68. Based on the foregoing, the Trustee may avoid the Regan Payment under Section 547(b) of the Code.

69. Pursuant to Section 550(a) of the Code, the Trustee may recover the Regan Payment, plus interest from the date such

payment was made, from Regan because Regan is the initial transferee of the Regan Payment.

WHEREFORE, the Trustee requests relief against Regan as more fully set forth below.

COUNT V
(Usurpation of Corporate Opportunity -- Johnston, Taylor and NAFA)

70. The Trustee restates, realleges, and reavers the contents of paragraphs 1 through 69 as though restated here in full.

71. On or about April 5, 1993, Johnston formed NAFA. At all relevant times hereto, Johnston has been the sole shareholder and director of NAFA.

72. Upon forming NAFA, Johnston transferred at least six employees of the Debtor, including Taylor, into NAFA's employ. These employees had access to all significant proprietary information and documents of the Debtor including, but not limited to, manufacturing specifications, client lists and marketing contacts.

73. During his tenure, and in his capacity, as chief executive officer of the Debtor, Johnston became aware of lucrative marketing opportunities for the Debtor's product in, among other places, Central America and South America.

74. During the pendency of this bankruptcy case, NAFA, at Johnston's direction and for his benefit, engaged in a systematic business marketing campaign which exploited the proprietary knowledge of the Debtor, including its existing customer lists

and advantageous business relationships. NAFA carried out this campaign without any oral or written consent from the Debtor, and at no time obtained the authorization of this Court.

75. More specifically, NAFA, at Johnston's direction and for his benefit, actively entered into negotiations with representatives of the governments of Ecuador, Paraguay, and Costa Rica, among others, in an effort to divert long-standing business opportunities from the Debtor to NAFA, for the benefit of Johnston, as NAFA's sole shareholder.

76. By way of example only, NAFA, by Taylor -- the former chief technical officer of the Debtor who, at this time, occupied the same position with NAFA -- sent a letter on April 29, 1993 to an individual by the name of Dr. Franklin Chinchilla (the "Chinchilla Letter"). Upon information and belief, Dr. Chinchilla was, at all relevant times hereto, an official of an organization by the name of RECOPE which, in turn, is the national oil company operated by the government of the Central American nation of Costa Rica. RECOPE was, at all relevant times hereto, an important customer of the Debtor. NAFA's letter -- sent on NAFA's letterhead, which listed the Debtor's address -- stated that NAFA was "in the process of acquiring the patents and all of the assets of [the Debtor], in order to be the future manufacturer and marketer of [the Debtor's] products." The Chinchilla Letter also states that [NAFA] is "positioned to manufacture any of the [Debtor's] products you have evaluated," and "desires to serve and support [the Costa Rican government] as

a valued customer." In the Chinchilla Letter, NAFA further seeks to arrange a meeting among Chinchilla, Taylor, and Johnston to discuss business opportunities. A true and accurate copy of the Chinchilla Letter is attached to this Complaint as Exhibit D.

77. Also by way of example only, Taylor sent a memo on May 4, 1993 to Mike Tarafa ("Tarafa"), with carbon copies of the memo going to Johnston and Ogden, among others (the "Tarafa Memo"). Upon information and belief, Tarafa was also, at all relevant times hereto, a Costa Rican citizen who served as a liaison between the Debtor and RECOPE. The Tarafa Memo, also sent on NAFA letterhead, advised the Debtor's Costa Rican customers that NAFA "has acquired an exclusive license to make, have made, use and sell, all of [the Debtor's] products, existing product names etc." In the Tarafa Memo, too, Taylor attempts to arrange a meeting between NAFA and various Costa Rican officials to discuss the manufacture and sale of the Debtor's products. A true and accurate copy of the Tarafa Memo is attached to this Complaint as Exhibit E.

78. NAFA has never been authorized to manufacture, market, sell, or take any other actions with respect to the Debtor's products, either at the time of the Chinchilla Letter or the Tarafa Memo or otherwise. Rather, the Debtor's manufacturing processes and marketing distribution networks were, at all relevant times hereto, extremely valuable and integral property of the Debtor's estate. Thus, the communications described above between NAFA and the Costa Rican officials were

misrepresentations, the primary purpose of which was to induce the Debtor's Costa Rican customers to cease doing business with the Debtor and commence doing business with NAFA.

79. Johnston, as the sole stockholder and director of NAFA, stood to benefit personally from NAFA's usurpation of this business opportunity of the Debtor's. Johnston knew, or should have known, of the existence of NAFA's marketing overtures to the Debtor's Central American and South American customers. Furthermore, Johnston knew, or should have known, that NAFA was not authorized to make such overtures, and that such overtures were, in fact, misrepresentations and blatant violations of, among other things, the automatic stay.

80. As a result of these actions by NAFA, Johnston and Taylor, the Debtor's business has sustained substantial damages, to the detriment of the Debtor's estate and its creditors. NAFA, Johnston and Taylor are all jointly and severally liable for their joint conduct.

WHEREFORE, the Trustee requests relief against NAFA, Johnston and Taylor, jointly and severally, as set more fully set forth below.

COUNT VI
(Waste of Corporate Assets -- Johnston and NAFA)

81. The Trustee restates, realleges, and reavers the contents of paragraphs 1 through 80 as though restated here in full.

82. At all relevant times hereto, Johnston served both as chief executive officer of the Debtor and as chief executive officer of NAFA.

83. In April, 1993, the Debtor and NAFA jointly propounded a plan of reorganization in this case. This plan (the "NAFA Plan") called not for the reorganization of the Debtor, but rather for the sale of all assets of the Debtor -- including all patents, trademarks, and other intellectual property -- to NAFA.

84. The NAFA Plan was withdrawn by the Debtor and NAFA, and is no longer before this Court.

85. The purchase price contemplated by the NAFA Plan did not represent a fair-market value for all the assets of the Debtor at the time the NAFA Plan was filed. Rather, the "purchase" price contemplated by the NAFA Plan consisted of the following elements: (a) NAFA's assumption of all prepetition and postpetition loan obligations to Johnston; (b) the payment of a twenty (20%) percent distribution to all of the Debtor's creditors holding a claim valued at $500.00 or less, in the aggregate amount of approximately $4,000.00 to $5,000.00; (c) a $375,000.00 distribution to the Debtor's creditors; and (d) the issuance of 2,400 shares of convertible preferred stock, having an aggregate "call" value of $240,000.00. Assuming that Johnston's purported loans are properly recharacterized as equity infusions (see Count XII of this Complaint, below), the NAFA Plan therefore contemplates the purchase of all assets of the Debtor for approximately 380,000.00 in cash, plus shares of stock in

NAFA. Upon information and belief, this did not represent fair-market value for all assets of the Debtor.

86. Based on the foregoing, the NAFA Plan constituted a knowing and willful attempt by Johnston and NAFA to use the vehicle of a reorganization plan to transfer the assets of the Debtor to NAFA for significantly less than their market price, to the detriment of the Debtor and its creditors.

87. As a result of Johnston's and NAFA's proposal of the NAFA Plan, efforts to find a third-party purchaser of the Debtor's assets and/or to propose a good-faith reorganization plan have been significantly and unnecessarily delayed and impeded. As a result, the value of the Debtor's estate has greatly diminished, thereby materially harming the Debtor's estate and its creditors.

WHEREFORE, the Trustee requests relief against Johnston and NAFA, jointly and severally, as set forth more fully below.

COUNT VII
(Breach of Fiduciary Duty -- Johnston, Moon, Montague, Ogden)

88. The Trustee restates, realleges and reavers the contents of paragraphs 1 through 87 as though restated here in full.

89. As chief executive officer and director of the Debtor, Johnston owed a fiduciary duty of care and loyalty to the Debtor. In their capacities as vice president (Moon), secretary (Montague) and treasurer (Ogden) of the Debtor, respectively,

these officers of the Debtor each owed a fiduciary duty of care and loyalty to the Debtor.

90. Johnston and each of the other officers (collectively, the "Officers") jointly and severally breached their fiduciary duty of care and loyalty when, in their respective capacities as officers of the Debtor, they authorized the payments listed at paragraph 27 above. The Debtor derived no benefit from any of the payments listed in paragraph 27 above.

91. The Officers also jointly and severally breached their fiduciary duty of care and loyalty to the Debtor by their direct and indirect participation in the creation of NAFA, and in authorizing, permitting or encouraging NAFA to engage in unfair business practices and usurpation of corporate opportunities of the Debtor.

92. At the time this case was commenced, the Debtor owned and was insured under a $1,000,000.00 Directors and Officers Insurance and Company Reimbursement Policy (Policy No. 436-98-45), issued by National Union Fire Insurance Company of Pittsburgh, Pennsylvania (the "D&O Policy"). Under the D&O Policy, the Debtor was insured against, among other things, claims or potential claims asserted against Johnston and the Debtor's other directors and officers for "any breach of duty, neglect, error" and the like committed by them in such capacity. As is customary, however, the D&O Policy was a "claims made" policy, and failure of the Debtor to make such claims known to the insurer by the policy expiration date rendered such claims

uninsured. However, the Officers permitted the D&O Policy to lapse on February 13, 1993, and failed to purchase a so-called "discovery period" available under the D&O Policy which would have lengthened the period during which insurable claims may have been brought under the D&O Policy. Both in allowing the D&O Policy to lapse, and in his failure to purchase the customary "discovery period" under the D&O Policy, the Officers effectively wasted a valuable asset of the Debtor's estate. In so doing, the Officers jointly and severally breached their fiduciary duty of care and loyalty to the Debtor.

93. As a direct and proximate result of the joint and several breach by each of the Officers of their fiduciary duty of care and loyalty, the estate of the Debtor was significantly and materially diminished.

WHEREFORE, the Trustee requests relief against Johnston, Moon, Montague and Ogden, jointly and severally, as set forth more fully below.

COUNT VIII
(Breach of Fiduciary Duty -- Johnston, Moon, Barry, McKinley, Henry)

94. The Trustee restates, realleges and reavers the contents of paragraphs 1 through 93 as though restated here in full.

95. As directors of the Debtor, Johnston, Moon, Barry, McKinley and Henry (collectively, the "Directors") owed a fiduciary duty of care and loyalty to the Debtor.

96. Each of the Directors breached his fiduciary duty of loyalty when, in their respective capacities, the Directors authorized the payments listed in paragraph 27 above.

97. As described above, the Debtor derived no benefit from any of the payments listed in paragraph 27 above. Rather, as set forth more fully above, Johnston, each member of the PMC Dissident Shareholder Committee, and J&C Resources -- all inside of the Debtor -- benefitted, either directly or indire.:ly, from the payments listed paragraph 27 above.

98. The Directors' decisions to authorize these payments did not exhibit the arm's-length fairness required of transactions of this type, as all payments were made to or for the benefit of insiders of the Debtor, and the Debtor and its shareholders derived no benefit from the payments.

99. The Directors also breached their duty of loyalty to the Debtor when they approved the NAFA Plan plan propounded jointly by the Debtor and by NAFA. The NAFA Plan ca_ ed for all assets of the Debtor to be transferred to NAFA for m_n less than fair-market value.

100. The NAFA Plan called for the Debtor to sell its assets to NAFA. At all relevant times after April 5, 1993, Johnston, Barry and Henry were all directors of NAFA.

101. The proposed sale of the Debtor's assets to NAFA was therefore an insider transaction, requiring arm's-length fairness. The NAFA Plan, as put forth by NAFA and the Debtor, did not exhibit this arm's-length fairness, as it did not

contemplate payment of fair market value by NAFA. Therefore, the Directors breached their duty of loyalty in supporting the NAFA Plan.

102. Furthermore, the Directors breached their fiduciary duty of care and loyalty to the Debtor by their direct and indirect participation in the creation of NAFA and in authorizing, permitting or encouraging NAFA to engage in unfair business practices and usurpation of corporate opportunities of the Debtor, as set forth more fully above.

103. As a direct and proximate result of the Directors' breach of their fiduciary duty of loyalty, the Debtor's estate was significantly and materially diminished.

WHEREFORE, the Trustee requests relief against Johnston, Moon, Barry, McKinley and Henry, jointly and severally, as set forth more fully below.

COUNT IX
(Fraudulent Transfers Under Bankruptcy Code Section 548(a)(2) — Johnston, the Members of the PMC Dissident Shareholder Committee, Robins Kaplan and Regan)

104. The Trustee restates, realleges and reavers the contents of paragraphs 1 through 103 as though restated here in full.

105. Each of Johnston, each member of the PMC Dissident Shareholder Committee, Robins Kaplan, and Regan (collectively, the "Transferees") received a payment from the Debtor during the one-year period preceding the Petition Date. The payments

received during this period by the Transferees are described in paragraph 27 above.

106. As set forth more fully above, the Debtor received less than a reasonably equivalent value for each of the payments listed in paragraph 27 above.

107. Each payment listed in paragraph 27 above was made at a time when the Debtor was insolvent; or, in the alternative, rendered the Debtor insolvent.

108. Each payment listed in paragraph 27 above therefore constitutes a fraudulent transfer as to the Debtor's creditors pursuant to Bankruptcy Code Sections 548(a)(2)(A) and 548(a)(2)(B)(i).

109. Pursuant to Section 550(a) of the Code, the Trustee may therefore recover each payment listed in paragraph 27 above, or the value of each such transfer, from its designated transferee, for the benefit of the estate.

WHEREFORE, the Trustee requests relief against Johnston, each member of the PMC Dissident Shareholder Committee, Robins Kaplan and Regan Associates, as more fully set forth below.

COUNT X
(Fraudulent Conveyances Under M.G.L. c. 109A -- Johnston, the Members of the PMC Dissident Shareholder Committee, Robins Kaplan and Regan)

110. The Trustee restates, realleges, and reavers the contents of paragraphs 1 through 109 as though restated here in full.

111. Each of the Transferees received a payment from the Debtor during the one-year period preceding the Petition Date. The payments received during this period by the Transferees are described in paragraph 27 above.

112. As set forth more fully above, the Debtor received less than equivalent value for each of the payments listed in paragraph 27 above.

113. Each of the payments listed in paragraph 27 above was made at a time when the Debtor was insolvent; or, in the alternative, rendered the Debtor insolvent.

114. Each payment listed in paragraph 27 above therefore constitutes a fraudulent conveyance as to the Debtor's creditors pursuant to M.G.L. c.109A, §§4 and 6.

WHEREFORE, the Trustee requests relief against each of the Transferees as set forth more fully below.

COUNT XI
(Equitable Subordination -- Johnston)

115. The Trustee restates, realleges and reavers the contents of paragraphs 1 through 114 as though restated here in full.

116. On or about April 29, 1993, Johnston filed a proof of claim against the Debtor's estate in the amount of $1,043,098.00. Johnston's claim was allegedly based on a prepetition loan in the original principal amount of $1,100,000.00 which he made to the Debtor on or before September 22, 1992 (the "Prepetition Loan").

In his proof of claim, Johnston classified his claim as a secured claim.

117. At all relevant times hereto, Johnston was an insider of the Debtor. At the time he allegedly loaned money to the Debtor, Johnston served as the Debtor's chief executive officer and was a director and controlling shareholder of the Debtor.

118. From the onset of the Proxy Fight, through the Petition Date, and continuing throughout the pendency of this Bankruptcy case, Johnston has engaged in a series of inequitable acts which, individually and collectively, have served to enhance Johnston's claim, to the detriment of other creditors of the estate.

119. During the spring of 1992, Johnston and the PMC Dissident Shareholder Committee initiated the Proxy Fight against the then-existing management of the Debtor. In connection with the Proxy Fight, Johnston and the PMC Dissident Shareholder Committee filed numerous proxy statements and related materials with the Securities Exchange Commission (the "SEC"). Those proxy materials purportedly disclosed, among other things, Johnston's and the PMC Dissident Shareholder Committee's holdings with respect to the Debtor's stock and their respective intentions in connection with the incipient Proxy Fight.

120. Upon information and belief, numerous statements made by Johnston and the PMC Dissident Shareholder Committee in their proxy materials were false and/or intentionally misleading, intended only to induce the Debtor's shareholders to vote for the

slate of directors proposed by the PMC Dissident Shareholder Committee. More specifically, those proxy materials, among other things: misrepresented the amount of Johnston's equity interest in the Debtor and the means by which he acquired such interest; misrepresented the source and amount of the funds expended and to be expended by the PMC Dissident Shareholder Committee in connection with the Proxy Fight; failed to disclose and/or misrepresented Johnston's motivation for initiating the Proxy Fight; and falsely stated that Johnston and others intended to infuse new equity into the Debtor, when in fact Johnston's intention throughout the Proxy Fight was to make one or more secured loans to the Debtor, as a means of obtaining a security interest in, and ultimately possession of, the Debtor's patents, trademarks, and other intellectual property.

121. After the PMC Dissident Shareholder Committee's successful prosecution of the Proxy Fight, Johnston, in his capacity as chief executive officer and director of the Debtor, either ordered or approved various payments to himself, the PMC Dissident Shareholder Committee, Robins Kaplan, and Regan. These payments are described in paragraph 27 of this Complaint. The Debtor derived no material benefit from any of the payments listed above, while Johnston, either directly or by virtue of his contingent liability for each underlying debt, benefitted from each of these payments. Thus, Johnston's approval of each of these payments represented an attempt by Johnston to improve his position, to the detriment of all creditors of the Debtor.

122. On September 22, 1992, while serving as chief executive officer and director of the Debtor, Johnston purported to loan approximately $1,100,000.00 to the Debtor, at a time when the Debtor was severely undercapitalized and no disinterested third party would have agreed to lend funds to the Debtor. As security for his purported loan, Johnston negotiated a security agreement, pursuant to which Johnston obtained a first-priority security interest in all of the Debtor's assets including all of the Debtor's patents, trademarks, and other intellectual property. Notwithstanding his stated intention of infusing new equity into the Debtor, as represented in his proxy materials, Johnston actually proceeded with a course of action whereby he attempted to position himself as a secured creditor of the Debtor, having a priority superior to that of all other creditors and equity interest holders of the Debtor.

123. Similarly, on or about February 12, 1993, Johnston purportedly made a postpetition, superpriority loan to the Debtor in the original amount of $155,000.00 (the "Postpetition Loan"). On or about March 4, 1993, the Debtor borrowed an additional $30,000.00 from Johnston. The Postpetition Loan, like the Prepetition Loan, was allegedly secured by a security interest in all assets of the Debtor, including its intellectual property.

124. Thereafter, on or about April 14, 1993, without Bankruptcy Court approval or authorization, Johnston caused the Debtor to "repay" $75,000.00 of the funds advanced the Debtor.

125. On or about July 29, 1993, Johnston made demand, by letter, for the immediate repayment of the balance of the Postpetition Loan. On or about August 13, 1993, Johnston filed a motion seeking an order compelling the Trustee to repay to Johnston $110,000.00, the amount allegedly outstanding on account of the Postpetition Loan. Both demands were made at a time when Johnston knew, or should have known, that there was insufficient cash in the Debtor's estate to repay the Postpetition Loan. Indeed, Johnston made demand for the express purpose of foreclosing upon his alleged first-priority interest in the Debtor's intellectual property, thereby obtaining title to the Debtor's most valuable assets -- its patents and trademarks -- for far less than their market value.

126. In addition to these attempts to secure ownership of the Debtor's assets in his personal capacity, Johnston also formed NAFA, for the express purpose of using NAFA as an alternate vehicle for obtaining ownership of the Debtor's patents and trademarks. As further described in paragraphs 54 through 63 above, NAFA was incorporated in Florida after the Petition Date and, throughout the pendency of this case, NAFA officials -- who, in almost all cases, were former employees of the Debtor -- have engaged in a concerted effort to divert the Debtor's business and customers to NAFA. Furthermore, NAFA and the Debtor (during the period when Johnston was chief executive of the Debtor) jointly propounded the NAFA Plan, pursuant to which all assets of the Debtor would be transferred to NAFA, free and clear of all liens

and encumbrances, for much less than their market value. In this way, Johnston attempted to obtain this Court's imprimatur for his scheme to transfer the assets of the Debtor, for minimal consideration, to NAFA, an entity of which he was the sole director and the only stockholder.

127. Both before and during the pendency of this bankruptcy case, Johnston has exploited his insider status, and has thereby unfairly advantaged his own claims against the estate, to the detriment of all disinterested claimholders.

128. Subordination of Johnston's claim, pursuant to Section 510(c) of the Bankruptcy Code, is consistent with the Bankruptcy Code and the policies underlying it.

129. Therefore, Johnston's claim should be equitably subordinated to those of all other creditors.

WHEREFORE, the Trustee requests relief against Johnston as set forth more fully below.

COUNT XII
(Recharacterization of Loan as Capital Investment -- Johnston)

130. The Trustee restates, realleges and reavers the contents of paragraphs 1 through 128 as though restated here in full.

131. At the time of Johnston's Prepetition Loan, no disinterested third party was willing to lend money to the Debtor on usual commercial terms. Johnston was personally aware that disinterested third-party lenders would not extend funds to the Debtor at this time, as Johnston personally and unsuccessfully

solicited at least five such potential lenders in an effort to attract investment. Indeed, in an August 31, 1992 letter to the Debtor's stockholders (the "August 31, 1992 Johnston Letter"), Johnston acknowledged that "[m]y agreement to lend personal funds came after we determined that no commercial lender contacted was willing to lend any money to [the Debtor] on any terms without my personal guaranty." A true and accurate copy of the August 31, 1992 Johnston Letter is attached to this Complaint as Exhibit F.

132. As a principal shareholder of the Debtor, Johnston had an incentive to protect his existing investment in the Debtor by making additional funding available to the Debtor, even at such times and under such conditions as a disinterested, third-party lender would have been unwilling to advance funds.

133. The Debtor was severely undercapitalized at the time of Johnston's Prepetition Loan to the Debtor. In the August 31, 1992 Johnston Letter, Johnston further stated that "[i]f [the Debtor] is to survive, and it is not by any means clear at this point whether that is possible, it will need additional funds and there can be no assurance we can find funding sources on any basis to assist [the Debtor] with its capital needs." A balance sheet attached to the August 31, 1992 Johnston Letter showed that, as of June 30, 1992, the Debtor had total assets of $409,745.00, as against total liabilities of $4,491,023.00. Furthermore, a written action of the Debtor's board of directors, adopted without a meeting on August 1, 1992, stated that it was "in the best interests of the [Debtor]" to approve the

Prepetition Loan offered by Johnston. Each of these facts evidences severe undercapitalization of the Debtor at the time of the Prepetition Loan.

134. Both because no disinterested lender would have extended credit at the time of the Prepetition Loan, and because the Debtor was severely undercapitalized at all relevant times hereto, this Court should, for equitable reasons, recharacterize Johnston's Prepetition Loan as a capital investment in the Debtor. For all purposes, Johnston's Prepetition Loan should be treated as an infusion of equity, not of debt, entitled to the same priority as that accorded to equity interests, not to secured claims.

WHEREFORE, the Trustee respectfully requests and demands judgment as follows:

1. On Count I, that this Court enter judgment in favor of the Trustee and against each of Johnston, Feiner, Moon and Thomas, jointly and severally, in the amount of $307,610.66.

2. On Count II, that this Court enter judgment in favor of the Trustee and against Robins Kaplan in the amount of $157,042.48, plus all allowable interest.

3. On Count III, that this Court enter judgment in favor of the Trustee and against J&C Resources in the amount of $157,042.48, plus all allowable interest.

4. On Count IV, that this Court enter judgment in favor of the Trustee and against Regan in the amount of $5,568.18, plus all allowable interest.

5. On Count V, that this Court enter judgment in favor of the Trustee and against each of Johnston, Taylor and NAFA, jointly and severally, in the amount of the Trustee's damages as proved.

6. On Count VI, that this Court enter judgment in favor of the Trustee and against Johnston and NAFA, jointly and severally, in the amount of the Trustee's damages as proved.

7. On Count VII, that this Court enter judgment in favor of the Trustee and against each of Johnston, Moon, Montague and Ogden, jointly and severally, in the amount of the Trustee's damages as proved.

8. On Count VIII, that this Court enter judgment in favor of the Trustee and against each of Johnston, Moon, Barry, McKinley and Henry, jointly and severally, in the amount of the Trustee's damages as proved.

9. On Count IX, that this Court set aside the payments to each of Johnston, the PMC Dissident Shareholder Committee, Robins Kaplan and Regan listed in paragraph 27 above as fraudulent transfers within the meaning of Bankruptcy Code Section 548(a)(1).

10. On Count X, that this Court set aside the payments to Johnston, the PMC Dissident Shareholder Committee, Robins Kaplan and Regan listed in paragraph 27 above as fraudulent transfers within the meaning of M.G.L. c.109A, §§4 and 6.

11. On Count XI, that this Court equitably subordinate Johnston's prepetition and postpetition claims against the Debtor's estate, pursuant to Section 510(c) of the Bankruptcy Code.

12. On Count XII, that this Court recharacterize Johnston's Prepetition Loan to the Debtor as a capital infusion, entitled to the same distribution priority as all equity interests in the Debtor.

13. That this Court grant to the Trustee such other and further relief as may be appropriate and just under all of the circumstances.

Dated: October 12, 1993

Respectfully submitted,

STEPHEN S. GRAY, AS CHAPTER 11
TRUSTEE OF THE ESTATE OF
POLAR MOLECULAR CORP.

By his attorneys,

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