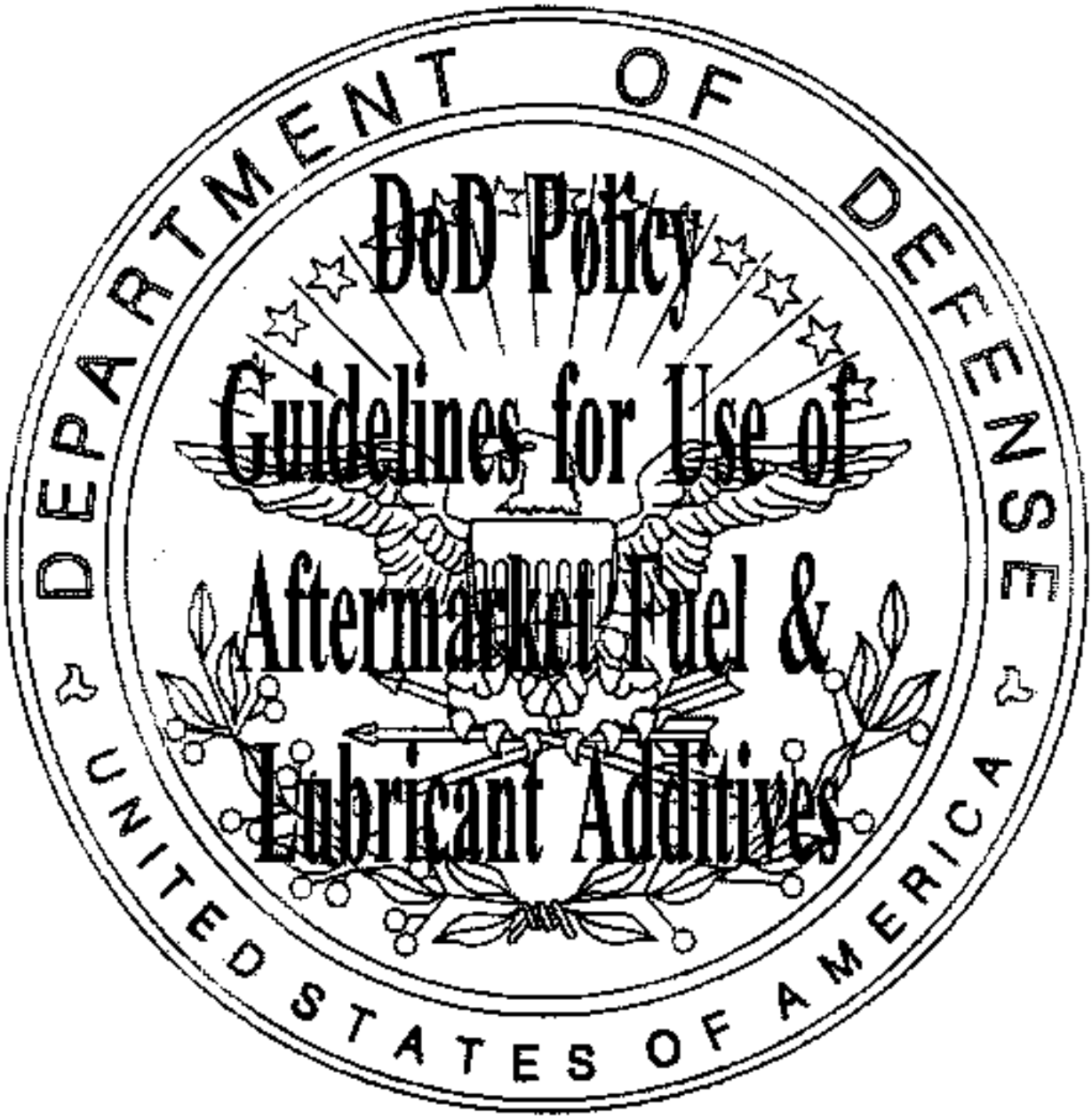

DoD Policy Guidelines for Use of Aftermarket Fuel & Lubricant Additives

JULY 1996

OFFICE OF THE UNDER SECRETARY OF DEFENSE

3000 DEFENSE PENTAGON
WASHINGTON DC 20301-3000

ACQUISITION AND TECHNOLOGY

16 MAY 1996

(L/MDM)

MEMORANDUM FOR DIRECTOR, U.S. ARMY MOBILITY TECHNOLOGY CENTER-BELVOIR

THROUGH: ASSISTANT SECRETARY OF ~~THE ARMY~~ (RESEARCH DEVELOPMENT AND ACQUISITION)

SUBJECT: DoD Policy Guide for Aftermarket Fuel and Lubricant ~~Additives~~

This is to authorize publication of the ***DoD Policy Guide for Aftermarket Fuel and Lubricant Additives*** and its distribution to all Military Components.

This policy guide provides instruction to the Components on the qualification and use of aftermarket fuel and lubricant additives within the Department of Defense. Its purpose is first to ensure that the use of aftermarket additives does not jeopardize the Defense mission, second to ensure that additives do not damage equipment, and third to ensure that manufacturers and DoD users are provided clear instruction on how aftermarket additives are qualified for use in DoD equipment.

As explained in the policy guide, qualified aftermarket additives may be used only in specifically designated equipment. However, DoD will encourage use of these additives for this authorized equipment where measurable benefits are found. Further, once independent test results confirm that use of the additive does generate measurable and tangible benefits and will not damage the DoD equipment it claims to benefit, DoD will agree to evaluate, report on the performance characteristics, and provide a mechanism for procurement of these additives.

James B. Emahiser

James B. Emahiser
Assistant Deputy Under Secretary
(Materiel and Distribution Management)

DOD POLICY FOR AFTERMARKET FUEL AND LUBRICANT ADDITIVES

I. PURPOSE

To provide Department of Defense policy, procedures and methodology for considering, accepting, and procuring fuel and lubricant additive products of a proprietary nature from sellers and distributors. Within the context of the document, fuel and lubricant "Aftermarket additives" are defined as packaged chemical ingredients not intended for use in refinery, bulk terminal, or blending plant applications. They are intended for use in facility fuel storage environments, fuel storage and distribution systems, motor pool, direct and general support maintenance centers, and depot-rebuild facilities. These additives use the following nomenclature: conditioners, treatments, improvers, supplements, aids, agents, tonics, inhibitors, modifiers, mixtures, and/or additives.

II. RATIONALE

Fuel and lubricant products procured by the Defense Logistics Agency (DLA) are managed, controlled and used by the individual military services. For example, the Army is responsible for and maintains the specifications for Fuels and Lubricants intended for ground vehicles and equipment systems, the Navy for Fuels and Lubricants intended for ship and watercraft systems, and the Air Force for Fuels and Lubricants intended for aircraft systems. Each military service maintains the lead responsibility for both bulk and packaged petroleum products used in their respective platform systems.

The policy and procedures governing the potential use of Aftermarket Fuel and Lubricant Additives intended for Ground Vehicle and Equipment Systems are given in Chapter III.

The policy prohibiting use of Aftermarket Fuel and Lubricant Additives intended for Ship and Watercraft Systems is given in Chapter IV.

The policy prohibiting use of Aftermarket Fuel and Lubricant Additives intended for Aircraft Systems is given in Chapter V.

III. POLICY FOR GROUND VEHICLE AND EQUIPMENT SYSTEM APPLICATIONS

A. GROUND FUEL AND LUBRICANT PRODUCTS.

Fuels used in ground vehicles and equipment systems consist of gasoline, diesel fuel, or aviation kerosene, depending on the engine/powerplant system. Spark-Ignition engine-powered vehicles and other gasoline-consuming equipment systems are required to use commercial gasolines described by the ASTM D4814 Standard Specification for Automotive Spark-Ignition Engine Fuel. In addition to the D4814 gasoline, these vehicles and equipment systems also use GASOHOL and other oxygenate-containing gasoline blends described by the Commercial Item Description CID A-A-52530 GASOHOL, Automotive.

Compression-Ignition engine-powered vehicles and other diesel fuel-consuming equipment systems use ASTM D975 Standard Specification for Diesel Fuel Oils. A new Commercial Item Description (CID) for the Diesel Fuel used at military installation in CONUS (CID A-A-52557 Fuel Oil Diesel, for Post, Camps and Stations) has been developed using the ASTM D975 specification. It includes additional requirements

covering particulate contamination and more restrictive cloud point limits. In addition to these diesel fuels, compression-ignition engines and other diesel fuel-consuming systems use the aviation kerosene turbine engine fuels described by MIL-T-83133 (Turbine Fuels, Aviation, Kerosene Types, NATO F-34 (JP-8) and NATO F-35), MIL-T-5624 Turbine Fuel, Aviation, Grade JP-5, or ASTM D1655 Standard Specification for Aviation Turbine Fuels (JET A or JET A1).

Fuel specifications and CIDs contain limiting requirements that ensure satisfactory performance and operability in all systems. To meet the limiting requirements, refiners are required to introduce specific additives needed to obtain the desired performance and to ensure highest quality. As a result, specifications and CIDs typically provide finished fuels that do not require additional additive treatment at the user level.

Engine oils and powertrain lubricants (e.g., transmission fluids, gear oils, etc) used in ground vehicles and equipment systems are covered by several specifications and CIDs describing lubricants based upon different performance levels and requirements. The specifications and CIDs describing required products are as follows:

- CID A-A-52039 Lubricating Oil, Automotive Engine, API Service SH
- CID A-A-52306 Lubricating Oil, Heavy-Duty Diesel Engine
- Military Specification MIL-L-2104 Lubricating Oil, Internal Combustion Engine, Combat/Tactical Service
- Military Specification MIL-L-46167 Lubricating Oil, Internal Combustion Engine, Arctic Grade
- Performance Specification MIL-PRF-2105 Lubricating Oil, Gear Multipurpose

Engine oils meeting the requirements of CID A-A-52039 are used in the commercial designed administrative fleet operating within the post-camp station arena. This service is referred to as non-tactical operations. Combat and tactical vehicles and equipment use MIL-L-2104 whereas MIL-L-46167 is for cold weather environments such as Alaska. MIL-L-2104 and MIL-L-46167 oils are designed for engine systems ranging from small two-cycle engines to large four-cycle and two-cycle engines powering the armored fleet. These oils are also designed to satisfy powershift transmission systems. CID A-A-52306 is now available for use in the engines of tactical wheeled vehicles. **It cannot be used in transmissions.**

Gear lubricants meeting the requirements of MIL-PRF-2105 are used in automotive gear units, heavy-duty industrial type inclosed gear units, steering gear units and fluid lubricated universal joints of administrative, tactical and combat ground vehicles and equipment systems.

Automotive engine and powertrain lubricants are formulated to provide satisfactory performance in a wide variety of vehicles and equipment systems that operate under extreme environmental and operational conditions. Base stocks and additive ingredients are blended to ensure the optimum responsiveness of the finished lubricants. Once these lubricants are formulated and qualified, controls are applied to the base stocks (both source and refining treatment), and additive systems. Additions of other non-blended or new ingredients to a finished formulation can reduce or impair the effectiveness of the existing additive system. For this reason, addition of new additives to finished lubricants is not generally practiced or recommended at the user level. These specifications and CIDs provide finished engine/powertrain lubricants not requiring additive treatments.

B. ACCEPTANCE AND APPROVAL PROCESS

Promoters typically are suppliers, distributors, or marketers of aftermarket additive products who seek testing, approval, or adoption of these products that would lead to the assignment of National Stock Numbers (NSN), and ultimately the use of their products in government vehicles.

Requests for considering aftermarket products often lack the technical data needed to make a determination of their potential use. The potential use of aftermarket additives must be carefully assessed to protect DOD personnel, ground vehicles and equipment.

The Acceptance and Approval Process consists of the following steps: (1) The promoter submits information on the results of standard prerequisite laboratory tests that have been conducted by independent testing laboratories, (2) the military service component (i.e., Army) reviews the completed test results, (3) a military base or installation commander forwards a recommendation for product acceptance (i.e., assuming that favorable results are obtained) to their major command who functions as a sponsor, (4) the major command, as the sponsoring organization, will recommend whether DOD should adopt the product, and (5) DOD will then request that the military service proponent (Army) conduct any additional testing needed and develop a new procurement package or modify an existing specification(s) to accommodate the new additive(s). In this process, the promoter (i.e., supplier, distributor, or marketer) is responsible for conducting the prerequisite laboratory screening tests, the military sponsor/service proponent (i.e., Army) is responsible for conducting any additional follow-on testing and for developing the procurement package.

The "screening test requirements" for aftermarket fuel and lubricant additives are performed by independent testing laboratories using standardized laboratory and engine tests. These industry developed tests objectively assess the performance of fuels and lubricants. The requirement for prerequisite screening tests is given under Army Regulation AR 70-12 Fuels and Lubricants Standardization Policy for Equipment Design, Operation, and Logistic Support, and described in Appendicies 1-4 of this document.

For acceptance, a candidate additive must meet the following specific goals:

1. The aftermarket additive package **must provide a measurable level of improvement** over that of the finished fuel or lubricant product being evaluated. This improvement must result in, but is not limited to such factors as, reduced fuel consumption, improved engine performance, reduced engine emissions, reduced wear, decreased overall engine and powertrain maintenance, and reduced corrosion.

2. The aftermarket additive **must not create any adverse side effects** when added to a finished fuel or lubricant product. These side effects are produced by incompatibility of the added ingredients with the additives used in the finished products, their potential anti-synergistic effects, non-miscibility and/or incompatibility, or any anticipated chemical reactions of these materials. Examples of adverse side effects are water emulsification, deposit formation in critical piston and engine areas, marginal fuel filtration, sludge formation, excessive wear, increased corrosion, increased emissions, or loss of additive response/effectiveness.

If the results of these "screening tests" support the claims, the sponsoring organization will conduct additional systems-oriented evaluations as needed on the candidate additive(s),and a purchase description/specification will then be developed allowing this additive to be used within the military's ground vehicle fleet. This process assures DOD monitoring and testing of potentially beneficial aftermarket fuel and lubricant products.

C. TESTING METHODOLOGY (SUPPLIER, DISTRIBUTOR, OR MARKETER RESPONSIBILITY)

A series of required screening tests addressing the above mentioned goals are outlined for each of the four (4) product application areas: gasoline/gasohol, diesel fuel, engine oils, and gear lubricants. These screening tests, developed with and using industry standard test methods, are conducted on fuel or lubricant products with and without the particular aftermarket additive being tested. This "with and without" methodology provides a direct comparison on the effect(s) of the aftermarket material.

Procedures for Aftermarket Gasoline/Gasohol Additives are given in Appendix 1, for Aftermarket Diesel Fuel Additives in Appendix 2, for Aftermarket Automotive Engine Oils in Appendix 3, and for Aftermarket Automotive Gear Lubricant Additives in Appendix 4. A "Significance of Tests Required" section is included following each set of procedures to provide the rationale for each.

D. TEST METHODOLOGY (MILITARY SERVICE PROPONENT RESPONSIBILITY)

Based upon the review and assessment of the results from procedures outlined in Appendices 1-4, the military service proponent (Army) determines the need for any additional follow-on systems testing and evaluation. The costs for conducting such testing and evaluation is the responsibility of DOD and the military sponsoring organization as allowed by the availability of funding. The extent of testing and evaluation depends upon the type of aftermarket additive (i.e., gasoline, engine oil, etc.), and if there are areas where additional data is needed for development of the procurement package.

Exceptions to these policy guidelines may be considered on a case by case basis. Request for exception with a strong justification should be made to the address given in Chapter VI.

IV. POLICY FOR SHIP AND WATERCRAFT SYSTEM APPLICATIONS

A. SHIPBOARD FUEL AND LUBRICANT PRODUCTS

Ship and watercraft systems primarily use diesel and distillate fuels described by MIL-F-16884 Fuel, Naval Distillate which meets requirements for compression-ignition engines and turbine engines that power ships and watercraft. In addition to MIL-F-16884, MIL-T-5624 Turbine Fuel, Aviation, Grade JP-5 is occasionally used.

Engine oils used in ship and watercraft systems fall under two major categories; those for compression-ignition engines and gas turbine engines. The shipboard compression-ignition engines use oils described by MIL-L-9000 Lubricating Oil, Shipboard Internal Combustion Engine, High Output Diesel. Shipboard gas turbine engines use MIL-L-23699 Lubricating Oil, Aircraft Turbine Engine, Synthetic Base, NATO Code Number 0-156. Powertrain and pump lubricants used in ships and watercraft systems are oils described by MIL-L-17331 Lubricating Oil, Steam Turbine and Gear Reduction.

Navy does not authorize use of any aftermarket fuel or lubricant additives in any compression-ignition and turbine engine, or powertrain or pump systems used aboard ships and watercraft.

B. RESTRICTIONS ON AFTERMARKET ADDITIVES

The Navy requires and uses fuels and lubricants meeting performance specifications for ship and watercraft systems. The products are blended and contain specific additives needed to meet limiting requirements within the specifications. Each supplier's product is compatible and interchangeable. Performance changes to the specifications are used to reflect any need for "additives" above those used by the refiners. Consequently, no aftermarket additives are permitted. Any additive is "qualified" only as an integral part of the fuel or lubricant specification.

V. POLICY FOR AIRCRAFT SYSTEM APPLICATIONS

A. AIRCRAFT FUEL AND LUBRICANT PRODUCTS

Fuel used in aircraft systems is either aviation gasoline or aviation kerosene depending upon the engine/powerplant system. Spark-ignition engine-powered aircraft use gasoline described by ASTM D910 Standard Specification for Aviation Gasoline. Turbine and turboshaft engine-powered aircraft use MIL-T-83133 Turbine Fuels Aviation, Kerosene Types, NATO F-34(JP-8) and NATO F-35, MIL-T-5624 Turbine Fuel, Aviation, Grade JP-5, and/or ASTM D1655 Standard Specification for Aviation Turbine Fuels (JET A or JET A1). Land-based aircraft can use any of the fuels, but carrier-based aircraft can use only MIL-T-5624(JP-5) when operating off aircraft carriers. This limitation is based upon a safety restriction and the minimum allowable flash point requirement.

Engine oils and powertrain lubricants used in aircraft systems are covered by several specifications and standards describing lubricants used in different powerplants, powertrains, their performance levels and requirements. Specifications and standards describing these product follow:

- SAE J1966 Lubricating Oil, Aircraft Piston Engine, (Non-Dispersant Mineral Oil)
- SAE J1899 Lubricating Oil, Aircraft Piston Engine, (Ashless Dispersant)
- Military Specification MIL-L-7808 Lubricating Oil, Aircraft Engine, Synthetic Base, NATO Code Number O-148
- Military Specification MIL-L-23699 Lubricating Oil, Aircraft Turbine Engine, Synthetic Base, NATO Code Number 0-156
- Military Specification MIL-L-27502 Lubricating Oil, Aircraft Turbine Engine, Ester Base
- Military Specification DOD-L-85734 Lubricating Oil, Helicopter Transmission System, Synthetic Base

As with aircraft fuels, engine oils fall into two major categories; spark-ignition engine oils and turbine or turboshaft engine oils. Spark-Ignition or reciprocating piston engines use oils described by SAE J1966 and SAE J1899. Turbine-engine powered aircraft use oils described by MIL-L-7808, MIL-L-27502, or MIL-L-23699. Turboshaft-engine powered aircraft use oils described by MIL-L-23699. Helicopter transmission systems use DOD-L-85734 products.

The Air Force does not authorize use of aftermarket fuel or lubricant additives in any spark-ignition, turboshaft, or turbine engine and transmission used to power aircraft. Use of unauthorized aftermarket additive could seriously jeopardize the air safety of military aircraft.

B. RESTRICTIONS ON AFTERMARKET ADDITIVES

The Army, Navy, and Air Force require and use fuels and lubricants meeting performance specifications for aircraft systems. The products are blended and contain specific additives needed to meet limiting requirements included within the specifications or standards. Each supplier's product is compatible and interchangeable. Performance changes to the specification or standard will reflect any need for "additives" other than those used by the refiner. No aftermarket additives are permitted in any product destined for aviation use. Any additive is "qualified" only as an integral part of the fuel or lubricant specification or standard.

VI. SUBMITTAL PROCEDURES

Upon completion of the test procedures as specified in Appendices 1-4 of Chapter III, forward the data to:

U.S. ARMY TANK-AUTOMOTIVE AND ARMAMENTS COMMAND
ATTN: AMSTA-TR-D/210 (FLTT)
WARREN, MI 48397-5000

Submit completed data as explained in Appendix 5. Direct questions about the specific requirements to the above address. The Fuels and Lubricants Technology Team (FLTT) will review and evaluate the completed data. If after review and evaluation, there is no justification supporting the claims and/or adverse side effects are indicated, the FLTT will advise the sponsoring military organization submitting the candidate aftermarket product of these findings. FLTT will recommend that no further efforts be pursued by the Department of Defense. If the submitted data does support the claims and no adverse side effects are evident, FLTT will advise the sponsoring military organization and recommend follow-on testing and evaluation. Once the additional work is completed, the development of a purchase description, CID, or a performance specification for the product will follow.

All technical data developed by the Department of Defense as a result of testing is public information and included in test reports. These reports are provided to the sponsoring military organization and distributed to technical personnel within Department of Defense and are available to other federal agencies as well as the public through National Technical Information Service (NTIS).

VII. SOURCES OF INFORMATION

Many offices within the Department of Defense provide guidance and information to assist individuals and organizations seeking to supply products to the military.

The military specifications, their associated Qualified Products Listing (QPL) and Federal Test Methods referenced in this document are available from the Defense Quality Standardization Office. Direct requests for copies of these documents from:

Defense Printing Service Detachment Office
Standardization Order Desk
700 Robbins Avenue
Building 4D (Customer Service)
Philadelphia, PA 19111-5094
Facsimile Number - (215) 697-2978

Requests must identify each standardization document or test procedure by symbol and title.

The Society of Automotive Engineers (SAE) publications referenced in this document are part of the SAE Handbook published annually. The specific SAE Information Reports revised annually, reflect new requirements, revisions, and other changes. Direct requests for copies of the SAE Handbook, or SAE Recommended Practice/Information Reports J183, J304, J312, J313, J1899, or J1966 to the following:

Society of Automotive Engineers, Inc.
400 Commonwealth Drive
Warrendale, PA 15096

The American Society for Testing and Materials (ASTM) methods and procedures referenced in this document are published annually. Direct requests for these documents to:

American Society for Testing and Materials
Publications Department
100 Barr Harbor Drive
West Conshohocken, PA 19428-2959
Telephone: (610) 832-9585
Facsimile: (610) 832-9555

The Federal Printing Office distributes the tests for fuel economy and exhaust emissions. Send requests for these documents to the following:

Federal Printing Office
Superintendent of Documents
Washington, DC 20402
Telephone: (202) 783-3230

Exhaust emissions, ask for:

Code of Federal Regulations
Title 40
Parts 81-99
Dated 1 July 1983
or
SN 022-033-95041-9

Fuel economy, ask for:

Code of Federal Regulations
Title 40
Parts 425-end
or
SN 022-033-95046-0

Direct any questions relative to this guide, its intended use, specific content, or test requirements to the following:

For Ground Fuels and Lubricants -

US ARMY TANK-AUTOMOTIVE AND ARMAMENTS COMMAND
ATTN: AMSTA-TR-D/210 (FLTT)
WARREN, MI 48397-5000
Telephone:
FACSIMILE : (810) 574-4244

For Ship and Watercraft Fuels and Lubricants -

NAVSEA
NON-METALLIC MATLS DIV/CODE 03M3
2531 JEFFERSON DAVIS HIGHWAY
ARLINGTON, VA 22242-5106
Telephone:
COMMERCIAL : (703) 602-0144, Extension 102
FACSIMILE : (703) 602-0247

For Aircraft Fuels and Lubricants -

NAVAIR
ATTN AIR 4.4.5
1421 JEFFERSON DAVIS HIGHWAY
ARLINGTON, VA 22243-5120
Telephone:
COMMERCIAL : (703) 604-3290, Extension 7856
FACSIMILE : (703) 604-3757

AIR FORCE WRIGHT LABORATORY
ATTN POSF
BUILDING 490
1790 LOOP ROAD NORTH

WRIGHT PATTERSON AFB OH 45433-7103
Telephone:
COMMERCIAL : (513) 255-2008
FACSIMILE : (513) 255-1125

SAN ANTONIO AIR LOGISTICS CTR
ATTN: SFTT
1014 BILLY MITCHELL BLVD STE 1
KELLY AFB, TX 78241-5603
Telephone:
COMMERCIAL: (210) 925-7613
FACSIMILE : (210) 925-9964

For additional information, a listing of all abbreviations used is given in Appendix 6.

VIII. REFERENCES

Use the current revision of each specification and standard cited below when consulting these references.

1. Army Regulation AR 70-12 Fuels and Lubricants Standardization Policy for Equipment Design, Operation and Logistic Support, 30 September 1992.

2. SAE Recommended Practice J183 Jun 91, Engine Oil Performance and Engine Service Classification.

3. SAE Standard J304 Jun 93, Engine Oil Tests.

4. SAE Recommended Practice J312 Jan 93, Automotive Gasolines.

5. SAE Recommended Practice J313 Mar 92, Diesel Fuels.

6. SAE Standard J1899 Jun 91, Lubricating Oil, Aircraft Piston Engine (Ashless Dispersant).

7. SAE Standard J1966 Jun 91, Lubricating Oil, Aircraft Piston Engine (Non-Dispersant Mineral Oil).

8. Standard Specification for Aviation Gasoline, ASTM D910.

9. Standard Specification for Diesel Fuel Oils, ASTM D975.

10. Standard Specification for Aviation Turbine Fuels, ASTM D1655.

11. Standard Specification for Automotive Spark-Ignition Engine Fuel, ASTM D4814.

12. Military Specification MIL-L-2104 Lubricating Oil, Internal Combustion Engine, Combat/Tactical Service.

13. Performance Specification MIL-PRF-2105 Lubricating Oil, Gear, Multipurpose.

14. Military Specification MIL-T-5624 Turbine Fuel, Aviation Grades JP-4 and JP-5.

15. Military Specification MIL-L-7808 Lubricating Oil, Aircraft Turbine Engine, Synthetic Base.

16. Military Specification MIL-L-9000 Lubricating Oil, Shipboard Internal Combustion Engine, High Output Diesel.

17. Military Specification MIL-F-16884 Fuel, Naval Distillate.

18. Military Specification MIL-L-17331 Lubricating Oil, Steam Turbine and Gear Reduction.

19. Military Specification MIL-L-23699 Lubricating Oil, Aircraft Turbine Engine, Synthetic Base, NATO Code Number 0-156.

20. Military Specification MIL-L-27502 Lubricating Oil, Aircraft Turbine Engine, Ester Base.

21. Military Specification MIL-L-46167 Lubricating Oil, Internal Combustion Engine, Arctic.
22. Military Specification MIL-T-83133 Turbine Fuel, Aviation Kerosene Type, Grade JP-8.
23. Military Specification MIL-L-85734 Lubricating Oil, Helicopter Transmission System, Synthetic Base.
24. Commercial Item Description (CID) A-A-52530, Gasohol, Automotive.
25. Commercial Item Description (CID) A-A-52557, Fuel Oil, Diesel, For Posts, Camps and Stations.
26. Commercial Item Description (CID) A-A-52039, Lubricating Oil, Automotive Engine, API Service, SH.
27. Commercial Item Description (CID) A-A-52306 Lubricating Oil, Heavy-Duty Diesel Engine.

APPENDIX 1

TEST PROCEDURES FOR GASOLINE/GASOHOL AFTERMARKET ADDITIVES

The following outlines the required tests for gasoline/gasohol "aftermarket additives". The supplier, distributor, or marketer of the additive is responsible for conducting these tests. The significance of the tests required is summarized in Attachment 1 of Appendix 1.

A. Gasoline Property Data

PURPOSE: To evaluate effects of additive on fuel specification requirements.

TEST REQUIRED: Report the following physical and chemical characteristics for a sample of gasoline and a sample of the same gasoline treated with the candidate additive. Use gasoline conforming to ASTM D 4814. In addition to the tests shown below, conduct elemental analyses for any elements present in the candidate additive.

Tests and Test Methods

TEST	ASTM METHOD NO.
Distillation	D 86, D 3710
Existent & Unwashed Gum	D 381
Sulfur	D 1266 or D 2622
Phosphorus	D 3231
Corrosiveness @ 50°C	D 130
Oxidation Stability	D 525
Hydrocarbon Types	D 1319
Carbon, Hydrogen, Oxygen, Nitrogen Analyses	------
Knock Characteristics, Research Octane Method	D 2699
Knock Characteristics, Motor Octane Method	D 2700

B. Emission and Fuel Economy Tests

PURPOSE: To validate improvements in fuel economy and any reduction in emissions, resulting from the additive being evaluated.

TEST REQUIRED: Conduct duplicate tests of reference fuel and reference fuel treated with the candidate additive in accordance with the latest amendments of the Code for Federal Regulations (CFR), Title 40 - Part 86, Subpart B (City Cycle and Emissions), and Part 600 (Highway Fuel Economy). In the event either set of duplicate tests do not produce repeatable results, conduct a third test for the fuel exhibiting non-repeatability. Conduct the test using a current model-year vehicle equipped with standard factory installed emission control systems. Lubricate the vehicle with Grade 10W/30 engine oil procured under The Commercial Item Description (CID) A-A-52039, Lubricating Oil, Automotive Engine, API Service SH, and with Grade 80W-90 gear lubricant qualified under Military Specification MIL-PRF-2105, "Lubricating Oil, Gear, Multipurpose." Conduct tests using the facility of an Environmental Protection Agency (EPA) approved laboratory. Obtain fuel economy data in conjunction with the above specified Subpart B and Part 600.

C. Sequence VE - Assessing Effects under Low-Temperature Stop-and-Go Operation

PURPOSE: To evaluate effects of the additive on overall engine performance and insure against its contribution towards engine deposits.

TEST REQUIRED: Conduct a gasoline engine test of reference fuel treated with the additive in accordance with the Sequence VE Test Method, ASTM D 5302. Use reference engine oil TMC 925-2 as the engine lubricant. Independent laboratories capable of conducting this test are Southwest Research Institute, 6220 Culebra Road, San Antonio, TX 78284, and EG&G Automotive, 5404 Bandera Road, San Antonio, TX 78238. Reference oil TMC 925-2 is available from the ASTM Test Monitor Center, ATTN: Manager of Operations, 6555 Penn Avenue, Pittsburgh, PA 15206-4489.

D. Induction System Deposition Tendencies

PURPOSE: To evaluate the induction system deposition tendencies of gasoline treated with additive.

TEST REQUIRED: Conduct duplicate tests of an unleaded gasoline conforming to ASTM D 4814 and the same gasoline treated with the candidate additive in accordance with FTMS Method 550, a copy is provided as Attachment 1 of Appendix 7. If either set of duplicate tests do not produce repeatable results, conduct a third test for the fuel exhibiting non-repeatability.

ATTACHMENT 1 OF APPENDIX 1

SIGNIFICANCE OF TESTS FOR GASOLINE/GASOHOL AFTERMARKET PRODUCTS

Test Parameter	Test Method	Significance
Copper Strip Corrosion @ 100°C	D130	Measures the conducted degree of copper corrosion due to mercaptan sulfur content.
Distillation	D 86	Determines the sample's volatility, which effects starting, vapor lock, acceleration and fuel economy.
Emission Tests	Title 40	Measures exhaust concentrations of unburned hydrocarbons, CO, and NOx.
Existent and Unwashed Gum	D 381	Measures nonvolatile oxidation products and heptane-insoluble products.
Fuel Economy Test	Title 40	Self explanatory.
Hydrocarbon Types	D 1319	Determines paraffin, cycloparaffin, olefin, and aromatic content. Indicates spark plug fouling.
Induction System	FTM 550	Measures the rate of deposit formation of the Tendencies Deposition carburetor, intake manifold, and intake valve regions.
Octane Method, Motor	D 2700	Measures antiknock quality.
Octane Method, Research	D 2699	Measures antiknock quality.
Oxidation Stability	D 525	Indicates the amount of gum formation during storage and overall stability.
Phosphorus	D 3231	Measures Phosphorus content. Phosphorus poisons catalytic converters and oxygen sensors.
Pre-ignition, Detonation/Rumble	N/A	Self-explanatory.
Sulfur	D 1266	Measures sulfur oxides formed during combustion. These oxides promote rusting, corrosion, and degrade crankcase lubricants.
Sequence VE	D5302	Determines the formation of sludge and varnish under low temperature, low speed, and "stop and go" driving. This can clog oil passages and screens, and cause valve, ring, and lifter sticking. Also, measures cam wear.

APPENDIX 2

TEST PROCEDURES FOR DIESEL FUEL ADDITIVES

The appendix outlines the required tests for diesel fuel "aftermarket additives." The supplier, distributor, or marketer of the additive is responsible for conducting these tests. The significance of the tests required is summarized in Attachment 1 of Appendix 2.

A. Diesel Fuel Property Data

PURPOSE: To evaluate effects of additive on fuel specification requirements.

TEST REQUIRED: Report the following physical and chemical characteristics for a sample of diesel fuel and sample of the same diesel fuel treated with the candidate additive. Use diesel fuel conforming to ASTM D975 or CID A-A-52557. In addition to the tests shown below, elemental analyses are required for any elements in the fuel additive.

Tests and Test Methods

Test	ASTM Method No.
Gravity, °API	D 287
Cloud Point	D 2500
Pour Point	D 97
Kinematic Viscosity @ 40°C	D 445
Distillation	D 86, D 2887
Flash Point	D 93
Carbon Residue on 10% Bottoms	D 524
Sulfur (1)	D 1552, D 129, or D 2622
Copper Strip Corrosion @ 100°C	D 130
Ash	D 482
Accelerated Stability	D 2274
Neutralization Numbers, TAN and TBN	D 974
Particulate Contamination	D 5452
Cetane Number	D 613
Carbon, Hydrogen, Oxygen, Nitrogen Analyses	-----

(1) D 1552 is the preferred method.

B. Emissions and Fuel Economy Tests

PURPOSE: To validate improvement in fuel economy and reduction in emissions resulting from additive being evaluated.

TEST REQUIRED: Conduct duplicate tests of reference fuel and reference fuel treated with the candidate additive in accordance with the latest amendments of the Code of Federal Regulations (CFR), Title 40 - Part 86, Subpart N (Gaseous Emissions and Particulates), and Subpart I (Smoke Exhaust). If either set of duplicate tests do not produce repeatable results, conduct a third test for the fuel exhibiting non-repeatability. Use a diesel engine having a maximum output rating of at least 200 horsepower. Lubricate the engine with reference oil REO 203, available from the Coordinating Research Council, 219 Center Parkway, Atlanta, GA 30346. Conduct Tests in an Environmental Protection Agency (EPA) approved laboratory. Obtain fuel economy data in conjunction with the above specified Subpart N and report it as Cycle Weighted Brake Specific Fuel Consumption. Make cycle weighting in accordance with the emissions procedure.

C. Caterpillar 1K Test - Assessing Effects Under High-Temperature, High-Output Operation for Determining Ring-Sticking and Deposit Tendencies

PURPOSE: To evaluate effects of the fuel additive on overall engine performance.

TEST REQUIRED: Conduct a diesel engine test of reference fuel treated with the candidate additive in accordance with the Caterpillar 1K Research Report RR: D2-1273. Conduct the test in a calibrated test stand. Use reference Engine Oil TMC 809 as the engine lubricant. Independent laboratories capable of conducting this test are: Southwest Research Institute, 6220 Culebra Road, San Antonio, TX 78284; EG&G Automotive, 5404 Bandera Road, San Antonio, TX 78238; and Auto Research Laboratories, Inc., 6947 West 59th Street, Chicago, IL 60638.

D. Filterability

PURPOSE: To evaluate the filterability tendencies of treated fuel.

TEST REQUIRED: Conduct filterability tests in accordance with Institute of Petroleum Standard IP-387. Conduct duplicate tests with a sample of diesel fuel conforming to ASTM D975 or CID A-A-52557 and a sample of the same diesel fuel treated with the candidate additive.

ATTACHMENT 1 OF APPENDIX 2

SIGNIFICANCE OF TESTS FOR DIESEL FUEL AFTERMARKET PRODUCTS

Test Parameter	Test Method	Significance
Accelerated Stability	D 2274	Measures the stability under accelerated oxidizing conditions.
Ash	D 482	Measures the non-combustible residue.
Carbon Residue on 10% Bottoms	D 524	Indicates relative coke and/or carbon forming tendency.
Caterpillar IK	*	Determines ring sticking and accumulation of deposits during high speed, DI turbocharged diesel engine operation.
Cetane Number	D 613	Indicates fuel quality as a function of ignition delay.
Cloud Point	D 2500	Indicates tendency of filter plugging due to wax formation.
Copper Strip Corrosion @ 100°C	D 130	Measures the relative degree of copper corrosion due to sulfur content.
Distillation	D 86	Determines the volatility which affects power output, fuel economy, viscosity, and starting.
Emission Test	Title 40	Measures exhaust concentrations of unburned hydrocarbons, CO, and NOx.
Fuel Economy Test	Title 40	Self-explanatory.
Filterability	IP 387	Determines filter plugging potential.
Kinematic Viscosity	D 445	Measures resistance to flow.
Pour Point	D 97	Determines lowest temperature the product can be pumped.
Sulfur	D 1552	Measures sulfur content.

* RR: D2-1273

APPENDIX 3

TEST PROCEDURES FOR AUTOMOTIVE ENGINE OILS

The appendix outlines the required tests for engine oil "aftermarket additives." The supplier, distributor, or marketer of the additive is responsible for conducting these tests. The significance of the tests required is summarized in Attachment 1 of Appendix 3.

A. Engine Oil Property Data

PURPOSE: To evaluate effects of the additive on chemical and physical properties.

TEST REQUIRED:Report the following physical and chemical characteristics for a sample of a Grade 10W-30, CID A-A-52039 engine oil and a sample of the lubricant treated with the candidate additive. In addition, to the tests shown below, elemental analyses are required for any elements present in the candidate additive.

Tests and Test Methods

Test	ASTM Test Method No.
Viscosity, Kinematic @ 100°C @ 40°C	D 445
Viscosity, Apparent @ -20° and -25°C	D 2602
Viscosity Index	D 2270
Pour Point	D 97
Stable Pour Point	(1)
Flash Point	D 92
Gravity, °API	D 287
Carbon Residue	D 524
Sulfated Residue	D 874
Sulfur (2)	D 129, D 1552, D 2622, D 4927, or D 4951
Phosphorus	D 1091, D 4047, D 4927, or D 4951
Evaporative Loss	D 2887

(1) Use Method 203 of FTMS 791C.
(2) D 1552 is the preferred method.

B. Pumpability

PURPOSE: To evaluate effects of the additive on low-temperature pumpability of engine oil using the Pumpability criteria.

TEST REQUIRED: Conduct low-temperature pumping tests in accordance with ASTM D 4684. Conduct duplicate tests with a sample of a Grade 10W-30, CID A-A-52039 engine oil and a sample of the same lubricant treated with the candidate additive.

C. Stability and Compatibility

PURPOSE: To evaluate stability and compatibility of the additive with military lubricants qualified under Military Specifications MIL-L-2104, MIL-L-21260, MIL-L-46167, or meeting CID A-A-52039, and CID A-A-52306.

TEST REQUIRED: Conduct a stability and compatibility test in accordance with Federal Test Method 3470. Mix the candidate additive with Grade 30, MIL-L-2104 Reference Oil and using the mixture complete the referenced test.

D. Foaming

PURPOSE: To evaluate the effects of the additive on the foaming tendencies of engine oil.

TEST REQUIRED: Conduct a test in accordance with ASTM Method D 892. Mix the candidate additive with Grade 30, MIL-L-2104 Reference Oil and using the mixture complete the referenced test.

E. Storage Stability

PURPOSE: To evaluate the storage stability of the additive and additive-oil mixtures.

TEST REQUIRED: Conduct storage stability tests in accordance with the procedure given in Attachment 2 of Appendix 7. Conduct duplicate tests using a sample of the candidate additive and a sample of additive mixed with Grade 30, MIL-L-2104 Reference Oil.

F. Engine Performance

PURPOSE: To evaluate effects of the additive on specification limiting engine performance.

TEST REQUIRED: Conduct the following tests using the reference oil blended with the candidate additive.

Engine Performance Tests

Test	Test Method	Reference Oil
Bearing Corrosion and Shear Stability	ASTM D 5119 (L-38)	TMC 701-1
Moisture-Corrosion	ASTM STP 315H (IID)	TMC 309
Oxidation and Wear	ASTM D 5533 (IIIE)	TMC 402-1
Low-Temperature Deposits and Wear	ASTM D 5302 (VE)	TMC 925-2
Ring-Sticking, Top Groove Fill, and Deposits in High-Speed, Turbocharged DI Diesel	RR: DO2:1273 (1K)	TMC 809

Conduct all tests using a calibrated test stand.

G. Transmission Performance

PURPOSE: To evaluate effects of additive on power transmissions.

TEST REQUIRED: Conduct the following tests using a Grade 10, MIL-L-2104 Reference Oil, and a mixture of a Grade 10, MIL-L-2104 Reference Oil and the candidate additive. Run the treated oil back-to-back with the neat reference oil.

Transmission Performance Tests

Test	Procedure
Antiwear Property	Allison Transmission Division C-4
Friction Retention	Allison Transmission Division C-4
Frictional Characteristics	SEQ 1220, SEQ FRRET of TO-4
Effects on Seals	Allison Transmission Division C-4

H. Fuel Economy

PURPOSE: To validate improvement in fuel economy.

TEST REQUIRED: Conduct economy tests in accordance with Standard Dynamometer Test Method for Measuring the Energy Conserving Quality of Engine Oils, Sequence VI-A developed by ASTM's Committee D2, Technical Division B on Automotive Lubricants. Perform the tests using a CID A-A-52039, Grade 10W-30 oil and the same product containing the candidate additive. Contact ASTM Headquarters to get a copy of this procedure. However, if no fuel improvement claims are made for the additive, do not conduct these tests.

The address is: ASTM Headquarters, 100 Bar Harbor Drive, West Conshohocken, PA 19428-2959; their facsimile number is (610) 832-9555

Qualified and Reference Oils. Qualified military engine oil refers to any product listed on the Qualified Product List for the specification cited. MIL-L-2104 Grade 10 and 30 Reference Oils are specified as follows:

Grade 10, 1125 ULTRALUBE ENGINE OIL SAE 10W, Qualification Number MC-3724
Grade 30, 1126 ULTRALUBE ENGINE OIL SAE 30, Qualification Number MC-3709

Order these products to Telephone (713)672-2401 or Telephone (713)633-2442. Send FAX's to (713)673-6112 or (713)672-2401. Direct all questions concerning your order and pricing to Telephone (713)672-2401.

Make arrangements for Engine Test Reference Oils TMC Oil 701-1, 309, 402-1, 809, and 925-2 with the ASTM Test Monitoring Center, 6555 Penn Avenue, Pittsburgh, PA 15206-4489.

The approved testing facility must perform the mixing of the aftermarket additive and the reference/qualified oil The aftermarket additive distributor/manufacturer must request the reference/qualified oil be shipped directly to the testing laboratory, or request the testing laboratory purchase the reference/qualified oils on the behalf of the aftermarket additive distributor/manufacturer.

ATTACHMENT 1 OF APPENDIX 3

SIGNIFICANCE OF TESTS FOR AUTOMOTIVE ENGINE OIL AFTERMARKET PRODUCTS

Test Parameter	Test Method	Significance
C-4	Allison Transmission Division	Measures effects of high pressure operation on scuffing, scoring, and chatter wear.
C-4 Effect on Seals	Allison Transmission Division	Measures effects of high temperature on polyacrylate, nitrile and silicone rubber seals.
C-4 Friction Retention	Allison Transmission Division	Measures clutch plate friction retention.
Carbon Residue	D 524	Indicates relative coke-forming propensity.
Flash Point	D 92	Indicates presence of volatile components necessary for fire precautions.
Foaming	D 892	Indicates tendency of sample to entrap air which may lead to cavitation bearing failure.
Fuel Economy	Title 40	Self-explanatory.
Gravity, °API	D 287	Measures Density.
CRC L-38	D 5119	Determines oxidation resistance, corrosive tendencies, sludge formation, varnish formation, and viscosity change.
Phosphorus	D 1091	Indicates additive content.
Pour Point	D 97	Indicates Low temperature flow point.
Pumpability	D 4624	Indicates lowest temperature an oil can be adequately pumped.
Stable Pour Point	FTM 203	Determines the temperature at which the sample turns solid after cyclic temperature operations.

Test Parameter	Test Method	Significance
Stability and Compatibility	FTM 3470	Assesses sample's homogeneity and miscibility with other oils.
Storage Stability	Attachment 2of Appendix 3	Self-explanatory.
Sulfated Ash	D 874	Indicates the concentration of known metal-containing additives.
Sulfur	D 1552	Indicates level of sulfur concentration which can induce corrosion.
TO-2	Caterpillar Tractor Company	Measures the friction retention of oils used in oil cooled clutches containing bronze friction materials.
Viscosity, Apparent	D 2602	Measures a sample's viscosity relative to engine cold cranking performance.
Viscosity Index	D 2270	Indicates the rate of change in viscosity as the temperature varies.
Viscosity, Kinematic	D 445	Measures the sample's resistance to flow and is a primary parameter in engine oil classification.
Sequence IID	STP 315	Indicates rusting and corrosion characteristics of engine oils under low-temperature, and "short trip" operating conditions.
Sequence IIIE	D 5533	Indicates sample's resistance to thermal and chemical oxidations thickening, deposit formation, andwear under high-temperature operating conditions.
Sequence VE	D 5302	Determines the tendency of sludge and varnish formation under low-temperature, low speed, and "stop and go" driving. This can clog oil passages and screens and cause valve, ring, and lifter sticking. Also measures cam wear.

APPENDIX 4

TEST PROCEDURES FOR AUTOMOTIVE GEAR LUBRICANTS

The appendix outlines the required tests for automotive gear lubricant "aftermarket additives." The supplier, distributor, or marketer of the additive is responsible for conducting these tests. The significance of the tests required is summarized in part under Attachment 1 of Appendix 3.

A. Gear Lubricant Property Data

PURPOSE: To evaluate effects of the additive on chemical and physical properties.

TEST REQUIRED: Report the following physical and chemical characteristics for a sample of a qualified, Grade 80W-90, MIL-PRF-2105 gear lubricant and a sample of the lubricant treated with the candidate additive. In addition to the tests shown below, elemental analyses are required for any elements present in the candidate additive.

Tests and Test Methods

Test	Test Method
Viscosity, Kinematic	
@ 100°C	ASTM D 445
@ 40°C	ASTM D 445
Viscosity, Apparent	
@ 26°C	ASTM D 2983
Channel Point	FTM 3456
Pour Point	ASTM D 97
Flash Point	ASTM D 92
Gravity, °API	
Pentane Insolubles	ASTM D 893
Sulfated Ash	ASTM D 874
Sulfur	ASTM D 1552, D 2622, D 129, D 4294,D 4927, D 4951
Phosphorus	ASTM D 1091, D 4047, D 4927, D 4951
Nitrogen	ASTM D 3228, D 4629(Modified)
Boron	ASTM D 811
Zinc	ASTM D 811, D 4628, D 4927, D 4951
Potassium	ASTM D 811
Chlorine	ASTM D 808, D 1317

B. Stability and Compatibility

PURPOSE: To evaluate stability and compatibility of the candidate additive with lubricants qualified under Performance Specification MIL-PRF-2105.

TEST REQUIRED: Conduct a stability test in accordance with Federal Test Method 3440, and a compatibility test in accordance with Federal Test Method 3430. Mix the additive with a qualified Grade 80W-90, MIL-PRF-2105 lubricant and use mixture in the referenced tests.

C. Foaming

PURPOSE: To evaluate the effects of the additive on the foaming tendencies of gear lubricant.

TEST REQUIRED: Conduct test in accordance with ASTM Method D 892. Mix the additive with a qualified Grade 80W-90, MIL-PRF-2105 lubricant and the qualified product and use the mixture in the referenced test.

D. Copper Corrosion

PURPOSE: To evaluate the effects of the additive on copper and copper alloy materials.

TEST REQUIRED: Conduct tests in accordance with ASTM D 130 for 3-hours at 121 ± 1°C. Mix the additive with a qualified Grade 80W-90, MIL-PRF-2105 lubricant and the qualified product and use mixture in the referenced test.

E. Gear Performance

PURPOSE: To evaluate the effects of the additive on specification limiting gear performance.

TEST REQUIRED: Conduct the following tests using a mixture of additive and reference lubricant.

Gear Performance Tests

Test Method(1)	Test	Reference Oil
Thermal Oxidation and Stability	L-60-1	TMC 131-3 & TMC 143
Moisture Corrosion	L-33	TMC 122-1 & TMC 125-1
Gear Scoring	L-42	TMC 108-4 & TMC 110-3
Gear-Distress and Deposits	L-37(2)	TMC 105-2 & TMC 103-2

(1) ASTM STP 512A
(2) L-37 with coated and uncoated gears

F. Fuel Economy

PURPOSE: To validate improvement in fuel economy.

TEST REQUIRED: Conduct tests in accordance with ASTM "Test Method for Evaluating Energy Conserving Gear Oils in Passenger Car and Light Truck Service." Contact ASTM Committee D.02.BO.03 Telephone No. (216)943-4200 for information concerning the method, its procedures and results.. Mix the additive with a qualified Grade 80W-90, MIL-PRF-2105 lubricant, and the qualified product and use the mixture in the referenced test.

APPENDIX 5

REPORTING REQUIREMENTS FOR TEST DATA

The appendix prescribes the procedures for submitting the completed test data review and evaluation.

A. Laboratory Reports

Individuals/organizations must supply two (2) copies of the final test report for each of the laboratory tests. For those engine tests and transmission fluid tests, two (2) additional copies are required. Supply all operational data, ratings, measurements, photographs, etc. in the format described in each of the test procedures. Include specified photographs in only one of the two copies.

B. Test Parts From Laboratory Tests

The following test parts shall be presented:

Test	Representative Parts*
L-38	o Piston o Two bearing halves
IID	o Two representative lifter bodies, plungers and push rods o Oil pump relief valve o All lifter balls
IIIE	o Pistons representative of the average and worst piston skirt varnish o Pistons representative of the average and worst oil ring land deposits
VE	o Four pistons o Oil pump relief valve o Worst and best followers o Worst and best cam lobe (or preferably whole camshaft)
IK	o Piston o Piston rings

*NOTE: Present any parts which show any abnormal wear or appearance.

APPENDIX 6

LISTING OF ABBREVIATIONS USED

ACS	American Chemical Society
API	American Petroleum Institute
AR	Army Regulation
ASTM	American Society For Testing and Materials
CID	Commercial Item Description
CONUS	Continental United States
CRC	Coordinating Research Council
DI	Direct Injection
DOD	Department of Defense
DSN	Defense Switch Network
FED STD	Federal Standard
FTM	Federal Test Method
FTMS	Federal Test Method Standard
FTP	Federal Test Procedure
IP	Institute of Petroleum
MIL	Military Specification
ML	Milliliter
N/A	Not Applicable
NAVAIR	Naval Air Systems Command
NAVSEA	Naval Sea Systems Command
NTIS	National Technical Information Service
QPL	Qualified Products Listing
PTFE	Polytetrafluoroethylene
REO	Reference Engine Oil
SAE	Society of Automotive Engineers
STP	Special Technical Publication
TAN	Total Acid Number
TBN	Total Base Number
TMC	Test Monitoring Center

APPENDIX 7

SPECIAL TEST METHODS

Special tests are included in Attachments 1 and 2 to this appendix.

ATTACHMENT 1 OF APPENDIX 7

INDUCTION SYSTEM DEPOSIT (ISD) TENDENCIES OF AUTOMOTIVE GASOLINE (FEDERAL TEST METHOD STD. NO. 791C, METHOD 550)

1. SCOPE

1.1 This method is used for determining the tendencies of motor gasolines to form deposits in the induction systems region (intake manifold and intake valve regions) of spark-ignition engines.

2. SUMMARY

2.1 A gasoline sample from a reservoir is metered into a spray nozzle where it is mixed and expelled in a flat spray pattern across an open span of 75 mm onto a weighted deposit-collecting tube of aluminum heated to 190°C. The weight gain of the deposit tube obtained from 100 mL of gasoline is the IS index and is reported in mg/100 mL.

3. APPARATUS

3.1 Induction System Deposit Apparatus (fig. 1) is available from Southwest Research Institute, San Antonio, Texas. Detailed engineering drawings are available from Southwest Research Institute for fabrication purposes. The apparatus consists of the following components:

a. Fuel Reservoir. A polytetrafluoroethylene (Teflon) bottle with a capacity of at least 200 mL and capable of withstanding pressures up to 0.70 kg/cm^2 gage.

b. Fuel metering system, capable of metering fuel flow up to 2 ± 0.1 mL/min.

c. Air metering system, capable of metering air flow to 15 ± 0.5 liters/min at 0.84 kg/cm^2 gage.

d. Spray nozzle, using air to atomize the fuel into a flat spray and directing the fuel onto the deposit-collecting tube.

e. Nozzle cooling jacket, permitting cooling of the nozzle to prevent fuel vaporization or vapor lock to occur in the nozzle.

f. Heating rod, having an outside diameter which closely matches the inside diameter of the deposit tube and is capable of operation at a wattage sufficient to produce tube temperatures up to 232°C.

g. Temperature controls, capable of controlling the heating rod output so the depositing surface of the deposit tube can be maintained within ± 1°C, in combination with a needle thermocouple accurate ± 1°C.

3.2 Deposit sample tube, made to type 6061-T6 aluminum tubing, containing a thermocouple probe hole, and the dimensions shown in fig. 2.

3.3 Desiccator, containing a desiccant.

3.4 Oven, explosion-proof, capable of maintaining a temperature of 102°C.

3.5 Balance, with sensitivity of 0.1 mg.

3.6 Millipore Filter apparatus, catalog No. XX1004700 with a No. LCWP04700, 10- m, PTFE (Teflon) filter.

4. MATERIALS

4.1 N-hexane, ACS Reagent Grade.

4.2 Toluene, ACS Reagent Grade.

4.3 Acetone, ACS Reagent Grade.

5. SAMPLE SIZE

5.1 Approximately 150 mL of the gasoline is required for each test run.

6. PROCEDURE

6.1 Preparation of the Deposit Tube.

a. Rinse the deposit tube with n-hexane followed by toluene, then acetone. Place the clean tube in an oven maintained at 102°C for approximately one hour (Note: After cleaning the tube, do not touch it with bare hands.)

b. Remove the tube from the oven and immediately place it in a desiccator to cool for at least two hours.

c. After the two-hour cool-down period, weigh the tube to the nearest 0.1 mg and then replace it in the desiccator.

d. Reweigh the tube after 10 minutes and repeat the weighing every 10 minutes until two consecutive weighings yield identical values. Record the weights and replace the sample tube in the desiccator until it is needed.

6.2 Preparation of Apparatus. Before each test, thoroughly clean the spray nozzle, fuel-flow meter, fuel lines, and reservoir with toluene and hexane and allow the components to air-dry as follows:

a. Close the fuel reservoir air valve and adjust the air-pressure regulator to 0.84 kg/cm^2 gage.

b. Open the air flow meter until the float is centered on 30 on the flow meter scale, then close the fuel drain and spray nozzle valves.

c. Remove the fuel reservoir cap, pour approximately 30 mL of toluene into the reservoir, and replace the cap.

d. Open the fuel pressure shutoff valve and adjust the fuel pressure regulator to 28 in water.

e. After placing a suitable receptacle under the fuel drain spout, open the fuel drain valve and allow approximately 15 mL of solvent to flow out, then close the valve.

f. Open the spray nozzle valve and allow the remaining solvent to flow through the fuel flow meter and the spray nozzle.

g. Repeat steps 6a through 6f using n-hexane.

h. Following step 6g, open the fuel drain valve and permit air to flow through the entire system for at least five minutes.

i. After completing the procedure of step 6h, close the following valves: fuel drain, spray nozzle, fuel pressure, air flow meter, and cooling water.

6.3 Preparation of the Fuel Sample. Using a standard Millipore Filter setup, filter 150 mL or more of the fuel sample through the 10- m PTFE (Teflon) membrane (No. LCWP04700) without using a vacuum. (Note: The primary purpose of filtration is to remove fuel contamination larger than 10- m which can cause spray nozzle plugging.)

6.4 Evaluation of the Fuel Sample. Complete all the steps listed under 6.2 before evaluating the fuel sample.

a. Remove the fuel reservoir cap and introduce approximately 30 mL of the pre-filtered gasoline sample into the reservoir and reinstall the reservoir cap.

b. Adjust the air pressure regulator to 0.84 kg/cm^2 gage and open the air flow meter valve until the float is centered on the flow meter scale.

c. Open the fuel pressure shutoff valve and adjust the fuel pressure regulator to 28 in water.

d. Open the fuel drain valve. After 10 mL of gasoline have passed through, close the valve.

e. Open the spray nozzle valve until the fuel flow meter indicates a flow of 100. After 10 mL of the fuel have passed through, close the spray nozzle valve.

f. Reopen and close the fuel drain valve momentarily to remove any remaining air.

g. Close the fuel pressure shutoff valve and remove the fuel reservoir cap.

h. Add a sufficient quantity of the gasoline sample to the reservoir to bring the level up to the 100-mL mark on the reservoir and replace the fuel reservoir cap.

i. Open the fuel pressure shutoff valve and adjust the fuel pressure regulator to 28 in water.

j. Place the deposit tube holder in the deposit chamber.

k. Remove the tared aluminum deposit tube from the desiccator and carefully position the tube in the deposit chamber taking care not to touch the tube with bare hands.

l. After connecting the heating rod to the receptacle, insert the rod into the aluminum deposit tube until it barely contacts the tube holder on the other end.

m. Install the spray nozzle and deposit tube thermocouples in the appropriate jacks and probe holes. (Note: The deposit tube thermocouple probe hole must be facing the spray nozzle.)

n. Turn on the main power switch and adjust the temperature control so that a deposit tube temperature of 190° ± 3°C is established, then open the cooling water valve to insure that the spray nozzle temperature will not exceed 24°C.

o. After the deposit tube temperature has stabilized at 190° ± 3°C, open the spray nozzle valve until the proper flow rate of 2 mL/min is obtained. (Note: This flow rate is extremely critical since the total test duration must not exceed 50 ± 3 min for a valid test). Record as the starting time for the test the moment when the spray nozzle valve is opened.

p. Carefully maintain the air, fuel, and tube-temperature levels until the 100-mL portion of the gasoline sample has been expended. Then close the spray nozzle valve and record the time of closure as the end of the test.

q. Maintain the temperature of the deposit tube at 190° ± 3°C for an additional 10 minutes, then turn off the power switch. Allow the temperature to fall to 120°C or less.

r. After removing the deposit-tube thermocouple and heating element, replace the thermocouple in the deposit tube to permit monitoring of the tube temperature down to 38°C. Then remove the thermocouple from the deposit tube.

s. Carefully remove the deposit tube and its holder from the deposit chamber, then dip the deposit tube consecutively in two separate beakers of n-hexane for 15 seconds each.

t. Place the deposit tube in an oven maintained at 100° ±3°C for at least 15 minutes.

u. Remove the deposit tube from the oven and place it in a desiccator for at least four hours.

v. Remove the deposit tube from the desiccator and weigh it. Then replace the tube in the desiccator. Repeat the procedure until two consecutive weighings yield identical values.

7. CALCULATION OF RESULTS

7.1 Calculate the ISD Index as follows:

$$ISD_t = W_f - W_i$$

Where :

ISD_t = *Induction System Deposit at test temperature (t) in mg/100 mL*

W_f = *Final weight of the deposit tube in mg*

W_i = *Initial weight of the deposit tube in mg*

ATTACHMENT 2 OF APPENDIX 7

STORAGE STABILITY TEST

1. SAMPLE

1.1 200 mL of the oil to be tested.

2. APPARATUS

2.1 100 mL cone-shaped centrifuge tubes as specified in Method 3003.9 of FTMS 791C.

2.2 Centrifuge with a diameter of swing (tip-to-tip of whirling tubes) 15 to 17 inches and shall be capable of being controlled at a speed of 1500 25 rpm.

Note 1. If the available centrifuge does not conform dimensionally to the preferred form, the speed of rotation of the available centrifuge must be adjusted to give the same centrifugal force at the tips of the tubes as that obtained with the prescribed instrument when operated at 1500 ± 25 rpm. The speed to operate the available centrifuge shall be calculated from the formula:

$$r.p.m. = \sqrt{\frac{16}{d}}\ x\ 1500$$

where: d = the diameter of the swing (tip-to-tip whirling tubes) of the available centrifuge.

2.3 Balance capable of weighing to 1 mg.

2.4 Constant temperature bath capable of being controlled at 120° ± 1°C.

2.5 Forced circulation oven capable of being controlled at 105° ± 3°C.

2.6 Desiccator capable of holding several centrifuge tubes.

3. MATERIALS

3.1 Naphtha, in accordance with either TT-N-95, Type II or MIL-N-15178, Type B.

3.2 Cleaning solution, consisting of concentrated sulfuric acid saturated with potassium dichromate.

3.3 Distilled water.

3.4 Denatured ethyl alcohol in accordance with MIL-A-6091 (ASG), Type I, or equal.

4. PROCEDURE

4.1 Preparation of centrifuge tubes. Clean two centrifuge tubes in the following manner:

(a) Rinse tubes with naphtha.

Note 2. Caution. Naphtha is flammable. Use only in a well-ventilated area. Keep all flames away from naphtha.

(b) Clean tubes with cleaning solution.

(c) Rinse tubes with distilled water.

(d) Rinse tubes with denatured ethyl alcohol.

Note 3. Caution. Denatured ethyl alcohol is flammable. Use only in a well-ventilated area. Keep all flames away from alcohol.

4.2 Support the centrifuge tubes in an upside down position in an oven maintained at 105° ± 3°C for at least one-half hour.

4.3 Remove the tubes from the oven, place them in a desiccator, and permit them to cool to room temperature.

4.4 Number each tube and weigh it to the nearest milligram.

4.5 Place 100 mL of the sample in each centrifuge tube.

4.6 Cork the filled centrifuge tubes and place them in an upright position in a constant temperature bath maintained at 120° ± 1°C for a period of one-half hour.

4.7 Remove the tubes from the bath and permit them to cool to room temperature. Place the tubes in an upright position, still corked, in a darkened area such as a drawer or cupboard at room temperature for a period of 120 ± 1 day.

4.8 Remove the tubes from the storage area, place them in a centrifuge, and operate the centrifuge at 1500 ± 25 rpm for a period of 30 ± 1 minute. If the residue is a solid, wash it several times with naphtha, a sufficient number of times to assure that it is free of oil.

Note 4. In transferring the centrifuge tubes from the storage area to the centrifuge, care must be taken not to disturb any material which may have separated from the oil.

4.9 Remove the centrifuge tubes from the centrifuge and decant and discard the supernatant oil. Permit the centrifuge tube to drain in an upside down position at room temperature for a period of two hours.

4.10 Place the centrifuge tubes in an upright position in an oven controlled at 104° ± 1°C for approximately two hours.

4.11 Remove the centrifuge tubes from the oven and place them in a desiccator to cool to room temperature. Weigh the tubes and contents to the nearest milligram. Subtract the weight of the empty centrifuge tubes to determine the weight of the separated material.

4.12 If the residue remains a liquid, centrifuge the tubes specified in paragraph 4.8. Remove the tubes from the centrifuge and note the volume of the separated liquids to the nearest 0.05 mL.

4.13 Where the separated residue is a solid, calculate the average amount of separated residue found in the sample using the following formula:

$$Average\ amount\ of\ \ separated\ \ residue\ (grams) = \frac{a+b}{c}$$

where: A = weight of separated residue found in one centrifuge tube.
B = weight of separated residue found in second centrifuge tube.

Calculate the percent insoluble residue in the sample from the formula:

$$Percent\ insoluble\ residue = \frac{Average\ amount\ of\ \ separated\ \ residue\ (grams)}{0.9\ x\ volume\ of\ \ sample}\ x\ 100$$

where: 0.9 = assumed specific gravity of the sample

4.14 Where the separated residue remains a liquid, calculate the average volume of separated residue found in the sample using the formula:

$$Average\ volume\ of\ \ separated\ \ residue\ (mL) = \frac{a+b}{2}$$

A = volume of separated residue found in one centrifuge tube.
B = volume of separated residue found in second centrifuge tube.

Calculate the percent insoluble residue in the sample from the formula:

$$Percent\ insoluble\ residue = \frac{Average\ amount\ of\ \ separated\ \ residue\ (mL)}{Volume\ of\ \ sample}\ x\ 100$$