GENERAL MOTORS MAINTENANCE LUBRICANT STANDARD LS2 FOR INDUSTRIAL EQUIPMENT AND MACHINE TOOLS

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REVISION DATE	CHANGE AUTHOR	DESCRIPTION OF CHANGE
November 2004	Donald J. Smolenski Oil Management	Substantive changes throughout document, correction of previous typos, update of rosters, new sections, and new appendix.
January 2011	Donald. J. Smolenski	Complete update

SCOPE

Maintenance lubricants are defined, for the purposes of this document, as those that lubricate various pieces of equipment in any plant. Metalworking fluids include metal forming and metal removal fluids, and other processing lubricants that intentionally come into contact with a work piece and tool. Specifications for both maintenance lubricants and metal removal fluids are contained in this document. Metal forming lubricants and other processing oils are not included.

FOREWORD

The LS2 Standard for Lubricants for Industrial Equipment and Machine Tools is issued by General Motors to provide GM Plants with performance descriptions for lubricants. These lubricants will provide optimum equipment performance and long life without detrimental effects on worker health. This standard is intended to provide an applications-oriented guide to lubricant selection and to address many common questions relating to maintenance lubricants and metal removal fluids.

The committee charged with developing this updated 2011 edition (which supersedes and replaces the 2004 edition) is composed of representatives from corporate staffs and manufacturing operations. This group, consisting of both engineering and maintenance personnel, both salaried and hourly, provides many years of in-plant experience and expertise. Chemical managers and lubricant and fluid suppliers also provide input. The mission of this committee is to manage the standards as necessary to:

- Enhance worker health and safety.
- Improve equipment reliability and life.
- Simplify and clarify the standards.
- Improve the likelihood of using the proper lubricant in any given plant application.
- Reduce the number of unneeded lubricants in the plants.
- Provide plants with a list of lubricants approved against these standards.
- Incorporate this standard into divisional and plant practices.
- Improve the awareness of and compliance to proper lubricant maintenance practices
- Drive common – use of best practices.

This standard is not intended to inhibit, but rather to encourage the development of new technology. Consequently, any aspect of the standard that is thought to inhibit the development of new lubricant technology should be brought to the attention of the standards committee. Note that the individual lubricant standards are minimum standards. Lubricants of higher quality than those specified may certainly be used and are encouraged where cost justified.

Top priority has been given to enhancement of safety in operation and maintenance of industrial equipment in conjunction with compliance with Federal, State, Provincial and municipal regulations, including national consensus standards and qualified testing laboratories' standards.

The standards described in this booklet provide a sound basis for safe, reliable lubrication for industrial equipment in General Motors plants. They are not intended for use at non-GM operations, and General Motors accepts no responsibility for their use outside GM.

TABLE OF CONTENTS

L1 GENERAL

L1 GENERAL. The General Motors Manufacturing Standards LS2 -- Lubricants for Industrial Equipment and Machine Tools -- are the recommended standards for manufacturing plant maintenance lubricants and metal removal fluids.

L1.1 REVISIONS. Questions on or suggestions for improvements to the LS2 Standards should be sent to:

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(248) 255-7892 Fax (586) 986-1910
Attn.: Dr. Donald J. Smolenski
or E-mail: donald.j.smolenski@gm.com

L1.2 RECLAMATION. Recycling of lubricants is encouraged where it is technically feasible and economically advantageous. See section L9 of this document for more information.

L1.3 APPROVED PRODUCTS. See section L2 of this standard for information on product approvals. **THE PRODUCT, AS DELIVERED, IS EXPECTED TO PASS ALL OF THE TEST REQUIREMENTS OF THE APPLICABLE STANDARD.**

L1.4 INTRODUCTION. This standard covers specifications for lubricants to be used for machine tools and production equipment as required in the General Motors LS1 Standard for Industrial Equipment and Machine Tools. The LS1 standard specifies that each point on production equipment where lubricant is manually applied shall be identified with a permanent plate bearing the appropriate General Motors lubricant number.

L1.4.1 Lubricant Number. The LS2 lubricant number consists of five parts as described in the following example:

L The initial letter defines the specification as a maintenance lubricant or metal removal fluid.

H The second letter defines the basic function (e.g., hydraulic oil) or principle use of the lubricant.

03 Two numerical digits indicating:
For oils: the ISO grade sans the last digit (e.g., ISO 32 = L_-03).
For greases: the NLGI Grade (except for NLGI No. 00 and 000, which are not generally recommended for plant use).

1 The fourth digit is used to differentiate products of the same type and viscosity or NLGI grade formulated to have somewhat different functional characteristics.

11 The final digits indicate the last year the standard was revised.

Appendix D contains information on equivalent lubricant codes used in other specifications, such as outside North America.

The various L-codes are as follows:

- LA- Air Cylinder/Valve, Air Tool Oils
- LB- General Purpose /Press Oils
- LC- Submerged Clutch and Brake Oils
- LD- Dry Film, Chain /Conveyor Lubricants
- LE- Environmentally Acceptable Fluids
- LF- Fire-Resistant Hydraulic Fluids
- LG- Greases
- LH- Antiwear Hydraulic Oils
- LJ- Compressor/Turbine Oils
- LM- Misting Oils
- LR- Gear Oils
- LS- Spindle Oils
- LW- Way Oils
- LX- Straight Cutting and Grinding Fluids
- LY- Aqueous Cutting and Grinding Fluids

L1.4.2 Viscosity. Kinematic viscosity at 40°C is used in accordance with the ISO Viscosity Grading System shown in the following table and displayed graphically in Appendix C.

ISO Grade	Viscosity at 40°C
2	1.8 - 2.2
3	2.7 - 3.3
5	4.5 - 5.5
7	6.3 - 7.7
10	9.0 - 11.0
15	13.5 - 16.5
22	19.8 - 24.2
32	28.8 - 35.2
46	41.4 - 50.6
68	61.2 - 74.8
100	90 - 110
150	135 - 165
220	198 - 242
320	288 - 352
460	414 - 506
680	612 - 748
1000	900 - 1100

L1.4.3 Grease Consistency. Grease consistency is classified according to the NLGI Consistency Classification:

NLGI Consistency No.	ASTM Worked Penetration at 25°C
000	445 to 475
00	400 to 430
0	355 to 385
1	310 to 340
2	265 to 295
3	220 to 250
4	175 to 205
5	130 to 160
6	85 to 115

L1.4.4 Cleanliness. Cleanliness of fluids is often specified using the following ISO 4406 particle count convention. The number and size of particles in a ml of fluid are determined. The 2 μm, 5 μm and 15 μm measurements are converted to codes using the table below, and the ISO particle count is reported as the Particle Count (2μm)/Particle Count (5μm)/ Particle Count (15 μm).

Number of Particles Greater Than Size, per ml	Range Code
0 - 0.02	1
0.02 - 0.04	2
0.04 - 0.08	3
0.08 - 0.15	4
0.15 - 0.3	5
0.3 - 0.6	6
0.6 - 1.3	7
1.3 - 2.5	8
2.5 - 5	9
5 - 10	10
10 - 20	11
20 - 40	12
40 - 80	13
80 - 160	14
160 - 320	15
320 - 640	16
640 - 1300	17
1300 - 2500	18
2500 - 5000	19
5000 - 10000	20
10000 - 29000	21
29000 - 40000	22
40000 - 80000	23
80000 - 160000	24
160000 -	25

For example, an oil with 7000 particles > 2μm /ml, 500 particles >5 μm /ml and 70 particles >15 μm/ml, would be rated ISO 20/16/13.

NOTE: If the newer particle count convention (ISO 11171) is used, the three number ISO code would correspond to 4, 6 and 14 μm particles. The two conventions are virtually equivalent. The convention difference is a result of the calibration method used for each.

L2 PRODUCT APPROVALS

L2 PRODUCT APPROVALS. As indicated in the individual lubricant standards in Section L5, products must be approved before they are introduced into the plants. This process is mandatory. Product approval will require disclosure of data to support that the candidate lubricant meets all requirements of the applicable standard. The L-forms in Appendix E are worksheets that contain the information that will be needed for an **on-line product submission.** There is one set of forms for each different type of lubricant.

L2.1 To help with the on-line submission process, see the Help & Training Tab on Supplypower.

L2.2 The first step in an on-line submission is to obtain a user ID for the GMR2/LS2 system (note that this is a different system and logon ID than the GM Supplypower system where LS2 resides). To obtain an ID, please send a request to donald.j.smolenski@gm.com. Include your name, title, company and address, phone, fax and e-mail.

L2.3 Once you receive an ID and password, go to: https://gmr2.ttsvcs.com/gmr2portal/ (upper right side) and log in to GMR2. Then click on LS2 under Site Navigation on the left side. Click on submit new form and begin to fill out the form (one for each lubricant – see below for definition of a unique lubricant).

L2.4 Supplier Information defaults based on the contact information of the individual logged in to the application. Standard Type is a drop down list based on current material standards. Product Name and Product Type (e.g., hydraulic fluid) are free text fields. For base Oil Composition and Additive Information, you can add or Delete rows as necessary.

L.2.4.1 The properties section populates based on standard type selected. Test standard is a drop down list for easy selection. Additional comments allow the submitter to include pertinent information for the review. You can add and remove multiple attachments; certain attachments are required (e.g., MSDS, test reports for bolded tests, ISO Certification).

L2.5 Save/Submit/Cancel feature – You must save or submit the form prior to navigating away from the page or the data will be lost. The application will log you out after a period of inactivity, so save work before walking away.

L2.6 Status can either be:
- o Pending Submittal – form is in progress and not complete, or
- o Submitted for Review - form has been finalized and submitted for review.
- o Returned to Supplier – for missing information.
- o Approved.

L2.7 For any questions or issues, please email feedback to:
- o GMR2Support@ttsvcs.com and
- o donald.j.smolenski@gm.com.

L2.8 **These electronic forms must be filled out completely for each lubricant for which approval is sought.** Base oil(s), additive package and concentrations of each define a lubricant. Changes to the base oil, additive package or concentration of either, or change in viscosity grade constitute a different lubricant and require a separate approval.

L2.9 Actual numerical results must be given (not "pass" or < or > the test limit) for *all* tests. Tests must be run on the identical lubricant for which approval is sought, unless specifically noted in the comments section.

L2.10 Base oil read across is not generally allowed. The required supporting information as specified on the forms must be attached. Formulation codes shown in supporting information must be clearly related to the candidate product.

L2.11 An MSDS completed in accordance with Appendix F must be attached for each product. Also enclose a current copy of an ISO or QS 9000 certificate.

L2.12 **APPROVED PRODUCTS** - Upon receiving concurrence from the approval committee, the lubricant will be placed on the LS2 approved products list. This list will contain the company, product designation and LS2 specification number. Proprietary formulation or test information will not be disclosed. Note

that this approval process does not address all health issues. All products are still subject to the approval of Hazardous Materials Approval Committee in each plant. **This is a different process than LS2 approval**.

L2.12.1 GM personnel, chemical managers and suppliers that are registered GM SupplyPower users may obtain a list of products approved against the various L-standards from the LS2 website.

L.2.13 It is the supplier, plant chemical manager and plant's responsibility to verify, through periodic inspection of incoming material, that the product delivered is the same as the product qualified. Viscosity and metals content, as well as infrared spectra (compare to approved product) are suggested tests for all bulk (tote or tank car) shipments. Drums and smaller lots may be randomly sampled periodically. In addition, we recommend limited plant trials before a complete change over to any new lubricant.

L3 STATISTICAL PROCESS CONTROL (SPC)

L3 STATISTICAL PROCESS CONTROL (SPC). The use of process control is a powerful tool for monitoring process accuracy and consistency. Implementation of process control, preferably statistical process control, is required as a condition of being a lubricant supplier to General Motors' operations. Suppliers must be either ISO 9000 or QS 9000 certified, and must provide a copy of the appropriate certificate. The chairman of the LS2 committee can also assist individual GM facilities with questions pertaining to SPC.

L4 LUBRICANT COMPATIBILITY

L4.1 WITH LUBRICANTS OF SIMILAR FUNCTIONAL CHARACTERISTICS. Mixing different lubricants may sometimes create serious compatibility problems. Two lubricating materials show incompatibility when a mixture of the products shows physical properties or service performance that is markedly inferior to those of either of the two products alone. Performance or properties inferior to one of the products and superior to the other may be due to simple mixing and would not be considered as evidence of incompatibility. Consequently, it is extremely important that lubricant suppliers under consideration determine that their products are compatible with current products. Documentation by independent testing may be required. The undesirable alternative is to drain and flush the system before changing lubricants.

L4.1.1 It is understood that greases represent a special case with respect to compatibility. Greases of different types of thickeners are sometimes incompatible. The attached table provides some general guidance with respect to the compatibility among greases of various types of thickeners**. IT SHOULD BE USED AS A GUIDE ONLY. WHEN DIFFERENT GREASES ARE LIKELY TO BE MIXED, SOME INITIAL COMPATABILITY TESTS SHOULD BE PERFORMED BY THE SUPPLIER PRIOR TO THE APPLICATION.**

L4.2 WITH LUBRICANTS OF DISSIMILAR FUNCTION. Without good lubricant stability, system components will fail to perform as intended, greatly reducing service life. When different lubricants, designed specifically for different applications, are commingled, either intentionally or unintentionally, the performance of the equipment may be severely compromised. For example, when hydraulic oil is contaminated by sulfurized cutting oil, major damage to the equipment is very likely to occur. **DON'T MIX DIFFERENT TYPES OF LUBRICANTS.**

L4.3 WITH SEALS. Natural rubber seals are generally not oil resistant and should not be used in lubrication systems using petroleum-based lubricants. Synthetic rubbers vary widely in their behavior when exposed to different lubricants. In contact with a given lubricant, some seals are unaffected, but others swell, shrink, or deteriorate. These conditions result from the elastomer/lubricant incompatibility that can cause them to lose their sealing force and/or extrude into the clearance space and destroy the seal. Most seals in contact with lubricants are made from nitrile rubbers. Other materials generally suitable for lubricant systems include neoprene and fluorocarbon rubbers; silicone elastomers are generally not used in GM plants.

L4.3.1 Lubricant seal compatibility requirements are as follows:

1. The equipment supplier shall provide components equipped with the proper seals to be compatible with the lubricant(s) recommended for each application.
2. Components that may be used with more than one type of lubricant shall be equipped with seals that are compatible with all types of recommended lubricants.
3. Many LS2 lubricant specifications include elastomer compatibility requirements. A standard SRE-NBR 1 material is identified with specific test conditions and passing limits for hardness and volume change. Lubricant suppliers are encouraged to test and report the compatibility of their lubricants and fluids with other common elastomers, as well. Compatibility is defined by conducting the compatibility test specified on elastomers of interest and meeting the passing limits for hardness and volume change. Many standard common elastomers (polyacrylate, nitrile, fluoroelastomer, NBR1 and LRCCP) are available from Test Engineering, Inc. in San Antonio (www.tei-net.com).

Most manufacturers of industrial equipment present extensive tables of materials compatible with their products. For further information, refer to the latest copy of GM Hydraulic Standard HS1 for Industrial Equipment.

L4.4 WITH METALS. Corrosion prevention capabilities of a lubricant are important because moisture is typically present in lubricant systems. Since most components have ferrous metal surfaces, subject to

rusting, corrosion prevention is essential, and is normally accomplished by means of a rust inhibitor in the lubricant. Galvanized and other zinc-coated surfaces should not be used because antirust additives used in some lubricants may attack zinc, and products of lubricant oxidation can react with it to form metallic soaps. Other materials susceptible to corrosion are magnesium-based alloys and lead. Magnesium alloys usually suffer heavy corrosion when water is present. Other corrosive agents, usually acidic in nature, may also be present in lubricants due to thermal or oxidative decomposition. In most cases, corrosion increases leakage by opening up tolerances of close fitting parts.

Guidelines for Grease Compatibility

C = Generally Compatible
B = Borderline
I = Incompatible
X = Not Determined

	Aluminum Complex	Barium	Barium Complex	Calcium	Calcium 12-hydroxy	Calcium Complex	Clay (Bentone)	Lithium	Lithium 12-hydroxy	Lithium Complex	Polyurea	Sodium
Aluminum Complex		I	I	I	C	I	I	B	I	B	B	I
Barium	I		C	I	C	I	I	I	I	I	I	X
Barium Complex	I	C		I	X	I	I	I	B	I	I	I
Calcium	I	I	I		C	B	B	C	B	C	B	I
Calcium 12-hydroxy	C	C	X	C		B	C	C	C	C	I	X
Calcium Complex	I	I	I	B	B		I	B	B	C	B	I
Clay (Bentone)	I	I	I	B	C	I		I	I	I	I	I
Lithium	B	I	I	C	C	B	I		C	C	B	B
Lithium 12-hydroxy	I	I	B	B	C	B	I	C		C	I	X
Lithium Complex	B	I	I	C	C	C	I	C	C		B	B
Polyurea	B	I	I	B	I	B	I	B	I	B		I
Sodium	I	X	I	I	X	I	I	B	X	B	I	

Data compiled from various sources

This table should be used as a guide only. Compatibility testing should be performed prior to mixing different greases.

GENERAL MOTORS MAINTENANCE LUBRICANT STANDARD LS2 FOR INDUSTRIAL EQUIPMENT AND MACHINE TOOLS Document No.: GM 1721

L5 INDIVIDUAL STANDARDS LA- THROUGH LY-

REVISED: January 1, 2011

THIS DOCUMENT SUPERSEDES AND REPLACES LS2 ISSUED IN 2004

The LS2 committee decided in January 1994 not to include a standard for aerosol lubricants for three main reasons:

1. There is concern about the propellants used in aerosol oils; CFC's are unacceptable, and hydrocarbons contribute to poorer plant air quality and can result in a fire or explosion hazard.
2. This is a general purpose lubricant; the performance requirements are not sufficiently severe to justify special materials.
3. If such lubricants are really needed, they are widely commercially available; plants are probably more likely to use such commercially available products, rather than special materials. Such materials shall be used only in accordance with applicable hazardous materials procedures in each facility.

GM LUBRICANT STANDARD NO. LA-01, 02, 03-1-11
AIR CYLINDER AND VALVE OIL/AIR TOOL OIL **PAGE 1 OF 3**

1 SCOPE The fluid defined by this specification is a high-quality ISO VG 10, 22, or 32 oil. It provides excellent demulsibility, good storage stability and excellent protection against rust, deposits, oxidation and wear. It meets the requirements of SAE MS1009 for PAC and PBC oils. It is intended for use in air cylinders, valves and tools. It is also good for airline lubricators. **Note: airline oilers are to be used only where permitted.**

2 REFERENCED STANDARDS

AIAG 39	ASTM D 5185	DIN 53521	ISO 2160
ASTM D 91	ASTM D 6304	DIN 53538	ISO 2592
ASTM D 92	ASTM E 1687	EPA SW-846	ISO 2909
ASTM D 97	BS 188	GM TMC003	ISO 3016
ASTM D 130	BS 4231	GM 1000M	ISO 3104
ASTM D 189	BS 4832	GM 9035P	ISO 3448
ASTM D 287	CETOP RP81H	IP 15	ISO 4263
ASTM D 445	Cin. Mil. Proc. B	IP 19	ISO 4406
ASTM D 471	DIN 51519	IP 36	ISO 6072
ASTM D 665	DIN 51561	IP 71	ISO 6247
ASTM D 892	DIN 51562	IP 135	ISO 6614
ASTM D 943	DIN 51566	IP 146	ISO 6615
ASTM D 1401	DIN 51585	IP 154	ISO 7120
ASTM D 2070	DIN 51587	IP 226	ISO 7619
ASTM D 2270	DIN 51599	IP 278	ISO 11171
ASTM D 2422	DIN 51759	ISO 868	SAE MS 1009
ASTM D 4172	DIN 53505	ISO 1817	

3 PHYSICAL PROPERTIES

Property	Value LA-01	LA-02	LA-03	Test Method ISO	ASTM	DIN	other
ISO Viscosity Grade	10	22	32	3448	D 2422	51519	BS 4231 IP 226
Kinematic Viscosity min	9	19.8	28.8	3104	D 445	51561	IP 71
at 40°C, cSt max	11	24.2	35.2			51562	BS 188
Kinematic Visc. at 100°C	Report						
Viscosity Index, min	90			2909	D 2270		IP 226
Pour Point, °C max	-20	-15	-10	3016	D 97		IP 15
Flash Point, °C min	165	175	190	2592	D 92		IP 36

4 PERFORMANCE A sample of the exact oil under consideration (i.e., no changes to base oil or additive package are allowed) shall be evaluated in a certified laboratory using the following tests:

Property	Value	Test Method ISO	ASTM	DIN	other
Rust Preventing Characteristics	Pass no Rust	7120	D 665B	51585	IP 135
Four-Ball Wear (20 kg load) Wear Scar Diameter, mm max	Report		D 4172		
Copper Corrosion (3h at 100°C)	1b max	2160	D 130	51759	IP 154
Water Separability, 30 minutes, max	40/37/3	6614	D 1401	51599	IP 19
Oxid. Stability, hr to TAN =2,min	1000	4263	D 943	51587	
Cleanliness, as Received, max	20/16/13	4406 11171			

4 PERFORMANCE (CONT.)

Property	Value	Test Method			
		ISO	ASTM	DIN	other
Compatibility With SRE-NBR 1 **(DIN 53538)** (168h100°C)or other seals and limits as agreed upon Volume change, % Shore A hardness change	 -10 to 10 -7 to 10	1817 868 6072 7619	D 471	53521 53505	CETOP RP 81H IP 278 BS 4832
Thermal Stability Acid Number Change, max Viscosity Change, 40/100°C, % max Sludge, mg/100 ml max Cu Rod Color (Cin. Mil.), max Copper Weight Loss, mg max Steel Rod Color (Cin.Mil.) max	 0.15 5 25 5 10 1		D 2070 (except 75 ml oil 101°C, 72 h)		Cin. Mil. Proc. B
Foaming Tendency (per D 892) Sequence I, II, and III, max	50/0	6247	D 892	51566	IP 146

5 CHEMICAL PROPERTIES The product shall not contain water, acid, particulates, or other substances detrimental to the proper function and performance of the components or system for which it is intended. It shall be free from noxious odors or masking fragrances. Identification colorants are permitted provided such do not adversely affect performance. The following requirements shall also be met:

Property	Value	Test Method			
		ISO	ASTM	DIN	other
API Gravity	Report		D 287		
Precipitation Number, max	0.05		D 91		
Conradson C Residue, to be run on base oil, % max	0.05	6615	D 189		
Water, as Received, ppm max	200		D 6304[#]		
Base Stock Requirements					Virgin or Rerefined
Tot. PolyNuclear Aromatics, ppm max	100				EPA SW-846 TN 8270*
Residual Elements (As, B, Ca, Mn, Mg, Na, Fe, Ni, Si, Cu, Sn, Cd, Cr, Pb, Ba, Zn), ppm max total/ each P, ppm max	25/2 5		D 5185		
Total Chlorinated Biphenyls	Not De-tectable				SW-846 TN 8082*
Total Organic Halogens, ppm max	5				SW-846 TN 9253*
Mutagenicity Fold Increase Mutagenicity Index, max Mutag. Potency Index, max	 Report 1 Report		E 1687		Modified Ames (or skin painting)

[#] This method is subject to interferences that can sometimes cause the reporting of erroneously high results. If an analysis produces a value for water content that exceeds the maximum limit, it is recommended that the plant work with the supplier to recheck the results. Other methods, such as distillation, FTIR, etc., may be used as agreed upon by the plant and supplier.

*****or other methods as agreed upon by the LS2 committee and supplier

6 INITIAL PRODUCT APPROVAL

6.1 Initial product approval is given by the General Motors LS2 Maintenance Lubricants Standards Committee. Only products listed in the Approved Product List have been qualified by the LS2 committee as meeting the requirements of this specification. No purchases or shipments are to be made until this approval has been completed.

6.2 The supplier shall furnish data showing the composition of the candidate lubricant, with regard to both the specific base stocks (crude source and refinery, etc.) and additive treatment (concentration and generic chemical description of each component).

6.3 The supplier shall submit test results from a laboratory acceptable to the LS2 committee confirming that the product submitted for approval meets all of the stated requirements. Test limits shown are absolute; test precision was considered when setting them.

6.4 Completed copies of the GM Material Safety Data Sheet, GM TMC003 (see Appendix F) shall be submitted for new products or formulation changes; restricted chemicals to be handled per GM1000M.

7 INSPECTION AND REJECTION

7.1 All shipments under contract or purchase order manufactured to this specification shall be identical in every respect to the product approved.

7.2 No changes in the formulation (including both base oil source and additive package and concentration) or manufacturing process are allowed without prior approval of the LS2 committee. Lack of such notification constitutes grounds for rejection of any shipment and removal from the Approved Product List.

7.3 The supplier shall be ISO 9000 or QS 9000 certified and shall perform regular quality control checks at each location where the material is manufactured. Such quality control data shall be made available to the purchaser upon request.

7.4 The purchaser may check incoming shipments for specification compliance; the supplier is responsible for incoming shipments meeting this specification without dependence upon purchaser's inspection. Non-compliance to physical and chemical requirements constitutes grounds for rejection of a shipment.

7.5 If physical or chemical analyses determine that the delivered lubricant is not in compliance with the requirements, the supplier may be held liable for loss of equipment warranty.

7.6 Infrared spectra (GM 9035P) of the incoming lubricant shipments shall not deviate significantly from that of the originally approved material.

8 COMPATIBILITY

Mixtures of the product approved and the product currently used shall pass all of the above requirements. The supplier is responsible that, when this product is mixed with a product already in use, there shall be no incompatibility or loss in operating performance. This product should not cause degradation or loss of performance of commonly used seals.

9 WASTE TREATMENT

The supplier shall be responsible to make known the processing procedures of any component of the lubricant for which waste treatability is in question.

10 GENERAL INFORMATION

10.1 Each container shall be clearly identified on the top and side. The identification shall contain the GM specification number at least 2 inches (5 cm) high on 5 gallon (20 L) or larger containers and prominently displayed on smaller containers.

10.2 All products shall be bar-coded according to AIAG 39.

10.3 This product shall be used only in accordance with applicable hazardous materials procedures in each facility.

10.4 This standard is under the control of the GM LS2 Committee. It was last revised in **2011**.

1 SCOPE The fluid defined by this specification is a rust and oxidation inhibited ISO VG 46 oil for general purpose lubrication. It meets the requirements of SAE MS1001 for AN oils.

2 REFERENCED STANDARDS

AIAG 39	ASTM D 6304	DIN 53538	ISO 2160
ASTM D 91	ASTM E 1687	EPA SW-846	ISO 2592
ASTM D 92	BS 188	GM TMC003	ISO 2909
ASTM D 97	BS 4231	GM 1000M	ISO 3016
ASTM D 130	BS 4832	GM 9035P	ISO 3104
ASTM D 287	CETOP RP81H	IP 15	ISO 3448
ASTM D 445	Cin. Mil. Proc. B	IP 19	ISO 4263
ASTM D 471	DIN 51519	IP 36	ISO 4406
ASTM D 664	DIN 51558	IP 71	ISO 6072
ASTM D 665	DIN 51561	IP 135	ISO 6614
ASTM D 892	DIN 51562	IP 139	ISO 6247
ASTM D 943	DIN 51566	IP 146	ISO 6618
ASTM D 974	DIN 51585	IP 154	ISO 7120
ASTM D 1401	DIN 51587	IP 177	ISO 7619
ASTM D 2070	DIN 51599	IP 226	ISO 11171
ASTM D 2270	DIN 51759	IP 278	SAE MS 1001
ASTM D 2422	DIN 53505	ISO 868	
ASTM D 5185	DIN 53521	ISO 1817	

3 PHYSICAL PROPERTIES

Property	Value	Test Method			
		ISO	ASTM	DIN	other
ISO Viscosity Grade	46	3448	D 2422	51519	BS 4231 IP 226
Kinematic Viscosity min at 40°C, cSt max	41.4 50.6	3104	D 445	51561 51562	IP 71 BS 188
Kinematic Viscosity at 100°C	Report				
Viscosity Index, min	90	2909	D 2270		IP 226
Pour Point, °C max	-10	3016	D 97		IP 15
Flash Point, °C min	190	2592	D 92		IP 36

4 PERFORMANCE A sample of the exact oil under consideration (i.e., no changes to base oil or additive package are allowed) shall be evaluated in a certified laboratory using the following tests:

Property	Value	Test Method			
		ISO	ASTM	DIN	other
Copper Corrosion (3h at 100°C)	1b max	2160	D 130	51759	IP 154
Thermal Stability Acid Number Change, max Viscosity Change, % 40/100°C, max Sludge, mg max Cu Rod Color (Cin. Mil.), max Copper Weight Loss, mg max Steel Rod Color (Cin.Mil.) max	 0.15 5 25 5 10 1		D 2070 (except 75 ml oil 101°C, 72 h)		Cin. Mil. Proc. B
Oxidation Stability, hours to TAN =2, min	1000	4263	D 943	51587	
Rust Preventing Characteristics	Pass no Rust	7120	D 665B	51585	IP 135

4 PERFORMANCE (CONT.)

Property	Value	Test Method			
		ISO	ASTM	DIN	other
Water Separability, 30 minutes, max	40/40/0	6614	D 1401	51599	IP 19
Compatibility With SRE-NBR 1 **(DIN 53538)** (168h100°C)or other seals and limits as agreed upon Volume change, % Shore A hardness change	 -10 to 10 -7 to 10	1817 868 6072 7619	D 471	53521 53505	CETOP RP 81H IP 278 BS 4832
Foaming Tendency (per D 892) Sequence I, II, and III, max	50/0	6247	D 892	51566	IP 146
Cleanliness, as Received, max	20/18/14	4406 11171			

5 CHEMICAL PROPERTIES The product shall not contain water, acid, particulates, or other substances detrimental to the proper function and performance of the components or system for which it is intended. It shall be free from noxious odors or masking fragrances. Identification colorants are permitted provided such do not adversely affect performance. The following requirements shall also be met:

Property	Value	Test Method			
		ISO	ASTM	DIN	other
API Gravity	Report		D 287		
Precipitation Number, max	0.05		D 91		
Acid Number, to be run on base oil, max	0.25	6618	D 974 D 664	51558	IP 139 IP 177
Water, as Received, ppm max	500		D 6304[#]		
Base Stock Requirements					Virgin or Rerefined
Tot. PolyNuclear Aromatics, ppm max	100				EPA SW-846 TN 8270*
Residual Elements (As, B, Ca, Mn, Mg, Na, Fe, Ni, Si, Cu, Sn, Cd, Cr, Pb, Ba, Zn), ppm max total/ each P, ppm max	 25/2 5		D 5185		
Total Chlorinated Biphenyls	Not De-tectable				EPA SW-846 TN 8082*
Total Organic Halogens, ppm Max	5				EPA SW-846 TN 9253*
Mutagenicity Fold Increase Mutagenicity Index, max Mutag. Potency Index, max	 Report 1 Report		E 1687		Modified Ames (or skin painting)

[#] This method is subject to interferences that can sometimes cause the reporting of erroneously high results. If an analysis produces a value for water content that exceeds the maximum limit, it is recommended that the plant work with the supplier to recheck the results. Other methods, such as distillation, FTIR, etc., may be used as agreed upon by the plant and supplier.
* or other methods as agreed upon by the LS2 committee and supplier

6 INITIAL PRODUCT APPROVAL

6.1 Initial product approval is given by the General Motors LS2 Maintenance Lubricants Standards Committee. Only products listed in the Approved Product List have been qualified by the LS2 committee as meeting the requirements of this specification. No purchases or shipments are to be made until this approval has been completed.

6.2 The supplier shall furnish data showing the composition of the candidate lubricant, with regard to both the specific base stocks (crude source and refinery, etc.) and additive treatment (concentration and generic chemical description of each component).

6.3 The supplier shall submit test results from a laboratory acceptable to the LS2 committee confirming that the product submitted for approval meets all of the stated requirements. Test limits shown are absolute; test precision was considered when setting them.

6.4 Completed copies of the GM Material Safety Data Sheet, GM TMC003 (see Appendix F) shall be submitted for new products or formulation changes; restricted chemicals to be handled per GM1000M.

7 INSPECTION AND REJECTION

7.1 All shipments under contract or purchase order manufactured to this specification shall be identical in every respect to the product approved.

7.2 No changes in the formulation (including both base oil source and additive package and concentration) or manufacturing process are allowed without prior approval of the LS2 committee. Lack of such notification constitutes grounds for rejection of any shipment and removal from the Approved Product List.

7.3 The supplier shall be ISO 9000 or QS 9000 certified and shall perform regular quality control checks at each location where the material is manufactured. Such quality control data shall be made available to the purchaser upon request.

7.4 The purchaser may check incoming shipments for specification compliance; the supplier is responsible for incoming shipments meeting this specification without dependence upon purchaser's inspection. Non-compliance to physical and chemical requirements constitutes grounds for rejection of a shipment.

7.5 If physical or chemical analyses determine that the delivered lubricant is not in compliance with the requirements, the supplier may be held liable for loss of equipment warranty.

7.6 Infrared spectra (GM 9035P) of the incoming lubricant shipments shall not deviate significantly from that of the originally approved material.

8 COMPATIBILITY

Mixtures of the product approved and the product currently used shall pass all of the above requirements. The supplier is responsible that, when this product is mixed with a product already in use, there shall be no incompatibility or loss in operating performance. This product should not cause degradation or loss of performance of commonly used seals.

9 WASTE TREATMENT

The supplier shall be responsible to make known the processing procedures of any component of the lubricant for which waste treatability is in question.

10 GENERAL INFORMATION

10.1 Each container shall be clearly identified on the top and side. The identification shall contain the GM specification number at least 2 inches (5 cm) high on 5 gallon (20 L) or larger containers and prominently displayed on smaller containers.

10.2 All products shall be bar-coded according to AIAG 39.

10.3 This product shall be used only in accordance with applicable hazardous materials procedures in each facility.

10.4 This standard is under the control of the GM LS2 Committee. It was last revised in **2011**.

GM LUBRICANT STANDARD NO. LB-22-1-11
HEAVY PRESS AND MACHINE OIL - 220 cSt **PAGE 1 OF 3**

1 SCOPE The fluid defined by this specification is a rust and oxidation inhibited ISO VG 220 oil for use in presses **requiring a non-EP oil**, as well as for general purpose lubrication requiring a high-viscosity fluid. It meets the requirements of SAE MS1001 for AN oils.

2 REFERENCED STANDARDS

AIAG 39	ASTM D 4172	DIN 53505	ISO 868
ASTM D 91	ASTM D 5185	DIN 53521	ISO 1817
ASTM D 92	ASTM D 6304	EPA SW-846	ISO 2160
ASTM D 97	ASTM E 1687	GM TMC003	ISO 2592
ASTM D 130	BS 188	GM 1000M	ISO 2909
ASTM D 287	BS 4231	GM 9035P	ISO 3016
ASTM D 445	BS 4832	IP 15	ISO 3104
ASTM D 471	CETOP RP81H	IP 19	ISO 3448
ASTM D 664	Cin. Mil. Proc. B	IP 36	ISO 4406
ASTM D 665	DIN 51519	IP 71	ISO 6072
ASTM D 892	DIN 51558	IP 135	ISO 6614
ASTM D 974	DIN 51561	IP 139	ISO 6247
ASTM D 2070	DIN 51562	IP 146	ISO 6618
ASTM D 2270	DIN 51566	IP 154	ISO 7120
ASTM D 2422	DIN 51585	IP 177	ISO 7619
ASTM D 2711	DIN 51599	IP 226	ISO 11171
ASTM D 2893	DIN 51759	IP 278	SAE MS1001

3 PHYSICAL PROPERTIES

Property	Value	Test Method			
		ISO	ASTM	DIN	other
ISO Viscosity Grade*	220	3448	D 2422	51519	BS 4231 IP 226
Kinematic Viscosity min at 40°C, cSt max	198 242	3104	D 445	51561 51562	IP 71 BS 188
Kinematic Viscosity at 100°C	Report				
Viscosity Index, min	90	2909	D 2270		IP 226
Pour Point, °C max	-10	3016	D 97		IP 15
Flash Point, °C min	210	2592	D 92		IP 36

* Heavier ISO viscosity grades may be substituted where appropriate.

4 PERFORMANCE A sample of the exact oil under consideration (i.e., no changes to base oil or additive package are allowed) shall be evaluated in a certified laboratory using the following tests:

Property	Value	Test Method			
		ISO	ASTM	DIN	other
Rust Preventing Characteristics	Pass no Rust	7120	D 665B	51585	IP 135
Thermal Stability Acid Number Change, max Viscosity Change, % 40/100°C, max Sludge, mg max Cu Rod Color (Cin. Mil.), max Copper Weight Loss, mg max Steel Rod Color (Cin.Mil.) max	 0.15 5 25 5 10 1		D 2070 (except 75 ml oil 101°C, 72 h)		Cin. Mil. Proc. B
Cleanliness, as Received, max	20/18/14	4406 11171			

4 PERFORMANCE (CONT.)

Property	Value	Test Method			
		ISO	ASTM	DIN	other
Copper Corrosion (3h at 100°C)	1b max	2160	D 130	51759	IP 154
Oxidation Stability at 121°C Viscosity Incrs. at 100°C, max Photos of Glassware after test	 6% Report		D 2893		
Demulsibility Water in Oil after 5 h, % max Emul. after Centrifuge, ml max Total Free Water, ml min	 1.0 2.0 60	6614	D 2711 X2	51599	IP 19
Four-Ball Wear (20 kg load) Wear Scar Diameter, mm max	 Report		D 4172		
Compatibility With SRE-NBR 1 **(DIN 53538)** (168h100°C)or other seals and limits as agreed upon Volume change, % Shore A hardness change	 -10 to 10 -7 to 10	1817 868 6072 7619	D 471	53521 53505	CETOP RP 81H IP 278 BS 4832
Foaming Tendency (per D 892) Sequence I, II, and III, max	50/0	6247	D 892	51566	IP 146

5 CHEMICAL PROPERTIES The product shall not contain water, acid, particulates, or other substances detrimental to the proper function and performance of the components or system for which it is intended. It shall be free from noxious odors or masking fragrances. Identification colorants are permitted provided such do not adversely affect performance. The following requirements shall also be met:

Property	Value	Test Method			
		ISO	ASTM	DIN	other
API Gravity	Report		D 287		
Precipitation Number, max	0.05		D 91		
Phosphorus content, ppm max	5				
Sulfur content, %	Report				
Acid Number of base oil, max	0.25	6618	D 974 D 664	51558	IP 139 IP 177
Water, as Received, ppm max	200		D 6304[#]		
Base Stock Requirements				Virgin or Rerefined	
Tot. PolyNuclear Aromatics, ppm max	100				SW-846 TN 8270*
Residual Elements (As, B, Ca, Mn, Mg, Na, Fe, Ni, Si, Cu, Sn, Cr, Cd Pb, Ba, Zn), ppm max total/ each P, ppm max	 25/2 5		D 5185		
Total Chlorinated Biphenyls	Not De-tectable				SW-846 TN 8082*
Total Organic Halogens, ppm max	5				SW-846 TN 9253*
Mutagenicity Fold Increase Mutagenicity Index, max Mutag. Potency Index, max	 Report 1 Report		E 1687		Modified Ames (or skin painting)

[#] Method is subject to interferences that can cause reporting of erroneously high results. If an analysis produces a value for water content that exceeds the maximum limit, it is recommended that the plant work with the supplier to recheck the results. Other methods, such as distillation, FTIR, etc., may be used as agreed upon by the plant and supplier.
* or other methods as agreed upon by the LS2 committee and supplier

6 INITIAL PRODUCT APPROVAL

6.1 Initial product approval is given by the General Motors LS2 Maintenance Lubricants Standards Committee. Only products listed in the Approved Product List have been qualified by the LS2 committee as meeting the requirements of this specification. No purchases or shipments are to be made until this approval has been completed.

6.2 The supplier shall furnish data showing the composition of the candidate lubricant, with regard to both the specific base stocks (crude source and refinery, etc.) and additive treatment (concentration and generic chemical description of each component).

6.3 The supplier shall submit test results from a laboratory acceptable to the LS2 committee confirming that the product submitted for approval meets all of the stated requirements. Test limits shown are absolute; test precision was considered when setting them.

6.4 Completed copies of the GM Material Safety Data Sheet, GM TMC003 (see Appendix F) shall be submitted for new products or formulation changes; restricted chemicals to be handled per GM1000M.

7 INSPECTION AND REJECTION

7.1 All shipments under contract or purchase order manufactured to this specification shall be identical in every respect to the product approved.

7.2 No changes in the formulation (including both base oil source and additive package and concentration) or manufacturing process are allowed without prior approval of the LS2 committee. Lack of such notification constitutes grounds for rejection of any shipment and removal from the Approved Product List.

7.3 The supplier shall be ISO 9000 or QS 9000 certified and shall perform regular quality control checks at each location where the material is manufactured. Such quality control data shall be made available to the purchaser upon request.

7.4 The purchaser may check incoming shipments for specification compliance; the supplier is responsible for incoming shipments meeting this specification without dependence upon purchaser's inspection. Non-compliance to physical and chemical requirements constitutes grounds for rejection of a shipment.

7.5 If physical or chemical analyses determine that the delivered lubricant is not in compliance with the requirements, the supplier may be held liable for loss of equipment warranty.

7.6 Infrared spectra (GM 9035P) of the incoming lubricant shipments shall not deviate significantly from that of the originally approved material.

8 COMPATIBILITY

Mixtures of the product approved and the product currently used should pass all of the above requirements. The supplier is responsible that, when this product is mixed with a product already in use, there shall be no incompatibility or loss in operating performance. This product should not cause degradation or loss of performance of commonly used seals.

9 WASTE TREATMENT

The supplier shall be responsible to make known the processing procedures of any component of the lubricant for which waste treatability is in question.

10 GENERAL INFORMATION

10.1 Each container shall be clearly identified on the top and side. The identification shall contain the GM specification number at least 2 inches (5 cm) high on 5 gallon (20 L) or larger containers and prominently displayed on smaller containers.

10.2 All products shall be bar-coded according to AIAG 39.

10.3 This product shall be used only in accordance with applicable hazardous materials procedures in each facility.

10.4 This standard is under the control of the GM LS2 Committee. It was last revised in **2011**.

GM LUBRICANT STANDARD NO. LC-06-1-11
SUBMERGED CLUTCH AND BRAKE OIL - 68 cSt

1 SCOPE The fluid defined by this specification is a high-quality ISO VG 68 detergent oil containing no zinc. Avoid fluids containing graphite, molybdenum disulfide, other friction modifiers or additives that will attack bronze. This fluid is intended for use in wet clutch/brake systems. This specification will cover most, but not all wet clutch and brake systems. In the event that an equipment manufacturer recommends a type of fluid not defined by this specification, contact that manufacturer for fluid recommendations.

2 REFERENCED STANDARDS

AIAG 39	ASTM E 1687	GM TMC003	GM 9035P
ASTM D 5185	EPA SW-846	GM 1000M	

3 PHYSICAL PROPERTIES This product must meet the applicable physical properties of either Dexron or Ford Type F transmission fluid as specified by the manufacturer of the equipment for which the lubricant is intended.

4 PERFORMANCE This product must meet the applicable performance requirements of either Dexron or Ford Type F transmission fluid as specified by the manufacturer of the equipment for which the lubricant is intended.

5 CHEMICAL PROPERTIES The product must meet the applicable chemical properties of either Dexron or Ford Type F transmission fluid as specified by the manufacturer of the equipment for which the lubricant is intended. It shall be free from noxious odors or masking fragrances. Identification colorants are permitted provided such do not adversely affect performance. The following requirements shall also be met:

Property	Value	Test Method			
		ISO	ASTM	DIN	Other
Base Stock Requirements					Virgin or Rerefined
Tot. PolyNuclear Aromatics, ppm max	100				EPA SW-846 TN 8270*
Residual Elements (As, B, Ca, Mn, Mg, Na, Fe, Ni, Si, Cu, Sn, Cd, Cr, Pb, Ba, Zn), ppm max total/ each P, ppm max	 25/25		D 5185		
Total Chlorinated Biphenyls	Not De-Tectable				SW-846 TN 8082*
Total Organic Halogens, ppm max	5				SW-846 TN 9253*
Mutagenicity Fold Increase Mutagenicity Index, max Mutag. Potency Index, max	 Report 1 Report		E 1687		Modified Ames (or skin painting)

*** or other methods as agreed upon by the LS2 committee and supplier**

6 INITIAL PRODUCT APPROVAL

6.1 Initial product approval is given by the General Motors LS2 Maintenance Lubricants Standards Committee. Only sources listed in the Approved Products List have been qualified by the LS2 committee as meeting the requirements of this specification. No purchases or shipments are to be made until this approval has been completed.

6.2 The supplier shall furnish data showing the composition of the candidate lubricant, with regard to both the specific base stocks (crude source and refinery, etc.) and additive treatment (concentration and generic chemical description of each component).

6.3 The supplier shall submit test results from a laboratory acceptable to the LS2 committee confirming that the product submitted for approval meets all of the stated requirements. Test limits shown are absolute; test precision was considered when setting them.

6.4 Completed copies of the GM Material Safety Data Sheet, GM TMC003 (see Appendix F) shall be submitted for new products or formulation changes; restricted chemicals to be handled per GM1000M. These MSDS's should be made available to plants upon request.

7 INSPECTION AND REJECTION

7.1 All shipments under contract or purchase order manufactured to this specification shall be identical in every respect to the product approved.

7.2 No changes in the formulation (including both base oil source and additive package and concentration) or manufacturing process are allowed without prior approval of the LS2 committee. Lack of such notification constitutes grounds for rejection of any shipment and removal from the Approved Products List.

7.3 The supplier shall be ISO 9000 or QS 9000 certified and shall perform regular quality control checks at each location where the material is manufactured. Such quality control data shall be made available to the purchaser upon request.

7.4 The purchaser may check incoming shipments for specification compliance; the supplier is responsible for incoming shipments meeting this specification without dependence upon purchaser's inspection. Non-compliance to physical and chemical requirements constitutes grounds for rejection of a shipment.

7.5 If physical or chemical analyses determine that the delivered lubricant is not in compliance with the requirements, the supplier may be held liable for loss of equipment warranty.

7.6 Infrared spectra (GM 9035P) of the incoming lubricant shipments shall not deviate significantly from that of the originally approved material.

8 COMPATIBILITY

Mixtures of the product approved and the product currently used shall pass all of the above requirements. The supplier is responsible that, when this product is mixed with a product already in use, there shall be no incompatibility or loss in operating performance. This product should not cause degradation or loss of performance of commonly used seals.

9 WASTE TREATMENT

The supplier shall be responsible to make known the processing procedures of any component of the lubricant for which waste treatability is in question.

10 GENERAL INFORMATION

10.1 Each container shall be clearly identified on the top and side. The identification shall contain the GM specification number at least 2 inches (5 cm) high on 5 gallon (20 L) or larger containers and prominently displayed on smaller containers.

10.2 All products shall be bar-coded according to AIAG 39.

10.3 This product shall be used only in accordance with applicable hazardous materials procedures in each facility.

10.4 This standard is under the control of the GM LS2 Committee. It was last revised in **2011**.

GM LUBRICANT STANDARD NO. LD-00-1-11
DRY FILM LUBRICANT

1 SCOPE The material defined by this specification is a dispersion of a solid lubricant, such as molybdenum disulfide, in a fluid carrier that has exceptional penetrating and spreading ability. The carrier evaporates upon application, leaving behind a rust-resistant solid lubricating film. Typical applications are pre-lubrication of extremely close tolerance parts, to aid in assembly; as a "dry" lubricant, where appropriate, such as in excessively dusty or gritty environments or where lubricant leakage or dripping cannot be tolerated. **Dry films are not recommended as a replacement for either oil (see LB) or grease (see LG) or in applications where high cyclic speeds or heavy loads prevail. Caution: carrier may be flammable, use only with adequate ventilation.**

2 REFERENCED STANDARDS

AIAG 39	ASTM D 4172	GM TMC003	IP 154
ASTM D 130	ASTM D 5183	GM 1000M	ISO 2160
ASTM D 665	DIN 51585	GM 9035P	ISO 7120
ASTM D 2783	DIN 51759	IP 135	

3 PERFORMANCE A sample of the lubricant under consideration shall be evaluated in a certified laboratory using the following tests:

Property	Value	Test Method			
		ISO	ASTM	DIN	Other
Rust Preventing Characteristics	Pass no Rust	7120	D 665A	51585	IP 135
Copper Corrosion (3h at 100°C)	1b max	2160	D 130	51759	IP 154
Stability	Shall not readily separate on standing				
Four-Ball Wear (20 kg load)* Wear Scar Diameter, mm max	Report		D 4172		
Four-Ball EP* Load Wear Index, kg min Weld Load, kg min	Report Report		D 2783		
Four-Ball Coeff. of Friction*	Report		D 5183		
Adherence	Satisfactory to user				
Drying Time, at room temp.	2-3 min.				

* Tests to be run after solvent has been allowed to evaporate, leaving a dry film.

4 CHEMICAL PROPERTIES The product shall not contain water, acid, or other substances detrimental to the proper function and performance of the components or system for which it is intended. It shall be free from noxious odors or masking fragrances. Identification colorants are permitted provided such do not adversely affect performance.

5 INITIAL PRODUCT APPROVAL

5.1 Initial product approval is given by the General Motors LS2 Maintenance Lubricants Standards Committee. Only sources listed in the Approved Products List have been qualified by the LS2 committee as meeting the requirements of this specification. No purchases or shipments are to be made until this approval has been completed.

5.2 The supplier shall furnish data showing the composition of the candidate lubricant, with regard to both the carrier and solid (concentration and generic chemical description of each component).

5.3 The supplier shall submit test results from a laboratory acceptable to the LS2 committee confirming that the product submitted for approval meets all of the stated requirements. Test limits shown are absolute; test precision was considered when setting them.

5.4 Completed copies of the GM Material Safety Data Sheet, GM TMC003 (see Appendix F) shall be submitted for new products or formulation changes; restricted chemicals to be handled per GM1000M. These MSDS's should be made available to plants upon request.

6 INSPECTION AND REJECTION

6.1 All shipments under contract or purchase order manufactured to this specification shall be identical in every respect to the initial samples approved.

6.2 No changes in the formulation or manufacturing process are allowed without prior approval of the LS2 committee. Lack of such notification constitutes grounds for rejection of any shipment and removal from the Approved Products List.

6.3 The supplier shall be ISO 9000 or QS 9000 certified and shall perform regular quality control checks at each location where the material is manufactured. Such quality control data shall be made available to the purchaser upon request.

6.4 The purchaser may check incoming shipments for specification compliance; the supplier assumes responsibility for incoming shipments meeting this specification without dependence upon purchaser's inspection. Non-compliance to physical and chemical requirements constitutes grounds for rejection of a shipment.

6.5 If physical and/or chemical analyses determine that the delivered lubricant is not in compliance with the requirements, the supplier may be held liable for loss of equipment warranty.

7 COMPATIBILITY

Mixtures of the product approved and the product currently used shall pass all of the above requirements. The supplier is responsible that, when this product is mixed with a product already in use, there shall be no incompatibility or loss in operating performance. This product should not cause degradation or loss of performance of commonly used seals.

8 GENERAL INFORMATION

8.1 Each container shall be clearly identified on the top and side. The identification shall contain the GM specification number at least 2 inches (5 cm) high on 5 gallon (20 L) or larger containers and prominently displayed on smaller containers.

8.2 All products shall be bar-coded according to AIAG 39.

8.3 This product shall be used only in accordance with applicable hazardous materials procedures in each facility.

8.4 This standard is under the control of the GM LS2 Committee. It was last revised in **2011**.

GM LUBRICANT STANDARD NO. LD-XX-2-11
CHAIN/CONVEYOR LUBRICANT – OIL BASED

1 SCOPE The material defined by this specification is a material for lubrication of conveyor chains and bearings operating at temperatures in excess of 175°C. It is an oil or ester based lubricant with antiwear and antioxidant additives. **This oil is not recommended as a replacement for grease (see LG) or in applications where high cyclic speeds or heavy loads prevail.**

2 REFERENCED STANDARDS

AIAG 39	ASTM D 5185	GM TMC003	ISO 2160
ASTM D 92	ASTM E 1687	GM 1000M	ISO 2592
ASTM D 97	BS 188	GM 9035P	ISO 2909
ASTM D 130	BS 4231	IP 15	ISO 3016
ASTM D 445	DIN 51519	IP 36	ISO 3104
ASTM D 665	DIN 51561	IP 71	ISO 3448
ASTM D 2270	DIN 51562	IP 135	ISO 7120
ASTM D 2422	DIN 51585	IP 154	
ASTM D 4172	DIN 51759	IP 226	
ASTM D 5183	EPA SW-846	IP 240	

3 PHYSICAL PROPERTIES

Property	Value LD-XX, where XX = ISO grade /10	Test Method			
		ISO	ASTM	DIN	Other
ISO Viscosity Grade	Report	3448	D 2422	51519	BS 4231 IP 226
Kinematic Viscosity at 40°C, cSt	ISO grade +/- 10%	3104	D 445	51561 51562	IP 71 BS 188
Kinematic Visc. at 100°C	Report				
Viscosity Index, min	Report	2909	D 2270		IP 226
Pour Point, °C, max	-10	3016	D 97		IP 15
Flash Point °C, min	≥ ISO 32: 190 ISO 22: 175 ≤ ISO 15: 165	2592	D 92		IP 36

4 PERFORMANCE A sample of the lubricant under consideration shall be evaluated in a certified laboratory using the following tests:

Property	Value	Test Method			
		ISO	ASTM	DIN	Other
Rust Preventing Characteristics	Pass no Rust	7120	D 665A	51585	IP 135
Copper Corrosion (3h at 100°C)	1b max	2160	D 130	51759	IP 154
Four-Ball Wear (20 kg load)* Wear Scar Diameter, mm max	Report		D 4172		
Four-Ball Coefficient of Friction	Report		D 5183		
Adherence	Satisfactory to user				

5 CHEMICAL PROPERTIES The product shall not contain water, acid, or other substances detrimental to the proper function and performance of the components or system for which it is intended. It shall be free from noxious odors or masking fragrances. Identification colorants are permitted provided such do not adversely affect performance. If it contains mineral oil, the following properties shall be met:

5 CHEMICAL PROPERTIES (CONT.)

Property	Value	Test Method			
		ISO	ASTM	DIN	Other
Base Stock Requirements				Virgin or	Rerefined
Tot. PolyNuclear Aromatics, ppm max	100				EPA SW-846 TN 8270*
Residual Elements (As, B, Ca, Mn, Mg, Na, Fe, Ni, Si, Cu, Sn, Cd, Cr, Pb, Ba, Zn), ppm max Total/ each P, ppm max	 25/2 5		D 5185		
Total Chlorinated Biphenyls	Not De-Tectable				SW-846 TN 8082*
Total Org. Halogens, ppm Max	5				SW-846 TN 9253*
Mutagenicity Fold Increase Mutagenicity Index, max Mutag. Potency Index, max	 Report 1 Report		E 1687		Modified Ames (or skin painting)

*** or other methods as agreed upon by the LS2 committee and supplier**

6 INITIAL PRODUCT APPROVAL

6.1 Initial product approval is given by the General Motors LS2 Maintenance Lubricants Standards Committee. Only sources listed in the Approved Product List have been qualified by the LS2 committee as meeting the requirements of this specification. No purchases or shipments are to be made until this approval has been completed.

6.2 The supplier shall furnish data showing the composition of the candidate lubricant, with regard to both the specific base stocks (crude source and refinery, etc.) and additive treatment (concentration and generic chemical description of each component).

6.3 The supplier shall submit test results from a laboratory acceptable to the LS2 committee confirming that the product submitted for approval meets all of the stated requirements. Test limits shown are absolute; test precision was considered when setting them.

6.4 Completed copies of the GM Material Safety Data Sheet, GM TMC003 (see Appendix F) shall be submitted for new products or formulation changes; restricted chemicals to be handled per GM1000M.

7 INSPECTION AND REJECTION

7.1 All shipments under contract or purchase order manufactured to this specification shall be identical in every respect to the product approved.

7.2 No changes in the formulation (including both base oil source and additive package and concentration) or manufacturing process are allowed without prior approval of the LS2 committee. Lack of such notification constitutes grounds for rejection of any shipment and removal from the Approved Product List.

7.3 The supplier shall be ISO 9000 or QS 9000 certified and shall perform regular quality control checks at each location where the material is manufactured. Such quality control data shall be made available to the purchaser upon request.

7.4 The purchaser may check incoming shipments for specification compliance; the supplier is responsible for incoming shipments meeting this specification without dependence upon purchaser's inspection. Non-compliance to physical and chemical requirements constitutes grounds for rejection of a shipment.

7.5 If physical or chemical analyses determine that the delivered lubricant is not in compliance with the requirements, the supplier may be held liable for loss of equipment warranty.
7.6 Infrared spectra (GM 9035P) of the incoming lubricant shipments shall not deviate significantly from that of the originally approved material.

8 COMPATIBILITY

Mixtures of the product approved and the product currently used shall pass all of the above requirements. The supplier is responsible that, when this product is mixed with a product already in use, there shall be no incompatibility or loss in operating performance. This product should not cause degradation or loss of performance of commonly used seals.

9 WASTE TREATMENT

The supplier shall be responsible to make known the processing procedures of any component of the lubricant for which waste treatability is in question.

10 GENERAL INFORMATION

10.1 Each container shall be clearly identified on the top and side. The identification shall contain the GM specification number at least 2 inches (5 cm) high on 5 gallon (20 L) or larger containers and prominently displayed on smaller containers.
10.2 All products shall be bar-coded according to AIAG 39.
10.3 This product shall be used only in accordance with applicable hazardous materials procedures in each facility.
10.4 This standard is under the control of the GM LS2 Committee. It was last revised in **2011.**

GM LUBRICANT STANDARD NO. LE-XX-1-11
ENVIRONMENTALLY ACCEPTABLE INDUSTRIAL LUBRICANTS

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1 SCOPE Lubricants defined by this specification are formulated with biodegradable materials. They are intended for use in applications where biodegradability and low ecotoxicity are required. However, since costs are generally higher than for conventional lubricants, environmentally acceptable lubricants should generally only be used where required.

2 REFERENCED STANDARDS
ASTM D 6046 (all applicable test procedures are referenced in this standard classification)

3 PERFORMANCE A sample of the exact oil under consideration (i.e., no changes to base oil or additive package are allowed) shall be classified by running the necessary tests in a certified laboratory:

Property	Value	Test Method			
		ISO	ASTM	DIN	Other
Environmental Impact - Environmental Persistence (Biodegradability)			D 6046		
Fresh Water	Pw1				
Marine	Pm1				
Soil	Ps1				
Anaerobic	Pa1				
Environmental Impact - Ecotoxicity			D 6046		
Fresh Water	Tw1				
Marine	Tm1				
Soil	Ts1				
Anaerobic	Ta1				
Environmental Impact - Bioaccumulation			D 6046		
Fresh Water	criteria				
Marine	not yet				
Soil	available				
Anaerobic					

Pw,m,s,a relate to environmental persistence in fresh water, marine, soil and anaerobic environments, respectively
Tw,m,s,a relate to ecotoxicity in fresh water, marine, soil and anaerobic environments, respectively

4 OTHER Any lubricant intended for an application where minimal environmental impact and biodegradability are requirements must pass all of the tests above. In addition, it must also pass all of the tests in Section L5 applicable to that particular type of lubricant. For instance, an ISO 46 environmentally acceptable hydraulic fluid must pass all of the tests above plus all of the tests required in the LH-04-1-11 standard. For some applications, environmentally acceptable lubricants may not be able to pass all of the applicable tests for the standard lubricant application. For example, the environmentally acceptable hydraulic oil may not pass the ASTM D 943 oxidation test required in LH-04-1-11 In such cases, the LS2 Committee should be consulted, and will make final decisions on performance compromises necessitated by the nature of the fluid. As far as the lubricant number, for environmentally acceptable lubricants, “LE/” should precede the standard designation. The fluid discussed in the example above would be “LE/LH-04-1-11”.

GM LUBRICANT STANDARD NO. LF-04-1-11
PHOSPHATE ESTER HYDRAULIC FLUID - 46 cSt

1 SCOPE The fluid defined by this specification is a phosphate ester hydraulic fluid formulated with additives to provide good oxidation resistance, corrosion protection and foam stability. It is intended for use in hydraulic pump systems where fire resistance is of great importance. LF-04-1 is an ISO VG 46 fluid. It meets the requirements of SAE MS 1005 for HFDR fluids. **CAUTION: This fluid may have undesirable effects on common seal materials used for oil-based fluids.**

2 REFERENCED STANDARDS

AIAG 39	ASTM E 659	EPA SW-846	ISO 2160
ASTM D 92	BS 188	FTM 6052.1	ISO 2592
ASTM D 95	BS 4231	FTM 6053.1	ISO 2909
ASTM D 97	BS 4385	GM TMC003	ISO 3016
ASTM D 130	BS 4832	GM 1000M	ISO 3104
ASTM D 287	CETOP RP81H	GM 9035P	ISO 3448
ASTM D 445	Denison P-46	IP 15	ISO 3733
ASTM D 471	DIN 51348	IP 36	ISO 4263
ASTM D 664	DIN 51381	IP 71	ISO 4406
ASTM D 665	DIN 51389	IP 74	ISO 6072
ASTM D 892	DIN 51519	IP 135	ISO 6247
ASTM D 943	DIN 51558	IP 139	ISO 6618
ASTM D 974	DIN 51561	IP 146	ISO 7120
ASTM D 1744	DIN 51562	IP 154	ISO 7619
ASTM D 2270	DIN 51566	IP 177	ISO 9120
ASTM D 2422	DIN 51585	IP 226	ISO 11171
ASTM D 2619	DIN 51587	IP 278	SAE MS 1005
ASTM D 3427	DIN 51759	IP 313	Vickers
ASTM D 5185	DIN 53505	ISO 868	M-2952-S
ASTM D 6304	DIN 53521	ISO 1817	

3 PHYSICAL PROPERTIES

Property	Value	Test Method			
		ISO	ASTM	DIN	Other
ISO Viscosity Grade	46	3448	D 2422	51519	BS 4231 IP 226
Kinematic Viscosity min at 40°C, cSt max	41.4 50.6	3104	D 445	51561 51562	IP 71 BS 188
Kinematic Viscosity at 100°C	Report				
Viscosity Index, min	Report	2909	D 2270		IP 226
Pour Point, °C max	-5	3016	D 97		IP 15
Flash Point, °C min	230	2592	D 92		IP 36
Fire Point, °C min	Report		D 92		

4 PERFORMANCE A sample of the exact oil under consideration (i.e., no changes to base fluid or additive package are allowed) shall be evaluated in a certified laboratory using the following tests:

Property	Value	Test Method			
		ISO	ASTM	DIN	Other
Copper Corrosion (3h at 100°C)	1b max	2160	D 130	51759	IP 154
Foaming Tendency (per D 892) Sequence I, II, and III, max	50/0	6247	D 892	51566	IP 146
Cleanliness, as Received, max	18/16/13	4406 11171			

4 PERFORMANCE (CONT.)

Property	Value	Test Method			
		ISO	ASTM	DIN	Other
Rust Preventing Characteristics	Pass	7120	D 665B	51585	IP 135
Oxid. Stab., hours (TAN =2) min	1000	4263	D 943	51587	
Vickers 35VQ25 Pump Test				51389	Vickers M-2952S IP 281
Vane Wear, mg max	10				
Ring Wear, mg max	50				
Piston Pump Test	Denison HF-5 App.				Denison H3058A
Hydrolytic Stability			D 2619	51348	
Cu Weight Loss, mg/cm^2 max	0.20				
Acidity of H2O, mg KOH max	4				
Spray Ignition Test Ignitability, min	Report	15029-2			
Manifold Ignition Test, °C	Report	20823			
Wick Flame Persistence, sec	Report	14935			
High-Pres. Spray Flammability* **FM or 7th Luxembourg (by location)**	**Approved**				6930
Compatibility With SRE-NBR 1 **(DIN 53538)** (168h100°C) or other seals and limits as agreed upon		1817 868 6072 7619	D 471	53521 53505	CETOP RP 81H IP 278 BS 4832
Volume change, %	0 to 12				
Shore A hardness change	0 to -7				
Air Release at 50°C, min. max	15	9120	D 3427	51381	IP 313

* Or Approval by Factory Mutual Engineering Corporation as a Group 1 Fluid

5 CHEMICAL PROPERTIES The product shall not contain water, acid, particulates, or other substances detrimental to the proper function and performance of the components or system for which it is intended. It shall be free from noxious odors or masking fragrances. Identification colorants are permitted provided such do not adversely affect performance. The following requirements shall also be met:

Property	Value	Test Method			
		ISO	ASTM	DIN	Other
API Gravity	Report		D 287		
Autoignition Temp., °C min	450		E 659		
Water Content, % max	0.1	3733	D 95 D 1744 D 6304		IP 74 BS 4385
Acid Number, max	0.15	6618	D 664 D 974	51558	IP 139 IP 177
Phosphate Ester Cont., % min	99				
Base Stock Requirements				Virgin or Rerefined	
Residual Elements (As, B, Ca, Mn, Mg, Na, Fe, Ni, Si, Cu, Sn, Cd, Cr, Pb, Ba, Zn), ppm max			D 5185		
total/ each	25/2				
P, ppm max	5				
Total Chlorinated Biphenyls	Not De-tectable				EPA SW-846 TN 8082*
Tot. Org. Halogens, ppm max	5				TN 9253*

***or other methods as agreed upon between the LS2 committee and supplier**

6 INITIAL PRODUCT APPROVAL

6.1 Initial product approval is given by the General Motors LS2 Maintenance Lubricants Standards Committee. Only sources listed in the Approved Products List have been qualified by the LS2 committee as meeting the requirements of this specification. No purchases or shipments are to be made until this approval has been completed.

6.2 The supplier shall furnish data showing the composition of the candidate lubricant, with regard to both the specific base fluid and additive treatment (concentration and generic chemical description of each component).

6.3 The supplier shall submit test results from a laboratory acceptable to the LS2 committee confirming that the product submitted for approval meets all of the stated requirements. Test limits shown are absolute; test precision was considered when setting them.

6.4 Completed copies of the GM Material Safety Data Sheet, GM TMC003 (see Appendix F) shall be submitted for new products or formulation changes; restricted chemicals to be handled per GM1000M.

7 INSPECTION AND REJECTION

7.1 All shipments under contract or purchase order manufactured to this specification shall be identical in every respect to the product approved.

7.2 No changes in the formulation (including both base fluid and additive package and concentration) or manufacturing process are allowed without prior approval of the LS2 committee. Lack of such notification constitutes grounds for rejection of any shipment and removal from the Approved Products List.

7.3 The supplier shall be ISO 9000 or QS 9000 certified and shall perform regular quality control checks at each location where the material is manufactured. Such quality control data shall be made available to the purchaser upon request.

7.4 The purchaser may check incoming shipments for specification compliance; the supplier is responsible for incoming shipments meeting this specification without dependence upon purchaser's inspection. Non-compliance to physical and chemical requirements constitutes grounds for rejection of a shipment.

7.5 If physical or chemical analyses determine that the delivered lubricant is not in compliance with the requirements, the supplier may be held liable for loss of equipment warranty.

7.6 Infrared spectra (GM 9035P) of the incoming lubricant shipments shall not deviate significantly from that of the originally approved material.

8 COMPATIBILITY

Mixtures of the product approved and the product currently used shall pass all of the above requirements. The supplier is responsible that, when this product is mixed with a product already in use, there shall be no incompatibility or loss in operating performance. This product should not cause degradation or loss of performance of commonly used seals.

9 WASTE TREATMENT

The supplier shall be responsible to make known the processing procedures of any component of the lubricant for which waste treatability is in question.

10 GENERAL INFORMATION

10.1 Each container shall be clearly identified on the top and side. The identification shall contain the GM specification number at least 2 inches (5 cm) high on 5 gallon (20 L) or larger containers and prominently displayed on smaller containers.

10.2 All products shall be bar-coded according to AIAG 39.

10.3 This product shall be used only in accordance with applicable hazardous materials procedures in each facility.

10.4 This standard is under the control of the GM LS2 Committee. It was last revised in **2011**.

GM LUBRICANT STANDARD NO. LF-04-2-11
WATER-GLYCOL HYDRAULIC FLUID - 46 cSt

1 SCOPE The fluid defined by this specification is a solution of water and diethylene or propylene glycol, formulated with additives to provide good wear protection, corrosion protection and foam stability. It is intended for use in hydraulic pump systems where fire resistance is of great importance. LF-04-1 is an ISO 46 fluid. It meets the requirements of SAE MS 1005, Part C for HFC fluids.

2 REFERENCED STANDARDS

AIAG 39	BS 4231	DIN 53538	ISO 868
ASTM D 95	BS 4385	FTM 6052.1	ISO 1817
ASTM D 97	BS 4832	FTM 6053.1	ISO 2160
ASTM D 130	CETOP RP67H	GM TMC003	ISO 3016
ASTM D 287	CETOP RP81H	GM 1000M	ISO 3104
ASTM D 445	DIN 51369	GM 9035P	ISO 3448
ASTM D 471	DIN 51381	IP 15	ISO 3733
ASTM D 665	DIN 51389	IP 71	ISO 4406
ASTM D 892	DIN 51519	IP 74	ISO 6072
ASTM D 1744	DIN 51561	IP 135	ISO 6247
ASTM D 2422	DIN 51562	IP 146	ISO 7120
ASTM D 2882	DIN 51566	IP 154	ISO 7619
ASTM D 3427	DIN 51585	IP 226	ISO 9120
ASTM D 6304	DIN 51759	IP 278	ISO 11171
ASTM E 659	DIN 53505	IP 281	SAE MS 1005
BS 188	DIN 53521	IP 313	

3 PHYSICAL PROPERTIES

Property	Value	Test Method			
		ISO	ASTM	DIN	Other
ISO Viscosity Grade	46	3448	D 2422	51519	BS 4231 IP 226
Kinematic Viscosity min at 40°C, cSt max	41.4 50.6	3104	D 445	51561 51562	IP 71 BS 188
Pour Point, °C max	-20	3016	D 97		IP 15

4 PERFORMANCE A sample of the exact oil under consideration (i.e., no changes to base fluid or additive package are allowed) shall be evaluated in a certified laboratory using the following tests:

Property	Value	Test Method			
		ISO	ASTM	DIN	Other
Copper Corrosion (3h at 100°C)	1b max	2160	D 130	51759	IP 154
Rust Preventing Characteristics	Pass no Rust	7120	D 665B	51585	IP 135
Foaming Tendency (per D 892) Sequence I, II, and III, max	50/0	6247	D 892	51566	IP 146
Vane Pump Test Ring and Vane Wear, mg max	50		D 2882	51389	CETOP RP67H IP 281
Spray Ignition Test Ignitability, min	Report	15029-2			
Manifold Ignition Test, °C	Report	20823			
Wick Flame Persistence, sec	Report	14935			

* Or Approval by Factory Mutual Engineering Corporation as a Group 1 Fluid

4 PERFORMANCE (CONT.)

Property	Value	Test Method			
		ISO	ASTM	DIN	Other
High-Pres. Spray Flammability* **FM or 7th Luxembourg**	**Approved (varies by Location)**				6930
Cleanliness, as Received, max	18/16/13	4406 11171			
Compatibility With SRE-NBR 1 **(DIN 53538)** (168h100°C) or other seals and limits as agreed upon Volume change, % Shore A hardness change	 -10 to 10 -7 to 2	1817 868 6072 7619	D 471	53521 53505	CETOP RP 81H IP 278 BS 4832
Air Release at 50°C, min. max	30	9120	D 3427	51381	IP 313

* Or Approval by Factory Mutual Engineering Corporation as a Group 1 Fluid

5 CHEMICAL PROPERTIES The product shall not contain acid, particulates, or other substances detrimental to the proper function and performance of the components or system for which it is intended. It shall be free from noxious odors or masking fragrances. Identification colorants are permitted provided such do not adversely affect performance. The following requirements shall also be met:

Property	Value	Test Method			
		ISO	ASTM	DIN	Other
API Gravity	Report		D 287		
Autoignition Temp., °C min	385		E 659		
Water Content, % min	35	3733	D 95 D 1744 D 6304		IP 74 BS 4385
pH at 20°C	6.7-11.0			51369	

6 INITIAL PRODUCT APPROVAL

6.1 Initial product approval is given by the General Motors LS2 Maintenance Lubricants Standards Committee. Only sources listed in the Approved Products List have been qualified by the LS2 committee as meeting the requirements of this specification. No purchases or shipments are to be made until this approval has been completed.

6.2 The supplier shall furnish data showing the composition of the candidate lubricant, with regard to both the specific base fluid and additive treatment (concentration and generic chemical description of each component).

6.3 The supplier shall submit test results from a laboratory acceptable to the LS2 committee confirming that the product submitted for approval meets all of the stated requirements. Test limits shown are absolute; test precision was considered when setting them.

6.4 Completed copies of the GM Material Safety Data Sheet, GM TMC003 (see Appendix F) shall be submitted for new products or formulation changes; restricted chemicals to be handled per GM1000M.

7 INSPECTION AND REJECTION

7.1 All shipments under contract or purchase order manufactured to this specification shall be identical in every respect to the product approved.

7.2 No changes in the formulation (including both base fluid and additive package and concentration) or manufacturing process are allowed without prior approval of the LS2 committee. Lack of such notification constitutes grounds for rejection of any shipment and removal from the Approved Products List.

7.3 The supplier shall be ISO 9000 or QS 9000 certified and shall perform regular quality control checks at each location where the material is manufactured. Such quality control data shall be made available to the purchaser upon request.

7.4 The purchaser may check incoming shipments for specification compliance; the supplier is responsible for incoming shipments meeting this specification without dependence upon purchaser's inspection. Non-compliance to physical and chemical requirements constitutes grounds for rejection of a shipment.

7.5 If physical or chemical analyses determine that the delivered lubricant is not in compliance with the requirements, the supplier may be held liable for loss of equipment warranty.

7.6 Infrared spectra (GM 9035P) of the incoming lubricant shipments shall not deviate significantly from that of the originally approved material.

8 COMPATIBILITY

Mixtures of the product approved and the product currently used shall pass all of the above requirements. The supplier is responsible that, when this product is mixed with a product already in use, there shall be no incompatibility or loss in operating performance. This product should not cause degradation or loss of performance of commonly used seals.

9 WASTE TREATMENT

The supplier shall be responsible to make known the processing procedures of any component of the lubricant for which waste treatability is in question.

10 GENERAL INFORMATION

10.1 Each container shall be clearly identified on the top and side. The identification shall contain the GM specification number at least 2 inches (5 cm) high on 5 gallon (20 L) or larger containers and prominently displayed on smaller containers.

10.2 All products shall be bar-coded according to AIAG 39.

10.3 This product shall be used only in accordance with applicable hazardous materials procedures in each facility.

10.4 This standard is under the control of the GM LS2 Committee. It was last revised in **2011**.

GM LUBRICANT STANDARD NO. LF-10-3-11
INVERT EMULSION HYDRAULIC FLUID - 100 cSt

1 SCOPE The fluid defined by this specification is an invert (oil-in-water) emulsion hydraulic fluid of ISO VG 100 grade that is rust and oxidation inhibited, has antiwear properties and is resistant to bacterial and fungal growth. It is intended for applications where fluid temperatures are limited to 0-70°C and fire hazards exist. It should not be used in piston pumps at pressures over 1500 psi (100 Bar). It meets the requirements of SAE MS 1005 for HFB fluids.

2 REFERENCED STANDARDS

AIAG 39	ASTM E 1687	EPA SW-846	ISO 1817
ASTM D 92	BS 188	FTM 6052.1	ISO 2160
ASTM D 95	BS 4231	FTM 6053.1	ISO 2592
ASTM D 97	BS 4385	GM TMC003	ISO 3016
ASTM D 130	BS 4832	GM 1000M	ISO 3104
ASTM D 287	CETOP RP81H	GM 9035P	ISO 3448
ASTM D 445	DIN 51389	IP 15	ISO 3733
ASTM D 471	DIN 51519	IP 36	ISO 4406
ASTM D 665	DIN 51561	IP 71	ISO 6072
ASTM D 892	DIN 51562	IP 74	ISO 6247
ASTM D 1744	DIN 51566	IP 135	ISO 7120
ASTM D 2422	DIN 51585	IP 146	ISO 7619
ASTM D 2882	DIN 51759	IP 154	ISO 11171
ASTM D 3707	DIN 53505	IP 226	SAE MS 1005
ASTM D 5185	DIN 53521	IP 278	
ASTM D 6304	DIN 53538	ISO 868	

3 PHYSICAL PROPERTIES

Property	Value	Test Method			
		ISO	ASTM	DIN	Other
ISO Viscosity Grade Other grades may be allowed	100	3448	D 2422	51519	BS 4231 IP 226
Kinematic Viscosity min at 40°C, cSt max	90 110	3104	D 445	51561 51562	IP 71 BS 188
Pour Point, °C max	-5	3016	D 97		IP 15
Flash Point, °C min	250	2592	D 92		IP 36

4 PERFORMANCE A sample of the exact oil under consideration (i.e., no changes to base fluid or additive package are allowed) shall be evaluated in a certified laboratory using the following tests:

Property	Value	Test Method			
		ISO	ASTM	DIN	Other
Copper Corrosion (3h at 49°C)	1b max	2160	D 130	51759	IP 154
Rust Preventing Characteristics*	Pass no Rust	7120	D 665A	51585	IP 135
Foaming Tendency (per D 892) Sequence I, II, and III, max	50/0	6247	D 892	51566	IP 146
Cleanliness, as Received, max	18/16/13	4406 11171			
Vane Pump Test Ring and Vane Wear, mg max	50		D 2882	51389	

* Run emulsion as is, no water additions.

4 PERFORMANCE (CONT.)

Property	Value	Test Method			
		ISO	ASTM	DIN	Other
Spray Ignition Test Ignitability, min	Report	15029-2			
Manifold Ignition Test, °C	Report	20823			
Wick Flame Persistence, sec	Report	14935			
High-Pres. Spray Flammability* **FM or 7th Luxembourg (by location)**	**Approved**				6930
Compatibility With SRE-NBR 1 **(DIN 53538)** (168h100°C) or other seals and limits as agreed upon Volume change, % Shore A hardness change	 -10 to 10 -7 t0 2	1817 868 6072 7619	D 471	53521 53505	CETOP RP 81H IP 278 BS 4832
Emulsion Stability 48 h 25 days at 50°C	 no sepa- ration 2A-2R		D 3707		

** Or Approval by Factory Mutual Engineering Corporation as a Group 2 Fluid

5 CHEMICAL PROPERTIES The product shall not contain acid, particulates, or other substances detrimental to the proper function and performance of the components or system for which it is intended. It shall be free from noxious odors or masking fragrances. Identification colorants are permitted provided such do not adversely affect performance. The following requirements shall also be met:

Property	Value	Test Method			
		ISO	ASTM	DIN	Other
API Gravity	Report		D 287		
Water Content, % min	40	3733	D 95 D 1744 D 6304		IP 74 BS 4385
Base Stock Requirements					Virgin or Rerefined
Tot. PolyNuclear Aromatics, ppm max	100				EPA SW-846 TN 8270*
Residual Elements (As, B, Ca, Mn, Mg, Na, Fe, Ni, Si, Cu, Sn, Cd, Cr, Pb, Ba, Zn), ppm max total/ each P, ppm max	 25/2 5		D 5185		
Total Chlorinated Biphenyls	Not De-Tectable				SW-846 TN 8082*
Total Organic Halogens, ppm Max	5				SW-846 TN 9253*
Mutagenicity Fold Increase Mutagenicity Index, max Mutag. Potency Index, max	 Report 1 Report		E 1687		Modified Ames (or skin painting)

***or other methods as agreed upon between the LS2 committee and supplier**

6 INITIAL PRODUCT APPROVAL

6.1 Initial product approval is given by the General Motors LS2 Maintenance Lubricants Standards Committee. Only sources listed in the Approved Products List have been qualified by the LS2 committee as meeting the requirements of this specification. No purchases or shipments are to be made until this approval has been completed.

6.2 The supplier shall furnish data showing the composition of the candidate lubricant, with regard to both the specific base oil and additive treatment (concentration and generic chemical description of each component).

6.3 The supplier shall submit test results from a laboratory acceptable to the LS2 committee confirming that the product submitted for approval meets all of the stated requirements. Test limits shown are absolute; test precision was considered when setting them.

6.4 Completed copies of the GM Material Safety Data Sheet, GM TMC003 (see Appendix F) shall be submitted for new products or formulation changes; restricted chemicals to be handled per GM1000M.

7 INSPECTION AND REJECTION

7.1 All shipments under contract or purchase order manufactured to this specification shall be identical in every respect to the product approved.

7.2 No changes in the formulation (including both base oil source and additive package and concentration) or manufacturing process are allowed without prior approval of the LS2 committee. Lack of such notification constitutes grounds for rejection of any shipment and removal from the Approved Products List.

7.3 The supplier shall be ISO 9000 or QS 9000 certified and shall perform regular quality control checks at each location where the material is manufactured. Such quality control data shall be made available to the purchaser upon request.

7.4 The purchaser may check incoming shipments for specification compliance; the supplier is responsible for incoming shipments meeting this specification without dependence upon purchaser's inspection. Non-compliance to physical and chemical requirements constitutes grounds for rejection of a shipment.

7.5 If physical or chemical analyses determine that the delivered lubricant is not in compliance with the requirements, the supplier may be held liable for loss of equipment warranty.

7.6 Infrared spectra (GM 9035P) of the incoming lubricant shipments shall not deviate significantly from that of the originally approved material.

8 COMPATIBILITY

Mixtures of the product approved and the product currently used shall pass all of the above requirements. The supplier is responsible that, when this product is mixed with a product already in use, there shall be no incompatibility or loss in operating performance. This product should not cause degradation or loss of performance of commonly used seals.

9 WASTE TREATMENT

The supplier shall be responsible to make known the processing procedures of any component of the lubricant for which waste treatability is in question.

10 GENERAL INFORMATION

10.1 Each container shall be clearly identified on the top and side. The identification shall contain the GM specification number at least 2 inches (5 cm) high on 5 gallon (20 L) or larger containers and prominently displayed on smaller containers.

10.2 All products shall be bar-coded according to AIAG 39.

10.3 This product shall be used only in accordance with applicable hazardous materials procedures in each facility.

10.4 This standard is under the control of the GM LS2 Committee. It was last revised in **2011**.

GM LUBRICANT STANDARD NO. LF-04, 06-4-11
POLYOL ESTER HYDRAULIC FLUID **PAGE 1 OF 3**

1 SCOPE The fluids defined by this specification are polyol ester hydraulic fluids formulated with additives to provide good oxidation resistance, corrosion protection and foam stability. They are intended for use in hydraulic pump systems where fire resistance is of great importance. They meet the requirements of SAE MS 1005 for HFDU fluids. **NOTE: polyol esters may severely affect commonly used seal materials. Seal materials must be specially selected for use with polyol ester fluids**.

2 REFERENCED STANDARDS

AIAG 39	ASTM D 5185	DIN 51759	IP 313
ASTM D 92	ASTM D 5621	DIN 53505	IP 334
ASTM D 95	ASTM D 6304	DIN 53521	ISO 868
ASTM D 97	ASTM E 659	FTM 6052.1	ISO 1817
ASTM D 130	BS 188	FTM 6053.1	ISO 2160
ASTM D 287	BS 4231	GM TMC003	ISO 2592
ASTM D 445	BS 4385	GM 1000M	ISO 2909
ASTM D 471	BS 4832	GM 9035P	ISO 3016
ASTM D 664	CETOP RP67H	IP 15	ISO 3104
ASTM D 665	CETOP RP81H	IP 36	ISO 3448
ASTM D 892	DIN 51348	IP 71	ISO 3733
ASTM D 943	DIN 51354	IP 74	ISO 4263
ASTM D 974	DIN 51381	IP 135	ISO 4406
ASTM D 1744	DIN 51382	IP 139	ISO 6072
ASTM D 2270	DIN 51389	IP 146	ISO 6247
ASTM D 2422	DIN 51519	IP 154	ISO 6618
ASTM D 2603	DIN 51558	IP 166	ISO 7120
ASTM D 2619	DIN 51561	IP 177	ISO 7619
ASTM D 2882	DIN 51562	IP 226	ISO 9120
ASTM D 3427	DIN 51566	IP 278	ISO 11171
ASTM D 3945	DIN 51585	IP 281	SAE MS 1005
ASTM D 5182	DIN 51587	IP 294	

3 PHYSICAL PROPERTIES

Property	Value		Test Method			
			ISO	ASTM	DIN	Other
ISO Viscosity Grade	46	68	3448	D 2422	51519	BS 4231 IP 226
Kinematic Viscosity min at 40°C, cSt max	41.4 50.6	61.2 74.8	3104	D 445	51561 51562	IP 71 BS 188
Kinematic Viscosity at 100°C	Report					
Viscosity Index, min	140		2909	D 2270		IP 226
Pour Point, °C max	-5		3016	D 97		IP 15
Flash Point, °C min	230		2592	D 92		IP 36

4 PERFORMANCE A sample of the exact oil under consideration (i.e., no changes to base fluid or additive package are allowed) shall be evaluated in a certified laboratory using the following tests:

Property	Value	Test Method			
		ISO	ASTM	DIN	Other
Copper Corrosion (3h at 100°C)	1b max	2160	D 130	51759	IP 154
Rust Preventing Characteristics	Pass	7120	D 665B	51585	IP 135
Foaming Tendency (per D 892) Sequence I, II, and III, max	50/0	6247	D 892	51566	IP 146

4 PERFORMANCE (CONT.)

Property	Value	Test Method			
		ISO	ASTM	DIN	Other
Cleanliness, as Received, max	18/16/13	4406 11171			
Oxidation Stability, hours min (ΔTAN = 2) run without water	500	4263	D 943	51587	
Vane Pump Test Ring and Vane Wear, mg max	50		D 2882	51389	CETOP RP67H IP 281
FZG Test, failure load stage	Report		D 5182	51354	IP 166 IP 334
Hydrolytic Stability Cu Weight Loss, mg/cm^2 max Acidity of Water, mg KOH max	 0.20 28		D 2619	51348	
Spray Ignition Test Ignitability, min	Report	15029-2			
Manifold Ignition Test, °C	Report	20823			
Wick Flame Persistence, sec	Report	14935			
High-Pres. Spray Flammability* **FM or 7th Luxembourg (by location)**	**Approved**				6930
Compatibility With SRE-NBR 1 **(DIN 53538)** (168h100°C) or other seals and limits as agreed upon Sealant, Volume change, % Shore A hardness change	 0 to 12 0 to -7	1817 868 6072 7619	D 471	53521 53505	CETOP RP 81H IP 278 BS 4832
Air Release at 50°C, min. max	15	9120	D 3427	51381	IP 313
Shear Stability	Report		D 2603 D 3945 D 5621	51382	IP 294

*Or Approval by Factory Mutual Engineering Corporation as a Group 2 Fluid

5 CHEMICAL PROPERTIES The product shall not contain water, acid, particulates, or other substances detrimental to the proper function and performance of the components or system for which it is intended. It shall be free from noxious odors or masking fragrances. Identification colorants are permitted provided such do not adversely affect performance. The following requirements shall also be met:

Property	Value	Test Method			
		ISO	ASTM	DIN	Other
API Gravity	Report		D 287		
Autoignition Temp., °C min	Report		E 659		
Water, as Received, ppm max	500	3733	D 6304		IP 74 BS 4385
Acid Number, max	3.0	6618	D 664 D 974	51558	IP 139 IP 177
Base Stock Requirements				Virgin or	Rerefined
Residual Elements (As, B, Ca, Mn, Mg, Na, Fe, Ni, Si, Cu, Sn, Cd, Cr, Pb, Ba, Zn), ppm max total/ each P, ppm max	 25/2 5		D 5185		

6 INITIAL PRODUCT APPROVAL

6.1 Initial product approval is given by the General Motors LS2 Maintenance Lubricants Standards Committee. Only sources listed in the Approved Products List have been qualified by the LS2 committee as meeting the requirements of this specification. No purchases or shipments are to be made until this approval has been completed.

6.2 The supplier shall furnish data showing the composition of the candidate lubricant, with regard to both the specific base fluid and additive treatment (concentration and generic chemical description of each component).

6.3 The supplier shall submit test results from a laboratory acceptable to the LS2 committee confirming that the product submitted for approval meets all of the stated requirements. Test limits shown are absolute; test precision was considered when setting them.

6.4 Completed copies of the GM Material Safety Data Sheet, GM TMC003 (see Appendix F) shall be submitted for new products or formulation changes; restricted chemicals to be handled per GM1000M.

7 INSPECTION AND REJECTION

7.1 All shipments under contract or purchase order manufactured to this specification shall be identical in every respect to the product approved.

7.2 No changes in the formulation (including both base fluid and additive package and concentration) or manufacturing process are allowed without prior approval of the LS2 committee. Lack of such notification constitutes grounds for rejection of any shipment and removal from the Approved Product List.

7.3 The supplier shall be ISO 9000 or QS 9000 certified and shall perform regular quality control checks at each location where the material is manufactured. Such quality control data shall be made available to the purchaser upon request.

7.4 The purchaser may check incoming shipments for specification compliance; the supplier is responsible for incoming shipments meeting this specification without dependence upon purchaser's inspection. Non-compliance to physical and chemical requirements constitutes grounds for rejection of a shipment.

7.5 If physical or chemical analyses determine that the delivered lubricant is not in compliance with the requirements, the supplier may be held liable for loss of equipment warranty.

7.6 Infrared spectra (GM 9035P) of the incoming lubricant shipments shall not deviate significantly from that of the originally approved material.

8 COMPATIBILITY

Mixtures of the product approved and the product currently used shall pass all of the above requirements. The supplier is responsible that, when this product is mixed with a product already in use, there shall be no incompatibility or loss in operating performance. This product should not cause degradation or loss of performance of commonly used seals.

9 WASTE TREATMENT

The supplier shall be responsible to make known the processing procedures of any component of the lubricant for which waste treatability is in question.

10 GENERAL INFORMATION

10.1 Each container shall be clearly identified on the top and side. The identification shall contain the GM specification number at least 2 inches (5 cm) high on 5 gallon (20 L) or larger containers and prominently displayed on smaller containers.

10.2 All products shall be bar-coded according to AIAG 39.

10.3 This product shall be used only in accordance with applicable hazardous materials procedures in each facility.

10.4 This standard is under the control of the GM LS2 Committee. It originated in **2011**.

GM LUBRICANT STANDARD NO. LF-03-5-11
HIGH WATER-BASED HYDRAULIC FLUID **PAGE 1 of 1**

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1 SCOPE The fluid defined by this specification is a high water-based, fire resistant hydraulic fluid that is prepared by mixing 5% of (either a soluble oil or chemical additive) concentrate with 95% water. It is recommended only for fluid temperatures of 0 - 70°C and pump pressures less than 1000 psi (70 Bar). It is not generally recommended for use in vane pumps.

NOTE: THE USE OF HIGH WATER-BASED HYDRAULIC FLUIDS IS DISCOURAGED. OTHER FIRE-RESISTANT HYDRAULIC FLUIDS ARE AVAILABLE. CONTACT THE LS2 COMMITTEE.

1 SCOPE These specifications define high-quality lubricating greases having premium properties and EP load-carrying capacity. These greases are suitable for equipment operating at slow to moderate speeds, moderate to heavy loads, and at temperatures up to 135°C. The requirements are similar for all. These specifications comply with SAE MS1011. **NOTE: Use caution when mixing different greases (see Section L4). Compatibility testing should be performed prior to mixing different greases.**

Suffix A — formulated with ISO VG 150 or lower base oil.
Suffix B — formulated with ISO VG higher than 150

1.1 LG-00-1
This NLGI No. 0 grease is typically used in anti-friction and plain bearings and shall be suitable for use in gear reducers that require NLGI No. 0 grease. For applications requiring dispensing at ambient temperatures down to 0°C, grease shall be made with ISO VG 150 or lower base oil. This grease shall be suitable for application by either manual means or automatic dispensing systems.

1.2 LG-01-1
This NLGI No. 1 grease is typically used in anti-friction and plain bearings, couplings, and slideways. For higher-speed applications or those requiring dispensing at ambient temperatures down to 0°C, grease shall be made with ISO VG 150 or lower base oil. This grease shall be suitable for application by either manual means or automatic dispensing systems capable of pumping NLGI No. 1 greases.

1.3 LG-02-1
This NLGI No. 2 grease is typically used in anti-friction and plain bearings, tapered roller bearings, couplings, and slideways. For higher-speed applications, up to 2500 rpm, Suffix A greases are to be used. For lower-speed, higher-load, or higher-temperature applications, Suffix B greases are to be used. This grease shall be suitable for application by either manual means or pressure gun. It is not intended for application by automatic dispensing systems.

2 REFERENCED STANDARDS

AIAG 39
ASTM D 92
ASTM D 128
ASTM D 217
ASTM D 445
ASTM D 566
ASTM D 611
ASTM D 942
ASTM D 1264
ASTM D 1742
ASTM D 1743
ASTM D 2265
ASTM D 2266
ASTM D 2270
ASTM D 2422
ASTM D 2509
ASTM D 2595
ASTM D 2596
ASTM D 3527
ASTM D 4048
ASTM D 4170
ASTM D 4290
ASTM D 4425
ASTM D 5185
ASTM D 6138
ASTM E 1687
BS 188
BS 4231
DIN 51350
DIN 51519
DIN 51550
DIN 51561
DIN 51562
DIN 51775
DIN 51787
DIN 51802
DIN 51806
DIN 51807
DIN 51808
DIN 51811
DIN 51817
EPA SW-846
GM TMC003
GM 1000M
GM 9035P
IP 2
IP 36
IP 50
IP 71
IP 112
IP 121
IP 132
IP 142
IP 215
IP 220
IP 239
ISO 2137
ISO 2160
ISO 2176
ISO 2592
ISO 2977
ISO 3104
ISO 3105
ISO 3448
SAE MS 1011

3 BASE OIL PHYSICAL PROPERTIES

Property	Value			Test Method			
Product Code, **LG-_ _ - 1-11**	00	01	02	ISO	ASTM	DIN	other
Base Oil ISO Viscosity Grade Suffix A Suffix B	150 or lower >150			3448	D 2422	51519	BS 4231
Base Oil Viscosity at 40°C, cSt Suffix A, B min/max	ISO grade +/- 10%			3104 3105	D 445	51550 51561 51562	IP 71 BS 188
Base Oil Viscosity at 100°C, cSt,	Report						
Base Oil Viscosity Index, min	75				D 2270		
Base Oil Flash Point, °C min	190			2592	D 92		IP 36

4 PERFORMANCE A sample of the exact grease under consideration (i.e., no changes to base oil, thickener or additive package are allowed) shall be evaluated in a certified laboratory using the following tests:

Property	Value			Test Method			
Product Code, **LG-_ _ - 1-11**	00	01	02	ISO	ASTM	DIN	other
Worked Penetration at 25°C min/max	355/385	310/340	265/295	2137	D 217		IP 50
Prolonged (10 000 strokes) Worked Penetration at 25°C min/max For polyurea greases: Report	340/400	295/355	250/310	2137	D 217		IP 50
Dropping Point, °C, min	175			2176	D 566 D 2265	51806	IP 132
Water Washout 79°C, % max	Report	8	8		D 1264	51807	IP 215
Rust Prevent. Characteristics	Pass				D 1743		
Emcor Rust Test, rating, max	No. 1				D 6138	51802	IP 220
Evaporation Loss, at 100°C, % max	3				D 2595		
Oil Separation, % max	20	10	10		D 4290		
Pressure Oil Separation, %, min/max	0.5 10.0	0.5 5.0	0.5 5.0		D 1742	51817	IP 121
Centrifugal Separation, K36 Value at 50°C, max	--------	Report	Report		D 4425		
Four Ball Wear, scar diameter, mm max	0.8				D 2266		
Timken OK Load, kg min	18.1				D 2509	51350	IP 239
Four Ball EP Load Wear Index, kg min Weld Load, kg min	40 250				D 2596	51350	
Fretting Wear Test , mg max	10				D 4170		
Life Performance, h min	NA	40	40		D 3527		

4 PERFORMANCE (CONT.)

Property	Value			Test Method			
Product Code, **LG-_ _ - 1-11**	00	01	02	ISO	ASTM	DIN	other
Oxidation Stability, pressure drop, kPa max	35				D 942	51808	IP 142
Cu Corrosion, 100°C, 24 h max	1b			2160	D 4048	51811	IP 112
Extracted-fluid Aniline Point, °C See Note 1 min	94			2977	D 128X1 D 611A2	51175 51787	IP 2

Note 1 — Base-oil aniline point shall not be substituted for Extracted-fluid Aniline Point. For ASTM D 128/X1: combine two, 10-g extractions or extract 20 g grease, instead of 10 g, to obtain enough sample to determine aniline point. Adjust reflux so that thimble does not fill to over-flowing. A clear sample is required for the ASTM D 611A2 Aniline Point test. If the extracted fluid is cloudy, centrifuge or filter it to obtain a clear sample.

5 CHEMICAL PROPERTIES The product shall not contain water, acid or other substances detrimental to the proper function and performance of the components or system for which it is intended. It shall be free from noxious odors or masking fragrances. Identification colorants are permitted provided such do not adversely affect performance. The following requirements shall also be met:

Property	Value			Test Method			
Product Code, **LG-_ _ - 1-11**	00	01	02	ISO	ASTM	DIN	other
Thickener Type & Conc.	Report						
Base Stock Requirements							Virgin or Rerefined
Total PolyNuclear Aromatics, ppm max	100						EPA SW-846 TN 8270*
Residual Elements As, B, Ca, Mn, Mg, Na, Fe, Ni, Si, Cu, Sn, Cd, Cr, Pb, Ba, Zn ppm total / ppm each max P, ppm max	25/2 5				D 5185		
Total Chlorinated Biphenyls	Not Detectable						EPA SW-846 TN 8082*
Total Organic Halogens, ppm max	5						EPA SW-846 TN 9253*
Mutagenicity Fold Increase Mutagenicity Index, max Mutag. Potency Index, max	 Report 1 Report				E 1687		Modified Ames (or skin painting)

***or other methods as agreed upon between the LS2 committee and supplier**

6 INITIAL SOURCE APPROVAL

6.1 Initial source approval is given by the General Motors LS2 Maintenance Lubricants Standards Committee. Only sources listed in the Approved Products List have been qualified by the LS2 committee as meeting the requirements of this specification. No purchases or shipments are to be made until this approval has been completed.

6.2 The supplier shall furnish data showing the composition of the candidate lubricant, with regard to the specific base stocks (crude source and refinery, etc.), thickener, and additive treatment (concentration and generic chemical description of each component).

6.3 The supplier shall submit test results from a laboratory acceptable to the LS2 committee confirming that the product submitted for approval meets all of the stated requirements. Test limits shown are absolute; test precision was considered when setting them.

6.4 Completed copies of the GM Material Safety Data Sheet, GM TMC003 (see Appendix F) shall be submitted for new products or formulation changes; restricted chemicals to be handled per GM1000M.

7 INSPECTION AND REJECTION

7.1 All shipments under contract or purchase order manufactured to this specification shall be identical in every respect to the initial samples approved.

7.2 No changes in the formulation (including the base oil source, thickener, and additive package and concentration) or manufacturing process are allowed without prior approval of the LS2 committee. Lack of such notification constitutes grounds for rejection of any shipment and removal from the Approved Products List.

7.3 The supplier shall be ISO 9000 or QS 9000 certified and shall perform regular quality control checks at each location where the material is manufactured. Such quality control data shall be made available to the purchaser upon request.

7.4 The purchaser may check incoming shipments for specification compliance; the supplier assumes responsibility for incoming shipments meeting this specification without dependence upon purchaser's inspection. Non-compliance with physical and chemical requirements constitutes grounds for rejection of a shipment.

7.5 If physical or chemical analyses determine that the delivered lubricant is not in compliance with the requirements, the supplier may be held liable for loss of equipment warranty.

7.6 Infrared spectra (GM 9035P) of the incoming lubricant shipments shall not deviate significantly from that of the originally approved material.

8 COMPATIBILITY

Mixtures of the product approved and the product currently used shall pass all of the above requirements. The supplier is responsible that, when this product is mixed with a product already in use, there shall be no incompatibility or loss in operating performance. This product should not cause degradation or loss of performance of commonly used seals.

9 WASTE TREATMENT

The supplier shall be responsible to make known the processing procedures of any component of the lubricant for which waste treatability is in question.

10 GENERAL INFORMATION

10.1 Each container shall be clearly identified on the top and side. The identification shall contain the GM specification number at least 2 inches (5 cm) high on 5 gallon (20 L) or larger containers and prominently displayed on smaller containers.

10.2 All products shall be bar-coded according to AIAG 39.

10.3 This product shall be used only in accordance with applicable hazardous materials procedures in each facility.

10.4 This standard is under the control of the GM LS2 Committee. It was last revised in **2011**.

GM LUBRICANT STANDARD NO. LG-01-2-11
FRETTING AND CORROSION INHIBITING GREASE NLGI NO. 1

1 SCOPE The grease defined in this specification shall be a uniform blend of hydrocarbon oil and thickener and shall contain additives to improve oxidation stability, corrosion inhibition, wear resistance, frictional characteristics and tackiness. This grease provides superior fretting wear and corrosion protection. It is intended for use in oscillating mechanisms open to the atmosphere, such as robot gears and bearings. **NOTE: Use caution when mixing different greases (see Section L4). Compatibility testing should be performed prior to mixing different greases.**

2 REFERENCED STANDARDS

AIAG 39	ASTM D 2422	DIN 51775	IP 71
ASTM D 92	ASTM D 4048	DIN 51787	IP 112
ASTM D 128	ASTM D 4170	DIN 51806	IP 132
ASTM D 217	ASTM D 5185	DIN 51807	IP 142
ASTM D 445	ASTM D 5969	DIN 51808	IP 215
ASTM D 566	ASTM E 1687	DIN 51811	ISO 2160
ASTM D 611	BS 188	EPA SW-846	ISO 2176
ASTM D 942	BS 4231	GM TMC003	ISO 2592
ASTM D 1264	DIN 51519	GM 1000M	ISO 2977
ASTM D 2265	DIN 51550	GM 9035P	ISO 3104
ASTM D 2266	DIN 51561	IP 2	ISO 3105
ASTM D 2270	DIN 51562	IP 36	ISO 3448

3 BASE OIL PHYSICAL PROPERTIES

Property	Value	Test Method			
		ISO	ASTM	DIN	other
Base Oil ISO Viscosity Grade	Report	3448	D 2422	51519	BS 4231
Base Oil Viscosity at 40°C, cSt min/max	ISO grade +/- 10%	3104 3105	D 445	51550 51561	IP 71 BS 188
Base Oil Viscosity at 100°C, cSt,	Report			51562	
Base Oil Viscosity Index, min	75		D 2270		
Base Oil Flash Point, °C min	190	2592	D 92		IP 36

4 PERFORMANCE A sample of the exact grease under consideration (i.e., no changes to base oil, thickener or additive package are allowed) shall be evaluated in a certified laboratory using the following tests:

Property	Value	Test Method			
		ISO	ASTM	DIN	other
Worked Penetration at 25°C min/max	280/325		D 217		
Dropping Point, °C min	200	2176	D 566 D 2265	51806	IP 132
Water Washout 79°C, % max	10		D 1264	51807	IP 215
Rust Prevent. Characteristics, w/ 97 vol % distilled water + 3 vol % synthetic sea-water, 24 h at 25°C	Pass		D 5969		
Four Ball Wear, scar diameter, mm max	0.8		D 2266		
Fretting Wear Test, mg max	2.0		D 4170		

4 PERFORMANCE (CONT.)

Property	Value	Test Method			
		ISO	ASTM	DIN	other
Cu Corrosion, 100°C, 24 h max	1b	2160	D 4048	51811	IP 112
Oxidation Stability, pressure drop, kPa max	35		D 942	51808	IP 142
Extracted-fluid Aniline Point, °C See Note 1 min	94	2977	D 128X1 D 611A2	51775 51787	IP 2

Note 1 — Base-oil aniline point shall not be substituted for Extracted-fluid Aniline Point. For ASTM D 128/X1: combine two, 10-g extractions or extract 20 g grease, instead of 10 g, to obtain enough sample to determine aniline point. Adjust reflux so that thimble does not fill to over-flowing. A clear sample is required for the ASTM D 611A2 Aniline Point test. If the extracted fluid is cloudy, centrifuge or filter it to obtain a clear sample.

5 CHEMICAL PROPERTIES The product shall not contain water, acid or other substances detrimental to the proper function and performance of the components or system for which it is intended. It shall be free from noxious odors or masking fragrances. Identification colorants are permitted provided such do not adversely affect performance. The following requirements shall also be met:

Property	Value	Test Method			
		ISO	ASTM	DIN	other
Thickener type and concentration	Report				
Tackiness Additive, %	Report				
Base Stock Requirements					Virgin or Rerefined
Total PolyNuclear Aromatics, ppm max	100				EPA SW-846 TN 8270*
Residual Elements As, B, Ca, Mn, Mg, Na, Fe, Ni, Si, Cu, Sn, Cd, Cr, Pb, Ba, Zn ppm total/ppm each max P, ppm max	 25/2 5		D 5185		
Total Chlorinated Biphenyls	Not Detectable				EPA SW-846 TN 8082*
Total Organic Halogens, ppm max	5				EPA SW-846 TN 9253*
Mutagenicity Fold Increase Mutagenicity Index, max Mutag. Potency Index, max	 Report 1 Report		E 1687		Modified Ames (or skin painting)

*** or other methods as agreed upon by the LS2 committee and supplier**

6 INITIAL SOURCE APPROVAL

6.1 Initial source approval is given by the General Motors LS2 Maintenance Lubricants Standards Committee. Only sources listed in the Approved Products List have been qualified by the LS2 committee as meeting the requirements of this specification. No purchases or shipments are to be made until this approval has been completed.

6.2 The supplier shall furnish data showing the composition of the candidate lubricant, with regard to the specific base stocks (crude source and refinery, etc.), thickener, and additive treatment (concentration and generic chemical description of each component).

6.3 The supplier shall submit test results from a laboratory acceptable to the LS2 committee confirming that the product submitted for approval meets all of the stated requirements. Test limits shown are absolute; test precision was considered when setting them.

6.4 Completed copies of the GM Material Safety Data Sheet, GM TMC003 (see Appendix F) shall be submitted for new products or formulation changes; restricted chemicals to be handled per GM1000M.

7 INSPECTION AND REJECTION

7.1 All shipments under contract or purchase order manufactured to this specification shall be identical in every respect to the initial samples approved.

7.2 No changes in the formulation (including the base oil source, thickener, and additive package and concentration) or manufacturing process are allowed without prior approval of the LS2 committee. Lack of such notification constitutes grounds for rejection of any shipment and removal from the Approved Products List.

7.3 The supplier shall be ISO 9000 or QS 9000 certified and shall perform regular quality control checks at each location where the material is manufactured. Such quality control data shall be made available to the purchaser upon request.

7.4 The purchaser may check incoming shipments for specification compliance; the supplier assumes responsibility for incoming shipments meeting this specification without dependence upon purchaser's inspection. Non-compliance with physical and chemical requirements constitutes grounds for rejection of a shipment.

7.5 If physical or chemical analyses determine that the delivered lubricant is not in compliance with the requirements, the supplier may be held liable for loss of equipment warranty.

7.6 Infrared spectra (GM 9035P) of the incoming lubricant shipments shall not deviate significantly from that of the originally approved material.

8 COMPATIBILITY

Mixtures of the product approved and the product currently used shall pass all of the above requirements. The supplier is responsible that, when this product is mixed with a product already in use, there shall be no incompatibility or loss in operating performance. This product should not cause degradation or loss of performance of commonly used seals.

9 WASTE TREATMENT

The supplier shall be responsible to make known the processing procedures of any component of the lubricant for which waste treatability is in question.

10 GENERAL INFORMATION

10.1 Each container shall be clearly identified on the top and side. The identification shall contain the GM specification number at least 2 inches (5 cm) high on 5 gallon (20 L) or larger containers and prominently displayed on smaller containers.

10.2 All products shall be bar-coded according to AIAG 39.

10.3 This product shall be used only in accordance with applicable hazardous materials procedures in each facility.

10.4 This standard is under the control of the GM LS2 Committee. It was last revised in **2011**.

GM LUBRICANT STANDARD NO. LG-02-3-11
HIGH-SPEED BEARING GREASE NLGI NO. 2 **PAGE 1 OF 4**

1 SCOPE This specification defines a high-quality lubricating grease having premium antiwear properties and load-carrying capacity oil for higher-speed applications. This grease is typically used in machine tools and in anti-friction bearings operating at moderate to high speeds (above 2500 rpm), moderate loads, and at temperatures up to 100°C. This grease shall be suitable for application by either manual means or automatic dispensing systems capable of pumping NLGI No. 2 greases. **NOTE: Use caution when mixing different greases (see Section L4). Compatibility testing should be performed prior to mixing different greases.**

2 REFERENCED STANDARDS

AIAG 39	ASTM D 2596	DIN 51775	IP 112
ASTM D 92	ASTM D 3336	DIN 51787	IP 121
ASTM D 128	ASTM D 3527	DIN 51802	IP 132
ASTM D 217	ASTM D 4048	DIN 51806	IP 142
ASTM D 445	ASTM D 4170	DIN 51807	IP 215
ASTM D 566	ASTM D 4290	DIN 51808	IP 220
ASTM D 611	ASTM D 5185	DIN 51811	ISO 2137
ASTM D 942	ASTM D 6138	DIN 51817	ISO 2160
ASTM D 1264	ASTM E 1687	EPA SW-846	ISO 2176
ASTM D 1742	BS 188	GM TMC003	ISO 2592
ASTM D 1743	BS 4231	GM 1000M	ISO 2977
ASTM D 2265	DIN 51350	GM 9035P	ISO 3104
ASTM D 2266	DIN 51519	IP 2	ISO 3105
ASTM D 2270	DIN 51550	IP 36	ISO 3448
ASTM D 2422	DIN 51561	IP 50	
ASTM D 2595	DIN 51562	IP 71	

3 BASE OIL PHYSICAL PROPERTIES

Property	Value	Test Method			
		ISO	ASTM	DIN	other
Base Oil ISO Viscosity Grade	<220	3448	D 2422	51519	BS 4231
Base Oil Viscosity at 40°C, cSt min/max	ISO grade +/- 10%	3104 3105	D 445	51550 51561	IP 71 BS 188
Base Oil Visc. at 100°C, cSt	Report			51562	
Base Oil Viscosity Index, min	75		D 2270		
Base Oil Flash Point, °C min	190	2592	D 92		IP 36

4 PERFORMANCE A sample of the exact grease under consideration (i.e., no changes to base oil, thickener or additive package are allowed) shall be evaluated in a certified laboratory using the following tests:

Property	Value	Test Method			
		ISO	ASTM	DIN	other
Worked Penetration at 25°C min/max	265 295	2137	D 217		IP 50
Prolonged (10 000 strokes) Worked Penetration at 25°C min/max For Polyurea greases: report	250 310	2137	D 217		IP 50
Dropping Point, °C min	175	2176	D 566 D 2265	51806	IP 132
Water Washout 79°C, % max	10		D1264	51807	IP 215

4 PERFORMANCE (CONT.)

Property	Value	Test Method			
		ISO	ASTM	DIN	other
Rust Prevent. Characteristics.	Pass		D 1743		
Emcor Rust Test, rating, max	No. 1		D 6138	51802	IP 220
Evaporation at 100°C, % max	3		D 2595		
Oil Separation, % max	10		D 4290		
Pressure Oil Separation, % min/max	0.5 5.0		D 1742	51817	IP 121
Four Ball Wear, scar diameter, mm max	0.8		D 2266		
Four Ball EP Load Wear Index, kg min Weld Load, kg min	 40 250		D 2596	51350	
Fretting Wear Test , mg max	10		D 4170		
Life Performance, h min	80		D 3527		
Oxidation Stability, pressure drop, kPa max	35		D 942	51808	IP 142
Cu Corrosion, 100°C, 24 h max	3b	2160	D 4048	51811	IP 112
Extracted-fluid Aniline Point, °C See Note 1 min	94	2977	D 128X1 D 611A2	51775 51787	IP 2
Performance in Ball Bearings L50 Life at 177°C, h min	250		D 3336		

Note 1 — Base-oil aniline point shall not be substituted for Extracted-fluid Aniline Point. For ASTM D 128/X1: combine two, 10-g extractions or extract 20 g grease, instead of 10 g, to obtain enough sample to determine aniline point. Adjust reflux so that thimble does not fill to over-flowing. A clear sample is required for the ASTM D 611A2 Aniline Point test. If the extracted fluid is cloudy, centrifuge or filter it to obtain a clear sample.

5 CHEMICAL PROPERTIES The product shall not contain water, acid or other substances detrimental to the proper function and performance of the components or system for which it is intended. It shall be free from noxious odors or masking fragrances. Identification colorants are permitted provided such do not adversely affect performance. The following requirements shall also be met:

Property	Value	Test Method			
		ISO	ASTM	DIN	other
Thickener Type and Concentration	Report				
Base Stock Requirements					Virgin or Rerefined
Total PolyNuclear Aromatics, ppm max	100				EPA SW-846 TN 8270*
Residual Elements As, B, Ca, Mn, Mg, Na, Fe, Ni, Si, Cu, Sn, Cd, Cr, Pb, Ba, Zn ppm total / ppm each max P, ppm max	 25 / 2 5		D 5185		

***or other methods as agreed upon between the LS2 committee and supplier**

5 CHEMICAL COMPOSITION (CONT.)

Property	Value	Test Method			
		ISO	ASTM	DIN	other
Base Stock Requirements, cont.					
Total Chlorinated Biphenyls	Not Detectable				EPA SW-846 TN 8082*
Total Organic Halogens, ppm max	5				EPA SW-846 TN 9253*
Mutagenicity Fold Increase Mutagenicity Index, max Mutag. Potency Index, max	 Report 1 Report		E 1687		Modified Ames (or skin painting)

***or other methods as agreed upon between the LS2 committee and supplier**

6 INITIAL SOURCE APPROVAL

6.1 Initial source approval is given by the General Motors LS2 Maintenance Lubricants Standards Committee. Only sources listed in the Approved Products List have been qualified by the LS2 committee as meeting the requirements of this specification. No purchases or shipments are to be made until this approval has been completed.

6.2 The supplier shall furnish data showing the composition of the candidate lubricant, with regard to the specific base stocks (crude source and refinery, etc.), thickener, and additive treatment (concentration and generic chemical description of each component).

6.3 The supplier shall submit test results from a laboratory acceptable to the LS2 committee confirming that the product submitted for approval meets all of the stated requirements. Test limits shown are absolute; test precision was considered when setting them.

6.4 Completed copies of the GM Material Safety Data Sheet, GM TMC003 (see Appendix F) shall be submitted for new products or formulation changes; restricted chemicals to be handled per GM1000M.

7 INSPECTION AND REJECTION

7.1 All shipments under contract or purchase order manufactured to this specification shall be identical in every respect to the initial samples approved.

7.2 No changes in the formulation (including the base oil source, thickener, and additive package and concentration) or manufacturing process are allowed without prior approval of the LS2 committee. Lack of such notification constitutes grounds for rejection of any shipment and removal from the Approved Products List.

7.3 The supplier shall be ISO 9000 or QS 9000 certified and shall perform regular quality control checks at each location where the material is manufactured. Such quality control data shall be made available to the purchaser upon request.

7.4 The purchaser may check incoming shipments for specification compliance; the supplier assumes responsibility for incoming shipments meeting this specification without dependence upon purchaser's inspection. Non-compliance with physical and chemical requirements constitutes grounds for rejection of a shipment.

7.5 If physical or chemical analyses determine that the delivered lubricant is not in compliance with the requirements, the supplier may be held liable for loss of equipment warranty.

7.6 Infrared spectra (GM 9035P) of the incoming lubricant shipments shall not deviate significantly from that of the originally approved material.

8 COMPATIBILITY

Mixtures of the product approved and the product currently used shall pass all of the above requirements. The supplier is responsible that, when this product is mixed with a product already in use, there shall be no incompatibility or loss in operating performance. This product should not cause degradation or loss of performance of commonly used seals.

9 WASTE TREATMENT

The supplier shall be responsible to make known the processing procedures of any component of the lubricant for which waste treatability is in question.

10 GENERAL INFORMATION

10.1 Each container shall be clearly identified on the top and side. The identification shall contain the GM specification number at least 2 inches (5 cm) high on 5 gallon (20 L) or larger containers and prominently displayed on smaller containers.

10.2 All products shall be bar-coded according to AIAG 39.

10.3 This product shall be used only in accordance with applicable hazardous materials procedures in each facility.

10.4 This standard is under the control of the GM LS2 Committee. It was last revised in **2011.**

1 SCOPE These specifications define high-quality lubricating greases having premium properties and load-carrying capacity. These greases are suitable for equipment operating at slow to moderate speeds, moderate to heavy loads, and at high temperatures. **NOTE: Use caution when mixing different greases (see Section L4). Compatibility testing should be performed prior to mixing different greases.**

1.1 LG-01-4

This NLGI No. 1 grease is typically used in anti-friction and plain bearings, couplings, and slideways. This grease shall be suitable for application by either manual means or automatic dispensing systems capable of pumping NLGI No. 1 greases.

1.2 LG-02-4

This NLGI No. 2 grease is typically used in anti-friction and plain bearings, tapered roller bearings, couplings, and slideways. This grease shall be suitable for application by either manual means or pressure gun. It is not intended for application by automatic dispensing systems.

2 REFERENCED STANDARDS

AIAG 39	ASTM D 2595	DIN 51562	IP 71
ASTM D 92	ASTM D 2596	DIN 51775	IP 112
ASTM D 128	ASTM D 3527	DIN 51787	IP 121
ASTM D 217	ASTM D 4048	DIN 51802	IP 132
ASTM D 445	ASTM D 4170	DIN 51806	IP 142
ASTM D 566	ASTM D 4290	DIN 51807	IP 215
ASTM D 611	ASTM D 4425	DIN 51808	IP 220
ASTM D 942	ASTM D 5185	DIN 51811	IP 239
ASTM D 1264	ASTM D 6138	DIN 51817	ISO 2137
ASTM D 1742	ASTM E 1687	EPA SW-846	ISO 2160
ASTM D 1743	BS 188	GM TMC003	ISO 2176
ASTM D 2265	BS 4231	GM 1000M	ISO 2592
ASTM D 2266	DIN 51350	GM 9035P	ISO 2977
ASTM D 2270	DIN 51519	IP 2	ISO 3104
ASTM D 2422	DIN 51550	IP 36	ISO 3105
ASTM D 2509	DIN 51561	IP 50	ISO 3448

3 BASE OIL PHYSICAL PROPERTIES

Property Product Code, **LG-_ _ - 4-11**	Value	Test Method			
		ISO	ASTM	DIN	other
Base Oil ISO Viscosity Grade	>150	3448	D 2422	51519	BS 4231
Base Oil Viscosity at 40°C, cSt min/max	ISO grade +/- 10%	3104 3105	D 445	51550 51561	IP 71 BS 188
Base Oil Viscosity at 100°C, cSt,	Report			51562	
Base Oil Viscosity Index, min	75		D 2270		
Base Oil Flash Point, °C min	190	2592	D 92		IP 36

4 PERFORMANCE A sample of the exact grease under consideration (i.e., no changes to base oil, thickener or additive package are allowed) shall be evaluated in a certified laboratory using the following tests:

Property	Value		Test Method			
Product Code, **LG-_ _ - 4-11**	**01**	**02**	ISO	ASTM	DIN	other
Worked Penetration at 25°C min/max	310/ 340	265/ 295	2137	D 217		IP 50
Prolonged (10 000 strokes) Worked Penetration at 25°C min/max For polyurea greases: report	295/ 355	250/ 310	2137	D 217		IP 50
Dropping Point, °C min	200		2176	D 566 D 2265	51806	IP 132
Water Washout 79°C, % max	8			D 1264	51807	IP 215
Rust Prevent. Characteristics	Pass			D 1743		
Emcor Rust Test, rating, max	No. 1			D 6138	51802	IP 220
Evaporation Loss, at 100°C, % max	2			D 2595		
Oil Separation, % max	10			D 4290		
Pressure Oil Separation, %, min/max	0.5 5.0			D 1742	51817	IP 121
Centrifugal Separation, K36 Value at 50°C, max	Report			D 4425		
Four Ball Wear, scar diameter, mm max	0.5			D 2266		
Timken OK Load, kg min	18.1			D 2509	51350	IP 239
Four Ball EP Load Wear Index, kg min Weld Load, kg min	40 250			D 2596	51350	
Fretting Wear Test , mg max	10			D 4170		
Life Performance, h min	40			D 3527		
Oxidation Stability, pressure drop, kPa max	35			D 942	51808	IP 142
Cu Corrosion, 100°C, 24 h max	1b		2160	D 4048	51811	IP 112
Extracted-fluid Aniline Point, °C See Note 1 min	94		2977	D 128X1 D 611A2	51175 51787	IP 2

Note 1 — Base-oil aniline point shall not be substituted for Extracted-fluid Aniline Point. For ASTM D 128/X1: combine two, 10-g extractions or extract 20 g grease, instead of 10 g, to obtain enough sample to determine aniline point. Adjust reflux so that thimble does not fill to over-flowing. A clear sample is required for the ASTM D 611A2 Aniline Point test. If the extracted fluid is cloudy, centrifuge or filter it to obtain a clear sample.

5 CHEMICAL PROPERTIES The product shall not contain water, acid or other substances detrimental to the proper function and performance of the components or system for which it is intended. It shall be free from noxious odors or masking fragrances. Identification colorants are permitted provided such do not adversely affect performance. The following requirements shall also be met:

Property Product Code, **LG-_ _ - 4-11**	Value	Test Method			
		ISO	ASTM	DIN	other
Thickener Type & Conc.	Report				
Base Stock Requirements					Virgin or Rerefined
Total PolyNuclear Aromatics, ppm max	100				EPA SW-846 TN 8270*
Residual Elements As, B, Ca, Mn, Mg, Na, Fe, Ni, Si, Cu, Sn, Cd, Cr, Pb, Ba, Zn ppm total / ppm each max P, ppm max	 25/2 5		D 5185		
Total Chlorinated Biphenyls	Not Detectable				EPA SW-846 TN 8020*
Total Organic Halogens, ppm max	5				EPA SW-846 TN 9253*
Mutagenicity Fold Increase Mutagenicity Index, max Mutag. Potency Index, max	 Report 1 Report		E 1687		Modified Ames (or skin painting)

***or other methods as agreed upon by the LS2 committee and supplier**

6 INITIAL SOURCE APPROVAL

6.1 Initial source approval is given by the General Motors LS2 Maintenance Lubricants Standards Committee. Only sources listed in the Approved Products List have been qualified by the LS2 committee as meeting the requirements of this specification. No purchases or shipments are to be made until this approval has been completed.

6.2 The supplier shall furnish data showing the composition of the candidate lubricant, with regard to the specific base stocks (crude source and refinery, etc.), thickener, and additive treatment (concentration and generic chemical description of each component).

6.3 The supplier shall submit test results from a laboratory acceptable to the LS2 committee confirming that the product submitted for approval meets all of the stated requirements. Test limits shown are absolute; test precision was considered when setting them.

6.4 Completed copies of the GM Material Safety Data Sheet, GM TMC003 (see Appendix F) shall be submitted for new products or formulation changes; restricted chemicals to be handled per GM1000M.

7 INSPECTION AND REJECTION

7.1 All shipments under contract or purchase order manufactured to this specification shall be identical in every respect to the initial samples approved.

7.2 No changes in the formulation (including the base oil source, thickener, and additive package and concentration) or manufacturing process are allowed without prior approval of the LS2 committee. Lack of such notification constitutes grounds for rejection of any shipment and removal from the Approved Products List.

7.3 The supplier shall be ISO 9000 or QS 9000 certified and shall perform regular quality control checks at each location where the material is manufactured. Such quality control data shall be made available to the purchaser upon request.

7.4 The purchaser may check incoming shipments for specification compliance; the supplier assumes responsibility for incoming shipments meeting this specification without dependence upon purchaser's inspection. Non-compliance with physical and chemical requirements constitutes grounds for rejection of a shipment.

7.5 If physical or chemical analyses determine that the delivered lubricant is not in compliance with the requirements, the supplier may be held liable for loss of equipment warranty.

7.6 Infrared spectra (GM 9035P) of the incoming lubricant shipments shall not deviate significantly from that of the originally approved material.

8 COMPATIBILITY

Mixtures of the product approved and the product currently used shall pass all of the above requirements. The supplier is responsible that, when this product is mixed with a product already in use, there shall be no incompatibility or loss in operating performance. This product should not cause degradation or loss of performance of commonly used seals.

9 WASTE TREATMENT

The supplier shall be responsible to make known the processing procedures of any component of the lubricant for which waste treatability is in question.

10 GENERAL INFORMATION

10.1 Each container shall be clearly identified on the top and side. The identification shall contain the GM specification number at least 2 inches (5 cm) high on 5 gallon (20 L) or larger containers and prominently displayed on smaller containers.

10.2 All products shall be bar-coded according to AIAG 39.

10.3 This product shall be used only in accordance with applicable hazardous materials procedures in each facility.

10.4 This standard is under the control of the GM LS2 Committee. It originated in **2011**.

GM LUBRICANT STANDARD NO. LH-02-1-11, LH-03-1-11, LH-04-1-11, LH-06-1-11
ANTIWEAR HYDRAULIC OIL

1 SCOPE The fluids defined by this specification are high-quality, antiwear hydraulic oils formulated with additives to provide good oxidation resistance, corrosion protection, demulsibility, and foam stability. These materials will be formulated with severely solvent refined or severely hydrotreated base stocks. They are intended for use in hydraulic pump systems operating at 90% of the rated pump pressure or at pressures over 1000 psi (70 Bar). These standards meet or exceed SAE MS 1004 and the appropriate ISO HM-standards.

2 REFERENCED STANDARDS

AIAG 39	ASTM E 1687	DIN 53505	ISO HM-68
ASTM D 92	BS 188	DIN 53521	ISO 868
ASTM D 97	BS 4231	DIN 53538	ISO 1817
ASTM D 130	BS 4459	EPA SW-846	ISO 2160
ASTM D 287	BS 4832	GM TMC003	ISO 2592
ASTM D 445	CETOP RP81H	GM 1000M	ISO 2909
ASTM D 471	Denison P-46	GM 9035P	ISO 3016
ASTM D 664	Denison T5D	IP 15	ISO 3104
ASTM D 665	Denison T6C	IP 19	ISO 3105
ASTM D 892	Denison T6H2OC	IP 36	ISO 3448
ASTM D 943	DIN 51354	IP 71	ISO 4263
ASTM D 974	DIN 51381	IP 135	ISO 4406
ASTM D 1401	DIN 51389	IP 139	ISO 6072
ASTM D 2070	DIN 51519	IP 146	ISO 6614
ASTM D 2270	DIN 51550	IP 154	ISO 6618
ASTM D 2422	DIN 51558	IP 166	ISO 7120
ASTM D 2619	DIN 51561	IP 177	ISO 7619
ASTM D 3427	DIN 51562	IP 226	ISO 11171
ASTM D 4628	DIN 51566	IP 278	SAE MS 1004
ASTM D 4951	DIN 51569	IP 281	TP-02100
ASTM D 5133	DIN 51585	IP 313	Vickers
ASTM D 5182	DIN 51587	IP 334	M-2952-S
ASTM D 5185	DIN 51599	ISO HM-32	
ASTM D 6304	DIN 51759	ISO HM-46	

3 PHYSICAL PROPERTIES

Property	Value				Test Method			
Product Code, **LH-_ _ - 1-11**	**02**	**03**	**04**	**06**	ISO	ASTM	DIN	Other
ISO Viscosity Grade	22	32	46	68	3448	D 2422	51519	BS 4231
Kinematic Viscosity at 40°C, cSt min	19.8	28.8	41.4	61.2	3104	D 445	51550	IP 71
Kinematic Viscosity at 40°C, cSt max	24.2	35.2	50.6	74.8	3105		51561	BS 188
Kinematic Viscosity at 100°C, cSt min	4.1	5.0	6.1	7.8			51562	
Kinematic Viscosity at 0°C, cSt max	300	420	780	1400		D5133	51569	
Viscosity Index, min	95				2909	D 2270		IP 226 BS 4459
Pour Point, °C max	-21	-18	-15	-12	3016	D 97		IP 15
Flash Point, °C min	175	190	190	195	2592	D 92		IP 36
Cu Corrosion (3h at 100°C), max	1b				2160	D 130	51759	IP 154

4 PERFORMANCE A sample of the exact oil under consideration (i.e., no changes to base oil or additive package are allowed*) shall be evaluated in a certified laboratory using the following tests:

Property	Value				Test Method			
Product Code, **LH-_ _ - 1-11**	**02**	**03**	**04**	**06**	ISO	ASTM	DIN	Other
Thermal Stability Acid Number Change, % max Vis. Change, 40/100°C, % max Sludge, mg/100 ml max Cu Rod Color (Cin. Mil.), max Copper Weight Loss, mg max Steel Rod Color (Cin. Mil.)	+/- 50 5 25 5 10 No Discoloration					D 2070		
Oxidation Stability, h to TAN=2, min	1500				4263	D 943	51587	
Rust Preventing Characteristics	Pass (no Rust)				7120	D 665B	51585	IP 135
Water Separability, 30 min., max	40/40/0				6614	D 1401	51599	IP 19
Foaming Tendency (per D 892) Sequence I, II, and III, max	50/0					D 892	51566 E	IP 146
Vickers 35VQ25 Pump Test* Vane Wear, mg max Ring Wear, mg max	10 50						51389	Vickers M-2952-S IP 281
Cleanliness, as Received, max	19/16/13				4406 11171			
Denison Vane Pump Test*# Vane Wear, in. max Cam Ring	0.010 no distress							Denison T5D,T6C
Denison Piston Pump Test*#	no smearing, scoring, scratching, bronze transfer							Denison P-46 or
Denison Vane, Piston Pump Test*#	Denison HFO approval							Denison T6H2OC
Filterability Without Water, sec. Max With 2% Water	600 not to exceed double the time without water							TP- 02100
Hydrolytic Stability Copper Weight Loss, mg/cm2 Acidity of Water Layer, mg KOH max	0.20 4					D 2619		
Compatibility With SRE-NBR 1 Seals **(DIN 53538)** (168 h, 100°C) or other seals and limits as agreed upon Volume change, % Shore A hardness change	0 to 15 0 to -8	0 to 12 0 to -7	0 to 10 0 to -6		1817 868 6072 7619	D 471	53521 53505	CETOP RP 81H IP 278 BS 4832
Air Release Properties at 50°C, minutes, max	5		10			D 3427	51381	IP 313
FZG Test, stages min failure load stage	10					D 5182	51354	IP 166 IP 334

* Pump wear tests may sometimes be extrapolated from a lighter ISO viscosity grade product to a heavier grade product, provided there have been no changes in additive package or base stock source.
# The T6H2OC can be run in lieu of T5D or T6C and P-46

5 CHEMICAL PROPERTIES The product shall not contain water, acid, particulates, or other substances detrimental to the proper function and performance of the components or system for which it is intended. It shall be free from noxious odors or masking fragrances. Identification colorants are permitted provided such do not adversely affect performance. The following requirements shall also be met:

Property	Value	Test Method			
	for all product codes:	ISO	ASTM	DIN	Other
API Gravity	Report		D 287		
Acid Number, max	1.0	6618	D 664 D 974	5155	IP 139 IP 177
Zinc Compound in Final Product, ppm, max	1000		D 4628 D 4951		
Water, as Received, ppm max	200	3733	D 6304[#]		
Base Stock Requirements					Virgin or Rerefined
Tot. PolyNuclear Aromatics, ppm max	100				EPA SW-846 TN 8270*
Residual Elements (As, B, Ca, Mn, Mg, Na, Fe, Ni, Si, Cu, Sn, Cd, Cr, Pb, Ba, Zn), ppm max total/ each P, ppm max	 25/2 5		D 5185		
Total Chlorinated Biphenyls	Not Detectable				EPA SW-846 TN 8082*
Total Organic Halogens, ppm max	5				EPA SW-846 TN 9253*
Mutagenicity Fold Increase Mutagenicity Index, max Mutag. Potency Index, max	 Report 1 Report		E 1687		Modified Ames (or skin painting)

*** or other methods as agreed upon by the LS2 committee and supplier**

[#] This method is subject to interferences that can sometimes cause erroneously high results to be reported. In the event that an analysis produces a value for water content that exceeds the maximum specification limit, it is recommended that the plant work with the supplier to recheck the results. Other methods, such as distillation, FTIR, etc., may be used as agreed upon by the plant and supplier.

6 INITIAL PRODUCT APPROVAL

6.1 Initial product approval is given by the General Motors LS2 Maintenance Lubricants Standards Committee. Only sources listed in the Approved Product List have been qualified by the LS2 committee as meeting the requirements of this specification. No purchases or shipments are to be made until this approval has been completed.

6.2 The supplier shall furnish data showing the composition of the candidate lubricant, with regard to both the specific base stocks (crude source and refinery, etc.) and additive treatment (concentration and generic chemical description of each component).

6.3 The supplier shall submit test results from a laboratory acceptable to the LS2 committee confirming that the product submitted for approval meets all of the stated requirements. Test limits shown are absolute; test precision was considered when setting them.

6.4 Completed copies of the GM Material Safety Data Sheet, GM TMC003 (see Appendix F) shall be submitted for new products or formulation changes; restricted chemicals to be handled per GM1000M.

7 INSPECTION AND REJECTION

7.1 All shipments under contract or purchase order manufactured to this specification shall be identical in every respect to the product approved.

7.2 No changes in the formulation (including both base oil source and additive package and concentration) or manufacturing process are allowed without prior approval of the LS2 committee. Lack of such notification constitutes grounds for rejection of any shipment and removal from the Approved Product List.

7.3 The supplier shall be ISO 9000 or QS 9000 certified and shall perform regular quality control checks at each location where the material is manufactured. Such quality control data shall be made available to the purchaser upon request.

7.4 The purchaser may check incoming shipments for specification compliance; the supplier is responsible for incoming shipments meeting this specification without dependence upon purchaser's inspection. Non-compliance to physical and chemical requirements constitutes grounds for rejection of a shipment.

7.5 If physical or chemical analyses determine that the delivered lubricant is not in compliance with the requirements, the supplier may be held liable for loss of equipment warranty.

7.6 Infrared spectra (GM 9035P) of the incoming lubricant shipments shall not deviate significantly from that of the originally approved material.

8 COMPATIBILITY

Mixtures of the product approved and the product currently used shall pass all of the above requirements. The supplier is responsible that, when this product is mixed with a product already in use, there shall be no incompatibility or loss in operating performance. This product should not cause degradation or loss of performance of commonly used seals.

9 WASTE TREATMENT

The supplier shall be responsible to make known the processing procedures of any component of the lubricant for which waste treatability is in question.

10 GENERAL INFORMATION

10.1 Each container shall be clearly identified on the top and side. The identification shall contain the GM specification number at least 2 inches (5 cm) high on 5 gallon (20 L) or larger containers and prominently displayed on smaller containers.

10.2 All products shall be bar-coded according to AIAG 39.

10.3 This product shall be used only in accordance with applicable hazardous materials procedures in each facility.

10.4 This standard is under the control of the GM LS2 Committee. It was last revised in **2011**.

GM LUBRICANT STANDARD NO. LH-02-2-11, LH-03-2-11, LH-04-2-11, LH-06-2-11
ZINC-FREE ANTIWEAR HYDRAULIC OIL

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1 SCOPE The fluids defined by this specification are high-quality, antiwear hydraulic oils formulated with additives to provide good oxidation resistance, corrosion protection, demulsibility, and foam stability. These materials will be formulated with severely solvent refined or severely hydrotreated base stocks. They are intended for use in hydraulic pump systems operating at 90% of the rated pump pressure or at pressures over 1000 psi. These fluids are particularly suited to applications where wastewater or other requirements prohibit zinc, or where compatibility between the hydraulic oil and coolants is a concern. These standards meet or exceed SAE MS 1004 and the appropriate ISO HM- standards.

2 REFERENCED STANDARDS

AIAG 39	ASTM E 1687	DIN 53505	ISO HM-68
ASTM D 92	BS 188	DIN 53521	ISO 868
ASTM D 97	BS 4231	DIN 53538	ISO 1817
ASTM D 130	BS 4459	EPA SW-846	ISO 2160
ASTM D 287	BS 4832	GM TMC003	ISO 2592
ASTM D 445	CETOP RP81H	GM 1000M	ISO 2909
ASTM D 471	Denison P-46	GM 9035P	ISO 3016
ASTM D 664	Denison T5D	IP 15	ISO 3104
ASTM D 665	Denison T6C	IP 19	ISO 3105
ASTM D 892	Denison T6H2OC	IP 36	ISO 3448
ASTM D 943	DIN 51354	IP 71	ISO 4263
ASTM D 974	DIN 51381	IP 135	ISO 4406
ASTM D 1401	DIN 51389	IP 139	ISO 6072
ASTM D 2070	DIN 51519	IP 146	ISO 6614
ASTM D 2270	DIN 51550	IP 154	ISO 6618
ASTM D 2422	DIN 51558	IP 166	ISO 7120
ASTM D 2619	DIN 51561	IP 177	ISO 7619
ASTM D 3427	DIN 51562	IP 226	ISO 11171
ASTM D 4628	DIN 51566	IP 278	SAE MS 1004
ASTM D 4951	DIN 51569	IP 281	TP-02100
ASTM D 5133	DIN 51585	IP 313	Vickers
ASTM D 5182	DIN 51587	IP 334	M-2952-S
ASTM D 5185	DIN 51599	ISO HM-32	
ASTM D 6304	DIN 51759	ISO HM-46	

3 PHYSICAL PROPERTIES

Property		Value				Test Method			
Product Code, **LH-_ _ - 2-11**		**02**	**03**	**04**	**06**	ISO	ASTM	DIN	Other
ISO Viscosity Grade		22	32	46	68	3448	D 2422	51519	BS 4231
Kinematic Viscosity at 40°C, cSt	min	19.8	28.8	41.4	61.2	3104	D 445	51550	IP 71
	max	24.2	35.2	50.6	74.8	3105		51561	BS 188
Kinematic Viscosity at 100°C, cSt	min	4.1	5.0	6.1	7.8			51562	
Kinematic Viscosity at 0°C, cSt	max	300	420	780	1400		D5133	51569	
Viscosity Index, min		95				2909	D 2270		IP 226 BS 4459
Pour Point, °C	max	-21	-18	-15	-12	3016	D 97		IP 15
Flash Point, °C	min	175	190	190	195	2592	D 92		IP 36
Cu Corrosion (3h at 100°C), max		1b				2160	D 130	51759	IP 154

4 PERFORMANCE A sample of the exact oil under consideration (i.e., no changes to base oil or additive package are allowed*) shall be evaluated in a certified laboratory using the following tests:

Property	Value				Test Method			
Product Code, **LH-_ _ - 1-11**	**02**	**03**	**04**	**06**	ISO	ASTM	DIN	Other
Thermal Stability Acid Number Change, % max Vis. Change, 40/100°C, % max Sludge, mg/100 ml max Cu Rod Color (Cin. Mil.), max Copper Weight Loss, mg max Steel Rod Color (Cin. Mil.)	+/- 50 5 25 5 10 No Discoloration					D 2070		
Oxidation Stability, h to TAN=2, min	1500				4263	D 943	51587	
Rust Preventing Characteristics	Pass (no Rust)				7120	D 665B	51585	IP 135
Water Separability, 30 min., max	40/40/0				6614	D 1401	51599	IP 19
Foaming Tendency (per D 892) Sequence I, II, and III, max	50/0					D 892	51566 E	IP 146
Vickers 35VQ25 Pump Test* Vane Wear, mg max Ring Wear, mg max	10 50						51389	Vickers M-2952-S IP 281
Cleanliness, as Received, max	19/16/13				4406 11171			
Denison Vane Pump Test*# Vane Wear, in. max Cam Ring	0.010 no distress							Denison T5D,T6C
Denison Piston Pump Test*#	no smearing, scoring, scratching, bronze transfer							Denison P-46 or
Denison Vane, Piston Pump Test*#	Denison HFO approval							Denison T6H2OC
Filterability Without Water, sec. Max With 2% Water	600 not to exceed double the time without water							TP-02100
Hydrolytic Stability Copper Weight Loss, mg/cm2 Acidity of Water Layer, mg KOH max	0.20 4					D 2619		
Compatibility With SRE-NBR 1 Seals **(DIN 53538)** (168 h, 100°C) or other seals and limits as agreed upon Volume change, % Shore A hardness change	0 to 15 0 to -8	0 to 12 0 to -7	0 to 10 0 to -6		1817 868 6072 7619	D 471	53521 53505	CETOP RP 81H IP 278 BS 4832
Air Release Properties at 50°C, minutes, max	5		10			D 3427	51381	IP 313
FZG Test, stages min failure Load stage	10					D 5182	51354	IP 166 IP 334

* Pump wear tests may sometimes be extrapolated from a lighter ISO viscosity grade product to a heavier grade product, provided there have been no changes in additive package or base stock source.
# The T6H2OC can be run in lieu of T5D or T6C and P-46

4 PERFORMANCE (CONT.)

Property	Value	Test Method			
	for all product codes:	ISO	ASTM	DIN	Other
Effects on Coolant	some plant or lab trials must be run to show an improvement in coolant and tool life when aqueous metal removal fluids are contaminated with this fluid compared to that with a like amount of a zinc-containing hydraulic oil				

5 CHEMICAL PROPERTIES The product shall not contain water, acid, particulates, or other substances detrimental to the proper function and performance of the components or system for which it is intended. It shall be free from noxious odors or masking fragrances. Identification colorants are permitted provided such do not adversely affect performance. The following requirements shall also be met:

Property	Value	Test Method			
	for all product codes:	ISO	ASTM	DIN	Other
API Gravity	Report		D 287		
Acid Number, max	1.0	6618	D 664 D 974	5155	IP 139 IP 177
Zinc Compound in Final Product, ppm, max	10		D 4628 D 4951		
Water, as Received, ppm max	200	3733	D 6304[#]		
Base Stock Requirements					Virgin or Rerefined
Tot. PolyNuclear Aromatics, ppm max	100				EPA SW-846 TN 8270*
Residual Elements (As, B, Ca, Mn, Mg, Na, Fe, Ni, Si, Cu, Sn, Cd, Cr, Pb, Ba, Zn), ppm max total/ each P, ppm max	 25/2 5		D 5185		
Total Chlorinated Biphenyls	Not Detectable				EPA SW-846 TN 8082*
Total Organic Halogens, ppm max	5				EPA SW-846 TN 9253*
Mutagenicity Fold Increase Mutagenicity Index, max Mutag. Potency Index, max	 Report 1 Report		E 1687		Modified Ames (or skin painting)

* or other methods as agreed upon by the LS2 committee and supplier

[#] This method is subject to interferences that can sometimes cause the reporting of erroneously high results. If an analysis produces a value for water content that exceeds the maximum limit, it is recommended that the plant work with the supplier to recheck the results. Other methods, such as distillation, FTIR, etc., may be used as agreed upon by the plant and supplier.

6 INITIAL PRODUCT APPROVAL

6.1 Initial product approval is given by the General Motors LS2 Maintenance Lubricants Standards Committee. Only sources listed in the Approved Products List have been qualified by the LS2 committee as meeting the requirements of this specification. No purchases or shipments are to be made until this approval has been completed.

6.2 The supplier shall furnish data showing the composition of the candidate lubricant, with regard to both the specific base stocks (crude source and refinery, etc.) and additive treatment (concentration and generic chemical description of each component).

6.3 The supplier shall submit test results from a laboratory acceptable to the LS2 committee confirming that the product submitted for approval meets all of the stated requirements. Test limits shown are absolute; test precision was considered when setting them.

6.4 Completed copies of the GM Material Safety Data Sheet, GM TMC003 (see Appendix F) shall be submitted for new products or formulation changes; restricted chemicals to be handled per GM1000M.

7 INSPECTION AND REJECTION

7.1 All shipments under contract or purchase order manufactured to this specification shall be identical in every respect to the product approved.

7.2 No changes in the formulation (including both base oil source and additive package and concentration) or manufacturing process are allowed without prior approval of the LS2 committee. Lack of such notification constitutes grounds for rejection of any shipment and removal from the Approved Products List.

7.3 The supplier shall be ISO 9000 or QS 9000 certified and shall perform regular quality control checks at each location where the material is manufactured. Such quality control data shall be made available to the purchaser upon request.

7.4 The purchaser may check incoming shipments for specification compliance; the supplier is responsible for incoming shipments meeting this specification without dependence upon purchaser's inspection. Non-compliance to physical and chemical requirements constitutes grounds for rejection of a shipment.

7.5 If physical or chemical analyses determine that the delivered lubricant is not in compliance with the requirements, the supplier may be held liable for loss of equipment warranty.

7.6 Infrared spectra (GM 9035P) of the incoming lubricant shipments shall not deviate significantly from that of the originally approved material.

8 COMPATIBILITY

Mixtures of the product approved and the product currently used shall pass all of the above requirements. The supplier is responsible that, when this product is mixed with a product already in use, there shall be no incompatibility or loss in operating performance. This product should not cause degradation or loss of performance of commonly used seals.

9 WASTE TREATMENT

The supplier shall be responsible to make known the processing procedures of any component of the lubricant for which waste treatability is in question.

10 GENERAL INFORMATION

10.1 Each container shall be clearly identified on the top and side. The identification shall contain the GM specification number at least 2 inches (5 cm) high on 5 gallon (20 L) or larger containers and prominently displayed on smaller containers.

10.2 All products shall be bar-coded according to AIAG 39.

10.3 This product shall be used only in accordance with applicable hazardous materials procedures in each facility.

10.4 This standard is under the control of the GM LS2 Committee. It was last revised in **2011**.

GM LUBRICANT STANDARD NO. LJ-03-1-11, LJ-04-1-11, LJ-06-1-11, LJ-10-1-11
COMPRESSOR/TURBINE OILS

1 SCOPE The fluids defined by this specification are high-quality oils formulated with additives to provide good oxidation resistance, corrosion protection, demulsibility and foam stability. These materials are to be formulated with severely solvent-refined or severely hydrotreated base stocks. They meet the requirements of SAE MS1010 for TSA oils and MS1003 for DAA and DAB fluids. They are intended for use in compressors and turbines**.** **Note: There are different types of compressor oils, only some covered by LS2. Pay close attention to equipment builder recommendations when selecting a compressor oil.**

2 REFERENCED STANDARDS

AIAG 39	ASTM D 5185	DIN 53538	ISO 2592
ASTM D 92	ASTM E 1687	EPA SW-846	ISO 2909
ASTM D 97	BS 188	GM TMC003	ISO 3016
ASTM D 130	BS 4231	GM 1000M	ISO 3104
ASTM D 189	BS 4832	GM 9035P	ISO 3105
ASTM D 287	CETOP RP81H	IP 15	ISO 3448
ASTM D 445	DIN 51519	IP 19	ISO 4263
ASTM D 471	DIN 51550	IP 36	ISO 4406
ASTM D 611	DIN 51561	IP 71	ISO 6072
ASTM D 665	DIN 51562	IP 135	ISO 6614
ASTM D 892	DIN 51566	IP 146	ISO 7120
ASTM D 943	DIN 51585	IP 154	ISO 7619
ASTM D 1401	DIN 51587	IP 226	ISO 11171
ASTM D 2070	DIN 51599	IP 278	SAE MS1003
ASTM D 2270	DIN 51759	ISO 868	SAE MS1010
ASTM D 2422	DIN 53505	ISO 1817	
ASTM D 4172	DIN 53521	ISO 2160	

3 PHYSICAL PROPERTIES

Property	Value				Test Method			
Product Code, **LJ-_ _ - 1-11**	**03**	**04**	**06**	**10**	ISO	ASTM	DIN	other
ISO Viscosity Grade	32	46	68	100	3448	D 2422	51519	BS 4231
Kinematic Viscosity min	28.8	41.4	61.2	90.0	3104	D 445	51550	IP 71
at 40°C, cSt max	35.2	50.6	74.8	110	3105		51561	BS 188
Kin. Viscosity at 100°C, cSt	report						51562	
Viscosity Index, min	95				2909	D 2270		IP 226
Pour Point, °C, max	-10				3016	D 97		IP 15
Flash Point, °C, min	190	190	190	195	2592	D 92		IP 36

4 PERFORMANCE A sample of the exact oil under consideration (i.e., no changes to base oil or additive package are allowed*) shall be evaluated in a certified laboratory using the following tests:

Property	Value	Test Method			
	for all product codes:	ISO	ASTM	DIN	Other
Cu Corrosion (3h at 100°C), max	1b	2160	D 130	51759	IP 154
Thermal Stability			D 2070		
Acid Number Change, % max	+/- 50 (or 0.15)				
Vis. Change, 40/100°C, % max	5				
Sludge, mg/100 ml max	25				
Cu Rod Color (Cin. Mil.), max	5				
Copper Weight Loss, mg max	10				
Steel Rod Color (Cin. Mil.)	No Discoloration				
Oxidation Stability, h min TAN=2	2000	4263	D 943	51587	

4 PERFORMANCE (CONT.)

Property	Value	Test Method			
	for all product codes:	ISO	ASTM	DIN	Other
Rust Preventing Characteristics	Pass (no Rust)	7120	D 665B	51585	IP 135
Water Separability, 30 min., max	40/40/0	6614	D 1401	51599	IP 19
Foaming Tendency (per D 892) Sequence I, II, and III, max	50/0		D 892	51566 E	IP 146
Cleanliness, as Received, max	20/17/14	4406 11171			
Four-Ball Wear (40 kg load) Wear Scar Diameter, mm max	0.40		D 4172		
Aniline Point	Report		D 611		
Compatibility With SRE-NBR 1 Seals **(DIN 53538)** (168 h, 100°C) or other seals and limits as agreed upon) Volume change, % Shore A hardness change	 -10 to 10 -7 to 10	1817 868 6072 7619	D 471	53521 53505	CETOP RP 81H IP 278 BS 4832

5 CHEMICAL PROPERTIES The product shall not contain water, acid, particulates, or other substances detrimental to the proper function and performance of the components or system for which it is intended. It shall be free from noxious odors or masking fragrances. Identification colorants are permitted provided such do not adversely affect performance. The following requirements shall also be met:

Property	Value	Test Method			
	for all product codes:	ISO	ASTM	DIN	Other
API Gravity	Report		D 287		
Conradson Carbon Residue, % Max	0.05		D 189		
Base Stock Requirements					Virgin or Rerefined
Tot. PolyNuclear Aromatics, ppm max	100				EPA SW-846 TN 8270*
Residual Elements (As, B, Ca, Mn, Mg, Na, Fe, Ni, Si, Cu, Sn, Cd, Cr, Pb, Ba, Zn), ppm max total/ each P, ppm max	 25/2 5		D 5185		
Total Chlorinated Biphenyls	Not Detectable				EPA SW-846 TN 8082*
Total Organic Halogens, ppm Max	5				EPA SW-846 TN 9253*
Mutagenicity Fold Increase Mutagenicity Index, max Mutag. Potency Index, max	 Report 1 Report		E 1687		Modified Ames (or skin painting)

*** or other methods as agreed upon by the LS2 Committee and supplier**

6 INITIAL SOURCE APPROVAL

6.1 Initial source approval is given by the General Motors LS2 Maintenance Lubricants Standards Committee. Only sources listed in the Approved Product List have been qualified by the LS2 committee as meeting the requirements of this specification. No purchases or shipments are to be made until this approval has been completed.

6.2 The supplier shall furnish data showing the composition of the candidate lubricant, with regard to both the specific base stocks (crude source and refinery, etc.) and additive treatment (concentration and generic chemical description of each component).

6.3 The supplier shall submit test results from a laboratory acceptable to the LS2 committee confirming that the product submitted for approval meets all of the stated requirements. Test limits shown are absolute; test precision was considered when setting them.

6.4 Completed copies of the GM Material Safety Data Sheet, GM TMC003 (see Appendix F) shall be submitted for new products or formulation changes; restricted chemicals to be handled per GM1000M

7 INSPECTION AND REJECTION

7.1 All shipments under contract or purchase order manufactured to this specification shall be identical in every respect to the product approved.

7.2 No changes in the formulation (including both base oil source and additive package and concentration) or manufacturing process are allowed without prior approval of the LS2 committee. Lack of such notification constitutes grounds for rejection of any shipment and removal from the Approved Products List.

7.3 The supplier shall be ISO 9000 or QS 9000 certified and shall perform regular quality control checks at each location where the material is manufactured. Such quality control data shall be made available to the purchaser upon request.

7.4 The purchaser may check incoming shipments for specification compliance; the supplier is responsible for incoming shipments meeting this specification without dependence upon purchaser's inspection. Non-compliance to physical and chemical requirements constitutes grounds for rejection of a shipment.

7.5 If physical or chemical analyses determine that the delivered lubricant is not in compliance with the requirements, the supplier may be held liable for loss of equipment warranty.

7.6 Infrared spectra (GM 9035P) of the incoming lubricant shipments shall not deviate significantly from that of the originally approved material.

8 COMPATIBILITY

Mixtures of the product approved and the product currently used shall pass all of the above requirements. The supplier is responsible that, when this product is mixed with a product already in use, there shall be no incompatibility or loss in operating performance. This product should not cause degradation or loss of performance of commonly used seals.

9 WASTE TREATMENT

The supplier shall be responsible to make known the processing procedures of any component of the lubricant for which waste treatability is in question.

10 GENERAL INFORMATION

10.1 Each container shall be clearly identified on the top and side. The identification shall contain the GM specification number at least 2 inches (5 cm) high on 5 gallon (20 L) or larger containers and prominently displayed on smaller containers.

10.2 All products shall be bar-coded according to AIAG 39.

10.3 This product shall be used only in accordance with applicable hazardous materials procedures in each facility.

10.4 This standard is under the control of the GM LS2 Committee. It was last revised in **2011**.

GM LUBRICANT STANDARD NO. LJ-03-2-11, LJ-04-2-11, LJ-06-2-11, LJ-10-2-11
SYNTHETIC COMPRESSOR/TURBINE OIL – ESTER BASED

1 SCOPE The fluids defined by this specification are oils formulated to provide good corrosion protection, demulsibility, foam stability and oxidation resistance for long service life and deposit-free operation. The materials are to be formulated primarily with polyol and dibasic acid esters or other suitable ester base stocks, such that they will have low volatility, high thermal stability and flash and autoignition temperatures, and natural film strength and lubricity. They meet the requirements of SAE MS1010 for TSC oils and MS1003 for DAJ fluids. Typical uses are: rotary vane and screw compressors, reciprocating compressors, and circulating systems where operating temperatures are extreme. **Note: There are different types of compressor oils, only some covered by LS2. Pay close attention to equipment builder recommendations when selecting a compressor oil.**

2 REFERENCED STANDARDS

AIAG 39	ASTM D 4172	DIN 53538	ISO 2909
ASTM D 92	ASTM D 5185	GM TMC003	ISO 3016
ASTM D 97	BS 188	GM 1000M	ISO 3104
ASTM D 130	BS 4231	GM 9035P	ISO 3105
ASTM D 189	BS 4832	IP 15	ISO 3448
ASTM D 287	CETOP RP81H	IP 19	ISO 4263
ASTM D 445	DIN 51519	IP 36	ISO 4406
ASTM D 471	DIN 51550	IP 71	ISO 6072
ASTM D 611	DIN 51561	IP 226	ISO 6614
ASTM D 665	DIN 51562	IP 135	ISO 7120
ASTM D 892	DIN 51566	IP 146	ISO 7619
ASTM D 943	DIN 51585	IP 154	ISO 11171
ASTM D 1401	DIN 51587	IP 278	SAE MS1003
ASTM D 2070	DIN 51599	ISO 868	SAE MS1010
ASTM D 2155	DIN 51759	ISO 1817	
ASTM D 2270	DIN 53505	ISO 2160	
ASTM D 2422	DIN 53521	ISO 2592	

3 PHYSICAL PROPERTIES

Property	Value				Test Method			
Product Code, **LJ-_ _ - 2-11**	**03**	**04**	**06**	**10**	ISO	ASTM	DIN	Other
ISO Viscosity Grade	32	46	68	100	3448	D 2422	51519	BS 4231
Kinematic Viscosity min	28.8	41.4	61.2	90.0	3104	D 445	51550	IP 71
At 40°C, cSt max	35.2	50.6	74.8	110	3105		51561	BS 188
Kin. Viscosity at 100°C, cSt	Report						51562	
Viscosity Index, min	85				2909	D 2270		IP 226
Pour Point, °C, max	-20			-15	3016	D 97		IP 15
Flash Point, °C, min	200				2592	D 92		IP 36

4 PERFORMANCE A sample of the exact oil under consideration (i.e., no changes to base oil or additive package are allowed*) shall be evaluated in a certified laboratory using the following tests:

Property	Value	Test Method			
	for all product codes:	ISO	ASTM	DIN	Other
Cu Corrosion (3h at 100°C), max	1b	2160	D 130	51759	IP 154
Oxidation Stability, h to **Δ**TAN=2 Run without water	Report	4263	D 943	51587	
Rust Preventing Characteristics	Pass (no Rust)	7120	D 665B	51585	IP 135
Water Separability, 30 min., max	40/37/3	6614	D 1401	51599	IP 19

4 PERFORMANCE (CONT.)

Property	Value	Test Method			
	for all product codes:	ISO	ASTM	DIN	Other
Foaming Tendency (per D 892) Sequence I, II, and III, max	 50/0		D 892	51566 E	IP 146
Thermal Stability Acid Number Change, % max Vis. Change, 40/100°C, % max Sludge, mg/100 ml max Cu Rod Color (Cin. Mil.), max Copper Weight Loss, mg max Steel Rod Color (Cin. Mil.)	 +/- 50 (or 0.15, abs.) 5 25 5 10 No Discoloration		D 2070		
Cleanliness, as Received, max	20/17/14	4406 11171			
Four-Ball Wear (40 kg load) Wear Scar Diameter, mm max	 0.40		D 4172		
Aniline Point	Report		D 611		
Compatibility With SRE-NBR 1 Seals **(DIN 53538)** (168 h, 100°C) or other seals and limits as agreed upon) Volume change, % Shore A hardness change	 -10 to 10 -7 to 10	1817 868 6072 7619	D 471	53521 53505	CETOP RP 81H IP 278 BS 4832

5 CHEMICAL PROPERTIES The product shall not contain water, acid, particulates, or other substances detrimental to the proper function and performance of the components or system for which it is intended. It shall be free from noxious odors or masking fragrances. Identification colorants are permitted provided such do not adversely affect performance. The following requirements shall also be met:

Property	Value	Test Method			
	for all product codes:	ISO	ASTM	DIN	Other
API Gravity	Report		D 287		
Autoignition Temperature, °C min	350		D 2155		
Conradson Carbon Residue, % Max	0.05		D 189		
Base Stock Requirements					
Residual Elements (As, B, Ca, Mn, Mg, Na, Fe, Ni, Si, Cu, Sn, Cd, Cr, Pb, Ba, Zn), ppm max total/ each P, ppm max	 25/2 5		D 5185		

6 INITIAL SOURCE APPROVAL

6.1 Initial source approval is given by the General Motors LS2 Maintenance Lubricants Standards Committee. Only sources listed in the Approved Products List have been qualified by the LS2 committee as meeting the requirements of this specification. No purchases or shipments are to be made until this approval has been completed.

6.2 The supplier shall furnish data showing the composition of the candidate lubricant, with regard to both the specific base stocks (crude source and refinery, etc.) and additive treatment (concentration and generic chemical description of each component).

6.3 The supplier shall submit test results from a laboratory acceptable to the LS2 committee confirming that the product submitted for approval meets all of the stated requirements. Test limits shown are absolute; test precision was considered when setting them.

6.4 Completed copies of the GM Material Safety Data Sheet, GM TMC003 (see Appendix F) shall be submitted for new products or formulation changes; restricted chemicals to be handled per GM1000M

7 INSPECTION AND REJECTION

7.1 All shipments under contract or purchase order manufactured to this specification shall be identical in every respect to the product approved.

7.2 No changes in the formulation (including both base fluid and additive package and concentration) or manufacturing process are allowed without prior approval of the LS2 committee. Lack of such notification constitutes grounds for rejection of any shipment and removal from the Approved Product List.

7.3 The supplier shall be ISO 9000 or QS 9000 certified and shall perform regular quality control checks at each location where the material is manufactured. Such quality control data shall be made available to the purchaser upon request.

7.4 The purchaser may check incoming shipments for specification compliance; the supplier is responsible for incoming shipments meeting this specification without dependence upon purchaser's inspection. Non-compliance to physical and chemical requirements constitutes grounds for rejection of a shipment.

7.5 If physical or chemical analyses determine that the delivered lubricant is not in compliance with the requirements, the supplier may be held liable for loss of equipment warranty.

7.6 Infrared spectra (GM 9035P) of the incoming lubricant shipments shall not deviate significantly from that of the originally approved material.

8 COMPATIBILITY

Mixtures of the product approved and the product currently used shall pass all of the above requirements. The supplier is responsible that, when this product is mixed with a product already in use, there shall be no incompatibility or loss in operating performance. This product should not cause degradation or loss of performance of commonly used seals.

9 WASTE TREATMENT

The supplier shall be responsible to make known the processing procedures of any component of the lubricant for which waste treatability is in question.

10 GENERAL INFORMATION

10.1 Each container shall be clearly identified on the top and side. The identification shall contain the GM specification number at least 2 inches (5 cm) high on 5 gallon (20 L) or larger containers and prominently displayed on smaller containers.

10.2 All products shall be bar-coded according to AIAG 39.

10.3 This product shall be used only in accordance with applicable hazardous materials procedures in each facility.

10.4 This standard is under the control of the GM LS2 Committee. It originated in **2011**

GM LUBRICANT STANDARD NO. LJ-03-3-11, LJ-04-3-11, LJ-06-3-11, LJ-10-3-11
SYNTHETIC COMPRESSOR/TURBINE OILS – NON ESTER

1 SCOPE The fluids defined by this specification are oils formulated to provide good corrosion protection, demulsibility, foam stability and oxidation resistance for long service. The materials are to be formulated primarily with poly-alpha olefins or other non-ester synthetic base stocks, such that they will have low volatility, high thermal stability and flash point, natural film strength and lubricity. They meet the requirements of SAE MS1010 for TSC oils and MS 1003 for DAJ fluids. Typical uses are: rotary vane and screw compressors, reciprocating compressors, and circulating systems with high operating temperatures. **Note: There are different types of compressor oils, only some covered by LS2. Pay close attention to equipment builder recommendations when selecting a compressor oil.**

2 REFERENCED STANDARDS

AIAG 39	ASTM D 4172	DIN 53521	ISO 2160
ASTM D 92	ASTM D 5185	DIN 53538	ISO 2592
ASTM D 97	ASTM E 1687	EPA SW-846	ISO 2909
ASTM D 130	BS 188	GM TMC003	ISO 3016
ASTM D 189	BS 4231	GM 1000M	ISO 3104
ASTM D 287	BS 4832	GM 9035P	ISO 3105
ASTM D 445	CETOP RP81H	IP 15	ISO 3448
ASTM D 471	DIN 51519	IP 19	ISO 4263
ASTM D 611	DIN 51550	IP 36	ISO 4406
ASTM D 665	DIN 51561	IP 71	ISO 6072
ASTM D 892	DIN 51562	IP 226	ISO 6614
ASTM D 943	DIN 51566	IP 135	ISO 7120
ASTM D 1401	DIN 51585	IP 146	ISO 7619
ASTM D 2070	DIN 51587	IP 154	ISO 11171
ASTM D 2155	DIN 51599	IP 278	SAE MS1003
ASTM D 2270	DIN 51759	ISO 868	SAE MS1010
ASTM D 2422	DIN 53505	ISO 1817	

3 PHYSICAL PROPERTIES

Property	Value				Test Method			
Product Code, **LJ-_ _ - 3-11**	**03**	**04**	**06**	**10**	ISO	ASTM	DIN	other
ISO Viscosity Grade	32	46	68	100	3448	D 2422	51519	BS 4231
Kinematic Viscosity min	28.8	41.4	61.2	90.0	3104	D 445	51550	IP 71
at 40°C, cSt max	35.2	50.6	74.8	110	3105		51561	BS 188
Kinematic Vis. At 100°C, cSt	Report						51562	
Viscosity Index, min	120				2909	D 2270		IP 226
Pour Point, °C, max	-25			-20	3016	D 97		IP 15
Flash Point, °C min	210				2592	D 92		IP 36

4 PERFORMANCE A sample of the exact oil under consideration (i.e., no changes to base oil or additive package are allowed*) shall be evaluated in a certified laboratory using the following tests:

Property	Value	Test Method			
	for all product codes:	ISO	ASTM	DIN	Other
Cu Corrosion (3h at 100°C), max	1b	2160	D 130	51759	IP 154
Oxid. Stability, h to ΔTAN=2, min Run without water	2000	4263	D 943	51587	
Rust Preventing Characteristics	Pass (no Rust)	7120	D 665B	51585	IP 135
Water Separability, 30 min., max	40/40/0	6614	D 1401	51599	IP 19
Foaming Tendency (per D892) Sequence I, II, and III, max	50/0		D 892	51566 E	IP 146

4 PERFORMANCE (CONT.)

Property	Value	Test Method			
	for all product codes:	ISO	ASTM	DIN	Other
Thermal Stability			D 2070		
Acid Number Change, % max	+/- 50 (or 0.15)				
Vis. Change, 40/100°C, % max	5				
Sludge, mg/100 ml max	25				
Cu Rod Color (Cin. Mil.), max	5				
Copper Weight Loss, mg max	10				
Steel Rod Color (Cin. Mil.)	No Discoloration				
Cleanliness, as Received, max	20/17/14	4406 11171			
Four-Ball Wear (40 kg load)			D 4172		
Wear Scar Diameter, mm max	0.40				
Aniline Point	Report		D 611		
Compatibility With SRE-NBR 1 Seals **(DIN 53538)** (68 h, 100°C) or other seals and limits as agreed upon)		1817 868 6072 7619	D 471	53521 53505	CETOP RP 81H IP 278 BS 4832
Volume change, %	-10 to 10				
Shore A hardness change	-7 to 10				

5 CHEMICAL PROPERTIES The product shall not contain water, acid, particulates, or other substances detrimental to the proper function and performance of the components or system for which it is intended. It shall be free from noxious odors or masking fragrances. Identification colorants are permitted provided such do not adversely affect performance. The following requirements shall also be met:

Property	Value	Test Method			
	for all product codes:	ISO	ASTM	DIN	Other
API Gravity	Report		D 287		
Autoignition Temperature, °C min	350		D 2155		
Conradson Carbon Res., % Max	0.05		D 189		
Base Stock Requirements@					Virgin or Rerefined
Tot. PolyNuclear Aromatics, ppm max	100				EPA SW-846 TN 8270*
Residual Elements (As, B, Ca, Mn, Mg, Na, Fe, Ni, Si, Cu, Sn, Cd, Cr, Pb, Ba, Zn), ppm max			D 5185		
total/ each	25/2				
P, ppm max	5				
Total Chlorinated Biphenyls	Not Detectable				SW-846 TN 8082*
Total Organic Halogens, ppm Max	5				SW-846 TN 9253*
Mutagenicity			E 1687		Modified Ames (or skin painting)
Fold Increase	Report				
Mutagenicity Index, max	1				
Mutag. Potency Index, max	Report				

@ not required, if there are is no mineral oil

* **or other methods as agreed upon between the LS2 Committee and supplier**

6 INITIAL SOURCE APPROVAL

6.1 Initial source approval is given by the General Motors LS2 Maintenance Lubricants Standards Committee. Only sources listed in the Approved Products List have been qualified by the LS2 committee as meeting the requirements of this specification. No purchases or shipments are to be made until this approval has been completed.

6.2 The supplier shall furnish data showing the composition of the candidate lubricant, with regard to both the specific base stocks (crude source and refinery, etc.) and additive treatment (concentration and generic chemical description of each component).

6.3 The supplier shall submit test results from a laboratory acceptable to the LS2 committee confirming that the product submitted for approval meets all of the stated requirements. Test limits shown are absolute; test precision was considered when setting them.

6.4 Completed copies of the GM Material Safety Data Sheet, GM TMC003 (see Appendix F) shall be submitted for new products or formulation changes; restricted chemicals to be handled per GM1000M

7 INSPECTION AND REJECTION

7.1 All shipments under contract or purchase order manufactured to this specification shall be identical in every respect to the product approved.

7.2 No changes in the formulation (including both base oil source and additive package and concentration) or manufacturing process are allowed without prior approval of the LS2 committee. Lack of such notification constitutes grounds for rejection of any shipment and removal from the Approved Product List.

7.3 The supplier shall be ISO 9000 or QS 9000 certified and shall perform regular quality control checks at each location where the material is manufactured. Such quality control data shall be made available to the purchaser upon request.

7.4 The purchaser may check incoming shipments for specification compliance; the supplier is responsible for incoming shipments meeting this specification without dependence upon purchaser's inspection. Non-compliance to physical and chemical requirements constitutes grounds for rejection of a shipment.

7.5 If physical or chemical analyses determine that the delivered lubricant is not in compliance with the requirements, the supplier may be held liable for loss of equipment warranty.

7.6 Infrared spectra (GM 9035P) of the incoming lubricant shipments shall not deviate significantly from that of the originally approved material.

8 COMPATIBILITY

Mixtures of the product approved and the product currently used shall pass all of the above requirements. The supplier is responsible that, when this product is mixed with a product already in use, there shall be no incompatibility or loss in operating performance. This product should not cause degradation or loss of performance of commonly used seals.

9 WASTE TREATMENT

The supplier shall be responsible to make known the processing procedures of any component of the lubricant for which waste treatability is in question.

10 GENERAL INFORMATION

10.1 Each container shall be clearly identified on the top and side. The identification shall contain the GM specification number at least 2 inches (5 cm) high on 5 gallon (20 L) or larger containers and prominently displayed on smaller containers.

10.2 All products shall be bar-coded according to AIAG 39.

10.3 This product shall be used only in accordance with applicable hazardous materials procedures in each facility.

10.4 This standard is under the control of the GM LS2 Committee. It originated in **2011**

GM LUBRICANT STANDARD NO. LM-10-1-11
MISTING OIL - 100 cSt **PAGE 1 OF 4**

1 SCOPE The fluid defined by this specification is a high-quality ISO VG 100 misting oil formulated with non-toxic extreme pressure additives. It shall provide good wear protection against heavy loads, good EP characteristics, oxidation stability, low fogging and good surface wetting characteristics. It is intended for use in mist lubrication systems. These oils are easily misted through such systems and can be reclassified to large drops on bearing surfaces. Typical uses are bearings, gears, screws and metallic ways.

2 REFERENCED STANDARDS

AIAG 39	ASTM D 2893	DIN 51585	IP 226
ASTM D 91	ASTM D 3705	DIN 51759	IP 240
ASTM D 92	ASTM D 4172	DIN 53505	IP 278
ASTM D 97	ASTM D 5182	DIN 53521	IP 334
ASTM D 130	ASTM D 5185	DIN 53538	ISO 868
ASTM D 287	ASTM E 1687	EPA SW-846	ISO 1817
ASTM D 445	BS 188	GM TMC003	ISO 2160
ASTM D 471	BS 4231	GM 1000M	ISO 2592
ASTM D 665	BS 4832	GM 9035P	ISO 2909
ASTM D 892	CETOP RP81H	IP 15	ISO 3016
ASTM D 2070	Cin. Mil. Proc. B	IP 36	ISO 3104
ASTM D 2270	DIN 51354	IP 71	ISO 3448
ASTM D 2422	DIN 51519	IP 135	ISO 6072
ASTM D 2711	DIN 51561	IP 146	ISO 6247
ASTM D 2782	DIN 51562	IP 154	ISO 7120
ASTM D 2783	DIN 51566	IP 166	ISO 7619

3 PHYSICAL PROPERTIES

Property		Value	Test Method			
			ISO	ASTM	DIN	other
ISO Viscosity Grade		100*	3448	D 2422	51519	BS 4231 IP 226
Kinematic Viscosity at 40°C, cSt	min max	90.0 110	3104	D 445	51561 51562	IP 71 BS 188
Kinematic Viscosity at 100°C		Report				
Viscosity Index,	min	90	2909	D 2270		IP 226
Pour Point, °C	max	-15	3016	D 97		IP 15
Flash Point, °C	min	200	2592	D 92		IP 36

* Other ISO grades may be used provided they meet all other requirements. Higher grades may require the use of thermal misting devices.

4 PERFORMANCE A sample of the exact oil under consideration (i.e., no changes to base oil or additive package are allowed) shall be evaluated in a certified laboratory using the following tests:

Property	Value	Test Method			
		ISO	ASTM	DIN	other
Copper Corrosion (3h at 100°C)	1b max	2160	D 130	51759	IP 154
Timken OK Load, kg min	27		D 2782		IP 240
Rust Preventing Characteristics	Pass no Rust	7120	D 665B	51585	IP 135

4 PERFORMANCE (CONT.)

Property	Value	Test Method			
		ISO	ASTM	DIN	other
Thermal Stability Acid Number Change, max Vis Change, 40/100°C, % max Sludge, mg/100 ml max Cu Rod Color (Cin. Mil.), max Copper Weight Loss, mg max Steel Rod Color (Cin. Mil.)	 0.15 5 25 5 10 No Discoloration		D 2070 (except 75 ml of oil, 101°C, 72 h)		Cin. Mil. Proc. B
Misting Properties Reclassified, % min Oil Lost in Manifold, % max Oil Lost in Stray Fog, % max	 50 Report 10		D 3705		
Oxidation Stability Vis Increase at 100°C, % max Precipitation Number, max	 5 0.1		D 2893		
Foaming Tendency (per D 892) Sequence I, II, and III	50/0 max	6247	D 892	51566	IP 146
FZG Test, stages min Failure stage	11		D 5182	51354	IP 334 IP 166
Four-Ball EP Load Wear Index, kg min Weld Load, kg min	 45 250		D 2783		
Four-Ball Wear (20 kg load) Wear Scar Diameter, mm max	 0.35		D 4172		
Demulsibility Water in Oil after 5 h, % max Emulsion after Centrifuge, ml max Total Free Water, ml min	 1.0 2.0 60		D 2711 X2		
Compatibility With SRE-NBR 1 Seals **(DIN 53538)** (168 h, 100°C) or other seals and limits as agreed upon) Volume change, % Shore A hardness change	 -10 to 10 -7 to 10	1817 868 6072 7619	D 471	53521 53505	CETOP RP 81H IP 278 BS 4832

5 CHEMICAL PROPERTIES The product shall not contain water, acid, particulates, or other substances detrimental to the proper function and performance of the components or system for which it is intended. It shall be free from noxious odors or masking fragrances. Identification colorants are permitted provided such do not adversely affect performance. The following requirements shall also be met:

Property	Value	Test Method			
		ISO	ASTM	DIN	other
API Gravity	Report		D 287		
Precipitation Number, max	0.05		D 91		
Base Stock Requirements					Virgin or Rerefined
Tot. PolyNuclear Aromatics, ppm max	100				EPA SW-846 TN 8270*
Residual Elements (As, B, Ca, Mn, Mg, Na, Fe, Ni, Si, Cu, Sn, Cd, Cr, Pb, Ba, Zn), ppm max total/ each P, ppm max	 25/2 5		D 5185		
Total Chlorinated Biphenyls	Not De-tectable				EPA SW-846 TN 8082*
Total Organic Halogens, ppm Max	5				EPA SW-846 TN 9253*
Mutagenicity Fold Increase Mutagenicity Index, max Mutag. Potency Index, max	 Report 1 Report		E 1687		Modified Ames (or skin painting)

*** or other methods as agreed upon by the LS2 committee and supplier**

6 INITIAL SOURCE APPROVAL

6.1 Initial source approval is given by the General Motors LS2 Maintenance Lubricants Standards Committee. Only sources listed in the Approved Products List have been qualified by the LS2 committee as meeting the requirements of this specification. No purchases or shipments are to be made until this approval has been completed.

6.2 The supplier shall furnish data showing the composition of the candidate lubricant, with regard to both the specific base stocks (crude source and refinery, etc.) and additive treatment (concentration and generic chemical description of each component).

6.3 The supplier shall submit test results from a laboratory acceptable to the LS2 committee confirming that the product submitted for approval meets all of the stated requirements. Test limits shown are absolute; test precision was considered when setting them.

6.4 Completed copies of the GM Material Safety Data Sheet, GM TMC003 (see Appendix F) shall be submitted for new products or formulation changes; restricted chemicals to be handled per GM1000M

7 INSPECTION AND REJECTION

7.1 All shipments under contract or purchase order manufactured to this specification shall be identical in every respect to the product approved.

7.2 No changes in the formulation (including both base oil source and additive package and concentration) or manufacturing process are allowed without prior approval of the LS2 committee. Lack of such notification constitutes grounds for rejection of any shipment and removal from the Approved Products List.

7.3 The supplier shall be ISO 9000 or QS 9000 certified and shall perform regular quality control checks at each location where the material is manufactured. Such quality control data shall be made available to the purchaser upon request.

7.4 The purchaser may check incoming shipments for specification compliance; the supplier is responsible for incoming shipments meeting this specification without dependence upon purchaser's inspection. Non-compliance to physical and chemical requirements constitutes grounds for rejection of a shipment.

7.5 If physical or chemical analyses determine that the delivered lubricant is not in compliance with the requirements, the supplier may be held liable for loss of equipment warranty.

7.6 Infrared spectra (GM 9035P) of the incoming lubricant shipments shall not deviate significantly from that of the originally approved material.

8 COMPATIBILITY

Mixtures of the product approved and the product currently used shall pass all of the above requirements. The supplier is responsible that, when this product is mixed with a product already in use, there shall be no incompatibility or loss in operating performance. This product should not cause degradation or loss of performance of commonly used seals.

9 WASTE TREATMENT

The supplier shall be responsible to make known the processing procedures of any component of the lubricant for which waste treatability is in question.

10 GENERAL INFORMATION

10.1 Each container shall be clearly identified on the top and side. The identification shall contain the GM specification number at least 2 inches (5 cm) high on 5 gallon (20 L) or larger containers and prominently displayed on smaller containers.

10.2 All products shall be bar-coded according to AIAG 39.

10.3 This product shall be used only in accordance with applicable hazardous materials procedures in each facility.

10.4 This standard is under the control of the GM LS2 Committee. It was last revised in **2011**.

1 SCOPE The fluids defined by this specification are gear oils containing non-corrosive and non-leaded extreme-pressure additives. They meet the requirements of AGMA Standard Specification 9005 for EP gear oils for closed and open gear drives, respectively and for presses requiring an EP oil. They also meet the requirements of the US Steel Specification 224 and SAE MS1002 for CKC fluids. These oils are intended for use in enclosed helical, herringbone, bevel and spur gear drives which are operated at speeds up to 3600 rpm or at pitch line velocities of up to 25 meters/second. Oils of ISO 460 or above may be used on all-steel worm gear drives requiring EP.

2 REFERENCED STANDARDS

AGMA 9005	ASTM D 4172	DIN 53505	ISO 868
AIAG 39	ASTM D 5182	DIN 53521	ISO 1817
ASTM D 91	ASTM D 5185	DIN 53538	ISO 2160
ASTM D 92	ASTM D 6304	EPA SW-846	ISO 2592
ASTM D 97	ASTM E 1687	GM TMC003	ISO 2909
ASTM D 130	BS 188	GM 1000M	ISO 3016
ASTM D 287	BS 4231	GM 9035P	ISO 3104
ASTM D 445	BS 4832	IP 15	ISO 3105
ASTM D 471	CETOP RP81H	IP 36	ISO 3448
ASTM D 665	Cin. Mil. Proc. B	IP 71	ISO 4406
ASTM D 892	DIN 51354	IP 135	ISO 6072
ASTM D 2070	DIN 51519	IP 146	ISO 6247
ASTM D 2270	DIN 51550	IP 154	ISO 7120
ASTM D 2422	DIN 51561	IP 166	ISO 7619
ASTM D 2711	DIN 51562	IP 226	ISO 11171
ASTM D 2782	DIN 51566	IP 240	SAE MS1002
ASTM D 2783	DIN 51585	IP 278	USS 224
ASTM D 2893	DIN 51759	IP 334	

3 PHYSICAL PROPERTIES

Property	Value							Test Method			
Product Code, **LR-_ _ - 1-11**	**06**	**10**	**15**	**22**	**32**	**46**	**68**	ISO	ASTM	DIN	Other
ISO Viscosity Grade	68	100	150	220	320	460	680	3448	D 2422	51519	BS 4231
AGMA Grade	2EP	3EP	4EP	5EP	6EP	7EP	8EP				AGMA 9005
Kinematic Viscosity at 40°C, min/max	61.2 74.8	90.0 110	135 165	198 242	288 352	414 506	612 748	3104 3105	D 445	51550 51561 51562	IP 71 BS 188
Kinematic Viscosity at 100°C	Report										
Viscosity Index, min	90							2909	D 2270		IP 226
Pour Point, °C, max	-15	-15	-15	-10	-10	-5	0	3016	D 97		IP 15
Flash Point, °C min	190	190	200	200	210	210	210	2592	D 92		IP 36

4 PERFORMANCE A sample of the exact oil under consideration (i.e., no changes to base oil or additive package are allowed) shall be evaluated in a certified laboratory using the following tests.

Property	Value	Test Method			
	for all product codes:	ISO	ASTM	DIN	Other
Copper Corrosion (3h at 100°C), max	1b	2160	D 130	51759	IP 154
Thermal Stability Acid Number Change, max Vis. Change, 40/100°C, % max Sludge, mg/100 ml max Cu Rod Color (Cin. Mil.), max Copper Weight Loss, mg max Steel Rod Color (Cin. Mil.)	 0.15 (report for 680) 5 (10 for 680) 25 5 10 No Discoloration		D 2070 (except 75 ml of oil, 101°C, 72 h)		Cin. Mil. Proc. B
Oxidation Stability (121 rather than 95°C) Vis. Increase at 100°C, %, max Photos of glassware after test	 6 (12% for ISO 680) Report		D 2893		
FZG Test, failure stage min	12		D 5182	51354	IP 166 IP 334
Cleanliness, as Received, max	20/18/14	4406 11171			
Timken OK Load, kg, min	27		D 2782		IP 240
Rust Preventing Characteristics	Pass (no Rust)	7120	D 665B	51585	IP 135
Demulsibility Water in Oil after 5 h, %, max Emulsion After Cntrfg., ml max Total Free Water, ml, min	 1.0 2.0 60		D 2711 X2		
Foaming Tendency (per D 892) Sequence I, II, and III, max	 50/0	6247	D 892	51566 E	IP 146
Four-Ball EP Load Wear Index, kg min Weld Load, kg min	 45 250		D 2783		
Four-Ball Wear (20 kg load) Wear Scar Diameter, mm max	 0.35		D 4172		
Compatibility With SRE-NBR 1 Seals **(DIN 53538)** (168 h, 100°C) or other seals and limits as agreed upon) Volume change, % Shore A hardness change	 -10 to 10 -7 to 10	1817 868 6072 7619	D 471	53521 53505	CETOP RP 81H IP 278 BS 4832

5 CHEMICAL PROPERTIES The product shall not contain water, acid, particulates, or other substances detrimental to the proper function and performance of the components or system for which it is intended. It shall be free from noxious odors or masking fragrances. Identification colorants are permitted provided such do not adversely affect performance. The following requirements shall also be met:

5 CHEMICAL PROPERTIES (CONT.)

Property	Value	Test Method			
	for all product codes:	ISO	ASTM	DIN	Other
API Gravity	Report		D 287		
Precipitation Number, max	Report		D 91		
Water, as Received, ppm max	200	3733	D 6304#		
Base Stock Requirements				Virgin or Rerefined	
Tot. PolyNuclear Aromatics, ppm max	100				EPA SW-846 TN 8270*
Residual Elements (As, B, Ca, Mn, Mg, Na, Fe, Ni, Si, Cu, Sn, Cd, Cr, Pb, Ba, Zn), ppm max total/ each P, ppm max	 25/2 5		D 5185		
Total Chlorinated Biphenyls	Not Detectable				EPA SW-846 TN 8082*
Total Organic Halogens, ppm max	5				EPA SW-846 TN 9253*
Mutagenicity Fold Increase Mutagenicity Index, max Mutag. Potency Index, max	 Report 1 Report		E 1687		Modified Ames (or skin painting)

* or other methods as agreed upon by the LS2 committee and supplier
# This method is subject to interferences that can sometimes cause the reporting of erroneously high results. If an analysis produces a value for water content that exceeds the maximum limit, it is recommended that the plant work with the supplier to recheck the results. Other methods, such as distillation, FTIR, etc., may be used as agreed upon by the plant and supplier.

6 INITIAL PRODUCT APPROVAL

6.1 Initial product approval is given by the General Motors LS2 Maintenance Lubricants Standards Committee. Only sources listed in the Approved Product List have been qualified by the LS2 committee as meeting the requirements of this specification. No purchases or shipments are to be made until this approval has been completed.

6.2 The supplier shall furnish data showing the composition of the candidate lubricant, with regard to both the specific base stocks (crude source and refinery, etc.) and additive treatment (concentration and generic chemical description of each component).

6.3 The supplier shall submit test results from a laboratory acceptable to the LS2 committee confirming that the product submitted for approval meets all of the stated requirements. Test limits shown are absolute; test precision was considered when setting them.

6.4 Completed copies of the GM Material Safety Data Sheet, GM TMC003 (see Appendix F) shall be submitted for new products or formulation changes; restricted chemicals to be handled per GM1000M.

7 INSPECTION AND REJECTION

7.1 All shipments under contract or purchase order manufactured to this specification shall be identical in every respect to the product approved.

7.2 No changes in the formulation (including both base oil source and additive package and concentration) or manufacturing process are allowed without prior approval of the LS2 committee. Lack of such notification constitutes grounds for rejection of any shipment and removal from the Approved Product List.

7 INSPECTION AND REJECTION (CONT.)

7.3 The supplier shall be ISO 9000 or QS 9000 certified and shall perform regular quality control checks at each location where the material is manufactured. Such quality control data shall be made available to the purchaser upon request.

7.4 The purchaser may check incoming shipments for specification compliance; the supplier is responsible for incoming shipments meeting this specification without dependence upon purchaser's inspection. Non-compliance to physical and chemical requirements constitutes grounds for rejection of a shipment.

7.5 If physical or chemical analyses determine that the delivered lubricant is not in compliance with the requirements, the supplier may be held liable for loss of equipment warranty.

7.6 Infrared spectra (GM 9035P) of the incoming lubricant shipments shall not deviate significantly from that of the originally approved material.

8 COMPATIBILITY

Mixtures of the product approved and the product currently used shall pass all of the above requirements. The supplier is responsible that, when this product is mixed with a product already in use, there shall be no incompatibility or loss in operating performance. This product should not cause degradation or loss of performance of commonly used seals.

9 WASTE TREATMENT

The supplier shall be responsible to make known the processing procedures of any component of the lubricant for which waste treatability is in question.

10 GENERAL INFORMATION

10.1 Each container shall be clearly identified on the top and side. The identification shall contain the GM specification number at least 2 inches (5 cm) high on 5 gallon (20 L) or larger containers and prominently displayed on smaller containers.

10.2 All products shall be bar-coded according to AIAG 39.

10.3 This product shall be used only in accordance with applicable hazardous materials procedures in each facility.

10.4 This standard is under the control of the GM LS2 Committee. It was last revised in **2011**.

1 SCOPE The fluids defined by this specification are ISO grade 460, 680 or 1000, American Gear Manufacturers Association (AGMA) 7, 8 or 8A, gear oils containing non-corrosive and non-leaded additives. These oils are intended specifically for use in worm gear drives with bronze components. They meet the requirements of SAE MS1002 for CKE oils.

2 REFERENCED STANDARDS

AGMA 9005	ASTM D 5185	DIN 53521	ISO 1817
AIAG 39	ASTM D 6304	DIN 53538	ISO 2160
ASTM D 91	ASTM E 1687	EPA SW-846	ISO 2592
ASTM D 92	BS 188	GM TMC003	ISO 2909
ASTM D 97	BS 4231	GM 1000M	ISO 3016
ASTM D 130	BS 4832	GM 9035P	ISO 3104
ASTM D 287	CETOP RP81H	IP 15	ISO 3105
ASTM D 445	Cin. Mil. Proc. B	IP 36	ISO 3448
ASTM D 471	DIN 51354	IP 71	ISO 4406
ASTM D 665	DIN 51519	IP 135	ISO 6072
ASTM D 892	DIN 51550	IP 146	ISO 6247
ASTM D 2070	DIN 51561	IP 154	ISO 7120
ASTM D 2270	DIN 51562	IP 166	ISO 7619
ASTM D 2422	DIN 51566	IP 226	ISO 11171
ASTM D 2893	DIN 51585	IP 278	SAE MS1002
ASTM D 4172	DIN 51759	IP 334	USS 224
ASTM D 5182	DIN 53505	ISO 868	

3 PHYSICAL PROPERTIES

Property	Value			Test Method			
	for all product codes:			ISO	ASTM	DIN	Other
ISO Viscosity Grade	460	680	1000	3448	D 2422	51519	BS 4231
AGMA Grade	7	8	8A				AGMA 9005
Kinematic Viscosity at 40°C, min/max	414 506	612 748	900 1100	3104 3105	D 445	51550 51561	IP 71 BS 188
Kinematic Viscosity at 100°C	Report					51562	
Viscosity Index, min	85			2909	D 2270		IP 226
Pour Point, °C, max	0			3016	D 97		IP 15
Flash Point, °C min	210			2592	D 92		IP 36

4 PERFORMANCE A sample of the exact oil under consideration (i.e., no changes to base oil or additive package are allowed) shall be evaluated in a certified laboratory using the following tests.

Property	Value	Test Method			
	for all product codes:	ISO	ASTM	DIN	Other
Copper Corrosion (3h at 100°C), max	1b	2160	D 130	51759	IP 154
Oxidation Stability (121 rather than 95°C)			D 2893		
Vis. Increase at 100°C, %, max	Report				
Photos of glassware after test	Report				

4 PERFORMANCE (CONT.)

Property	Value			Test Method			
	460	680	1000	ISO	ASTM	DIN	Other
Thermal Stability Acid Number Change, max Vis. Change, 40/100°C, % max Sludge, mg/100 ml max Cu Rod Color (Cin. Mil.), max Copper Weight Loss, mg max Steel Rod Color (Cin. Mil.)	Report Report Report Report Report Report				D 2070 (except 75 ml of oil, 101°C, 72 h)		Cin. Mil. Proc. B
FZG Test, failure stage min	8	9	10		D 5182	51354	IP 166 IP 334
Cleanliness, as Received, max	20/18/14			4406 11171			
Rust Preventing Characteristics	Pass (no Rust)			7120	D 665B	51585	IP 135
Foaming Tendency (per D 892) Sequence I, II, and III, max	50/0			6247	D 892	51566 E	IP 146
Four-Ball Wear (20 kg load) Wear Scar Diameter, mm max	0.35				D 4172		
Compatibility With SRE-NBR 1 Seals **(DIN 53538)** (168 h, 100°C) or other seals and limits as agreed upon Volume change, % Shore A hardness change	-10 to 10 -7 to 10			1817 868 6072 7619	D 471	53521 53505	CETOP RP 81H IP 278 BS 4832

5 CHEMICAL PROPERTIES The product shall not contain water, acid, particulates, or other substances detrimental to the proper function and performance of the components or system for which it is intended. It shall be free from noxious odors or masking fragrances. Identification colorants are permitted provided such do not adversely affect performance. The following requirements shall also be met:

Property	Value	Test Method			
	for all product codes:	ISO	ASTM	DIN	Other
API Gravity	Report		D 287		
Precipitation Number, max	Report		D 91		
Water, as Received, ppm max	200	3733	D 6304[#]		

* or other methods as agreed upon by the LS2 committee and supplier

[#] This method is subject to interferences that can sometimes cause the reporting of erroneously high results. If an analysis produces a value for water content that exceeds the maximum limit, it is recommended that the plant work with the supplier to recheck the results. Other methods, such as distillation, FTIR, etc., may be used as agreed upon by the plant and supplier.

5 CHEMICAL PROPERTIES (CONT.)

Property	Value	Test Method			
	for all product codes:	ISO	ASTM	DIN	Other
Base Stock Requirements					Virgin or Rerefined
Tot. PolyNuclear Aromatics, ppm max	100				EPA SW-846 TN 8270*
Residual Elements (As, B, Ca, Mn, Mg, Na, Fe, Ni, Si, Cu, Sn, Cd, Cr, Pb, Ba, Zn), ppm max total/ each P, ppm max	 25/2 5		D 5185		
Total Chlorinated Biphenyls	Not Detectable				EPA SW-846 TN 8082*
Total Organic Halogens, ppm max	5				EPA SW-846 TN 9253*
Mutagenicity Fold Increase Mutagenicity Index, max Mutag. Potency Index, max	 Report 1 Report		E 1687		Modified Ames (or skin painting)

* or other methods as agreed upon by the LS2 committee and supplier

6 INITIAL PRODUCT APPROVAL

6.1 Initial product approval is given by the General Motors LS2 Maintenance Lubricants Standards Committee. Only sources listed in the Approved Product List have been qualified by the LS2 committee as meeting the requirements of this specification. No purchases or shipments are to be made until this approval has been completed.

6.2 The supplier shall furnish data showing the composition of the candidate lubricant, with regard to both the specific base stocks (crude source and refinery, etc.) and additive treatment (concentration and generic chemical description of each component).

6.3 The supplier shall submit test results from a laboratory acceptable to the LS2 committee confirming that the product submitted for approval meets all of the stated requirements. Test limits shown are absolute; test precision was considered when setting them.

6.4 Completed copies of the GM Material Safety Data Sheet, GM TMC003 (see Appendix F) shall be submitted for new products or formulation changes; restricted chemicals to be handled per GM1000M.

7 INSPECTION AND REJECTION

7.1 All shipments under contract or purchase order manufactured to this specification shall be identical in every respect to the product approved.

7.2 No changes in the formulation (including both base oil source and additive package and concentration) or manufacturing process are allowed without prior approval of the LS2 committee. Lack of such notification constitutes grounds for rejection of any shipment and removal from the Approved Product List.

7.3 The supplier shall be ISO 9000 or QS 9000 certified and shall perform regular quality control checks at each location where the material is manufactured. Such quality control data shall be made available to the purchaser upon request.

7 INSPECTION AND REJECTION (CONT.)

7.4 The purchaser may check incoming shipments for specification compliance; the supplier is responsible for incoming shipments meeting this specification without dependence upon purchaser's inspection. Non-compliance to physical and chemical requirements constitutes grounds for rejection of a shipment.

7.5 If physical or chemical analyses determine that the delivered lubricant is not in compliance with the requirements, the supplier may be held liable for loss of equipment warranty.

7.6 Infrared spectra (GM 9035P) of the incoming lubricant shipments shall not deviate significantly from that of the originally approved material.

8 COMPATIBILITY

Mixtures of the product approved and the product currently used shall pass all of the above requirements. The supplier is responsible that, when this product is mixed with a product already in use, there shall be no incompatibility or loss in operating performance. This product should not cause degradation or loss of performance of commonly used seals.

9 WASTE TREATMENT

The supplier shall be responsible to make known the processing procedures of any component of the lubricant for which waste treatability is in question.

10 GENERAL INFORMATION

10.1 Each container shall be clearly identified on the top and side. The identification shall contain the GM specification number at least 2 inches (5 cm) high on 5 gallon (20 L) or larger containers and prominently displayed on smaller containers.

10.2 All products shall be bar-coded according to AIAG 39.

10.3 This product shall be used only in accordance with applicable hazardous materials procedures in each facility.

10.4 This standard is under the control of the GM LS2 Committee. It was last revised in **2011**.

1 SCOPE The fluids defined by this specification are gear oils formulated with synthetic base oils and contain non-corrosive and non-leaded extreme-pressure additives. They meet the requirements of AGMA Standard Specifications 9005 for EP gear oils for closed and open gear drives, respectively. They also meet the requirements of the US Steel Specification 224 and SAE MS1002 for CKC fluids. These oils are intended for use in enclosed helical, herringbone, bevel and spur gear drives which are operated at speeds up to 3600 rpm or at pitch line velocities of up to 25 meters/second. Specifically, they are designed for high-temperature use or where extended drain capabilities are desired. Oils of ISO 460 or above may be used on all-steel worm gear drives requiring EP.

2 REFERENCED STANDARDS

AGMA 9005	ASTM D 4172	DIN 53505	ISO 868
AIAG 39	ASTM D 5182	DIN 53521	ISO 1817
ASTM D 91	ASTM D 5185	DIN 53538	ISO 2160
ASTM D 92	ASTM D 6304	EPA SW-846	ISO 2592
ASTM D 97	ASTM E 1687	GM TMC003	ISO 2909
ASTM D 130	BS 188	GM 1000M	ISO 3016
ASTM D 287	BS 4231	GM 9035P	ISO 3104
ASTM D 445	BS 4832	IP 15	ISO 3105
ASTM D 471	CETOP RP81H	IP 36	ISO 3448
ASTM D 665	Cin. Mil. Proc. B	IP 71	ISO 4406
ASTM D 892	DIN 51354	IP 135	ISO 6072
ASTM D 2070	DIN 51519	IP 146	ISO 6247
ASTM D 2270	DIN 51550	IP 154	ISO 7120
ASTM D 2422	DIN 51561	IP 166	ISO 7619
ASTM D 2711	DIN 51562	IP 226	ISO 11171
ASTM D 2782	DIN 51566	IP 240	SAE MS1002
ASTM D 2783	DIN 51585	IP 278	USS 224
ASTM D 2893	DIN 51759	IP 334	

3 PHYSICAL PROPERTIES

Property	Value							Test Method			
Product Code, **LR-_ _ - 3-11**	**06**	**10**	**15**	**22**	**32**	**46**	**68**	ISO	ASTM	DIN	other
ISO Viscosity Grade	68	100	150	220	320	460	680	3448	D 2422	51519	BS 4231
AGMA Grade	2EP	3EP	4EP	5EP	6EP	7EP	8EP				AGMA 9005
Kinematic Viscosity at 40°C, min/max	61.2 74.8	90.0 110	135 165	198 242	288 352	414 506	612 748	3104 3105	D 445	51550 51561 51562	IP 71 BS 188
Kinematic Viscosity at 100°C	Report										
Viscosity Index, min	120							2909	D 2270		IP 226
Pour Point, °C, max	-24	-24	-24	-21	-21	-15	-9	3016	D 97		IP 15
Flash Point, °C min	200	200	210	210	220	220	220	2592	D 92		IP 36

4 PERFORMANCE A sample of the exact oil under consideration (i.e., no changes to base oil or additive package are allowed) shall be evaluated in a certified laboratory using the following tests.

Property	Value	Test Method			
	for all product codes:	ISO	ASTM	DIN	Other
Copper Corrosion (3h at 100°C), max	1b	2160	D 130	51759	IP 154
Thermal Stability Acid Number Change, max Vis. Change, 40/100°C, % max Sludge, mg/100 ml max Cu Rod Color (Cin. Mil.), max Copper Weight Loss, mg max Steel Rod Color (Cin. Mil.)	 0.15 5 15 5 10 No Discoloration		D 2070 (except 75 ml of oil, 101°C, 72 h)		Cin. Mil. Proc. B
Oxidation Stability (135 rather than 95°C) Vis. Increase at 100°C, %, max Photos of glassware after test	 6 (12% for ISO 680) Report		D 2893		
FZG Test, failure stage min	12		D 5182	51354	IP 166 IP 334
Cleanliness, as Received, max	20/18/14	4406 11171			
Timken OK Load, kg, min	27		D 2782		IP 240
Rust Preventing Characteristics	Pass (no Rust)	7120	D 665B	51585	IP 135
Demulsibility Water in Oil after 5 h, %, max Emulsion After Cntrfg., ml max Total Free Water, ml, min	 1.0 2.0 60		D 2711 X2		
Foaming Tendency (per D 892) Sequence I, II, and III, max	 50/0	6247	D 892	51566 E	IP 146
Four-Ball EP Load Wear Index, kg min Weld Load, kg min	 45 250		D 2783		
Four-Ball Wear (20 kg load) Wear Scar Diameter, mm max	 0.35		D 4172		
Compatibility With SRE-NBR 1 Seals **(DIN 53538)** (168 h, 100°C) or other seals and limits as agreed upon Volume change, % Shore A hardness change	 -10 to 10 -7 to 10	1817 868 6072 7619	D 471	53521 53505	CETOP RP 81H IP 278 BS 4832

5 CHEMICAL PROPERTIES The product shall not contain water, acid, particulates, or other substances detrimental to the proper function and performance of the components or system for which it is intended. It shall be free from noxious odors or masking fragrances. Identification colorants are permitted provided such do not adversely affect performance. The following requirements shall also be met:

5 CHEMICAL PROPERTIES (CONT.)

Property	Value	Test Method			
	for all product codes:	ISO	ASTM	DIN	Other
API Gravity	Report		D 287		
Precipitation Number, max	0.05		D 91		
Water, as Received, ppm max	200	3733	D 6304[#]		
Base Stock Requirements	Only required for Any mineral oil Components				
Tot. PolyNuclear Aromatics, ppm max	100				EPA SW-846 TN 8270*
Residual Elements (As, B, Ca, Mn, Mg, Na, Fe, Ni, Si, Cu, Sn, Cd, Cr, Pb, Ba, Zn), ppm max total/ each P, ppm max	 25/2 5		D 5185		
Total Chlorinated Biphenyls	Not Detectable				EPA SW-846 TN 8082*
Total Organic Halogens, ppm max	5				EPA SW-846 TN 9253*
Mutagenicity Fold Increase Mutagenicity Index, max Mutag. Potency Index, max	 Report 1 Report		E 1687		Modified Ames (or skin painting)

* or other methods as agreed upon by the LS2 committee and supplier

[#] This method is subject to interferences that can sometimes cause the reporting of erroneously high results. If an analysis produces a value for water content that exceeds the maximum limit, it is recommended that the plant work with the supplier to recheck the results. Other methods, such as distillation, FTIR, etc., may be used as agreed upon by the plant and supplier.

6 INITIAL PRODUCT APPROVAL

6.1 Initial product approval is given by the General Motors LS2 Maintenance Lubricants Standards Committee. Only sources listed in the Approved Product List have been qualified by the LS2 committee as meeting the requirements of this specification. No purchases or shipments are to be made until this approval has been completed.

6.2 The supplier shall furnish data showing the composition of the candidate lubricant, with regard to both the specific base stocks (crude source and refinery, etc.) and additive treatment (concentration and generic chemical description of each component).

6.3 The supplier shall submit test results from a laboratory acceptable to the LS2 committee confirming that the product submitted for approval meets all of the stated requirements. Test limits shown are absolute; test precision was considered when setting them.

6.4 Completed copies of the GM Material Safety Data Sheet, GM TMC003 (see Appendix F) shall be submitted for new products or formulation changes; restricted chemicals to be handled per GM1000M.

7 INSPECTION AND REJECTION

7.1 All shipments under contract or purchase order manufactured to this specification shall be identical in every respect to the product approved.

7 INSPECTION AND REJECTION (CONT.)

7.2 No changes in the formulation (including both base oil source and additive package and concentration) or manufacturing process are allowed without prior approval of the LS2 committee. Lack of such notification constitutes grounds for rejection of any shipment and removal from the Approved Product List.

7.3 The supplier shall be ISO 9000 or QS 9000 certified and shall perform regular quality control checks at each location where the material is manufactured. Such quality control data shall be made available to the purchaser upon request.

7.4 The purchaser may check incoming shipments for specification compliance; the supplier is responsible for incoming shipments meeting this specification without dependence upon purchaser's inspection. Non-compliance to physical and chemical requirements constitutes grounds for rejection of a shipment.

7.5 If physical or chemical analyses determine that the delivered lubricant is not in compliance with the requirements, the supplier may be held liable for loss of equipment warranty.

7.6 Infrared spectra (GM 9035P) of the incoming lubricant shipments shall not deviate significantly from that of the originally approved material.

8 COMPATIBILITY

Mixtures of the product approved and the product currently used shall pass all of the above requirements. The supplier is responsible that, when this product is mixed with a product already in use, there shall be no incompatibility or loss in operating performance. This product should not cause degradation or loss of performance of commonly used seals.

9 WASTE TREATMENT

The supplier shall be responsible to make known the processing procedures of any component of the lubricant for which waste treatability is in question.

10 GENERAL INFORMATION

10.1 Each container shall be clearly identified on the top and side. The identification shall contain the GM specification number at least 2 inches (5 cm) high on 5 gallon (20 L) or larger containers and prominently displayed on smaller containers.

10.2 All products shall be bar-coded according to AIAG 39.

10.3 This product shall be used only in accordance with applicable hazardous materials procedures in each facility.

10.4 This standard is under the control of the GM LS2 Committee. It originated in **2011**.

GM LUBRICANT STANDARD NO. LS-01-1-11, LS-02-1-11, LS-03-1-11
SPINDLE OILS

1 SCOPE The fluids defined by this specification are rust and oxidation inhibited spindle oils. These lubricants are used for high-speed, light-to-medium load spindle applications where heat dissipation is important. They meet the requirements of SAE MS 1006 for FD oils.

2 REFERENCED STANDARDS

AIAG 39	ASTM D 4628	DIN 51759	ISO 868
ASTM D 91	ASTM D 4951	DIN 53505	ISO 1817
ASTM D 92	ASTM D 5185	DIN 53521	ISO 2160
ASTM D 97	ASTM D 6304	DIN 53538	ISO 2592
ASTM D 130	ASTM E 1687	EPA SW-846	ISO 2909
ASTM D 287	BS 188	GM TMC003	ISO 3016
ASTM D 445	BS 4231	GM 1000M	ISO 3104
ASTM D 471	BS 4459	GM 9035P	ISO 3105
ASTM D 611	BS 4832	IP 15	ISO 3448
ASTM D 664	CETOP RP81H	IP 19	ISO 4263
ASTM D 665	DIN 51519	IP 36	ISO 4406
ASTM D 892	DIN 51550	IP 71	ISO 6072
ASTM D 943	DIN 51558	IP 135	ISO 6614
ASTM D 974	DIN 51561	IP 139	ISO 6618
ASTM D 1401	DIN 51562	IP 146	ISO 7120
ASTM D 2070	DIN 51566	IP 154	ISO 7619
ASTM D 2270	DIN 51585	IP 177	ISO 11171
ASTM D 2422	DIN 51587	IP 226	SAE MS 1006
ASTM D 4172	DIN 51599	IP 278	

3 PHYSICAL PROPERTIES

Property		Value				Test Method			
Product Code, **LS-_ _ - 1-11**		**01A**	**01B**	**02**	**03**	ISO	ASTM	DIN	other
ISO Viscosity Grade		10	15	22	32	3448	D 2422	51519	BS 4231
Kinematic Viscosity at 40°C, cSt	min	9.0	13.5	19.8	28.8	3104	D 445	51550	IP 71
	max	11	16.5	24.2	35.2	3105		51561	BS 188
Kinematic Viscosity at 100°C, cSt		Report						51562	
Viscosity Index,	min	95				2909	D 2270		IP 226 BS 4459
Pour Point, °C	max	-20		-15	-10	3016	D 97		IP 15
Flash Point, °C	min	165		175	190	2592	D 92		IP 36

4 PERFORMANCE A sample of the exact oil under consideration (i.e., no changes to base oil or additive package are allowed) shall be evaluated in a certified laboratory using the following tests:

Property	Value	Test Method			
	for all product codes:	ISO	ASTM	DIN	Other
Copper Corrosion (3h at 100°C), max	1b	2160	D 130	51759	IP 154
Oxidation Stability, h to TAN =2, min	1500	4263	D 943	51587	
Rust Preventing Characteristics	Pass (no Rust)	7120	D 665B	51585	IP 135
Water Separability, 30 min., max	40/40/0	6614	D 1401	51599	IP 19

4 PERFORMANCE (CONT.)

Property	Value	Test Method			
	for all product codes:	ISO	ASTM	DIN	Other
Thermal Stability			D 2070		
Acid Number Change, max	0.15				
Vis. Change, 40/100°C, % max	5				
Sludge, mg/100 ml max	25				
Cu Rod Color (Cin. Mil.), max	5				
Copper Weight Loss, mg max	10				
Steel Rod Color (Cin. Mil.)	No Discoloration				
Four-Ball Wear (20 kg load)			D 4172		
Wear Scar Diameter, mm, max	0.35				
Foaming Tendency (per D 892)			D 892	51566	IP 146
Sequence I, II, and III, max	50/0			E	
Cleanliness, as Received, max	20/18/14	4406 11171			
Compatibility With SRE-NBR 1		1817	D 471	53521	CETOP
Seals **(DIN 53538)** (168 h, 100°C)		868		53505	RP 81H
or other seals and limits as		6072			IP 278
agreed upon		7619			BS 4832
Volume change, %	-10 to 10				
Shore A hardness change	-7 to 10				

5 CHEMICAL PROPERTIES The product shall not contain water, acid, particulates, or other substances detrimental to the proper function and performance of the components or system for which it is intended. It shall be free from noxious odors or masking fragrances. Identification colorants are permitted provided such do not adversely affect performance. The following requirements shall also be met:

Property	Value	Test Method			
	for all product codes:	ISO	ASTM	DIN	Other
API Gravity	Report		D 287		
Acid Number, max	0.25	6618	D 664 D 974	51558	IP 139 IP 177
Precipitation Number, max	0.05		D 91		
Aniline Point, °C, min	85		D 611		
Zinc Compound in Final Product, ppm max	10000		D 4628 D 4951		
Tackifier added?	Report				
Water, as Received, ppm max	200	3733	D 6304[#]		
Base Stock Requirements					Virgin or Rerefined
Tot. PolyNuclear Aromatics, ppm max	100				EPA SW-846 TN 8270*

***** or other methods as agreed upon by the LS2 committee and supplier

[#] This method is subject to interferences that can sometimes cause the reporting of erroneously high results. If an analysis produces a value for water content that exceeds the maximum limit, it is recommended that the plant work with the supplier to recheck the results. Other methods, such as distillation, FTIR, etc., may be used as agreed upon by the plant and supplier.

5 CHEMICAL PROPERTIES (CONT.)

Property	Value	Test Method			
	for all product codes:	ISO	ASTM	DIN	Other
Base Stock Requirements, cont.					
Residual Elements (As, B, Ca, Mn, Mg, Na, Fe, Ni, Si, Cu, Sn, Cd, Cr, Pb, Ba, Zn), ppm max total/ each P, ppm max	 25/2 5		D 5185		
Total Chlorinated Biphenyls	Not Detectable				EPA SW-846 TN 8082*
Total Organic Halogens, ppm max	5				EPA SW-846 TN 9253*
Mutagenicity Fold Increase Mutagenicity Index, max Mutag. Potency Index, max	 Report 1 Report		E 1687		Modified Ames (or skin painting)

*** or other methods as agreed upon by the LS2 committee and supplier**

6 INITIAL PRODUCT APPROVAL

6.1 Initial product approval is given by the General Motors LS2 Maintenance Lubricants Standards Committee. Only sources listed in the Approved Product List have been qualified by the LS2 committee as meeting the requirements of this specification. No purchases or shipments are to be made until this approval has been completed.

6.2 The supplier shall furnish data showing the composition of the candidate lubricant, with regard to both the specific base stocks (crude source and refinery, etc.) and additive treatment (concentration and generic chemical description of each component).

6.3 The supplier shall submit test results from a laboratory acceptable to the LS2 committee confirming that the product submitted for approval meets all of the stated requirements. Test limits shown are absolute; test precision was considered when setting them.

6.4 Completed copies of the GM Material Safety Data Sheet, GM TMC003 (see Appendix F) shall be submitted for new products or formulation changes; restricted chemicals to be handled per GM1000M.

7 INSPECTION AND REJECTION

7.1 All shipments under contract or purchase order manufactured to this specification shall be identical in every respect to the product approved.

7.2 No changes in the formulation (including both base oil source and additive package and concentration) or manufacturing process are allowed without prior approval of the LS2 committee. Lack of such notification constitutes grounds for rejection of any shipment and removal from the Approved Product List.

7.3 The supplier shall be ISO 9000 or QS 9000 certified and shall perform regular quality control checks at each location where the material is manufactured. Such quality control data shall be made available to the purchaser upon request.

7.4 The purchaser may check incoming shipments for specification compliance; the supplier is responsible for incoming shipments meeting this specification without dependence upon purchaser's inspection. Non-compliance to physical and chemical requirements constitutes grounds for rejection of a shipment.

7.5 If physical or chemical analyses determine that the delivered lubricant is not in compliance with the requirements, the supplier may be held liable for loss of equipment warranty.

7.6 Infrared spectra (GM 9035P) of the incoming lubricant shipments shall not deviate significantly from that of the originally approved material.

8 COMPATIBILITY

Mixtures of the product approved and the product currently used shall pass all of the above requirements. The supplier is responsible that, when this product is mixed with a product already in use, there shall be no incompatibility or loss in operating performance. This product should not cause degradation or loss of performance of commonly used seals.

9 WASTE TREATMENT

The supplier shall be responsible to make known the processing procedures of any component of the lubricant for which waste treatability is in question.

10 GENERAL INFORMATION

10.1 Each container shall be clearly identified on the top and side. The identification shall contain the GM specification number at least 2 inches (5 cm) high on 5 gallon (20 L) or larger containers and prominently displayed on smaller containers.

10.2 All products shall be bar-coded according to AIAG 39.

10.3 This product shall be used only in accordance with applicable hazardous materials procedures in each facility.

10.4 This standard is under the control of the GM LS2 Committee. It was last revised in **2011**.

GM LUBRICANT STANDARD NO. LS-00(A and B)-2-11, LS-01-2-11 HIGH SPEED SPINDLE OILS

1 SCOPE The fluids defined by this specification are rust and oxidation inhibited spindle oils. These lubricants are used for very high-speed, light-to-medium load spindle applications where cleanliness and heat dissipation are very important. They meet the requirements of SAE MS1006 for FD oils.

2 REFERENCED STANDARDS

AIAG 39	ASTM D 4628	DIN 51759	ISO 868
ASTM D 91	ASTM D 4951	DIN 53505	ISO 1817
ASTM D 92	ASTM D 5185	DIN 53521	ISO 2160
ASTM D 97	ASTM D 6304	DIN 53538	ISO 2592
ASTM D 130	ASTM E 1687	EPA SW-846	ISO 2909
ASTM D 287	BS 188	GM TMC 003	ISO 3016
ASTM D 445	BS 4231	GM 1000M	ISO 3104
ASTM D 471	BS 4459	GM 9035P	ISO 3105
ASTM D 611	BS 4832	IP 15	ISO 3448
ASTM D 664	CETOP RP81H	IP 19	ISO 4263
ASTM D 665	DIN 51519	IP 36	ISO 4406
ASTM D 892	DIN 51550	IP 71	ISO 6072
ASTM D 943	DIN 51558	IP 135	ISO 6614
ASTM D 974	DIN 51561	IP 139	ISO 6618
ASTM D 1401	DIN 51562	IP 146	ISO 7120
ASTM D 2070	DIN 51566	IP 154	ISO 7619
ASTM D 2270	DIN 51585	IP 177	ISO 11171
ASTM D 2422	DIN 51587	IP 226	SAE MS1006
ASTM D 4172	DIN 51599	IP 278	

3 PHYSICAL PROPERTIES

Property		Value			Test Method			
Product Code, **LS-_ _ - 2-11**		**00A**	**00B**	**01**	ISO	ASTM	DIN	Other
ISO Viscosity Grade		2	5	10	3448	D 2422	51519	BS 4231
Kinematic Viscosity at 40°C, cSt	min	1.8	5.4	9.0	3104	D 445	51550	IP 71
	max	2.2	6.6	11.0	3105		51561	BS 188
Kinematic Viscosity at 100°C, cSt		Report					51562	
Viscosity Index	min	Report			2909	D 2270		IP 226 BS 4459
Pour Point, °C	max	-25	-20	-20	3016	D 97		IP 15
Flash Point, °C	min	140	150	165	2592	D 92		IP 36

4 PERFORMANCE A sample of the exact oil under consideration (i.e., no changes to base oil or additive package are allowed) shall be evaluated in a certified laboratory using the following tests:

Property	Value	Test Method			
	for all product codes:	ISO	ASTM	DIN	Other
Copper Corrosion (3h at 100°C), max	1b	2160	D 130	51759	IP 154
Oxidation Stability, h to TAN=2, min	3000	4263	D 943	51587	
Rust Preventing Characteristics	Pass (no Rust)	7120	D 665B	51585	IP 135
Water Separability, 30 min., max	40/40/0	6614	D 1401	51599	IP 19

4 PERFORMANCE (CONT.)

Property	Value	Test Method			
	for all product codes:	ISO	ASTM	DIN	Other
Thermal Stability			D 2070		
Acid Number Change, max	0.15				
Vis. Change, 40/100°C, % max	5				
Sludge, mg/100 ml max	15				
Cu Rod Color (Cin. Mil.), max	5				
Copper Weight Loss, mg max	10				
Steel Rod Color (Cin. Mil.)	No Discoloration				
Four-Ball Wear (20 kg load)			D 4172		
Wear Scar Diameter, mm, max	Report				
Foaming Tendency (per D 892)			D 892	51566	IP 146
Sequence I, II, and III, max	50/0			E	
Cleanliness, as Received, max	16/12/10	4406 11171			
Compatibility With SRE-NBR 1		1817	D 471	53521	CETOP
Seals **(DIN 53538)** (168 h, 100°C)		868		53505	RP 81H
or other seals and limits as		6072			IP 278
agreed upon		7619			BS 4832
Volume change, %	Report				
Shore A hardness change	Report				

5 CHEMICAL PROPERTIES The product shall not contain water, acid, particulates, or other substances detrimental to the proper function and performance of the components or system for which it is intended. It shall be free from noxious odors or masking fragrances. Identification colorants are permitted provided such do not adversely affect performance. The following requirements shall also be met:

Property	Value	Test Method			
	for all product codes:	ISO	ASTM	DIN	Other
API Gravity	Report		D 287		
Acid Number, max	Report	6618	D 664 D 974	51558	IP 139 IP 177
Precipitation Number, max	0.05		D 91		
Aniline Point, °C, min	85		D 611		
Zinc Compound in Final Product, ppm	Report		D 4628 D 4951		
Water, as Received, ppm max	200	3733	D 6304[#]		
Base Stock Requirements					Virgin or Rerefined
Tot. PolyNuclear Aromatics, ppm max	100				EPA SW-846 TN 8270*

***** or other methods as agreed upon by the LS2 committee and supplier

[#] This method is subject to interferences that can sometimes cause the reporting of erroneously high results. If an analysis produces a value for water content that exceeds the maximum limit, it is recommended that the plant work with the supplier to recheck the results. Other methods, such as distillation, FTIR, etc., may be used as agreed upon by the plant and supplier.

5 CHEMICAL PROPERTIES (CONT.)

Property	Value	Test Method			
	for all product codes:	ISO	ASTM	DIN	Other
Base Stock Requirements, cont.					
Residual Elements (As, B, Ca, Mn, Mg, Na, Fe, Ni, Si, Cu, Sn, Cd, Cr, Pb, Ba, Zn), ppm max total/ each P, ppm max	 25/2 5		D 5185		
Total Chlorinated Biphenyls	Not Detectable				EPA SW-846 TN 8082*
Total Organic Halogens, ppm max	5				EPA SW-846 TN 9253*
Mutagenicity Fold Increase Mutagenicity Index, max Mutag. Potency Index, max	 Report 1 Report		E 1687		Modified Ames (or skin painting)

*** or other methods as agreed upon by the LS2 committee and supplier**

6 INITIAL PRODUCT APPROVAL

6.1 Initial product approval is given by the General Motors LS2 Maintenance Lubricants Standards Committee. Only sources listed in the Approved Product List have been qualified by the LS2 committee as meeting the requirements of this specification. No purchases or shipments are to be made until this approval has been completed.

6.2 The supplier shall furnish data showing the composition of the candidate lubricant, with regard to both the specific base stocks (crude source and refinery, etc.) and additive treatment (concentration and generic chemical description of each component).

6.3 The supplier shall submit test results from a laboratory acceptable to the LS2 committee confirming that the product submitted for approval meets all of the stated requirements. Test limits shown are absolute; test precision was considered when setting them.

6.4 Completed copies of the GM Material Safety Data Sheet, GM TMC003 (see Appendix F) shall be submitted for new products or formulation changes; restricted chemicals to be handled per GM1000M.

7 INSPECTION AND REJECTION

7.1 All shipments under contract or purchase order manufactured to this specification shall be identical in every respect to the product approved.

7.2 No changes in the formulation (including both base oil source and additive package and concentration) or manufacturing process are allowed without prior approval of the LS2 committee. Lack of such notification constitutes grounds for rejection of any shipment and removal from the Approved Product List.

7.3 The supplier shall be ISO 9000 or QS 9000 certified and shall perform regular quality control checks at each location where the material is manufactured. Such quality control data shall be made available to the purchaser upon request.

7.4 The purchaser may check incoming shipments for specification compliance; the supplier is responsible for incoming shipments meeting this specification without dependence upon purchaser's inspection. Non-compliance to physical and chemical requirements constitutes grounds for rejection of a shipment.

7.5 If physical or chemical analyses determine that the delivered lubricant is not in compliance with the requirements, the supplier may be held liable for loss of equipment warranty.

7.6 Infrared spectra (GM 9035P) of the incoming lubricant shipments shall not deviate significantly from that of the originally approved material.

8 COMPATIBILITY

Mixtures of the product approved and the product currently used shall pass all of the above requirements. The supplier is responsible that, when this product is mixed with a product already in use, there shall be no incompatibility or loss in operating performance. This product should not cause degradation or loss of performance of commonly used seals.

9 WASTE TREATMENT

The supplier shall be responsible to make known the processing procedures of any component of the lubricant for which waste treatability is in question.

10 GENERAL INFORMATION

10.1 Each container shall be clearly identified on the top and side. The identification shall contain the GM specification number at least 2 inches (5 cm) high on 5 gallon (20 L) or larger containers and prominently displayed on smaller containers.

10.2 All products shall be bar-coded according to AIAG 39.

10.3 This product shall be used only in accordance with applicable hazardous materials procedures in each facility.

10.4This standard is under the control of the GM LS2 Committee. It originated in **2011**.

GM LUBRICANT STANDARD NO. LW-03-1-11, LW-06-1-11, LW-22-1-11 LIGHT, MEDIUM AND HEAVY WAY OILS

1 SCOPE The fluids defined by this specification will be formulated with severely solvent-refined or severely hydrotreated base stocks with non-corrosive lubricity and tackiness additives. ISO 32 and 68 fluids are intended for lubrication of moderately loaded slideways that operate in the stick-slip region; ISO 220 fluids are for heavily loaded slideways. These materials shall exhibit resistance to gel formation and have good EP characteristics to prevent chatter and scoring. They shall meet the requirements of SAE MS1007.

2 REFERENCED STANDARDS

AFNOR NFT60-183	ASTM D 2782	DIN 51585	ISO 2160
AIAG 39	ASTM D 2877	DIN 51599	ISO 2592
ASTM D 91	ASTM D 5185	DIN 51759	ISO 2909
ASTM D 92	ASTM D 6304	EPA SW-846	ISO 3016
ASTM D 97	ASTM E 1687	GM TMC003	ISO 3104
ASTM D 130	BS 188	GM 1000M	ISO 3105
ASTM D 287	BS 4231	GM 9035P	ISO 3448
ASTM D 445	BS 4459	IP 15	ISO 3733
ASTM D 473	Cin. Mil.	IP 19	ISO 4406
ASTM D 665	Stick Slip	IP 36	ISO 6614
ASTM D 1401	DIN 51519	IP 71	ISO 7120
ASTM D 2270	DIN 51550	IP 135	ISO 11171
ASTM D 2422	DIN 51561	IP 154	SAE MS1007
ASTM D 2711	DIN 51562	IP 226	

3 PHYSICAL PROPERTIES

Property		Value			Test Method			
Product Code, **LW-_ _ - 1-11**		**03**	**06**	**22**	ISO	ASTM	DIN	Other
ISO Viscosity Grade		32	68	220	3448	D 2422	51519	BS 4231
Kinematic Viscosity at 40°C, cSt	min	28.8	61.2	198	3104	D 445	51550	IP 71
	max	35.2	74.8	242	3105		51561	BS 188
Kinematic Viscosity at 100°C, cSt		Report					51562	
Viscosity Index	min	Report			2909	D 2270		IP 226 BS 4459
Pour Point, °C	max	-15	-10	-10	3016	D 97		IP 15
Flash Point, °C	min	190	190	200	2592	D 92		IP 36

4 PERFORMANCE A sample of the exact oil under consideration (i.e., no changes to base oil or additive package are allowed) shall be evaluated in a certified laboratory using the following tests:

Property	Value	Test Method			
	for all product codes:	ISO	ASTM	DIN	Other
Copper Corrosion (3h at 100°C), max	1b	2160	D 130	51759	IP 154
Rust Preventing Characteristics	Pass (no Rust)	7120	D 665B	51585	IP 135
Water Separability, 30 min., max	40/37/3	6614	D 1401	51599	IP 19
Demulsibility			D 2711		
Water in Oil After 5 h, % max	1.0				
Emulsion After Cntrfg., ml max	2.0				
Total Free Water, ml min	60				

4 PERFORMANCE (CONT.)

Property	Value			Test Method			
Product Code, **LW-_ _ - 1-11**	**03**	**06**	**22**	ISO	ASTM	DIN	Other
Timken OK Load, kg min	16	16	27		D 2782		
Stick Slip Ratio of static/kinetic coefficients of friction, max	0.80				D 2877 -70		Cin. Mil. Stick Slip AFNOR NFT 60-183
Cleanliness, as Received, max	20/18/14			4406 11171			

5 CHEMICAL PROPERTIES The product shall not contain water, acid, particulates, or other substances detrimental to the proper function and performance of the components or system for which it is intended. It shall be free from noxious odors or masking fragrances. Identification colorants are permitted provided such do not adversely affect performance. The following requirements shall also be met:

Property	Value	Test Method			
	for all product codes:	ISO	ASTM	DIN	Other
API Gravity	Report		D 287		
Sediment	Nil		D 473		
Precipitation Number, max	0.05		D 91		
Water, as Received, ppm max	500	3733	D 6304[#]		
Tackifier added?	Report				
Base Stock Requirements					Virgin or Rerefined
Tot. PolyNuclear Aromatics, ppm max	100				EPA SW-846 TN 8270
Residual Elements (As, B, Ca, Mn, Mg, Na, Fe, Ni, Si, Cu, Sn, Cd, Cr, Pb, Ba, Zn), ppm max total/ each P, ppm max	 25/2 5		D 5185		
Total Chlorinated Biphenyls	Not Detectable				EPA SW-846 TN 8082*
Total Organic Halogens, ppm max	5				EPA SW-846 TN 9253*
Mutagenicity Fold Increase Mutagenicity Index, max Mutag. Potency Index, max	 Report 1 Report		E-1687		Modified Ames (or skin painting)

***** or other methods as agreed upon by the LS2 committee and supplier

[#] This method is subject to interferences that can sometimes cause the reporting of erroneously high results. If an analysis produces a value for water content that exceeds the maximum limit, it is recommended that the plant work with the supplier to recheck the results. Other methods, such as distillation, FTIR, etc., may be used as agreed upon by the plant and supplier.

6 INITIAL PRODUCT APPROVAL

6.1 Initial product approval is given by the General Motors LS2 Maintenance Lubricants Standards Committee. Only sources listed in the Approved Product List have been qualified by the LS2 committee as meeting the requirements of this specification. No purchases or shipments are to be made until this approval has been completed.

6.2 The supplier shall furnish data showing the composition of the candidate lubricant, with regard to both the specific base stocks (crude source and refinery, etc.) and additive treatment (concentration and generic chemical description of each component).

6.3 The supplier shall submit test results from a laboratory acceptable to the LS2 committee confirming that the product submitted for approval meets all of the stated requirements. Test limits shown are absolute; test precision was considered when setting them.

6.4 Completed copies of the GM Material Safety Data Sheet, GM TMC003 (see Appendix F) shall be submitted for new products or formulation changes; restricted chemicals to be handled per GM1000M.

7 INSPECTION AND REJECTION

7.1 All shipments under contract or purchase order manufactured to this specification shall be identical in every respect to the product approved.

7.2 No changes in the formulation (including both base oil source and additive package and concentration) or manufacturing process are allowed without prior approval of the LS2 committee. Lack of such notification constitutes grounds for rejection of any shipment and removal from the Approved Product List.

7.3 The supplier shall be ISO 9000 or QS 9000 certified and shall perform regular quality control checks at each location where the material is manufactured. Such quality control data shall be made available to the purchaser upon request.

7.4 The purchaser may check incoming shipments for specification compliance; the supplier is responsible for incoming shipments meeting this specification without dependence upon purchaser's inspection. Non-compliance to physical and chemical requirements constitutes grounds for rejection of a shipment.

7.5 If physical or chemical analyses determine that the delivered lubricant is not in compliance with the requirements, the supplier may be held liable for loss of equipment warranty.

7.6 Infrared spectra (GM 9035P) of the incoming lubricant shipments shall not deviate significantly from that of the originally approved material.

8 COMPATIBILITY

Mixtures of the product approved and the product currently used shall pass all of the above requirements. The supplier is responsible that, when this product is mixed with a product already in use, there shall be no incompatibility or loss in operating performance. This product should not cause degradation or loss of performance of commonly used seals.

9 WASTE TREATMENT

The supplier shall be responsible to make known the processing procedures of any component of the lubricant for which waste treatability is in question.

10 GENERAL INFORMATION

10.1 Each container shall be clearly identified on the top and side. The identification shall contain the GM specification number at least 2 inches (5 cm) high on 5 gallon (20 L) or larger containers and prominently displayed on smaller containers.

10.2 All products shall be bar-coded according to AIAG 39.

10.3 This product shall be used only in accordance with applicable hazardous materials procedures in each facility.

10.4 This standard is under the control of the GM LS2 Committee. It was last revised in **2011**.

GM LUBRICANT STANDARD NO. LX-xx-1,2,3,4,5,6-11
METAL REMOVAL FLUIDS - STRAIGHT OILS **PAGE 1 OF 5**

1 SCOPE The fluids defined by this specification are high-quality, straight cutting and grinding fluids. They will be formulated with severely solvent refined or severely hydrotreated mineral base oils, synthetic base oils or vegetable oils and corrosion preventatives. They are intended for metal removal operations where lubricity is a primary concern. These standards meet or exceed SAE MS1008. The individual fluids are categorized as follows:

Product type and/ or end user requirements, Fluid having:	Symbol LX-xx-	Cutting	Grinding	Friction [1] Reducing Properties	Extreme [2] Pressure Properties	Extreme [3] Pressure Properties
Basic properties	1	•				
Friction reducing properties	2	•		•		
Extreme pressure (E.P.) properties, chemically non-active	3	•	•		•	
E.P. properties, chemically active	4	•				•
Friction reducing and E.P. properties, chemically non-active	5	•	•	•	•	
Friction reducing and E.P. properties, chemically active	6	•	•	•		•

1 Friction modified 2 Not corrosive to copper 3 Corrosive to copper

2 REFERENCED STANDARDS

AIAG 39	ASTM D 4052	DIN 51759	IP 278
ASTM D 92	ASTM D 4172	DIN 53505	IP 284
ASTM D 94	ASTM D 4294	DIN 53521	ISO 686
ASTM D 97	ASTM D 4927	DIN 53538	ISO 1817
ASTM D 128	ASTM D 4951	EPA 24	ISO 2049
ASTM D 129	ASTM D 5183	EPA SW-846	ISO 2160
ASTM D 130	ASTM D 5185	GM1000M	ISO 2592
ASTM D 445	ASTM E 1131	GM 9035P	ISO 2909
ASTM D 471	ASTM E 1687	GMTMC003	ISO 3016
ASTM D 664	ASTM F 1110	IP 15	ISO 3104
ASTM D 665	BS 188	IP 36	ISO 3105
ASTM D 808	BS 4231	IP 61	ISO 3448
ASTM D 892	BS 4459	IP 71	ISO 3675
ASTM D 1298	BS 4832	IP 135	ISO 6072
ASTM D 1500	CETOP RP81H	IP 136	ISO 6247
ASTM D 1662	DIN 51519	IP 139	ISO 6293
ASTM D 1833	DIN 51550	IP 146	ISO 6618
ASTM D 2070	DIN 51558	IP 154	ISO 7120
ASTM D 2270	DIN 51561	IP 160	ISO 7619
ASTM D 2422	DIN 51562	IP 177	SAE MS1008
ASTM D 2783	DIN 51566	IP 185	
ASTM D 2893	DIN 51585	IP 196	
ASTM D 3238	DIN 51757	IP 226	

3 PHYSICAL PROPERTIES

Property	Value, _=						Test Method			
Product Code, **LX-xx- _-11**	**1**	**2**	**3**	**4**	**5**	**6**	ISO	DIN	ASTM	other
Pour Point, °C, max	5						3016		D 97	IP 15
Flash Point, °C	ISO VG 2 >110 ISO VG 22 >150 ISO VG 3-7 > 120 ISO VG 32-46 > 160 ISO VG 10 > 140 ISO VG 68 > 170 ISO VG 100 > 200 (If viscosity is between ISO grades, fluid must meet flash point requirement of the lower grade)						2592		D 92	IP 36
ISO Viscosity Grade	Report (If viscosity is between grades, state ISO grades between which it falls)						3448	51519	D 2422	BS 4231
Kinematic Viscosity at 40°C, cSt	Report normal range						3104 3105	51550 51561 51562	D 445	IP 71 BS 188
Viscosity Index	Report						2909		D2270	IP 226 BS4459

4 PERFORMANCE A sample of the exact fluid under consideration (i.e., no changes to base fluid or additive package are allowed) shall be evaluated in a certified laboratory using the following tests:

Property	Value, _=						Test Method			
Product Code, **LX-xx- _-11**	**1**	**2**	**3**	**4**	**5**	**6**	ISO	DIN	ASTM	Other
Rust Preventing Characteristics	Pass (no rust)						7120	51585	D 665B	IP 135
Copper Corrosion (3 hr., 100°C), max	1B			Re-port	1B	Re-port	2160	51759	D 130	IP 154
Four Ball EP Load Wear Index, kg, min Weld Load, kg, min	Report Report		45 Min 200 Min (For EP classification; may not reflect machining performance)						D 2783	
Compatibility With SRE-NBR1 Seals **(DIN 53538)** (168 h, 100°C) or other seals and limits as agreed upon Volume change, % Shore A hardness Change	Report 7 to +10						1817 686 6072 7619	53 521 53 505	D 471	CETOP RP81H, IP 278, BS 4832
Corrosive Effect on Aluminum Run using Al 319, 356, 380, 383, 390	1 Max								F 1110	

4 PERFORMANCE, CONT.

Property	Value, _=						Test Method			
Product Code, **LX-xx- _-11**	**1**	**2**	**3**	**4**	**5**	**6**	ISO	DIN	ASTM	other
Foaming Tendency (Per ASTM D 892) Sequence I, II, III	Report						6247	51566	D 892	IP 146
Misting Properties	As agreed upon between user and supplier									
Machining Properties	As agreed upon between user and supplier									
Four Ball Coefficient of Friction	NA	Re-port	NA		Re-port	Re-port			D 5183	
Thermal Stability Acid No. Change, % Vis. Ch., 40/100°C,% Sludge, mg/100 ml Cu Rod Color CM Cu Weight Loss, mg Steel Rod Color CM	Report Report Report Report Report Report Not required for type 4 or 6								D 2070 (75 ml oil, 101°C, 72h)	CM Proc. B
Oxidation Stability Viscosity Increase at 100°C, % max	Report								D 2893 (at 121°C)	
Four-Ball Wear (20 kg load) Wear Scar Diameter, mm, max	Report								D 4172	
Waste Treatability	As agreed upon between user and supplier									
Filterability (use 20u paper in lieu of 1.6 μm and recirculate sample for 24 hours)	Report								D 2068	

5 CHEMICAL PROPERTIES The product shall not contain water or other substances detrimental to the proper function and performance of the components or system for which it is intended. It shall be free from noxious odors. Identification colorants and some odorants are permitted provided such do not adversely affect performance. The following requirements shall also be met:

5 CHEMICAL PROPERTIES (CONT.)

Property	Value	Test Method			
	for all product codes:	ISO	DIN	ASTM	Other
Saponification number	Report	6293		D 94	IP 136: Sec. 1
Volatile Organics, by TGA or oven method, %	Report			E 1131	EPA 24
Chlorine, %	Report*			D 808	
Total Sulfur, %	Report*			D 129 D 4294 D 4951	IP 61
Active Sulfur, %	Report*			D 1662	
Phosphorus, %	Report*			D 4927 D 4951	
Total Acid Number and Base Number	Report	6618	51 558 Part 1	D 664	IP 177 IP 139
Fatty Acid, %	Report*			D 128	IP 284
Esters, % (Includes fats, fatty acids, and esters)	Report*			D 128	IP 284
Density	Report	3675	51757	D 4052 D 1298	IP 160
Color	Report (or indicate, if dyed)	2049		D 1500	IP 196
Odor - method modified as appropriate	As agreed upon between user, supplier			D 1833	IP 185
Base Stock Requirements	(Virgin, Re-refined or Reclaimed)				
Paraffinic, Naphthenic, Aromatic Content				D 3238	
Tot. PolyNuclear Aromatics, ppm max	100				EPA SW-846 TN 8270*
Residual Elements (As, B, Ca, Mn, Mg, Na, Fe, Ni, Si, Cu, Sn, Cd, Cr, Pb, Ba, Zn), ppm max total/ each P, ppm max	 25/2 5			D 5185	
Total Chlorinated Biphenyls	Not Detectable				SW-846 TN 8082*
Total Organic Halogens, ppm max	5				SW-846 TN 9253*
Mutagenicity Fold Increase Mutagenicity Index, max Mutag. Potency Index, max	 Report 1 Report			E 1687	Modified Ames (or skin painting)

*** Equivalent methods may be used as agreed upon between user and supplier**

6 INITIAL SOURCE APPROVAL

6.1 Initial source approval is given by the General Motors LS2 Maintenance Lubricants Standards Committee. Only sources listed in the Approved Product List have been qualified by the LS2 committee as meeting the requirements of this specification. No purchases or shipments are to be made until this approval has been completed.

6 INITIAL SOURCE APPROVAL (Cont.)

6.2 The supplier shall furnish data showing the composition of the candidate lubricant, with regard to both the specific base stocks (crude source and refinery, etc.) and additive treatment (concentration and generic chemical description of each component).

6.3 The supplier shall submit test results from a laboratory acceptable to the LS2 committee confirming that the product submitted for approval meets all of the stated requirements. Test limits shown are absolute; test precision was considered when setting them.

6.4 Completed copies of the GM Material Safety Data Sheet, GM TMC003 (see Appendix F) shall be submitted for new products or formulation changes; restricted chemicals to be handled per GM1000M.

7 INSPECTION AND REJECTION

7.1 All shipments under contract or purchase order manufactured to this specification shall be identical in every respect to the product approved.

7.2 No changes in the formulation (including both base oil source and additive package and concentration) or manufacturing process are allowed without prior approval of the LS2 committee. Lack of such notification constitutes grounds for rejection of any shipment and removal from the Approved Product List.

7.3 The supplier shall be ISO 9000 or QS 9000 certified and shall perform regular quality control checks at each location where the material is manufactured. Such quality control data shall be made available to the purchaser upon request.

7.4 The purchaser may check incoming shipments for specification compliance; the supplier is responsible for incoming shipments meeting this specification without dependence upon purchaser's inspection. Non-compliance to physical and chemical requirements constitutes grounds for rejection of a shipment.

7.5 If physical or chemical analyses determine that the delivered lubricant is not in compliance with the requirements, the supplier may be held liable for loss of equipment warranty.

7.6 Infrared spectra (GM 9035P) of the incoming lubricant shipments shall not deviate significantly from that of the originally approved material.

8 COMPATIBILITY

Mixtures of the product approved and the product currently used shall pass all of the above requirements. The supplier is responsible that, when this product is mixed with a product already in use, there shall be no incompatibility or loss in operating performance. This product should not cause degradation or loss of performance of commonly used seals.

9 WASTE TREATMENT

The supplier shall be responsible to make known the processing procedures of any component of the lubricant for which waste treatability is in question.

10 GENERAL INFORMATION

10.1 Each container shall be clearly identified on the top and side. The identification shall contain the GM specification number at least 2 inches (5 cm) high on 5 gallon (20 L) or larger containers and prominently displayed on smaller containers.

10.2 All products shall be bar-coded according to AIAG 39.

10.3 This product shall be used only in accordance with applicable hazardous materials procedures in each facility.

10.4 This standard is under the control of the GM LS2 Maintenance Lubricant Standards Committee. It was last revised in **2011**.

GM LUBRICANT STANDARD NO. LY-00-1,2,3,4,5,6,7,8-11
METAL REMOVAL FLUIDS - AQUEOUS FLUIDS **PAGE 1 OF 9**

1 SCOPE The fluids defined by this specification are high-quality, aqueous cutting and grinding fluids formulated with corrosion preventatives, intended for metal removal operations where cooling is a primary concern. These standards meet or exceed SAE MS1008 and include fluids traditionally defined as water soluble, semi-synthetic and synthetic. The individual fluids are categorized as follows:

Product type and/ or end user requirements, Concentrates, blended with water, giving:	Symbol LY-00-	Emul-sion	Micro-emul-sion	Solu-tion	Friction [1] Reducing Properties	Extreme Pressure Properties	Typical De-scription
Milky emulsions	1	•					Soluble oils
Milky emulsions having friction reducing properties	2	•			•		Soluble oils
Milky emulsions extreme pressure (E.P.) properties	3	•				•	Soluble oils
Milky emulsions having friction reducing (F.R.) and E.P. properties	4	•			•	•	Soluble oils
Translucent emulsions (micro-emulsion)	5		•				Semi-synthetic
Translucent emulsions (micro-emulsions) having F.R. and/or E.P. properties	6		•		• **and/or** •		Semi-synthetic
Transparent solutions	7			•			Synthetic
Transparent solutions having friction reducing and/ or E.P. properties	8			•	• **and/or** •		Synthetic

1 Friction modified

2 REFERENCED STANDARDS

AFNOR NFT 60-187	ASTM D 3238	DIN 51519	IP 177
AIAG 39	ASTM D 3519	DIN 51550	IP 196
ASTM D 92	ASTM D 3946	DIN 51558	IP 276
ASTM D 97	ASTM D 4052	DIN 51561	IP 278
ASTM D 128	ASTM D 4294	DIN 51562	IP 284
ASTM D 129	ASTM D 4627	DIN 51569	ISO 868
ASTM D 130	ASTM D 4927	DIN 51757	ISO 1817
ASTM D 445	ASTM D 4951	DIN 51759	ISO 2049
ASTM D 471	ASTM D 5183	DIN 53505	ISO 2160
ASTM D 664	ASTM D 5185	DIN 53521	ISO 2592
ASTM D 808	ASTM E 70	DIN 53538	ISO 3016
ASTM D 974	ASTM E 1687	EPA SW-846	ISO 3104
ASTM D 1298	ASTM F 1110	GM1000M	ISO 3105
ASTM D 1401	BS 188	GM 9035P	ISO 3448
ASTM D 1500	BS 4231	GMTMC003	ISO 3675
ASTM D 1662	BS 4832	IP 15	ISO 3696
ASTM D 2068	CETOP RP81H	IP 36	ISO 3771
ASTM D 2422	DIN 38405	IP 61	ISO 6072
ASTM D 2783	DIN 38406	IP 71	ISO 6618
ASTM D 2896	DIN 38409	IP 139	ISO 7619
ASTM D 3228	DIN 51360	IP 154	SAE MS1008
	DIN 51369	IP 160	

3 PHYSICAL PROPERTIES

These tests to be run on the undiluted concentrate:

Property	Value, _=						Test Method			
Product Code, **LY-00- _-11**	**1/2**	**3/4**	**5**	**6**	**7**	**8**	ISO	DIN	ASTM	other
Description	soluble oil		semi-synthetic		synthetic					
Pour Point, °C	Report						3016		D 97	IP 15
ISO Viscosity Grade	Report*						3448	51519 51550	D 2422	BS 4231
Kinematic Viscosity at 40°C, cSt	Report						3104 3105	51550 51561 51562	D 445	IP 71 BS 188
Flash Point, °C	Report						2592		D 92	IP 36

*** For a fluid with a viscosity between grades, state the grades between which it falls**

4 PERFORMANCE A sample of the exact fluid under consideration (i.e., no changes to base fluid or additive package are allowed) shall be evaluated in a certified laboratory using the following tests:

These tests to be run on the undiluted concentrate:

Property	Value, _=						Test Method			
Product Code, **LY-00- _-11**	**1/2**	**3/4**	**5**	**6**	**7**	**8**	ISO	DIN	ASTM	other
Description	soluble oil		semi-synthetic		synthetic					
Four Ball EP Load Wear Index, kg Weld Load, kg (For EP classification purposes only)	Re-port	45 200 min	Re-port	45 200 min	Re-port	45 200 min			D 2783	
Emulsion Stability	Report				NA					AFNOR NFT 60-187
Corrosive Effect on Iron Chips	Report breakpoint concentration							51360	D 4627	
Copper Corrosion (3 hours at 100°C), max	1B	Re-port	1B	Re-port	1B	Re-port	2160	51759	D 130	IP 154
Corrosive Effect on Al Run using Al 319, 356, 380, 383, 390	1 Max								F 1110	
Compatibility With SRE-NBR1 Seals **(DIN 53538)** (168 h, 100°C) or other seals and limits as agreed upon Volume change, % Shore A hardness Change	Report -7 to +10						1817 6072 868 7619	53521 53505	D 471	CETOP RP81H, IP 278, BS 4832

4 PERFORMANCE, CONT.

These tests to be run, unless otherwise specified, at the manufacturer's recommended concentration using the standard plant water specified in the Annex A on page 5-102, or local plant water as agreed upon between user and supplier:

Property	Value, _=						Test Method			
Product Code, **LY-00- _-11**	**1/2**	**3/4**	**5**	**6**	**7**	**8**	ISO	DIN	ASTM	other
Description	soluble oil		semi-synthetic		synthetic					
Foam by Blender Test*****; Maximum Foam Height Time to Defoam to 10 mm After Filterability Test: Maximum Foam Height Time to Defoam to 10 mm	Report Report Report Report								D 3519	
Filterability, re-circulate sample for 24 h)	use 20 μm paper in lieu of 1.6 μm Report FBT								D 2068	
Misting Tendency	As agreed upon between user and supplier									
Machining Properties	As agreed upon between user and supplier									
Coefficient of Friction	Report (Not Required for types 1,3, 5, 7)								D 5183	
Sticking/Gumming Tendency use Annex A water	Report									Annex B, p 5-103
Bioresistance[#], 5% solution Bacteria, fungal counts, odor, pH at 0, 5, 8, 13 days	Report								D 3946	
Tramp Oil Rejection Blend 50 ml 5% MRF conc. in water w/ 50 ml fluid A, let stand in graduated cylinder for 24 hrs; repeat w/fluid B. Oil, ml Emulsion, ml Fluid, ml	Fluid A = ISO 46 hydraulic fluid Fluid B = ISO 68 way lube Report Report Report								D 1401 modi-fied	
Waste Treatability, mg/L Biochemical Oxygen Demand Chemical Oxygen Demand Total Kjeldahl Nitrogen	 Report Report Report								 D 3228	 EPA 405.1 EPA 410.1 EPA 351.3

*** Run at 5% in DI water and at 5% in standard water (see Annex A, p. 5-102)**

[#] This test can also be run for mycobacteria specifically, if desired

5 CHEMICAL PROPERTIES The product shall not contain substances detrimental to the proper function and performance of the components or system for which it is intended. It shall be free from noxious odors. Identification colorants and some odorants are permitted provided such do not adversely affect performance. The following requirements shall also be met:

These tests to be run at the manufacturer's recommended concentration using the standard plant water specified in Annex A or local plant water as agreed upon between user and supplier:

Property	Value, _=						Test Method			
Product Code, **LY-00- _-11**	**1/2**	**3/4**	**5**	**6**	**7**	**8**	ISO	DIN	ASTM	other
Description	soluble oil		semi-synth.		synthetic					
Base no., mg KOH	Report						3771		D 2896	IP 276
pH at 5% dilution	Report							51369	E 70	

These tests to be run on the undiluted concentrate:

Property	Value, _=						Test Method			
Product Code, **LY-00- _-11**	**1/2**	**3/4**	**5**	**6**	**7**	**8**	ISO	DIN	ASTM	other
Description	soluble oil		semi-synthetic		synthetic					
Density	Report						3675	51757	D 4052 D 1298	IP 160
Color	Report						2049		D 1500	IP 196
Mineral base oil content, mass %	Report				NA					
Chlorine, %	Report*								D 808	
Total Sulfur, %	Report*								D 129, D 4294 D 4951	IP 61
Active Sulfur, %	Report*								D 1662	
Esters, % (Incl. fats, fatty acids, and esters)	Report*								D 128	IP 284
Fatty Acid, %	Report*				NA				D 128	IP 284
Recommended hard-ness range of water	Report									
Phosphorus, %	Report*								D 4927 D 4951	

***Equivalent methods may be used as agreed upon between user and supplier**

These tests to be run on the undiluted concentrate:

Property	Value, _=						Test Method			
Product Code, **LY-00- _-11**	**1/2**	**3/4**	**5**	**6**	**7**	**8**	ISO	DIN	ASTM	other
Description	soluble oil		semi-synthetic		synthetic					
Base Stock Requirements	(Virgin, Re-refined or Reclaimed)									
Paraffinic, Naphthenic, Aromatic Content	Report*				NA				D 3238	
Tot. PolyNuclear Aromatics, ppm max	100				NA					EPA SW-846 TN 8270*
Residual Elements (As, B, Ca, Mn, Mg, Na, Fe, Ni, Si, Cu, Sn, Cd, Cr, Pb, Ba, Zn), ppm max/ total/ each P, ppm max	25/2 5				NA NA				D 5185	
Total Chlorinated Biphenyls	Not Detectable				NA					SW-846 TN 8082*
Total Organic Halogens, ppm max	5				NA					SW-846 TN 9253*
Mutagenicity Fold Increase Mutagenicity Ind. max Mutag. Potency Index	 Report 1 Report				NA				E 1687	Modified Ames (or skin painting)

*** Equivalent methods may be used as agreed upon between user and supplier**

6 INITIAL SOURCE APPROVAL

6.1 Initial source approval is given by the General Motors LS2 Maintenance Lubricants Standards Committee. Only sources listed in the Approved Product List have been qualified by the LS2 committee as meeting the requirements of this specification. No purchases or shipments are to be made until this approval has been completed.

6.2 The supplier shall furnish data showing the composition of the candidate lubricant, with regard to both the specific base fluid and additive treatment (concentration and generic chemical description of each component).

6.3 The supplier shall submit test results from a laboratory acceptable to the LS2 committee confirming that the product submitted for approval meets all of the stated requirements. Test limits shown are absolute; test precision was considered when setting them.

6.4 Completed copies of the GM Material Safety Data Sheet, GM TMC003 (see Appendix F) shall be submitted for new products or formulation changes; restricted chemicals to be handled per GM1000M.

7 INSPECTION AND REJECTION

7.1 All shipments under contract or purchase order manufactured to this specification shall be identical in every respect to the product approved.

7.2 No changes in the formulation (including both base fluid source and additive package and concentration) or manufacturing process are allowed without prior approval of the LS2 committee. Lack of such notification constitutes grounds for rejection of any shipment and removal from the Approved Product List.

7.3 The supplier shall be ISO 9000 or QS 9000 certified and shall perform regular quality control checks at each location where the material is manufactured. Such quality control data shall be made available to the purchaser upon request.

7.4 The purchaser may check incoming shipments for specification compliance; the supplier is responsible for incoming shipments meeting this specification without dependence upon purchaser's inspection. Non-compliance to physical and chemical requirements constitutes grounds for rejection of a shipment.

7.5 If physical or chemical analyses determine that the delivered lubricant is not in compliance with the requirements, the supplier may be held liable for loss of equipment warranty.

7.6 Infrared spectra (GM 9035P) of the incoming lubricant shipments shall not deviate significantly from that of the originally approved material.

8 COMPATIBILITY

Mixtures of the product approved and the product currently used shall pass all of the above requirements. The supplier is responsible that, when this product is mixed with a product already in use, there shall be no incompatibility or loss in operating performance. This product should not cause degradation or loss of performance of commonly used seals.

9 WASTE TREATMENT

The supplier shall be responsible to make known the processing procedures of any component of the lubricant for which waste treatability is in question.

10 GENERAL INFORMATION

10.1 Each container shall be clearly identified on the top and side. The identification shall contain the GM specification number at least 2 inches (5 cm) high on 5 gallon (20 L) or larger containers and prominently displayed on smaller containers.

10.2 All products shall be bar-coded according to AIAG 39.

10.3 This product shall be used only in accordance with applicable hazardous materials procedures in each facility.

10.4 This standard is under the control of the GM LS2 Maintenance Lubricant Standards Committee. It was last revised in **2011**.

ANNEX A -- PROPERTIES AND REQUIREMENTS FOR STANDARD WATER

Property	Nominal Value	Test Method			
		ISO	DIN	ASTM	other
pH value	6.5 - 8.5		DEV - C5	E 70	
Sum of alkaline earth's (Ca^{2+} + Mg^{2+}), mmol/l	3.58		DIN 38 406, Part 3		
Acid content up to pH 4.3 (bicarbonate HCO_3^-), mmol/l	3.0		DIN 38 409, Part 7 DEV - H7		
Ca^{2+} ions, mg/l	61		DIN 38 406, Part 3		
Mg^{2+} ions, mg/l	50		DIN 38 406, Part 3		
Na^+ ions, mg/l	113				
Cl^- ions, mg/l	201		DEV - D1		
SO_4^{2-} ions, mg/l	145		DEV - D5		
NO_3^- ions, mg/l	20		DIN 38 405, Part 9 DEV D9		
Total iron, mg/l	≤ 1		DEV - E1		

The standard water is produced by dissolving the following chemicals in deionized water:

Additives (by analysis)	Units	Additive amount	Additive corresponds to
Magnesium chloride, hexahydrate $MgCl_2 \cdot 6H_2O$	mg/l	420	146.6 mg/l Cl^- 50.2 mg/l Mg^{2+}
Calcium sulfate dihydrate, $CaSO_4 \cdot 2H_2O$	mg/l	260	60.6 mg/l Ca^{2+} 145.1 mg/l SO_4^{2-}
Sodium bicarbonate, $NaHCO_3$	mg/l	255	69.9 mg/l Na^+ 185.5 mg/l HCO_3^-
Sodium chloride, NaCl	mg/l	90	35.4 mg/l Na^+ 54.6 mg/l Cl^-
Sodium nitrate, $NaNO_3$	mg/l	27	7.3 mg/l Na^+ 19.7 mg/l NO_3^-

ANNEX B – AQUEOUS MACHINING FLUIDS, EVALUATION OF GUMMING TENDENCY (From SAE MS 1008)

B.1 Scope
This annex describes a method for evaluating the residue-forming tendency of aqueous machining fluids. This method applies to categories MAA to MAH.

B.2 Referenced Standards
ISO 3696:1987 Water for analytical laboratory use - Specification and test methods
ISO/DIS 6344-1:1986 Coated abrasives - Grain size analysis Part 1: Definitions, designation and principle

B.3 Definition
Gumming: through evaporation in the air, aqueous fluids leave organic and/or mineral residues (gums). Depending on their consistency and their resolubility in water or in the machining fluid, these residues may have harmful consequences on the operation of the machines, for example: blocking of spindles, tool turrets, table saddles, slideways, or measuring gauges. These consequences are referred to as gumming.

B.4 Preparation of the aqueous fluids
The aqueous fluid shall be prepared at the recommended concentration of use, using water agreed upon between the end user and the supplier. This water can be either the process water of the end user or any artificial water of pre-determined hardness (for example, see Annex A).

B.5.1 Principle
Specified volumes of the machining fluid at the concentration normally used are placed in watch glasses and submitted to evaporation under specified conditions. After evaporation, the fluidity of the residue and its solubility in water are determined under specified conditions.

B.5.2 Reagents and materials
B.5.2.1 Water, type 2, according to ISO 3696.
B.5.2.2 Mixture, made up of 50 ml of toluene (B.5.2.4), plus 5 ml of water (B.5.2.1), plus 495 ml of anhydrous isopropyl alcohol (B.5.2.5).
B.5.2.3 Water, type 3, according to ISO 3696.
BC.5.2.4 Toluene, technical grade
B.5.2.5 Isopropyl alcohol, technical grade

B.5.3 Apparatus
Usual laboratory apparatus and glassware together with the following:
B.5.3.1 Watch glasses, with external diameter of 100 mm.
B.5.3.2 Beaker, of 1000 ml capacity, low-sided.
B.5.3.3 Separatory funnel, of 100 ml capacity, and support.
B.5.3.4 Natural convection oven, capable of maintaining a temperature of 70 °C ± 2 °C.
B.5.3.5 Forced convection oven, capable of maintaining a temperature of 70 °C ± 2 °C.
B.5.3.6 Mechanical agitator, capable of operating at 600 rpm, and its chuck.
B.5.3.7 Agitator, with a stainless steel blade 120 mm long, 19 mm wide, and 1.5 mm thick.
B.5.3.8 Desiccator, equipped with a dehydrating agent (e.g., silica gel).
B.5.3.9 Folded filter paper, 185 mm diameter.

B.5.4 Procedure
NOTE - This test can also be used to evaluate the gumming tendency of an aqueous machining fluid in use. In this case, care must be taken to separate out foreign oils, using the separatory funnel (B.5.3.3) for 4 h. The separated aqueous phase is then filtered on the folded filter paper (B.5.3.9) placed in a funnel.

ANNEX B, Cont.

B.5.4.1 Evaporation
Into two watch glasses (B.5.3.1), tared beforehand to the nearest mg, transfer 20 ml of the product to be tested. Place the watch glass respectively:

- in a natural convection oven set to 70 ± 2 °C for 24 h;
- in a forced air oven set to 70 ± 2 °C for 15 h.

At the end of the periods indicated, remove the watch glasses from the ovens and place them in the desiccator (B.5.3.8) to cool for 1 h. Then weigh each of the watch glasses and determine the mass of the dry residue A.

B.5.4.2 Evaluation of the residue
B.5.4.2.1 Flow properties
One of the two watch glasses (B.5.3.1) containing the residue after evaporation is maintained in a vertical position (between the thumb and forefinger). The time taken for the first drop to appear on the edge of the watch glass is then measured.

If this time is :

- < 30 s, the residue is considered fluid;
- > 30 s, the residue is considered non-fluid.

The appearance of the residue is also noted:

- presence or absence of crystalline deposits;
- adhesive aspect (creation of a thread by pulling).

B.5.4.2.2 Determination of the resolubility of the residue
A diagram of the apparatus is given in Figure B.1.

The mechanical agitator (B.5.3.6), fitted with its blade (B.5.3.7), is positioned so that the edges of the blade are situated 10 mm from the bottom of the beaker (B.5.3.2) and 15 mm from the edge. The beaker (B.5.3.2) is filled with water (B.5.2.1) to a point 35 mm below the upper edge. The watch glass is fixed onto the support, with the concave side towards the blade of the agitator. The watch glass must be totally immersed in the water, with its lowest edge 10 mm from the bottom of the beaker and the edges of the horizontal diameter touching the side of the beaker. Set the agitator rotating at a speed of 600 revs/min for 15 min ± 15 s.

At the end of this time, remove the watch glass, dip it three times for 2 s in a beaker containing water (B.5.2.3) and leave to drain for 15 s ± 1 s. If residues have been deposited on the back of the watch glass, remove them using a paper soaked in the mixture (B.5.2.2). Then, dry the watch glass in the oven (B.5.3.4) for 2 h ± 5 min at 70 °C ± 2 °C. At the end of this time, leave it to cool for 1 h in the desiccator (B.5.3.8). Then weigh the watch glass and deduce the mass of residue B.

B.5.5 Calculation

$$S = \frac{A-B}{A} \; 100 = \frac{C}{A} \; 100$$

where:

S in the resolubility of the residue in % (m/m);
A is the mass of dry residue obtained in B.5.4.1;
B is the mass of residue obtained in B.5.4.2.2;
C is equal to A - B, the mass of soluble product.

ANNEX B, Cont.

B.5.6 Expression of results
The fluidity and the appearance of the residue are expressed according to B.5.4.2.

The resolubility of the residue S (%) is determined on the residues obtained under the two types of evaporation conditions (B.5.4.1) (S_{24h} and S_{15h}).

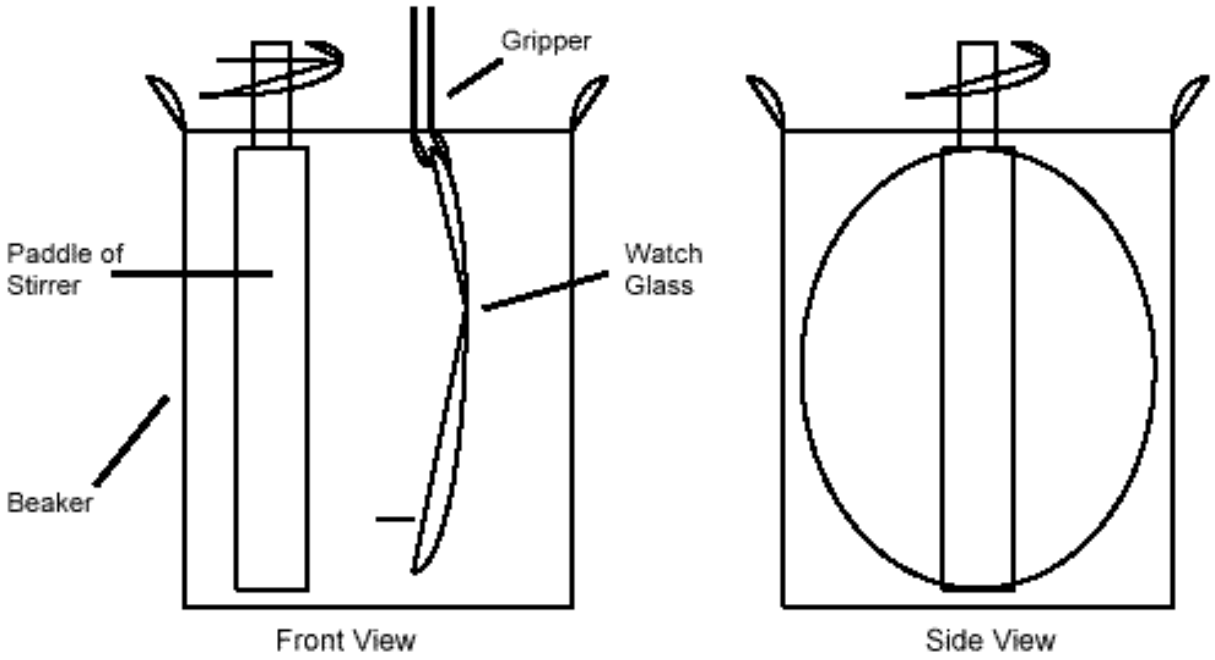

Figure B.1 Device to solubilize the residue

L6 SUPPLEMENTS

L6 USE OF LUBRICANT SUPPLEMENTS TO ENHANCE PERFORMANCE.

L6.1 We strongly discourage the use of additives or supplements. Most do not provide any benefit. A lubricant that meets the applicable LS2 standard is all that is required, in most cases.

L.6.1.1 Suppliers who give testimonials regarding lubricant supplements often approach plant personnel. Often only the company selling the product analyzes the data in support of the supplement. When such practices are used, plant personnel may receive insufficient information and may purchase products that will have unknown consequences in use.

L6.1.2 Testimonial letters shall not be considered scientific evidence. "Evidence" presented in testimonials is generally not complete and may not include the same tests both with and without the lubricant supplement. We strongly recommend that plant personnel use caution when considering the purchase of any type of lubricant supplement, additive or "treatment".

L6.1.3 Documentation in support of the supplement should include identical tests run with and without the supplement conducted by an independent testing laboratory, preferably using ASTM standard test methods, or using equipment comparable to that used in the plant. If independent documentation of the benefits of a particular oil supplement is lacking, the supplier should be asked to generate the necessary tests conducted by a neutral party.

L6.2 RECOMMENDED TESTING. Oil supplements that claim to reduce friction, wear, and energy consumption must pass (at the recommended treat rate in the current lubricant) the following tests. **The tests shall be run at the supplier's expense at a laboratory acceptable to the LS2 committee.**

- All tests required for the applicable standard, as found in section L5 of this document (e.g., for an ISO 46 hydraulic fluid, LH-04-1 would be the applicable standard).
- (If energy savings is claimed) Energy consumption in a controlled test, compared to that without the supplement, measured in kilowatt hours, rather than current, in amps. GM R&D ran carefully controlled tests on several additives for which energy savings were claimed and most provided no benefit.
- Tests on the effect of the oil supplement on seal compatibility.
- Inspection of components from plant equipment or laboratory tests in which the supplement was tested for effects of additives on metal surfaces.

Before using any additive or supplement, please contact the chair of the LS2 committee for advice.

L7 PROACTIVE MAINTENANCE

L7.1 INTRODUCTION. Running industrial equipment to breakdown is very costly due to downtime, required parts inventory, maintenance personnel and repair costs. Furthermore, equipment that is failing does not work properly and production can suffer significantly. Consequently, the cost of maintenance is rapidly expanding. For this reason, GM plants have utilized preventative, predictive, and proactive maintenance schedules to alleviate high production costs. This section briefly summarizes this subject. For more detailed information the reader is advised to consult with the UAW/GM Quality Network Planned Maintenance organization.

L7.1.1 Preventative Maintenance is work scheduled to make repairs on a repetitive basis; includes repairs that are planned and completed prior to breakdown (e.g., change the oil filter every three months or five thousand miles, whichever occurs first). Preventive methods are any processes put in place to ensure that the repetitive work occurs. This can be a manual or computerized system. When preventative maintenance is implemented well it can typically produce savings in excess of 28% over "breakdown" maintenance, where maintenance is performed when a machine has failed to perform as expected [7.1]. However, the benefit is partly wasted, because maintenance performed in accordance with a schedule is very inefficient, compared with maintenance performed as justified by the equipment's condition.

L7.1.2 Predictive maintenance, also called condition monitoring, is a way to achieve typical additional savings of 16% over preventative maintenance [7.1]. Work scheduled to monitor machine condition, predict pending failure and make repairs on an as-needed basis; includes work being completed prior to breakdown (i.e., change the oil filter when the pressure drop across the filter increases to XX psi, lighting the monitor lamp reading “service the oil filter within 500 miles or engine damage may occur”). The owner operator may initiate predictive maintenance, by machine condition monitoring or by periodic inspections by trades personnel. Examples of predictive technologies are vibration analysis, infrared, ultrasonic and oil analysis. The use of these techniques has been an effective way of recognizing symptoms of impending machine failure. The major benefit is an early warning that reduces the number of "catastrophic failures" and allows for scheduling downtime. This approach recognizes the small failures that begin chain reactions that ultimately lead to massive equipment failure and costly downtime.

L7.1.3 Proactive maintenance is recognized as the single most important means of achieving savings compared to the conventional maintenance techniques. Greater than 99% savings over “breakdown” maintenance [7.1] have been seen with an effective proactive maintenance program. The proactive maintenance approach is maintenance activity that is planned and scheduled as opposed to reactive, unscheduled and emergency or breakdown activity. Work that includes all predictive and preventive activities, it attempts to avoid the underlying conditions that lead to fluid degradation and machine faults and degradation. Unlike predictive or preventative maintenance approaches, proactive maintenance is aimed at monitoring and correcting the root causes of failure - not just symptoms - early in machine life.

Often times, the symptoms of failure mask the root cause. For example, equipment failure is often attributed to poor quality or bad lubricant, but the root cause may be contamination of the lubricant.

Consequently, proactive maintenance is an approach carried out in a systematic way to detect and correct root-cause aberrations that lead to failure. The longevity of system components can be greatly extended by maintaining critical parameters within acceptable limits through the practice of "detection and correction" of root-cause aberrations. Changes that can occur in each of the key parameters often result in the following sequence of events:

- material/fluid deterioration;
- equipment performance degradation;

- total loss in component and/or system functionality.

An effective oil analysis program combined with the recycling of industrial lubricants is one effective way of correcting the root causes of fluid degradation and machine failures.

L7.2 ROOT CAUSES FOR FAILURE. Any system condition that can lead to material and/or performance degradation is designated as a "root cause of failure". Eight "root causes of failure" are commonly found in hydraulic systems [7.2]. They include: contamination, leakage, degradation of a fluid's chemical properties, degradation of a fluid's physical properties, cavitation effects, temperature effects, accelerated wear and mechanical instabilities. For the most part, the principles apply for many other industrial lube systems, as well. These are briefly discussed below.

L7.2.1 Contamination. The sources of contamination in the fluid must be recognized, identified, analyzed, quantified, removed and maintained at a level below the critical tolerances of the individual components of the system. These critical (life dependent) root causes for failure are given below. These include particulates, air, water, and microbial contamination.

7.2.1.1 Particulate contamination is found in operating systems in all shapes or forms, and in a variety of particle distributions. There are four primary sources of particulate contaminants in hydraulic and lubricating systems. Built-in contaminants come from components, fluids, hoses, reservoirs, etc. Generated contaminants result from the assembly of a system, break-in of a system, operation of a system and fluid breakdown. Externally ingressed contaminants enter a system through reservoir breathing, cylinder rod seals and bearing seals, while maintenance-related contaminants are introduced when equipment is disassembled and re-assembled and makeup oil is added. Typically, there are three types of failure modes associated with particulate contamination:

7.2.1.2 Contaminant wear is a failure mode that occurs when solid particles are entrained into the fluid. The entrained particles sometimes become embedded into other softer particles in the fluid and as the fluid flows through clearance spaces, the particle proceeds to cut and destroy the harder surface. This is a form of particle abrasion. Impingement erosion, another form of contaminant wear, occurs where high velocity fluids can strike or impinge on other surfaces, such as in a control valve orifice.

7.2.1.3 Particle jam occurs when one or more particles bridge an orifice or clearance space and prevent or impede the movement of fluid or mechanical elements. The service life of a pump has been correlated with contamination level and Omega rating (a term that reflects the component sensitivity at operating conditions).

7.2.1.4 Silt lock is a condition that occurs in a control valve at the entrance of a clearance space between the spool and the valve bore. Seizure occurs when the valve's movements are restricted due to very small particles that have become wedged between critical clearances. Relatively few particles are needed to bridge the entrance of a clearance and cause seizure.

7.2.1.5 Maintaining the contamination level of a fluid within acceptable limits is essential in avoiding contaminant wear, jam and lock.

7.2.1.6 Fluid cleanliness levels are expressed, and can be monitored, by the International Standards Organization (ISO) Cleanliness Code, ISO 4406. Selecting three ISO range numbers that correspond to the number of particles in a milliliter of fluid greater than 2, 5, and 15 microns, or 4, 6 and 14 microns, (see Section L1) creates an ISO Code.

7.2.1.7 Air contamination not only degrades the performance of the system, but also oxidizes the fluid, which in turn reduces the service life of the equipment components.

Entrained air, i.e., air that is dissolved within the fluid, may not create any major problems for the hydraulic or other lube oil systems, as

long as it remains dissolved within the fluid. If, however, there is a sudden pressure drop anywhere within the system, the air bubbles released from the fluid may adversely affect the system's mechanical performance. The presence of minute air bubbles in a colloidal-like suspension, giving the liquid a cloudy or hazy appearance, are difficult to expel, as distinct from foam.

Because entrained air is compressible, it can cause erratic and inefficient operation of the hydraulic system. The amount of air that a fluid can absorb is also a function of pressure. At 1500 psi (100 Bar), a saturated fluid can hold 100 times more air than it can hold at atmospheric pressure [7.2]. Consequently, if dissolved air is not removed, the system may suffer severe consequences.

Undissolved air can create a variety of problems within the system, including mechanical problems, higher operating temperatures, accelerated oxidation of the fluid, foaming, and loss of liquid. Foaming, the occurrence of a frothy mixture of air and fluid, can result from excessive agitation, improper fluid levels, air leaks, etc.

7.2.1.8 **Water contamination** of oil is serious, because it causes oxidation and acid formation, which promotes metallic corrosion. Metal corrosion is the result of an electrochemical reaction. For corrosion to occur, an electrolytic cell must exist. Such a cell requires an anode, where oxidation and metal dissolution takes place; a cathode, where reduction of oxygen takes place; a suitable electrolyte (in this case water) and an external path connecting the anode and cathode. Corrosion reactions are accelerated by the presence of oxygen and higher temperatures.

Because of oil's affinity for water, water is nearly always present in fluid systems. Water may be present as dissolved water, as free water, or as an emulsion. Sources of water contamination include:

- heat exchanger or coolant leaks;
- seal leaks;
- condensation of humid air;
- inadequate reservoir covers;
- temperature drops in the system,

Causing dissolved water to condense.

The amount of dissolved water a fluid can absorb depends on the oil's base stock, viscosity, additive package, and temperature. The saturation level for typical hydraulic oil at a normal operating temperature is about 200-400 ppm. Above this level, the oil takes on a cloudy appearance. An increase in temperature will cause the fluid to absorb more water and then, when the temperature decreases, the water is desorbed and entrained droplets appear (giving rise to a cloudy/milky appearance).

Entrained or free water, because of differences in specific gravity, separates from the system's fluid. In mineral-base oils, water collects at the bottom of the fluid. In phosphate esters and chlorinated hydrocarbons, free water floats on top of the fluid.

Water causes rust and corrosion, emulsions and sludge formation and the loss of additives. Excessive amounts of water have an adverse effect on the performance of the manufacturing lubricants and significantly reduce the operating life of the manufacturing equipment.

7.2.1.9 **Microbial contamination** is due to the presence of microorganisms in water-containing fluid systems. Microorganisms that give rise to contamination problems include the following: viruses, bacteria, fungi, protozoa, and algae. High microbial activity leads to the following:

- short fluid life;
- degraded workpiece surface finish;
- short filter life;
- rapid metal corrosion;
- fluid discoloration;
- foul odors.

In general, mineral-based industrial fluids have been relatively free from this form of contaminant. However, with the increasing use of water-based fluids, microbial contamination is an increasing problem.

L7.2.2 **Leakage.** All fluid systems leak, either internally or externally. Leakage is an unwanted loss of fluid from a system that

could also jeopardize, degrade or destroy a system's functional integrity.
Some of the causes of leakage include:

- improper equipment design and component selection;
- severe operating conditions;
- poor manufacturing methods through assembly and poor component quality;
- poor maintenance practices.

Some of the major sources affecting component and system leakage are:

- worn or damaged seals;
- wrong seal for the specific application;
- vibration sensitive fittings;
- improperly manufactured or installed hoses;
- variations in fixed clearance sealing surfaces.

Elastomers used in seals are subject to stress relaxations that cause significant expansion and contraction of the sealing material. This results in wide variations in the sealing force. Seals can also swell or shrink due to elastomer/fluid incompatibility. In addition, line fittings are very sensitive to machine vibration. Thus, if the fitting cannot maintain a proper sealing force, the machine will leak.

Internal leakage occurs in all fluid systems. Excessive leakage generates heat, reduces system efficiency, and contributes to the deterioration of the system fluid.

L7.2.3 Degradation of Fluid's Chemical Properties. Good fluid chemical stability is essential for system components to operate as intended. Without good fluid stability, the system will experience significantly reduced service life. Therefore, the condition of the fluid can play a very important role in diagnosing the system's condition, and it should be monitored or trended on a regular basis.

Fluids, both in storage and through service, are constantly degrading due to stress imposed by the system and exposure to the environment. When fluids degrade, chemical reactions produce soluble and insoluble compounds that show up as resins, sludges, and acidic materials. The chemical decomposition process is accelerated by temperature, pressure, contamination (e.g., aeration, moisture, dirt and metal wear particles) and mechanical agitation. The degradation products have an adverse effect on the fluid's performance by causing physical changes to the fluid, e.g., an increase in viscosity or the neutralization number. Other telltale indicators of chemical instability are odor, color, acidity, and the presence of insoluble products. Normally, a hydraulic fluid that has been oxidized tends to have a color that is darker than normal. By trending the chemical properties of the fluid, it is possible to predict, well in advance, conditions that will indicate when the system components may fail to perform as intended.

L7.2.4 Degradation of Fluid's Physical Properties. Some of the more important physical properties of the fluids are lubricity, viscosity and viscosity index, heat transfer properties, shear stability, bulk modulus, density, dielectric constant, flammability, specific gravity, surface tension, and vapor pressure.

The physical properties of the fluid vary with:

- the state conditions of the system, e.g., temperature and pressure;
- the chemical composition of the fluid;
- mechanical agitation and shear;
- the type and amount of contamination present.

If the system is physically stable, the physical properties of the system will return to their normal values after the system has been perturbed. The situation becomes a concern when the properties fail to return to their normal values. Obviously, the severity of the service conditions determines the rate at which the system degrades. Changes in the operating conditions can be so severe that the fluid's physical properties can be so severely altered that the fluid will be unsuitable for its intended use.

Physical changes brought about by the chemical decomposition of the fluid are generally irreversible. To insure a proper functioning system, it is important to monitor periodically the fluid's physical properties. By trending the physical properties of the fluid, it is possible to predict, well in advance,

conditions that indicate when the system components will fail to perform as intended.

L7.2.5 Cavitation Effects. Cavitation is the formation and the collapse of cavities, usually air, in a moving liquid. Evidence of cavitation in a system includes: noise and chatter, jerkiness, high fluid temperature, loss of pump prime, decrease in volumetric efficiency, lack of system stiffness, loss of power, poor heat transfer characteristics, and physical damage to components.

Cavitation occurs when an air or vapor pocket (bubble) forms due to lowering the pressure in a liquid, often as a result of a solid body, such as a propeller or piston, moving through the liquid. Cavitation can occur in a hydraulic system as a result of low fluid levels that draw (entrained) air into the system, producing tiny bubbles that expand explosively at the pump outlet, causing metal erosion and eventual pump destruction. When the bubbles collapse at higher pressure, the implosions can quickly fatigue and fracture adjacent material and cause an accelerated increase in fluid temperature. Cavitation damage depends on many factors, including:

- exposed material;
- fluid velocity;
- vapor pressure of the fluid;
- entrained air content;
- surface tension of the fluid;
- fluid viscosity.

As the severity of cavitation increases, the amount of wear debris (i.e., particles less than 30 microns) increases, indicating the enlargement of pump clearances and the loss of volumetric efficiency. Eventually, the loss of material leads to the catastrophic failure of the pump.

L7.2.6 Temperature Effects. All fluids have normal operating temperature ranges. If fluids are used at either higher or lower temperatures for extended periods of time, fluid properties and performance characteristics of the fluid system tend to degrade.

When the fluid temperature is too low, the viscosity of the fluid is drastically increased and flow may be severely inhibited. The loss of fluid mobility affects pumpability, the system's response to input commands, and degrades important elastomer properties in seals. At high temperatures, the fluid has a lower viscosity. High temperatures accelerate wear, decrease the surface tension of the fluid, destroy hydrodynamic lubrication, accelerate leakage past seals, cause thermal lock, increase gas solubility, increase the oxidation rate of the fluid, affect fluid compressibility, and accelerate the depletion of additives critical to the proper function of the system. In general, a 10°C increase in temperature will double the corrosion rate of a system.

L7.2.7 Accelerated Wear. Wear is the unwanted displacement or removal of surface material and it always occurs to some extent in an operating system. When the wear is mild, the system is considered to be wear stable. However, when the wear becomes excessive, and sufficient wear debris is produced, then the performance of the system is affected (e.g., higher temperatures, increased oxidation rates, etc.,) and impending failure can be anticipated. Some of the wear modes of failure encountered in practice include the following [7.3]:

L7.2.8 Fluid to surface wear.

L7.2.8.1 Cavitation is the formation of an air or vapor pocket (or bubble) due to the lowering of pressure in a liquid, often as a result of a solid body moving through the liquid. It can also occur as a result of low fluid levels that draw air into the system, producing tiny bubbles that expand explosively at the pump outlet causing metal erosion.

L7.2.8.2 Erosion is the progressive removal of a machine surface by cavitation or by particle impingement at high velocities, such as in sandblasting.

L7.2.9 Surface to surface wear.

L7.2.9.1 Abrasion is the general wearing away of a surface by the action of foreign matter, such as dirt, grit, or metallic particles in the lubricant. This type of wear has been referred to as cutting, plowing, gouging, lapping, grinding, and broaching.

L7.2.9.2 Adhesion or adhesive wear is surface damage resulting from welding, subsequent

rupture and material transfer that occurs when interacting asperities on adjacent surfaces (in intimate contact) slide relative to each other. In adhesive wear, material is torn or transferred from one surface and made to adhere to another. This type of wear is also referred to as scuffing, scoring, galling, and seizing.

L7.2.9.3 Delamination occurs when subsurface cracks form and propagate parallel to the surface causing metal to flake off the surface. This type of wear has been called plastic deformation, Beilby layer, and dislocation wear.

L7.2.9.4 Fretting wear is surface damage that occurs when two contacting surfaces experience oscillatory displacement of small amplitude. At the contact areas, lubricant is squeezed out, resulting in metal-to-metal contact and severe localized wear. In a corrosive environment, wear is accelerated and the process is called fretting corrosion.

L7.2.9.5 Surface fatigue wear is due to the formation of surface or subsurface cracks and crack propagation. It results from cyclic loading of a surface and is sometimes called spalling.

L7.2.10 Environment to surface wear.
Corrosion is surface damage that results from the exposure of a metal to a reactive environment - the atmosphere, moisture, or the system fluid. The process results in the loss of a metal due to an electrochemical (oxidation/reduction) reaction between the metal and the environment. Some of the factors that govern corrosion processes include: oxygen concentration, hydrogen ion activity, temperature, electrical resistance of the fluid (i.e., water), stress conditions and presence of dissimilar metals. Aqueous corrosion occurs as uniform, pitting and intergranular.

L7.2.10.1 Electrokinetic wear is caused by static electricity generated at the wearing surface. Static electricity is generated when two dissimilar materials (i.e., solid phases, a gas moving past a liquid or a solid, or a liquid moving past another liquid or a solid) contact each other, then separate.

L7.2.10.2 Hydrogen - induced wear is material damage that results from the presence, absorption, and interaction of hydrogen, usually in conjunction with residual or applied tensile stresses. The damage shows up in the form of flakes, surface cracks, blisters, and single fissures. It occurs in an environment that is the source of hydrogen, such as water, moist air, hydrocarbons, acids, and corrosion products. This type of wear can lead to catastrophic failures of the metals and component systems.

L7.2.10.3 Radiation wear is material damage caused from the exposure to a radiation source in the environment.

Wear can be monitored by wear debris and oil analysis, including particle count, oil condition analyzers, tribometric, ferro-graphic and spectrographic techniques.

L7.2.11 Mechanical Instabilities. Many mechanical components within a system are critical to whether the equipment will satisfy its intended purpose. The capability to load control elements, the stability of feedback elements, and the properties of the engineering materials are critical factors in achieving mechanical stability.

Mechanical failure is any change in the control function, material properties, the size and/or shape of a structure that prevents the machine from successfully performing its intended function. A system can lose its mechanical stability due to: deficiencies in the design of the control elements and/or machine structures; improper and/or excessive loading of the machine components; deficiencies in material specification and selection; deficiencies in material composition; deficiencies in material processing; and in the inadequate and/or improper maintenance of machines and/or manufacturing fluids.

L7.3 THE PROACTIVE APPROACH.
The proactive approach is not an approach that reacts to material, component, and/or performance type failure. Rather, it is an approach used to **prevent** system de-gradation. It can be likened to preventative medicine (proactive maintenance) as

opposed to by-pass surgery (breakdown maintenance). For proactive maintenance to be successful, plant personnel must gather and analyze data from all sources, including the monitoring of "root causes of failure" and information from preventative maintenance programs. **By applying these approaches, maintenance budgets can be cut, machine uptime increased, and equipment parts inventory significantly reduced.**

Studies have indicated that 80% of all hydraulic related problems are related to inadequate contamination control practices [7.3]. Proactive maintenance and oil analysis strategies combined with recycling programs minimize effects due to contamination, higher fluid temperatures, and oxygen effects due to entrained air from leaking systems.

L7.4 MAINTENANCE OF METAL REMOVAL FLUIDS (See LS2 Section L15 for more detailed information). Aqueous metal removal fluids pose specific maintenance challenges. To obtain optimum cutting performance and optimal bath life, it is critical to maintain proper concentration and pH while minimizing tramp oil contamination and microbial growth. A great deal of useful information on managing metal removal fluids can be found at the Organization Resources Counselor's website:

www.orc-dc.com

L7.5 REFERENCES

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7.2 E. C. Fitch, ***Extending Component Service Life Through Proactive Maintenance,*** Technical Application Article #9, Tribolics, Inc., Stillwater, OK, October, 1992.

7.3. E. C. Fitch, ***Proactive Maintenance for Mechanical Systems***, Elsevier Science Publishers Ltd., England, 1992.

L8 OIL ANALYSES

L8.1 **USED OIL TESTING** is essential to determine the condition of the oil and its suitability for continued use or reclamation. It is also absolutely necessary to determine that recycled oil has chemical and physical properties and performance characteristics as good as or better than the virgin oil. When a new recycling process is being considered, as many of the following tests as practical shall be run. These tests shall also be repeated periodically depending on the volume of lubricant recycled. It is important to obtain a representative sample in a clean, dry container.

L8.1.1 **Appearance, color and odor, of the oil** can provide a quick way to detect changes in the condition of the oil, including contamination with other products, water and oxidation. Although appearance, color and odor do not give quantitative information about the condition of the fluid, much valuable information can be determined knowing what to look for and by using this information in conjunction with other tests. Such tests include particle count to insure target cleanliness and physical and chemical properties of the fluid to determine oil degradation. The following table gives some typical plant observations and recommended action.

Observations	Recommended Action
Clear, sparkling, golden color for some hydraulic fluids, clear red for automatic transmission fluid. Note: some new oils may not be a clear, golden color, e.g., gear oils.	Periodically check oil condition/particle count to ensure target cleanliness.
Cloudy/milky appearance with the presence of free water and/or coolant	Dehydrate and filter. Check oil condition (water concentration) particle count after treatment to insure the treatment has restored the oil to its target cleanliness. Check viscosity, metals for additive depletion, and physical and chemical properties for oil degradation.
Hazy appearance	Dehydrate and filter. Check to see if target cleanliness has been achieved.
Dark coloration	May indicate the presence of oil oxidation. Check metals for possible additive depletion and the need to re-additize, or the presence of the wrong lubricant. Run differential scanning calorimetry to determine oxidative stability. If dark coloration persists, check for the presence of dissolved metals.

L8.1.2 **The presence of water** in a lubricant promotes corrosion and rusting in the system and may result in the formation of an emulsion that will adversely affect lubrication performance. Water can also destroy the antiwear additives. Water in excess of 100 ppm is evidenced by haziness or cloudiness, and quantitatively determined by the Karl Fischer titration method (ASTM D 1744). There are also several commercially available water detectors on the market that can determine water contamination in lubricants down to the ppm level. Centrifuging, filtration, air stripping, or vacuum distillation can remove water.

L8.1.2.1 **The rust test** (ASTM D 665A/B) provides an indication of the rust protection properties of the lubricant in the presence of distilled water (A) and synthetic seawater (B). Recycled lubricants shall pass this test.

L8.1.3 **Kinematic viscosity**, determined by ASTM D 445, is an important characteristic of the oil. Viscosity is generally reported in cSt (mm^2/sec) or ISO viscosity grade. A reduction in viscosity may indicate contamination with a lighter product (such as a solvent), whereas an increase in viscosity may indicate contamination with a heavier

product or formation of oxidation products. Generally, any change in viscosity of 10% or more is an indication that the fluid is nearing the end of its useful life.

L8.1.4 **The total acid number** (TAN) is the amount of potassium hydroxide (KOH) required to neutralize one gram of oil sample; an increase in this measurement may be due to oxidation or contamination with another fluid. Potentiometric titration (ASTM D 664) or a color-indicator titration (ASTM D 974) may determine acid number. Oxidation-related problems involve gum and varnish formation. For most industrial fluids, TAN will be 1 or less initially and increase throughout the oil's life.

L8.1.5 **Determination of insolubles** (ASTM D 893, ASTM D 128) in the oil provides a measurement of the types and amounts of contaminants in the oil. The n-pentane insolubles represent dirt, grit, wear metals, and oxidation products. Toluene insolubles provide a measurement of the contaminants less the oxidation products, since toluene dissolves oxidation by-products.

Particulate type contaminants may be removed by filtration or centrifuging. Often, these type of measurements can be performed at a plant using a variety of patch tests where the fluid is treated with a solvent and then drawn through a fine (typically 0.8 micron) sieve filter. The contaminants can be readily seen on the screen; for a more quantitative measurement, the amount of contaminants on the filter patch can be determined colorimetrically using a spectrophotometer. The critical particle size that must be controlled for many common hydraulic and lube system components is typically 0.5 - 5 microns to maximize component life.

L8.1.6 **Infrared analysis** is a useful technique to identify the presence of additives (or loss of additive package), oxidation products, and other contaminants in the oil. Specific absorption bands, assignable to chemical species, can be used to monitor the concentrations of such species.

L8.1.7 **The rotary bomb oxidation test** (ASTM D 2722) provides an indication of the oxidation inhibitor content remaining in the used oil. Oils that are low in oxidation inhibitor but do not show excessive oxidation by other laboratory tests should be re-additized with an approved oxidation inhibitor. The use of the wrong type and/or wrong concentration may cause harmful varnish and sludge formation in the equipment. This test is recommended for use with turbine oils.

L8.1.8 **Trace metal analyses provide a measurement of contaminants, additive content and wear** metals in the oil. Spectrographic analysis or atomic absorption may determine trace metals. Excessive wear metals are detrimental and promote additional wear and act as catalysts in promoting oxidation. They may also provide an early indication of an incipient wear failure. Additive metals shall be present in concentrations not significantly different from that in the new oil.

L8.1.9 **Wear debris analysis** indicates the presence of wear debris in hydraulic and other lubrication fluids (e. g., bearings, gearboxes, etc.). This type of analysis may indicate an impending component failure. Maintenance should be scheduled before harm to other components and catastrophic failure occurs. The types and relative amounts of wear metals can be measured using atomic emission or inductively coupled plasma spectrometry (ICP can measure 20 or more elements at one time). Ferrography can detect and measure wear debris during the early stages of equipment failure.

L8.1.10 **Particle count testing** provides a determination of the number of particulates in a specific size range using the International Standards Organization (ISO) Cleanliness Code, ISO 4406. An ISO Code is created by selecting three ISO range numbers that correspond to the number of particles in a milliliter of fluid greater than 2, 5, and 15 or 4, 6 and 14 microns. See Section L.1.4.4. Consult with the equipment manufacturers for their recommended cleanliness levels (ISO codes) for their equipment.

This test is strongly recommended for hydraulic oils and other lube oils used in

critical applications. The first step in setting the appropriate cleanliness (using a particle counter or by other methods discussed later) for a particular system is to develop an understanding of what factors contribute to a system's contamination. Using an approved particle counting procedure, the number and size (in micrometers) of solid particles in a milliliter of fluid is determined.

Currently, there are different types of particle counters available, including optical, laser, and mechanical filtration on a micro-sieve. The type selected has to be evaluated in terms of the application, the type of results desired (i.e., laboratory vs. "quick and dirty"), and the cost effectiveness of the analyzers.

L8.1.10.1 Optical microscopy involves the use of a compound microscope to classify particles, in terms of size and number, that are collected on a membrane filter. An imprinted grid on the membrane allows the total number of particles to be estimated by statistical methods. This is generally conducted in an analytical laboratory.

L8.1.10.2 Image analyzer systems are sophisticated microscopic systems involving a microscope, a television camera, a dedicated computer, and a viewing screen similar to a television screen. Samples are prepared by filtering them through a special calibrated membrane and then the filtered particles are viewed and counted on the television screen.

L8.1.10.3 Light extinction counters consist of three parts: a light source (generally white light), an object cell, and a photo diode, all arranged in series. The light source focuses a light beam on the object cell, illuminating its contents. The photo diode measures light intensity and produces an electrical output proportional to the degree of light extinction. Both the scattered light and the reduction of the transmitted light are functions of particle size in the fluid. This is mature technology, the light source is relatively inexpensive, but the equipment needs to be calibrated frequently. Cost effective systems are available for plant use.

Laser counters are state-of-the-art, laser-based sensor units. In this type, the fluid passes through a sensor, passing a view volume area, where the laser beam is focused. Particles in the fluid deflect bursts of light energy to a solid-state diode, which converts each burst of light into pulses of electrical energy. The electrical pulses are proportional to the particle size. A digital counter sorts and counts the pulses according to their magnitude. This is an excellent laboratory instrument. Laser counters that are portable are available for plant and replicate laboratory results quite well.

L8.1.10.4 Mechanical filtration counters assess particle size and concentration by using the mechanical filtration characteristics of solid particles exposed to a micro-sieve. During the test, fluid passes through a calibrated micro-sieve wafer, leaving particles on the wafer surface. As the fluid passes through the wafer, the particles will eventually block the pores of the filter, restricting flow. The flow restriction is affected by the particle concentration and the particle-size distribution in the contaminated fluid.

For a given distribution of particle sizes, there is corresponding characteristic flow rate degradation. The microprocessor, using a mathematical algorithm, converts the decay curves into particle size distributions. This unit has widespread application for use in plant applications. It is portable and is capable of making distinct statements about particle size distributions in contaminated fluids. The major drawback for this equipment is that measurements are made at one sieve size. ISO cleanliness values at other micron sizes are calculated using a mathematical algorithm and decay data generated from AC fine dust measurements.

L8.1.10.5 General comments. It is important to recognize that the presence of air, free water, and particulate matter will be reflected in the cleanliness rating. In order that the ISO codes reflect particulate contamination alone, it may be necessary to exclude air and free water. Otherwise the true particulate contamination level may be masked by dispersed water droplets and/or air bubbles. Air bubbles can be coalesced by placing the sample in an ultrasonic bath for about 30

seconds and water can be removed by a variety of dehydration techniques.

In a plant situation, a variety of purification schemes (i.e., deaeration, dehydration, and filtration) can be used in conjunction with particle counter measurements to return the fluid to the target cleanliness level desired. Particle counters used in plant situations need not have the sophistication required of laboratory instruments, since they are generally used to "trend" the condition of the fluids in machines. "Trending" allows the plant personnel to ascertain whether the condition of the fluid has remained the same or has deteriorated over a period of time. It also helps determine whether filtering and/or dehydration processes have been effective in restoring used oil back to a "new condition".

L8.1.11 Oil quality analyzers are used to determine the condition of used oil and monitor the "health" of plant equipment. There is equipment available that uses micro-based measurements of the time-rate-of-change of an oil's dielectric properties, in the presence of a time-varying magnetic field. The analyzer detects the presence of wear indicators, such as ferromagnetic particles (e.g., iron), contaminants such as water, coolants, glycol, the products of oil oxidation, etc.

Although this method does not give an ISO cleanliness rating directly, it can be used in conjunction with other particle counters and predictive maintenance approaches. Samples can be routinely analyzed on-site, as part of a regular predictive maintenance program, providing an early indication of contamination problems. On-site oil analysis has the advantage of providing immediate feedback to the plant personnel using the equipment, to help find and fix contamination problems.

L8.1.12 Water separability or demulsibility, as determined by ASTM D 1401 or D 2711, indicates the ability of oil to separate water. Steam turbine and hydraulic oils must possess good water separating properties, since oil-water emulsions can lead to oxidation and unsatisfactory lubrication. The recycled lubricant shall meet the applicable LS2 standard.

L8.1.13 Identification of hazardous materials.

L8.1.13 .1 Polynuclear aromatic compounds (PNA's) or Polycyclic Aromatic Hydrocarbons (PAH's) are polycyclic, fused-ring, or condensed-ring aromatic compounds. They can be created during high-temperature processes, such as combustion and thermal quenching pro-cesses. They are also present in inadequately refined petroleum stocks. PNA’s have been shown to be potentially carcinogenic and are believed to be primary actors in the induction of skin cancer. Chemical (gas chromatography/mass spectrometry/ selective ion monitoring (GC/MS/SIM)) methods are available for their analysis. PNA's can be determined by commercial testing laboratories employing EPA SW-846 or EPA 8100 (GC/MS). The summation of the 16 PAH's determined by the standardized test must be less than 1000 ppm.

L8.1.13 .2 The Ames Salmonella Mutagenicity Assay (modified Ames test, ASTM E 1687), measures an oil's mutagenic potential, and is particularly sensitive to PNA's/PAH's. Fold Increase (FI) is the maximum increase in the number of revertant colonies that grow compared to the solvent control. The value is determined by dividing the number of revertants for the highest aliquot by the solvent blank. A value greater than 2 indicates the existence of mutagenic activity. Mutagenicity Index (MI) and Mutagenicity Potency Index (MPI) are other criteria used for the interpretation of test data. They both use the same data that is used for determining fold increase, but the information is processed differently. An MI less than or equal to 1 is generally considered to be a pass.

L8.1.13 .3 Polychlorinated biphenys (PCB's) are a class of synthetic chemicals consisting of a homologous series of compounds beginning with monochlorobiphenyl and ending with decachlorobiphenyl. They do not occur naturally in petroleum, but are found as contaminants in used oil, especially transformer oils. They are hazardous, and any oil contaminated with PCB's must be handled in strict accordance with state and federal regulations. They are not permitted in

GM LS2 approved products. They can be destroyed, however, by hydrotreating. The concentration of PCB's in oil can be determined by EPA SW-846, Technique No. 8082. Virgin or recycled products shall contain no detectable PCB's.

L9 RECYCLING TECHNOLOGY

L9.1 RECYCLING USED INDUSTRIAL LUBRICANTS.

Fluid management programs involving the recycling of used oils may be used in many industrial applications to extend lubricant life, reduce disposal costs and address environmental issues. Recycled lubricants shall meet all applicable LS2 standards. Lubricants undergo changes in physical and chemical properties with service. These changes may include contamination with water, other fluids, such as coolants, and particulate matter (e.g., dirt, wear metals), formation of oxidation products resulting from air and high temperatures, and the loss of performance by the depletion of additives.

L9.1.1 **Recycling** is a generic term that involves a variety of types of oil purification methods that restore spent oils to a useable material.

L9.1.2 **Reclaiming** generally employs methods to remove insoluble contaminants from used oils, such as water and solids. Under some conditions, the recycled oil achieves a state approximately equal to that of the virgin oil (i.e., as clean as or cleaner than new oil).

L9.1.3 **Reconditioning** is a type of reclaiming that is done on-site, at the machine, typically using portable recycling equipment.

L9.1.4 **Reprocessing** involves the use of cleaning and refining methods so that used oil can be used as a fuel.

L9.1.5 **Re-refining** involves processes that produce a high quality base stock. The re-refining process involves dehydration, fuel stripping, vacuum distillation and hydrotreating.

L9.2 RECYCLING TECHNIQUES.

L9.2.1 **Gravity settling** is the simplest method of separating oil, water, and particulate matter. It is commonly done in a heated tank (to accelerate the process), with or without additives, and may take several days to break an oil-water emulsion. This method utilizes gravity to separate materials of different densities.

L9.2.2 **Centrifuging** separates materials of different densities, such as oil, water, and solids, through centrifugal force. Centrifuging serves the same function as settling, but in a shorter time. Centrifuging is an efficient method to remove large amounts of water. The technique is limited to removing only free water (down to about 150 ppm) and to handling a maximum solids content of 0.5%. It is not suitable for removing entrained gases or in separating liquids with similar specific gravities.

L9.2.3 **Vacuum dehydration** is a very efficient way to remove dissolved gases and both free and dissolved water. Vacuum dehydration involves exposing the oil/water mixture to heat and vacuum over a large surface area. Under vacuum, lower boiling materials, such as water, solvents, etc., are flashed off from the oil. Dehydration carried out under vacuum, at a moderate temperature (40-70°C), removes water, gases and volatile contaminants, generally without contributing to the further oxidation of the oil and without removing essential oil additives. This process is often used in conjunction with different types of filters.

L9.2.4 **Filtration** is another process for removing solids from liquids. Filters are available in a wide variety of types, shapes and sizes, and are used to remove particles that are coarse to sub-micron in size. Screening is the most basic form of filtration. Fluids are passed through coarse screens with openings larger than most other types of filters. The purpose is to remove coarse particulate matter prior to processing.

Another very common type is the disposable cartridge type that use paper, cloth, synthetic fibers, felted materials, or mat elements. The use of mechanical filtration can provide high cleanliness levels, in terms of particulate matter, and contribute significantly to the life of the oil and the equipment. Permanent types of filters consist of flat beds, belts, and screens over which the fluid passes to remove the particulates. The advantage of this type is that the filter media can be cleaned manually by back flushing. Fuller's earth or diatomaceous earth filters permit the removal of fine particulate matter and other contaminants, including polar materials, such as oxidation products and additive materials.

These types of filters can also remove oils containing polar additives such as antioxidants, rust inhibitors, demulsifiers, and other types of additives.

L9.2.5 **Coalescing filters** involve a separation process similar to filtration and are capable of removing free water from oil. The oil water mixture passes through the coalescer cartridge or packed bed reactor (at a low flow density) where small water droplets are attracted to each other to form larger droplets that precipitate down to the bottom of the reactor chamber. Coalescence is limited to removing only free water (down to 150 ppm) and is limited to low-viscosity oils (typically less than ISO 46).

L9.2.6 **Air stripping** is a process where dissolved gases and free and dissolved water are removed. During this process, the oil/water mixture is pumped under pressure through a venturi. At the venturi, air is induced into the oil/water mixture and moisture is transferred to the air. Upon leaving the venturi, the air, moisture and oil are effectively separated. In this process, the ability to entrain moisture increases exponentially with temperature (i.e., the removal of water is more efficient at higher temperatures). The major concern is that the oil may become oxidized. If this is a concern, an inert gas, such as helium, can be used.

L9.2.7 **Electrostatic filtration** is another process being used extensively within GM plants. It involves the use of electrophoresis and dielectrophoresis to clean the oil. Electrophoresis involves the application of an electric field to the fluid, causing the charged (suspended) particles to move towards oppositely charged electrodes. Dielectrophoresis utilizes a non-uniform electric field to enhance the collection of suspended particles where the field is the strongest. Studies have shown that this process minimizes the build-up of oil oxidation products within the fluid. Combined with standard filtration, the process effectively cleans the fluid to an ISO cleanliness level suitable for most stringent applications. Water removal may be a problem with most commercial units, however.

L9.3 **IMPORTANCE OF SEGREGATION.**
The key to successful recycling is segregation of the fluid at the point of use. Used industrial hydraulic or other manufacturing lubricants can be recycled in-plant to yield an oil as good in quality as a virgin oil, and as clean as or cleaner than a new oil, provided the used oil is kept segregated from other fluids.

The used oil should be collected separately from other fluids and stored in a segregated system. Indiscriminate dumping of used oil from a machine's reservoir is not only wasteful, but complicates the recovery process. The use of dedicated storage containers, with the provision for heating, will assist in the settling of particulate matter and water, provided that the oil is not severely overheated. The segregated oil can then be filtered to remove particulate and wear solids; dehydrated to remove water; degassed to remove entrained air; clay treated to remove oxidation products and other compounds produced during use; and replenished with additives (re-additized), if necessary.

Extreme care must be taken to prevent contamination with other types of lubricants, coolants, cleaners, and solvents. Mixing with most other types of industrial lubricants will adversely affect the water separating properties and render the oil unsuitable for reclamation, or will at least complicate the oil reclamation process. For example, used hydraulic oil contaminated by sulfurized cutting oil cannot be recycled for hydraulic oil use by usual in-plant processing.

L9.3.1 **Water** is a serious contaminant of oil, because it contributes to the formation of oil oxidation and acid formation, which promote metal corrosion. Degradation of hydraulic oil or other lubricants through oxidation results in the formation of acids, sludges, and sticky gums, which increase viscosity, reduce lubricity, and minimize the corrosion resistance of the oil. Oxidation products and other contaminants increase the susceptibility of oil to form thick water-in-oil emulsions, which collect dirt and rust. When circulated through equipment, these emulsions increase friction and wear.

L9.3.2 **Particulate contamination**, including dirt, wear particles, solvents, rust, fibrous material, oxidation products, etc., will adversely affect oil quality and performance. The effect on machine down time can be catastrophic.

L9.3.3 **PolyNuclear aromatic compounds (PNA's)** are polycyclic, fused-ring, or condensed-ring aromatic compounds. They can be created during high temperature processes, such as combustion and thermal quenching. They have been shown to be potentially carcinogenic and are believed to be primary actors in the induction of skin cancer.

L9.3.4 **Polychlorinated biphenyls (PCB's)** are a class of synthetic chemicals consisting of a homologous series of compounds beginning with monochlorobiphenyl and ending with decachlorobiphenyl. They do not occur naturally in petroleum, but are found as contaminants in used oil, especially transformer oils. They are considered to be hazardous, and any oil contaminated with PCB's must be handled in strict accordance with state and federal regulations. PCB's are not permitted in GM products.

L9.4 IN-PLANT RECYCLING.

In-plant reclamation of hydraulic and lubricating fluids can be carried out very successfully. This can be done at the individual machines or at a central plant processing location, where the fluid from each machine is collected, recycled, and returned to the individual machines.

L9.4.1 **Reconditioning at individual machines**. Probably the simplest and the most straightforward approach is to use a portable oil reclamation system and connect it to the individual machines, as needed. For example, using this type of system, it is possible to restore the hydraulic oil from a machine's reservoir and internal parts (15-1200 gallons, 60-4500 L) to a new oil condition very efficiently. In this way, the accumulation of contaminants, such as water, dirt, and gas can be minimized, and these oils can be used almost indefinitely. This type of process is much like a kidney dialysis system used in medicine today.

A portable oil reclamation system generally combines micro filtration with low-temperature vacuum dehydration, air stripping, or electrostatic filtration. In some of the units being used in GM plants, an ultra fine filter removes nearly all of the particulates, such as dirt, wear metals, rust, and suspended particles.

Vacuum dehydration eliminates free, dissolved, and emulsified water, gases, such as oxygen, and volatile impurities. These units have also been used to successfully remove certain water-soluble coolants from hydraulic oil systems, at significant savings to GM plants. This type of operation has the flexibility of being able to move the portable unit wherever needed. It can be used on systems that have oil reservoirs ranging from about 15-1200 gallons (60-4500 L) of fluid. Dehydration carried out under vacuum, at a moderate temperature (40-70°C), removes water, gases, and volatile contaminants, generally without contributing to the further oxidation of the oil and without removing essential oil additives.

Oil reclamation systems similar to these have also been used successfully, both within and outside GM, to reclaim other types of oils, including: turbine, straight cutting, machine, vacuum pump, quench, gear, circulation, transmission, synthetic diesters, heat transfer, transformer, compressor, and synthetic phosphate esters.

Air stripping is also used to remove dissolved gases and free and dissolved water. The process is very effective in removing even very large quantities of water from the oil. The equipment generally works more efficiently at temperatures higher than those normally used with vacuum dehydrators. A concern is that, with repetitive use, air may oxidize the oil.

Electrostatic filtration is another process that is being used extensively within GM plants. It involves the use of electrophoresis and dielectrophoresis to clean the oil. Studies have indicated that this process minimizes the build-up of oil oxidation products within the fluid. Combined with standard filtration, the process effectively cleans the fluid to an ISO cleanliness level suitable for most stringent

applications. Water removal may be a problem with most commercial units, however.

By restoring the plant's hydraulic and spindle oils to a "new oil condition", many GM plants have accomplished (and documented) the following:

- reduced costs associated with the purchase of new oil;
- minimized disposal costs associated with used oils;
- significantly decreased system problems;
- dramatically decreased scrap rate;
- decreased lost production (i.e., manufactured parts) due to downtime;
- increased up-time;
- reduced labor costs associated with reduced maintenance.

L9.4.2 Central (segregated) processing.

L9.4.2.1 Stationary in-plant reclamation systems are being used in several GM plants where segregated oil is being reclaimed on site. An in-plant oil purification system, similar to that discussed above, except that the unit is permanently installed, is used as part of an in-plant processing unit. The major advantage is that larger quantities (500-2000 gallons, 2000-7500 L per batch) of industrial hydraulic fluids can be recycled on site, with the added advantage of the oil never leaving the plant.

The process is ideal because the used oil is segregated, dehydrated, additives are replenished (with new oil or an additive package). The recycled oil is then returned for use, without the danger of being contaminated by some other external source.

Hydraulic oil, for example, requiring recycling may come from three sources:

- oil that is collected in a sump from slowly leaking equipment and is usually transported periodically to a settling tank, unless it contains other plant fluids that are not compatible with the hydraulic fluid;
- oil that has leaked from older equipment and is being fed directly to a settling tank by gravity feed;
- used oil in plant equipment that is changed periodically, as part of a preventative or proactive maintenance schedule.

Using this type of process, the oil is generally passed through a rotary or a coarse strainer to remove coarse particulate matter (i.e., dirt from the plant floor, wear debris from machine parts, etc.,) before the oil-water mixture is collected in a settling tank. The oil in the settling tank may be heated preferably at a temperature less than 70°C, for a day or two, or until water becomes separated from the oil.

The water with entrained oil can be treated by reverse osmosis or any other acceptable wastewater treatment method before the water is sent to the drain. The oil is then passed through a cartridge filter, or some other appropriate filter medium (5-15 μm), through a heat exchanger, which heats the oil, preferably to a temperature less than 70°C. It is imperative that the oil not be “cooked” too long at an elevated temperature to prevent the oil from being oxidized. Oxidation products can cause serious maintenance problems, especially with high-pressure injection molding equipment that operates with tight tolerances.

The remaining traces of water are removed in a vacuum dehydrator. The dehydrated oil is then passed through a cartridge (polishing) filter (1-5 μm) before it is stored in a batch tank, while it is analyzed in a chemical laboratory. Again, it is important that the recycled oil meets all requirements of the LS2 Standard before it is reintroduced into the equipment. Once the recycled oil has been approved, it is returned to the equipment. If the laboratory results indicate that the recycled oil needs to be re-additized, one way is to blend the recycled oil with virgin oil in a suitable blending vessel, and returned to the equipment. In some plants, the ratio of 20% virgin to 80% recycled has been used effectively; however, the ratio used will depend on the extent to which the additives have been depleted. Note: because an oil is labeled as a “virgin oil”, do not assume that it will meet the ISO cleanliness levels required for the equipment. Often, “virgin oils” need to be filtered before use.

L9.4.2.2 The use of commercial mobile oil reclamation systems is another variation to the above approach. In this approach, larger quantities of hydraulic or other fluids that were

segregated (500-20,000 gallons, 2000-75,000 L per batch) have been recycled on-site by using commercial mobile units that utilize equipment similar to that previously described for in-plant recycling. These mobile units contain filters, centrifuging equipment, dehydration equipment (either vacuum dehydrators or vacuum distillation units) and tanks for blending and compounding. Some units have small analytical laboratories (e.g., water content, ISO cleanliness levels, TAN, patch test, etc.,) on board to check the recycling process

Attractive features of this option are that it requires no capital expenditures, it cuts new oil costs dramatically, solves disposal problems and associated costs, and provides the plant with a recycled fluid that has not left the plant for processing. This insures that the plant is reusing its own oil that has not been contaminated by other sources.

For any plant utilizing this approach, it is essential that the provider of this service be well qualified to deliver the service and that they will insure that the reclaimed hydraulic oil will meet the GM LS2 Standard requirements. As a precautionary measure, it is very advisable that when considering this approach, plant personnel should require the provider of the service to make limited plant trials. This will help substantiate their claims and provide actual test data from an independent and certified testing laboratory confirming that the recycled products meet all of the LS2 requirements. To help find organizations qualified to provide this service, check with the LS2 Committee. Test recycled oil routinely to insure that it meets the applicable GM LS2 Standard.

Plant personnel that have used this service have reported the following:

- significant virgin oil cost savings;
- no disposal costs - transportation of used oils has been eliminated;
- environmental liability reduced - no off-site disposal;
- routine quality control monitoring - analytical testing and certification provided;
- no capital expenditures.

L9.5 Out-Plant Recycling.

L9.5.1 Recycling commingled fluids. In far too many cases, metalworking fluids, water-based hydraulic oils, parts washer wastes, tramp oils, and chlorinated solvents are commingled with used hydraulic oil. This practice not only complicates the waste treatment operation, but produces oil that is almost impossible to process in-plant. It is a very costly way to do business, because it increases the reprocessing operation and disposal costs. **Indiscriminate dumping of already segregated used industrial oil into a wastewater treatment facility should be avoided at all times.**

L9.5.2 Re-refined oils are being used more extensively in GM plants. In such cases, some plants have been able to work out arrangements with re-refiners to collect the commingled oily-waste, re-process the used oil, and produce a re-refined oil that meets regulatory and quality standards in the marketplace. Many GM plants are presently using such re-refined hydraulic fluids at significant cost savings. Re-refined oils that are approved against the LS2 Standards are safe and acceptable for use in GM plants.

The re-refining process generally consists of dehydration, fuel stripping, vacuum distillation, and "severe" hydrotreating where the oil is contacted with hydrogen under high temperature and pressure in the presence of a catalyst. During the final stage of hydro-treating, sulfur, nitrogen, chlorine, and oxygenated compounds are removed. Also, traces of heavy metals and other impurities are eliminated. Volatile materials are removed during the distillation process, heavy metals are removed in the distillation bottoms, PCB's, dioxins, and furans are destroyed during hydrotreating, and PNA's are "reduced" during the hydrotreating process.

L9.5.3 Recycling for secondary use. Another alternative exists for the re-use of commingled oils. Sometimes such oils can be reclaimed on-site and used in a less demanding application. We call this “cascading”. For instance, a hydraulic fluid co-mingled with water-soluble cutting oil may be able to be reclaimed on site and used as a general-purpose cutting oil.

L10 BUSINESS CASE CALCULATIONS

When a proactive maintenance, recycling or other lubricant program is initiated, it is useful to perform business case calculations to determine if the program yields net savings. The first step in doing so is benchmarking the current process, including all costs that can reasonably be estimated. After the program is initiated, total costs are again tracked, and the difference is the net savings. The following template provides a general approach to developing a business case for a proactive maintenance, recycling, leak prevention or other lubricant program.

Costs	Before	After
Lubricant purchases, volume x cost/volume		
Machine repair, total		
parts costs		
labor costs		
Downtime (hours) x cost/hour		
Waste oil disposal costs		
Cost of PM or Recycling Program		
materials	0	
equipment	0	
labor	0	
purchased services	0	
Other*		
Total:		

*Other may include, but are not limited to, part or assembly scrap rate, electrical energy consumption, laboratory charges, etc.

Net Savings = Total Costs Before Initiating Program - Total Costs After Initiating Program

This calculation assumes that production volume is relatively constant. If this is not the case, it is useful to "normalize" the costs by dividing by the production volume:

$$\text{Net Vol. Adjusted Savings} = \frac{\text{Total Costs Before Program}}{\text{Production Volume Before}} - \frac{\text{Total Costs After Program}}{\text{Production Volume After}}$$

This Net Volume Adjusted Savings will be on a per part or per assembly basis.

Note that this template is very general. Also, it may be impossible to estimate all costs for every program. If all costs that are likely to increase under the program are covered, the calculation will likely be conservative. To illustrate the concept of these business case calculations, a few simple examples are included.

L10.1 Overall Plant Usage Savings Calculation

Example 1.
2009 overall plant usage: 65,000 gallons hydraulic oil @$3.80/gallon
2010 overall plant usage: 60,000 gallons hydraulic oil
Savings: 5,000 gallons hydraulic oil
(This assumes production volume is the same in 2009 & 2010)
Amount saved: $19,000 (5,000 gallons x $3.80 per gallon)

Example 2.
If production volume is 10% less in 2010 than 2009.
2009 overall plant usage: 65,000 gallons
2010 overall plant usage: 60,000 gallons
Expected 2010 usage: 58,500 gallons (65, 000 gallons x 90%)
Amount saved: none (1,500 gallons more than expected were used)

Example 3.
If production volume is 10% more in 2010 than 2009.
2009 overall plant usage: 65,000 liters
2010 overall plant usage: 60,000 liters
Expected 2010 usage: 71,500 liters (65,000 liters x 110%)
Liters saved: 11,500 liters
Amount saved: $20,700 (11,500 liters x $1.80 per liter)

Note: all examples assume oil usage is proportional to production volume, and that oil usage is spread over the entire plant machine population. This may or may not be a reasonable assumption.

L10.2 Individual Machine Savings

Example 4.
Machine A uses 100 liters per month of hydraulic oil. After repairs, the usage is reduced to 100 liters for three months.

3 month usage prior to repair: 300 liters
3 month usage after repair: 100 liters
3 month savings: 200 liters
Annual savings: 800 liters (200 liters per quarter x 4 quarters)
Amount saved: $1440 (800 liters per year x $1.80 per liter)

Example 5.
In any of the examples, you could also have savings in repairs, safety, housekeeping, waste treatment, machine coolant, and disposal cost.

Repair savings equals = (labor to repair damage + parts + lost production) - cost of lubrication fix

Housekeeping savings = avoidance of (cost of labor to clean + materials (such as floor dry))

Safety savings = See health and safety representative for help

Coolant savings = Cost of recharging (new coolant) + labor (dumping & recharging) + disposal of old coolant

Disposal cost savings = See waste treatment and finance personnel. Cost per gallon of hazardous waste removal and/or cost per gallon of treatment of waste fluid

L11 OIL MANAGEMENT

L11 Improving GM's environmental performance will be most successful when there is a good business case to do so. This program provides opportunities for significant cost savings while encouraging good environmental stewardship. Overall, fluid life extension and recycling, either on-site or off-site, make good sense. Environmental liability is minimized and the company's image as a responsible corporate citizen is enhanced. In addition, significant cost savings are realized. Just look through your plant for recycling opportunities. You might be surprised to find that doing the right thing environmentally is quite often the right thing financially. Remember that anything produced that is not a useable, saleable product is waste, and should be minimized.

At General Motors, we are guided by a set of environmental principles, the second of which is particularly appropriate to this effort: "We are committed to reducing waste and pollutants, conserving resources and recycling materials at every stage of the product life cycle". The program has several goals.

- Utilize a closed loop system
- Don't ever compromise health and safety
- Optimize cost over the *system*
- Make no technical compromises
- Minimize environmental liability
- Encourage plant acceptance
- Enhance the company's green image
- Reduce non-product output

The flow chart on page 11-3 describes each step that should be considered in setting up an oil management program. Each numbered box on the flow chart corresponds to a subsection in section L11 that describes the function in more detail. For instance, the description for flow chart box 1 is found in subsection L11.1.

L11.1 LUBRICANT AND FLUID SPECIFICATION The first step in an optimal oil management is proper specification and selection of lubricants and fluids. **Maintenance lubricants** lubricate a machine or a piece of equipment. Examples are hydraulic fluids, gear oils, spindle lubricants, greases, etc. The lubricants are typically internal to the machine, are generally (well, hopefully) of continued use. Some may, however, be consumed in performing their function (e.g., way lubricants, greases), and are considered once through or total loss. Any maintenance lubricant covered by the GM LS2 standard must meet the LS2 requirements.

Metalworking fluids cool and lubricate a workpiece and tool. These include metal removal fluids and metal forming fluids. Examples are cutting fluids, grinding oils, stamping and forming oils. The GM LS2 committee has developed standards for metal removal fluids (see Section L5, LX- and LY-) that are subject to frequent updates. Plant trials are recommended before broad use, however.

Proper specifications allow product consolidation and reduce plant lube problems, oil usage and oil-related costs. Quality control specifications for incoming materials help ensure that the proper product is delivered. Periodically checking metals, water, viscosity and particulates is a good idea.

L11.2 MINIMIZE FLUID CONTAMINATION, DEGRADATION AND CONSUMPTION that occur during use. An effective proactive maintenance program can minimize or eliminate lubricant contamination and degradation, as well as consumption. Reducing consumption involves stopping leaks or performing oil analyses and proactive maintenance to extend oil change intervals and fix root causes of problems that shorten oil life. Proactive maintenance includes oil analyses, thermography, vibration analysis, etc., and is best when several methods are used in concert. Proactive maintenance is often labor intensive, but one can argue that the labor is more effectively used for it than fixing problems causing breakdowns. The rewards can be substantial. A down side is that this can be very system specific.

Eliminating root causes of problems to extend lubricant life and reduce consumption is the first line of defense and one of the most effective ways of reducing costs. More information on proactive maintenance is available in Section L7. In-plant recycling is the next option (see Section L9). Despite best efforts, lubricants will become contaminated and degraded due to old or malfunctioning equipment, accidents, mis-application, just plain mistakes or extended use. Lubricants that have become contaminated with water or solids can often be recycled on site.

However, when solvents or other lubricants contaminate the fluid or it has become badly oxidized, on site recycling becomes much more difficult.

L11.3 RECONDITIONING AT THE MACHINE. If the lubricant is still in the equipment (as opposed to all over the floor!), the first consideration should be to use portable equipment that can be connected directly to the machine to "re-condition" the fluid. This is fairly straightforward, involving means of removing water, such as vacuum dehydration or other methods, followed by filtration of contaminant particles. The risks are that the process will not remove the water and particulates, or may somehow otherwise damage the oil. These risks will be minimized by good equipment, experienced operators and the use of oil analyses to check the process.

This again is fairly labor intensive and somewhat system specific. There are also capital costs involved, but these are generally not significant when analyzed in terms of a payback period. The rewards for recycling at the machine can be significant. We have documented savings in oil purchase costs, waste oil disposal, equipment repair parts and labor and scrap rate. In one study, the cost of the recycling unit was repaid in less than one month!

Here is how to get started in using portable recycling equipment:

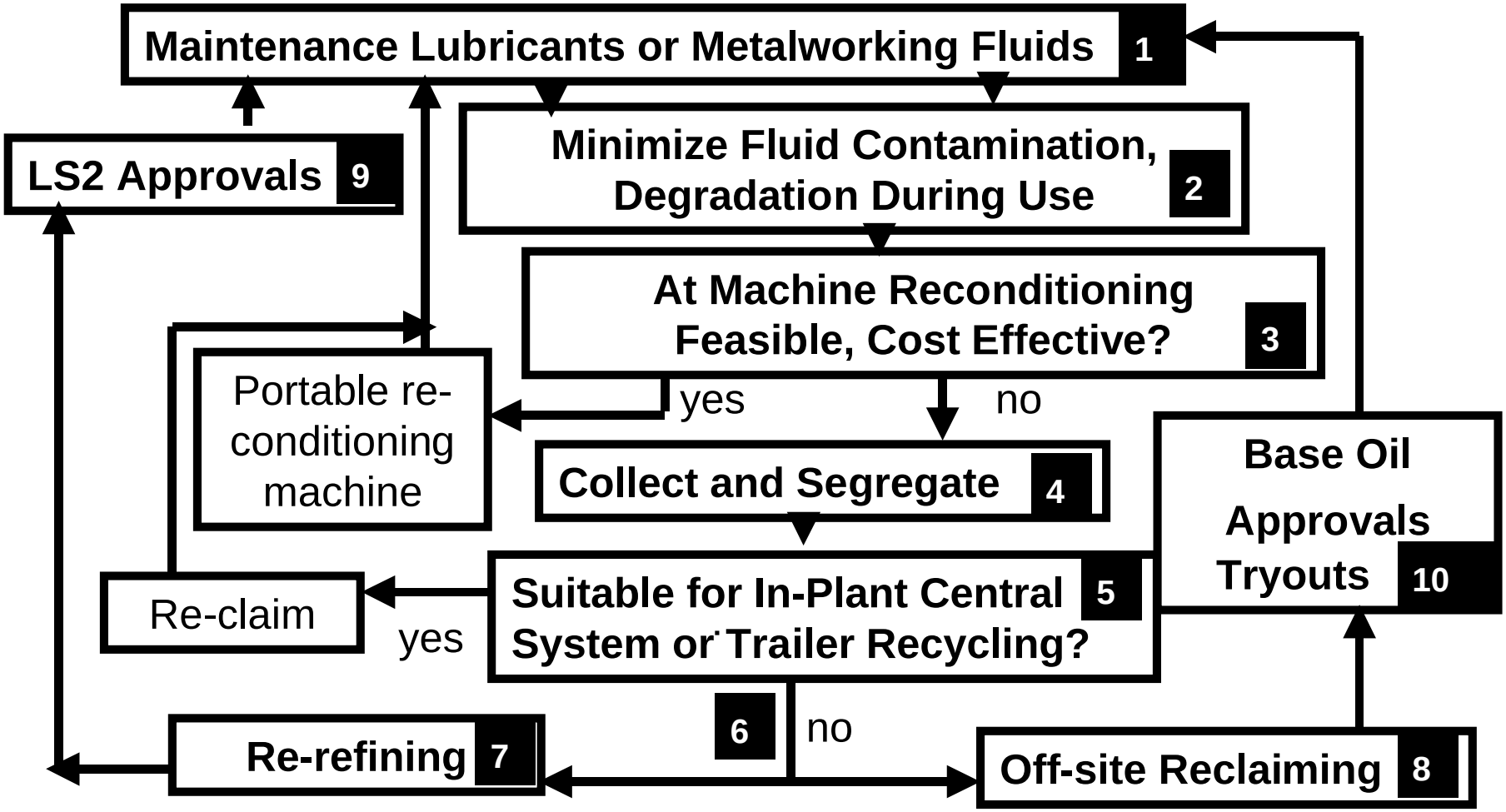
- Perform oil analyses to determine the nature, rate and degree of contamination of a lubricant. Section L8 provides guidance on oil analyses.
- Decide on target condition after recycling.
- Contact manufacturers of portable recycling equipment and request product literature (contact the LS2 chair for assistance).
- Invite several with the most (apparent) related experience to visit, view equipment, discuss contaminant level and targets, recommend recycling equipment and quote cost. Don't be afraid to ask whether they offer free trials (and forget the donuts and ball caps - this decision is too important...).
- Select the best piece of equipment, based on processing capabilities (throughput, ability to achieve targets), maintenance requirements and cost.
    - Run trials, in conjunction with oil analyses, to prove out equipment capability.
    - Set recycling intervals based on contaminant targets and contamination rate; verify periodically with oil analyses.
    - Track cost savings associated with reducing new oil purchase and waste oil disposal costs, machine repair and scrap rate reduction, etc. Ideally, tracking these costs will allow for expansion of the program and generation of even greater savings.

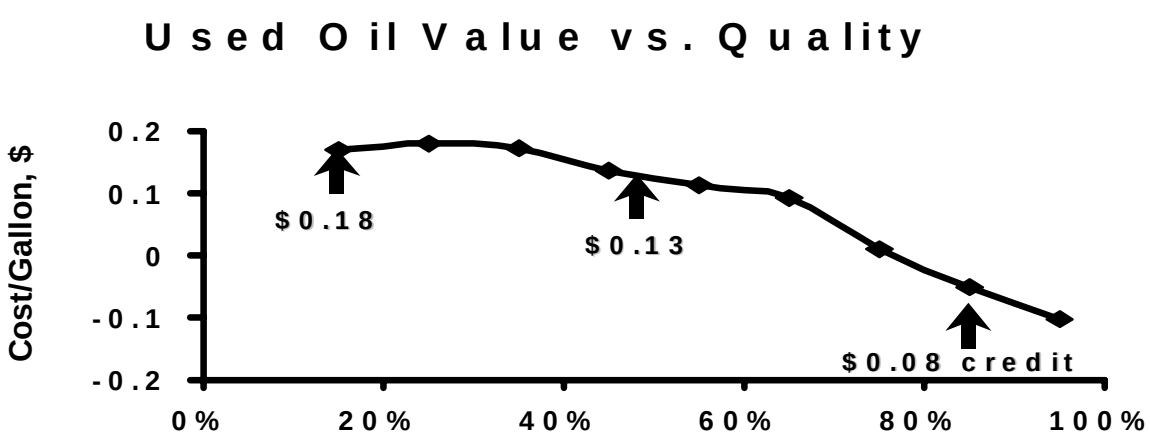
L11.4 COLLECT AND SEGREGATE used oil that cannot be reconditioned at the machine. Used oil should be considered a valuable resource rather than a waste (For some people, empty beer bottles are trash. For others they are a source of income from return deposits). What happens next to a used oil stream depends largely on its quality. Quality is defined in terms of its level of contamination with water, solids, other fluids, etc. The higher the quality of the used oil stream, the more valuable it is and the more recycling options there are. Keeping different quality or types (e.g., cutting oil and hydraulic fluid) of streams segregated is a good practice where possible. Don't mix a high oil, low solids content stream with one that is high in water, solids and other solvents, or the remaining mixture will have a lower value than the sum of the two component streams.

L11.4.1 Improve the quality of used oil where possible. There are many techniques for doing this, including settling (with or without heat), the use of polymers or flocculants, and the use of membranes. Typically, a plant will pay to have low oil content streams hauled away, while receiving payment for high oil content streams. It should be fairly straightforward to decide whether or not it is cost effective to improve the quality of a used oil stream. Don't forget to include transportation costs in your calculations. With higher oil content streams, there will be a lot fewer transports.

The figure on 11-4 illustrates cost as a function of used oil quality. This includes both processing and transportation and is an example only. The difference in cost or payment per gallon between two different

Oil Management Program





used oil streams is theoretically the amount of money that could be spent on site to improve oil content.

This figure also illustrates the importance of segregating streams. If a plant has two streams of roughly equal volume, one at 15% oil and one at 90% oil, they will pay on average the mean cost of the two streams, ($0.18 + (-0.08))/2 or $0/05/gallon. If they allow the two streams to commingle, the resultant stream will be 52% oil and will have a disposal cost of $0.13/gallon, or $0.08//gallon higher than when the streams were kept separate.

L11.5 CONTRACT RECLAIMING TRAILER or central fixed recycling system (batch recycling, on-site) often is used quite successfully. If it is not practical or cost effective to recycle at the machine, often the oil can be collected at a central plant facility. If the various streams are segregated, the process can be much more flexible and cost effective. A permanent central recycling facility can be installed to recycle the fluid, but this requires capital and in-plant expertise in recycling. Several companies provide a service where a trailer comes and recycles the fluid on site.

In this case, no capital or plant expertise is required. Conducting the appropriate oil analyses and pilot trials before using a recycled fluid in critical plant equipment minimizes the risks. Often the trailer is a good intermediate step prior to the installation of a permanent in-house recycling process. This will allow generation of reliable cost savings data and a good estimate of the expected payback period on the cost of the equipment for a central system.

Evaluating potential trailer recycling services is much like evaluating portable recycling equipment:

- Perform oil analyses to characterize your used oil stream. Use the LS2 Standard for guidance on the appropriate analyses.
- Contact suppliers of trailer recycling services and request product literature (contact the chair for assistance).
- Determine what products could be produced from the used oil and decide on target composition after recycling.
- Invite several with most related experience to visit, tour facility, discuss target products, specifications, re-additization, etc., and quote cost.
- Select the best supplier based on processing capabilities (throughput, ability to achieve targets) and anticipated cost savings.
- Run a trial in conjunction with oil analyses to prove out capability.
- Track savings associated with reducing oil purchase and disposal costs.

All in plant recycling operations should be explored before going offsite. It is bad business to transport a lot of water, if it is avoidable.

Such central or trailer recycling would also encompass "cascading". In this case, a spent lubricant such as hydraulic fluid that has been contaminated or otherwise become unfit for continued use in an hydraulic system, is recycled and used in an application that has less demanding requirements, such as a general purpose cutting oil.

L11.6 OFF-SITE RECYCLING is the last option, if trucking a lot of water around isn't avoidable. The corporate program determines whether the used oil taken off-site is reprocessed or re-refined for all large used oil volume generator plants. The choice is based on both processing and transportation cost for typical plant stream(s). Backhaul credits, where the supplier delivers a recycled fluid and then returns the truck with a load of used oil, can further enhance savings. But what are the risks and rewards of off-site recycling? The cost savings are the most obvious rewards, although they are not likely to be as large as for on-site recycling. The risks are the same as for on-site, and can be minimized by good product specifications, oil analyses and pilot trials. Worker acceptance may be an issue that may not arise in on-site recycling. Honest communication and a program to address all perceived concerns will help minimize worker objections.

L11.7 RE-REFINING can be used to handle most types of oils, even those contaminated with high levels of undesirable materials. Re-refining involves separation processes, and hydrotreating (reacting with hydrogen at high temperatures and pressures in the presence of a catalyst) to chemically alter the undesirable contaminants. Re-refining is required to produce high-quality (i.e., oils that meet LS2!) maintenance lubricants from used oil. Contact the LS2 chair for information on the corporate contract for re-refining.

L11.8 RECLAIMING OR RE-PROCESSING can be used to produce cutting and grinding fluids. Reprocessing involves physical processes to remove the undesirable contaminants of the oil; vacuum distillation, centrifuging and clay filtration are a few examples. Because reprocessing does not generally remove the additives (often the most expensive components of the cutting fluids), significant savings can be realized through the use of reprocessed cutting fluids. Reprocessing cannot generally produce a high quality hydraulic fluid from a non-segregated stream, however. Information on the corporate contracts for re-processing can be obtained from the LS2 chair.

L11.9 LS2 APPROVALS are required for all maintenance lubricants. No maintenance lubricants should be brought into a GM plant unless they have been approved against LS2. The approval process requires disclosure of product formulation information as well as a complete package of test data for each product. Details on the approval process are contained in Section L2 and the required forms are in Appendix E. A list of products currently approved is available from the LS2 website.

L11.10 BASE OIL APPROVALS are required for all metalworking fluids. Data for any mineral oil component of metal removal fluids should be sent to the same address as for LS2 maintenance lubricant approvals. The required forms are available on the LS2 website. Plant trials to evaluate all important performance attributes, such as effect on tool life, misting, corrosion, foaming, etc. should be performed before widespread use of the fluid.

L12 FLUID AND LUBRICANT CHANGE PROCESS

L12 Here are the general processes for making changes to fluids and lubricants in your plant. Recognize that every plant is different and may have slightly different approval processes required to implement a change, so these directions are necessarily somewhat general in nature. **When you encounter problems, contact the LS2 committee for help!**

L12.1 MAINTENANCE LUBRICANTS The process for changing maintenance lubes is as follows:

- Identify non-LS2-approved fluids and lubricants for which the LS2 committee has mandated the use of approved products.
- Identify problem lubricants (health concerns, poor performance, high cost, other), or opportunities for consolidation.
- Identify candidate replacement products from the LS2 approved products list (see LS2 website, gmsupplypower.com). Do not consider unapproved products!
- Discuss price and service with candidate suppliers, and select replacements.
- Request approval from the plant's Hazardous Materials Control Committee.
- Follow the applicable change request process in your plant, notifying and getting sign off from all stakeholders.
- Provide new supplier(s) with samples of the current products and ask them to verify compatibility with new products.
- Change fill point and distribution system labels as needed.
- Purchase the new product(s) and begin use. We recommend phasing in less critical applications first and critical applications as experience and comfort levels dictate. Frequent oil analysis is suggested for the first several months of use to verify that there are no compatibility or other problems.
- Track costs before and after the substitution(s) – see LS2 section L10 Business Case Template.

L12.2 METAL REMOVAL FLUIDS The process for evaluating potential new metal removal fluids is as follows:

- Identify problem fluids (health concerns, poor tool life, disposal issues, high cost, other), or opportunities for consolidation, and target fluids for replacement.
- Ensure that any candidate products are approved against the GM LS2 base oil approval list (see LS2 website, LS2 Section L2), unless the formulation contains no mineral oil. Do not even consider a product that has not been shown to meet the base oil specifications!
- Request LS2 performance and quality control data (see LS2, section L5, LX- or LY- specifications, as appropriate) from potential suppliers. Data readily available from the supplier is a good sign. Willingness to run tests in a reasonable period of time is also good. Unwillingness to provide data or run tests should disqualify the supplier.
- Based on the LS2 performance data, does the candidate product appear to be as good as or better than the current fluid?
- Request a full-disclosure MSDS meeting requirements of LS2 Appendix F (GM TMC003). **Unwillingness to provide full disclosure MSDS will disqualify supplier.**
- Select the most promising formulations.
- Submit for Productive Material Review Process approval (see section L15).
- Get plant Hazardous Materials Control Committee (HMCC) and other approvals to pilot test the most promising candidates.
- Follow the applicable change request process in your plant, notifying and getting sign off from all stakeholders.
- Pilot test in a small system for six months, if possible, to determine the effects on the following parameters:
  - quantitatively: any health complaints, misting, tool life, parts quality
  - qualitatively: operator acceptability, corrosion, foaming, waste treatability, filtration, system compatibility (seals, lubricants, etc.), and biological stability.
- Review cost book implications: coolant life, recharge costs, drag out, tool life, disposal, etc., and generate a cost book. Consult the template in section L10 of LS2 for help. Is there a good business case for the switch?
- If successful, get full HMCC and other approvals and cautiously expand use. Be aware that all processes and materials are not alike. A fluid that works well in milling may not work well in turning, or that works well on cast iron may not work well on aluminum.
- **Carefully Track costs before and after the substitution(s) – see LS2 section L10, Business Case Template.**

L13 STORAGE AND HANDLING

L13.1 GENERAL

LS2 specifications define a lubricant's physical, chemical and performance properties, while the LS2 approval process will identify products that meet the applicable specifications. Together they should ensure that the lubricant delivered to your plant should provide superior performance – theoretically, anyway. Poor in-plant storage and handling practices can result in a lubricant that is dirty, wet or otherwise contaminated being delivered to the equipment. The first step in any good proactive maintenance program to ensure maximum life of your lubricants, and ultimately your equipment, is to ensure proper in-plant storage and handling.

L13.2 PACKAGING

Lubricants may be purchased in pails (20 liters/5 gallons), drums (200 liters/55 gallons), totes (1000-1600 liters/250-450 gallons) or in bulk tanker loads. The choice depends on several factors, including consumption rate, need to have an adequate supply for unexpected usage or delivery delays, whether the product is a common lubricant or specialty item and the condition and size of the lubricant storage facility. Buying in bulk can often result in substantial cost savings, but may not be advisable, unless you have an indoor, dry facility for storing your lubricants.

L13.3 STORAGE LIFE

Most lubricant suppliers will recommend storage or shelf lives primarily based on the type of lubricant. Each lubricant type has typical additive treatments that have fairly definitive shelf lives. Certain greases, for example may lose performance in less than one year, whereas lightly-additized compressor-turbine fluids may have storage lives of two or more years. Contact your lubricant supplier for storage life recommendations.

For pails, drums or totes, always follow the first in-first out rule. For bulk storage, the new lubricant will generally be pumped in on top of the old, so it is a good idea to try to run the bulk tank down as low as possible (without risking running out, if there is a delivery delay).

L13.3.1 Factors most critically affecting storage life of most lubricants are temperature, humidity and particulates. Extreme hot or cold can cause chemical degradation. High temperatures may accelerate oxidation of lightly inhibited oils. Low temperatures can cause wax formation and pour point problems or additive "drop out" with some types of oils. Fluctuating temperatures will cause outside air to be sucked into the container, even though a drum, for instance is sealed and does not leak lubricant through the bung. This air exchange can result in moisture and small particulates entering the container. Petroleum lubricants will absorb the moisture, and this will degrade the additive package. Particulates are problematic, especially for hydraulic systems.

L.13.4 LUBRICANT STORAGE RECOMMENDATIONS

L13.4.1 Indoor Storage Pails, drums and totes must be stored in a clean and dry location. Storage temperatures should remain moderate at all times. Lubricants in storage should be located away from all types of industrial contamination including dust and humidity. Bungs must be kept tight at all times and drum covers should be used whenever drums are stored in the upright position. Ideally, lubricants are stored in the horizontal position on proper storage racks allowing the containers to be rotated and used on a first-in, first-out basis.

L13.4.2 Outdoor Storage While indoor storage of lubricants is recommended, this is not always possible due to environmental, financial or space constraints. If lubricants must be stored outdoors, track lubricant consumption carefully and replenish inventories "just-in-time" to minimize exposure to adverse conditions. If lubricants must be stored outside, shelter them from rain, snow and other elements. Lay drums on their sides with the bungs at 3 and 9 o'clock position below the lubricant level. This will greatly reduce the risk of the seals drying out and the ingestion of moisture and particulates caused by breathing. If the drums must be placed upright in outdoor storage, employ drum covers or tilt drums to drain the moisture that gathers on the top around the bungs. Avoid outdoor storage of water-based fluids altogether, as extreme temperatures can have an even more damaging effect through freezing and evaporation.

L13.4.3 Opened Containers Once the seal is broken and the container is put into use, care must be taken to prevent contamination. If equipped with a proper pressure relief, bulk tanks should use desiccant filter or bladder breathers to control contamination ingestion. Drums and pails should be capped when not in use. If your drums are frequently used, bung breather filters may be your best solution.

L13.5 LUBRICANT LABELING

Two common lubricant problems are cross contamination and lubricant confusion. All drums must be clearly labeled and stenciled to ensure proper product identification (see section 10, no. 10.1 of any individual LS2 lubricant specification). Avoid using labeling methods that are not legible or may wear out over time. Take extra care in the labeling of containers that must be stored outdoors since the elements may damage the label. Color coding labels simplifies the process, reducing the risk of misapplication. See LS2 Appendix G for suggested coding.

L13.5.1 Lubricant Dispensing Equipment Identification Lubricant dispensing equipment often lies at the root of cross contamination problems. By dispensing oil through equipment that was previously used with a different lubricant, the two fluids mix. This cross contamination reduces the effectiveness of oil analysis trending, as well. Equipment such as transport containers, hand pumps, transfer carts and filter carts should be labeled to match the lubricant. Where mixing is unavoidable, verify compatibility in advance with the lubricant supplier. Extend the identification process to the machine's lubricant fill ports. Using identification tags (see Appendix G) helps to ensure that the proper lubricant is added to the reservoir. If dispensing equipment must be used for a variety of lubricants, employ a proper cleaning or flushing procedure that emphasizes the removal of the previous lubricant and other contamination to minimize risk

L13.6 RE-SUSPENDING ADDITIVES

Before dispensing stored lubricants with questionable storage stability, agitate them on a drum tumbler to re-suspend additives that may have dropped out during storage. Use oil analysis to confirm the oil is still acceptable. This problem can be even more evident in large bulk oil systems where oil remains static for long periods of time. For these systems, a circulating system provides constant turnover to keep the additives evenly distributed. Equip such a circulating rig with dirt and water removal filters to further ensure protection.

L13.7 OIL CLEANLINESS

In many cases, new oil can be the dirtiest oil in the plant. The containers used to store lubricants are often reused and may be subjected to many extreme conditions before they reach your plant. Currently, **lubricant suppliers are required to ensure cleanliness of the lubricant they provide at point of delivery, if the product is LS2 approved.** Despite this, cleanliness of new oils typically can be significantly poorer than ISO 19/16/13. This new oil contamination level is too high for immediate service without conditioning. Routine analysis of new oils should be employed to ensure effective contamination control.

Lubricants in storage are also subject to particle agglomeration. Agglomeration occurs when smaller particles combine to form larger, more harmful particles. These harmful particles will typically fall to the bottom of the container. Even when taking the best care possible to store lubricants, they are subject to contamination ingression when filling or topping up systems. Therefore it is absolutely necessary that the lubricant be filtered with an appropriate filter element prior to entering your equipment. Here are some lubricant dispensing tips:

- Be sure that the proper transfer equipment is being used for the lubricant being dispensed. Whether you are topping up your system directly or filling a smaller portable container, be sure that the lubricant has been filtered.
- It is recommended that the oil be cycled through a high efficiency filter element with a beta rating matching your equipment requirements. If your storage method exposes the lubricant to moist environments, two-stage filtering with a water absorbing filter element is highly recommended.
- When transferring lubricants to portable containers, be sure to avoid the use of galvanized containers since the additive in the lubricant may react with the zinc plating, forming metal soaps that clog small openings and orifices in industrial machinery.

- Avoid using open or dirty containers for transfer purposes. Use properly identified, capped containers for low volume transfers.

L13.8 SUMMARY

An effective proactive maintenance program requires effective storage and delivery of lubricants. Protecting your lubricants, and ultimately your equipment, from the harmful effects of contamination and lubricant degradation begins with proper in-plant storage. These simple steps can substantially impact the useful life of your lubricants and your equipment.

L13.9 REFERENCES

1. *Wills, George, Lubrication Fundamentals, Marcel Dekker, Inc., 1980.*
2. Godin, Frank (EMA Canada), Kopschinsky, Jay (Schematic Approach Inc.).

L14 GENERAL MOTOTRS POLICY STATEMENT WITH RESPECT TO EQUIPMENT WARRANTY AND THE USE OF SPECIAL FLUIDS OR LUBRICANTS

General Motors plants now purchase industrial lubricants approved against the GM LS2 Maintenance Lubricant Standards. LS2 covers most plant lubricants and defines physical and chemical properties and significant performance attributes. Equipment manufacturers sometimes require the use of a "special" lubricant as a condition of equipment warranty, which may force the plant to inventory another lubricant in addition to that used in similar machines.

GM fully expects that the equipment manufacturer will honor their equipment warranty if any appropriate LS2-approved lubricants are used. This is consistent with policy stated in the GM LS1 Lubricant Standard for Industrial Equipment and Machine Tools and the GM Reliability and Maintainability Specifications (GM-3800). Upon request, we can provide the equipment manufacturer with a copy of the LS2 specification for specific lubricants of interest. If upon review of this specification, the equipment manufacturer has any *technical* concerns about key properties that they believe are not adequately addressed by LS2, we welcome the opportunity to discuss these concerns with them. However, requiring the use of a given lubricant without specific definable technical justification is no longer acceptable, and may be cause for rejection of future equipment purchases. In addition, GM has serious concerns about the legality of requiring the use of particular maintenance products in order to maintain the warranty on equipment.

If the equipment manufacturer has any questions or would like to discuss this matter, please contact Dr. Donald Smolenski, LS2 Chair, donald.j.smolenski@gm.com or (248) 255-7892.

L15 GM POWERTRAIN HEALTH AND SAFETY GUIDELINES FOR METAL REMOVAL FLUID SYSTEMS

L15.1 INTRODUCTION

Metal removal fluids (MRFs) are used in machining and grinding operations to cool the tool-work piece interface, reduce friction, and flush away chips and metal fines. They have been used in industry for decades. MRFs are water or oil based formulations that are acceptable to use and work around. However, like most tools, they have the potential to cause problems if not handled or maintained properly. The problems associated with MRFs typically result from a failure to follow simple, common sense practices for their use and maintenance.

The development and implementation of a management plan is critical for effective control of MRF systems and employee exposures. Each GM Powertrain facility using MRFs is required to define in a written plan how systems are monitored, and the person/persons responsible for performing these functions. Additionally, the plan should include the GMPT protocol established for investigating respiratory illness cases.

The plan should contain, at a minimum, the following elements:

A. Designation of MRF Management Responsibilities
   - o Identify the person or team with overall responsibility for the program.
   - o Identify person or team responsible for routine system monitoring and maintenance, including tank-side additions of biocides, concentrates, additives or water to replenish system losses.

B. Written Testing Protocols:
   - o Each system should have a specific sampling protocol developed to identify sampling frequency, sampling collection, handling, and results tracking.

C. Data Collection and Tracking System
   - o Encourage the use of a database system.

D. MRF System Monitoring, Maintenance, Contamination Control, and Cleaning

E. MRF Exposure Control Plan

These guidelines are provided for GMPT operations as basic methods and procedures considered effective in properly maintaining MRFs and controlling employee exposures. These guidelines are not intended to be comprehensive in scope, but serve as a common template for MRF management at GMPT facilities. Provisions for large (≥1000 gallons) and small (<1000 gallons) systems are referenced in this guidance document. It is understood that all elements in the following sections may not be applicable or feasible to every plant or operation. Operations such as toolrooms, laboratories, project engineering or performance build centers should be reviewed on a case by case basis, with the appropriate subject matter experts, to ensure appropriate controls are in place to maintain MRFs and control employee exposures.

L15.2 MRF SYSTEM MANAGEMENT PLAN

The development and implementation of a management plan is critical for effective control of MRF systems and employee exposures. A plan for MRF management can be simple or complex, but should define how systems are monitored and maintained, and identify those responsible for performing these functions. The plan should be in written form and should consider at least the following elements.

A. Fluid Selection
   - o Define objectives for the selection of MRFs
   - o Selection criteria will comply with the Metal Removal Fluid Strategy Team (MRFST) requirements and Productive Material Review (PMRv) approval
   - o MRFST is responsible for:
     - Supporting new technologies for MRFs (testing, performance, etc.)
     - Establishing common selection process for MRFs used at GMPT Facilities
     - Driving communication with chemical suppliers and GMPT facilities
   - o A plant must have prior PMRV approval for a new or expanded use of an MRF
     - PMRV is a GM health and environ-mental review process where productive (direct) materials and high volume indirect materials (i.e., MRF) are evaluated for toxicology, industrial hygiene, waste management, and permitting concerns.
     -

- https://gmsupplypower.covisint.com/web/portal/document- library?p_p_id=20&p_p_lifecycle=0&p_p_state=maximized&p_p_mode=view&_20_struts_action=%2Fdocument_library%2Fview&_20_folderId=4498117
- All material safety data sheets (MSDS) must meet GM Requirement TMC 003 and be submitted with the PMRv request.
- The facility's Hazardous Material Control Committee (HMCC) must also approve the product before use.

B. Statement of MRF Management Requirements

- o Define objectives for managing MRF systems and controlling employee exposures.
- o Describe the commitment to achieve the MRF management goals and objectives.

C. Designation of MRF Management Responsibilities

- o Identify the individual or team, including a Metal Removal Fluid Control Committee (MRFCC) with overall responsibility for coordinating the MRF management program at each plant.
- o Identify the individual or team responsible for routine system monitoring and maintenance including tank-side additions of biocides, MRF additives and concentrates or water to replenish system losses.
- o Fluid selection criteria must comply with corporate and regulatory requirements.
- o The plant must have prior divisional approval (PMRV) for new or extended use of MRFs.

D. Written MRF Testing Protocols

- o Standard operating procedures (SOP) should specify MRF sampling frequency as well as where system test samples are collected, how they are treated or handled after collection, which tests are performed, the specific protocol for each test, and who is responsible for performing sampling, testing and recording results.

E. MRF System Data Collection and Tracking

- o The data should include observations made at the system, laboratory analyses and data on tank-side additions.
- o The data should be tabulated in a manner that reveals relationships and trends to improve fluid management techniques.
- o Production and quality data may also provide useful information in assessing system performance.
- o Data collection and tracking should be responsive to allow feedback on MRF conditions and facilitate proactive intervention before the MRF system experiences significant problems.

F. Employee Participation

- o The only way to effectively manage MRFs is to enlist the aid of the people who work with the system every day. Included in this group are personnel from manufacturing, maintenance, technical support groups and MRF suppliers.
- o Employees who operate the machines are usually most knowledgeable about system operating conditions. Worker observations should be reported, documented and correlated with data from laboratory analyses and chemical additions.

G. MRF System Life Cycle

Even well managed systems eventually reach the end of their useful life. MRF system managers or coordinators should develop guidelines and procedures for when systems need to be drained, cleaned, and recharged (DCR) and how to accomplish this task.

L15.3 MRF EXPOSURE REDUCTION

MRF systems should be designed or modified to minimize factors that may contaminate the fluid or increase employee exposure to MRFs. The following steps can be taken to reduce employee exposure to MRF aerosol.

A. The flow of MRF at each operation should be interrupted or cycled-off when machining or grinding is not occurring.

B. Reduce fluid pressure to the minimum required. A high-volume, low-pressure flow of MRF delivered directly to the cutting zone is usually most effective.

C. Install splash guarding, enclosures and local exhaust ventilation on point sources of aerosol. Enclosures should extend to the MRF flume.

D. The use of sluice or flume systems to move chips can be a source of aerosol. Mechanically ventilating the sluice can reduce MRF aerosol.

E. Use solid sump covers to reduce aerosols released from entrained air in the MRF.

F. Minimize the accumulation of tramp oil because it can vaporize on hot surfaces and condense as aerosol. Tramp oil can also enhance microbial growth in a MRF system.

G. Increase fluid flow (not pressure) where smoke is generated from excessive heat. Multi-point flood application of coolant may be required. "Thru – tool" coolant application is most effective cooling the tool-chip interface.

H. Consider remote operating stations and controls to relocate employees away from the emission source.

I. Plan additions of MRF maintenance chemicals. Sump maintenance chemicals and biocides should be added in a manner that will least affect machine operators and area personnel.

J. Ensure that MRF Exposure Control Plan includes annual Aerosol Maps, an Air Sample Plan (ASP) focused on personal exposure samples and tracking of results that exceed established guidelines.

K. Personal exposure samples exceeding established guidelines will be documented and reviewed with the PSRB and control methods will be implemented utilizing the hierarchy of controls.

L15.4 EMPLOYEE TRAINING

A. Machine operators should be trained to understand how MRFs work and what affects them. For example, employees should know what can affect the proper functioning of a particular MRF system and shorten or prolong its useful life.

B. Employees should know what are the warning signs of impending system problems, who to contact when these signs are observed, and what happens when a system goes bad.

C. Employee training should include information on the potential hazards from exposure to MRFs and how to avoid them, as well as standards of personal conduct and their impact on the system.

D. MRFs and additives should always be used in accordance with instructions on labels and Material Safety Data Sheets (MSDS). All transfer containers used should be labeled. Employee training, conforming to applicable hazard communication standards, shall also be provided each time a new MRF or additive is used, or when new employees are assigned to all machining operations.

L15.5 PERSONAL PROTECTIVE EQUIPMENT

A. Personal protective equipment (e.g., safety glasses, protective gloves etc.) should be worn as specified in the manufacturer's MSDS and plant safety policies. A risk assessment should be performed to determine the personal protective equipment appropriate for each job.

B. Employees assigned to do DCR tasks should follow local Safe Work Practices (SWPs).

L15.6 MEDICAL SURVEILLANCE

A. Medical surveillance should be offered to employees who regularly work in wet machining and grinding operations for the early detection and prevention of potential adverse effects.

L15.7 MRF CONTAMINATION CONTROL

A. Maintain cleanliness of the MRF by removing metallic fines, particulates and tramp oil.

B. Keep chips and swarf from accumulating in trenches. In-floor trenches should be designed with a U-shaped cross section to maintain good flow at low volume.

C. Observe filter paper usage, appearance, filter-cake, for MRF system problems.

D. Nozzles supplying MRF to move chips and swarf should have outlets free of obstructions. They should be aimed so that the MRF stream travels several feet down the flume before contacting the walls.

E. Flumes should be designed to prevent chips and swarf from accumulating and allow fluid circulation in order to reduce microbial growth.

F. Flumes should be covered to prevent the release of aerosol and prevent dirt and debris from contaminating the system.

G. Where metal removal is minimized (e.g., grinding) or where lightweight metal is machined, the use of high volume, low pressure flushing should be considered.

H. Machine seals, greases and paints should be compatible with the MRF.

I. Seals that fit properly and do not fail are important to reduce contamination with hydraulic

fluid. Repairing leaks in hydraulic systems is imperative.

J. Avoid splashing MRF onto machine ways unless the MRF is specifically designed to replace way lubricants**.**

K. Machines should be cleaned at least once a shift to remove chips, swarf, etc.

L. A compatible cleaning product should be used for cleaning machines and machine tools.

M. Avoid draining or pumping contaminated fluid from stagnant areas back into the fluid systems

L15.8 MRF SYSTEM MONITORING AND MAINTENANCE

A. MRF systems are maintained by monitoring and control plans which are documented for each system. Factors that should be monitored and controlled include: MRF concentration, pH, suspended particulate matter, tramp oil, microbial levels and biocide concentration (if biocides are used). All data should be logged as part of a tracking system. Specific monitoring methods are prescribed in LS2 Appendix H.

B. Recommendations for large (≥1000 gallons) system monitoring intervals are as follows:

- At least three times per week, test MRF concentration, pH, and check system operating level.
- At least twice weekly, test for bacteria, mold, fungi, and tramp oil. Solids should be checked periodically.
- If sufficient data are available, frequencies may be determined using Statistical Process Control [SPC] methods.

C. Recommendations for small (<1000 gallons) system monitoring intervals are as follows:

- At least once per week, test MRF concentration, pH, and check system operating level. (Or determine frequency based on tracking history of the SPC data).
- Test for bacteria, mold, fungi, tramp oil and solids when observations or other monitoring methods indicate possible contamination OR at least every 6 months.
- If sufficient data are available, frequencies may be determined using Statistical Process Control [SPC] methods

D. Other parameters that may be useful in assessing system performance as needed:

- Total alkalinity, conductivity, hardness, chlorides, chip corrosion, rust inhibitor, dissolved oxygen, biocide concentration, and acid split for soluble oils and semi-synthetics.

E. Typical values for all MRF systems are:

- The pH should generally be less than 9.5, but greater than 8.9. Consult the fluid supplier for specific guidance.
- MRF concentration should not exceed the manufacturer's recommended levels.
- Suspended particulate should be kept below 50 ppm. However, appropriate levels of particulate matter vary for different types of systems. For example, grinding and honing operations should maintain suspended particulate below 10 PPM for particles >10μm in diameter.
- Tramp oil should not exceed 5%. The actual level should be set based on individual system characteristics.
- Bacterial levels should preferably be kept below 100,000 (10^5) colonies/cc, and not exceed 1 million (10^6) colonies/cc. Consult your fluid or biocide supplier for specific recommendations. Regular fluid tests for dissolved oxygen may be useful for managing bacterial concentration.
- Yeast and fungi should be absent, but are often difficult to detect prior to visible growth. Your fluid supplier can give assistance if this problem is suspected.
- Biocide levels should never exceed the manufacturer's recommended level.

F. Sampling and sample preparation are as important as the analysis.

- The sample should be representative of the bulk fluid and analyses should be completed before the sample changes (usually within 48 hours). See Appendix H, MRF Procedure 1 for guidance on sampling procedures.

G. Additions or changes to a MRF must be controlled. The decision to add chemicals or biocides should only be made by the MRF coordinator or management team. Any addition of chemicals should be done by, or under the direction of, the designated person or team.

H. All additions or changes to MRF systems, production changes, unusual circumstances, and observations on MRF systems should be documented. The identity of the individual making the entry should be recorded as well.

I. Biocide additions must be carefully controlled. Concentrations should never exceed the manufacturer's recommended level. Biocide changes may occasionally be required to maintain microbial control.

J. System drain, clean, and recharge (DCR) should be scheduled through the chemical management committee at the facility, and should follow standard operating procedures. Best practices in this area include a cleaning checklist used by local plant personnel to affirm DCR was completed and is satisfactory.

K. During extended shutdowns, the plant must develop and implement a plan to maintain the fluid systems.

L. The table below (MRF System Monitoring and Maintenance Recommendations) summarizes recommendations for MRF in both large and small systems. Analytical methods and limits may vary based upon specific fluid formulations and need to be reviewed on a case by case basis

L15.9 RECOMMENDED PROCEDURE FOR CHANGING METAL REMOVAL FLUIDS

A. Notify the WWTP Manager and jointly develop a plan in advance of a DCR. Remove all workpieces from the line**.**

B. Use personal protective equipment in accordance with Safe Work Practices (SWPs).

C. Where required, add a biocide that will work effectively with your contaminated (dirty) fluid and circulate thoroughly before pumping out and disposing of the old MRF. Drain the delivery lines, if possible.

D. Remove all chips and swarf from machines, flumes, trenches, lines, and sumps. Remove covers and guards to give access to hidden areas for proper cleaning. Inform cleaning crews of any potential additional hazards presented by the removal of covers and guards.

E. Add a compatible sump/machine cleaner following the manufacturer's directions (including the compatibility with metal surfaces) and refill the system with fresh water and agitate for thorough mixing. Circulate this solution and high-pressure wash all contaminated surfaces, spraying it onto machine tool surfaces that are not wetted by the normal flow of the circulating MRF. If the high-pressure spray does not adequately remove the buildup, attempt to scrape it off manually using a long handled instrument while standing outside of the system, if possible. Pump out the cleaning solution.

F. Refill with sufficient fresh water, circulate thoroughly, and rinse off all surfaces. Dump the rinse water and refill with fresh water, again circulating and thoroughly washing and rinsing down all appropriate equipment (but not through the machine, as this will cause rusting). This should be done as often as necessary to assure complete removal of the cleaning solution. A small amount of MRF concentrate may be added to the rinse water to prevent rapid rusting while the equipment is being rinsed.

G. Change all filters in the MRF system and wipe out the filter canister in the process.

H. Immediately after the last rinse has been pumped out, refill with water and MRF concentrate to the proper concentration, circulate the MRF and wet those surfaces that may rust. Run all axes through the full extent of travel to lubricate the ways and remove fluid from the bearing packs.

I. After re-filling the machine tool, turn on the MRF and attempt to catch the fluid coming out of the coolant lines before it returns to the sump until clean fluid can be seen coming out of the lines. Also drain wash off hoses in a similar fashion to prevent contaminated fluid from returning to the system. Dispose of the spent fluid.

J. Note when the system was changed. Each system should have written cleaning instructions and follow-up checklist to ensure proper cleaning techniques are followed.

L15.10 MRF SYSTEM MANAGEMENT CHECKLIST

A checklist is provided as *Attachment A* to assist in the operation and maintenance of MRF systems and affected work areas.

MRF System Monitoring & Maintenance Recommendations

Parameter	Method	Testing frequency for large systems (≥1000 gallons)	Testing frequency for small systems (<1000 gallons)	Limits	Comments
Concentration	Recommended: MRF Concentration by Alkalinity Titration (LS2 Appendix H MRF Procedure 4)	3 times/week		As recommended by fluid supplier for specific operation	Should also check system operating level whenever checking concentration
	Alternative: MRF Concentration by Refractometer (LS2 Appendix H MRF Procedure 3)		Once/week	As recommended by fluid supplier for specific operation	Must calibrate refractometer by Alkalinity Titration method on a regular basis
	Alternative: MRF Concentration by Cationic Titration (LS2 Appendix H MRF Procedure 7)				This method can supplant alkalinity titration when inter-ferences are encountered
pH	Recommended: MRF pH Determination (LS2 Appendix H MRF Procedure 5)	3 times/week		8.9-9.5 (synthetic fluids may fall outside these limits)	Reference MRF manufacturer's recommendations
	Alternative: pH by indicator paper		Once/week	8.9-9.5	Reference manufacturer's recommendations
Sensory Evaluations	Recommended: MRF Sensory Evaluation (LS2 Appendix H MRF Procedure 2) Should be performed by the machine operator.	Daily	Daily	No unusual appearance or odor	Change in appearance or odor suggest need for additional testing
Total, Tramp and Free Oil	Recommended: MRF Free Oil, Tramp and Total Oil Determination (LS2 Appendix H MRF Procedure 6)	Twice/week	If visual observation (see LS2 sensory evaluation) indicates significant floating oil	Tramp oil < 5% Free oil < 5% (see LS2 MRF Procedure 6 for definition)	If tramp and/or free oil regularly exceed 5%, corrective action should be implemented. Some tramp oil can emulsify; conversely, some product oil can come out of suspension.
Gram negative bacteria	Use commercially available Dipslide and follow manufacturer's directions; may sometimes extend incubation time (LS2 Appendix H MRF Procedure 8)	Twice/week	If odor or other monitoring methods indicate possible bacterial contamination or every 6 months	Gram negative: Not to Exceed: $<10^6$ Recommended: $< 10^5$	Reference MRF manufacturer's recommendation
	Plate count, dissolved oxygen (LS2 Appendix H MRF Procedure 8)				Only in response to problems

MRF System Monitoring & Maintenance Recommendations

Parameter	Method	Testing frequency for large systems (≥1000 gallons)	Testing frequency for small systems (<1000 gallons)	Limits	Comments
Fungus	Use commercially available Dipslide and follow manufacturer's directions (LS2 Appendix H MRF Procedure 8)	Twice/week	If odor or other monitoring methods indicate possible fungal contamination or every 6 months	Not present	Fungi are generally present in a biofilm and may not be detectable in a fluid sample
Mycobacteria	GMPT Mycobacteria Assessment Procedure				
Sediment – dirt and fines	Gravimetric filtration or centrifugation (LS2 Appendix H MRF Procedure 9)	Once/week	As visual observations or filtration issues dictate	<50 ppm	Grinding and honing operations should maintain suspended particulate below 10 ppm for particles 10 micrometers in diameter.
	Particle counts, image analysis (LS2 Appendix H MRF Procedure 9)				May be used for critical operations
Water Condition	Conductivity (LS2 Appendix H MRF Procedure 10)				In response to problems
	Hardness (Use commercially available test kit or test strips and follow manufacturer's recommendations.)				As dictated by hardness of makeup water. Consult fluid manufacturer regarding allowable hardness of make-up water and in-use MRF.
	Chlorides				In response to rusting or emulsion instability
Biocide, rust preventative, EP or other component concentration	High Pressure Liquid or Gas Chromatography, Mass Spectrometry, Ion Chromatography, Infrared Spectroscopy, Atomic Absorption, etc.				Only in response to problems
Other	Temperature			Note any significant changes	

ATTACHMENT A
METAL REMOVAL FLUID SYSTEM MANAGEMENT CHECKLIST

Plant:_____ **Operation:**_____

Department:_____ **Bay/Column:**_____

Date:_____ **Completed by:**_____

Instructions: Place a check in the appropriate boxes below. If "No" is checked, make comments and recommend corrective actions if possible. If an item does not apply to the plant/department/operation, check the "NA" box. Detail corrective actions or comments in the space provided.

	Yes	No	NA	Corrective Action or Comment
Hazard Communications				
• Are the metal removal fluids currently being used according to the Safe Use Instructions and Material Safety Data Sheet?				
• Are metal removal fluid containers labeled properly and are employees using product as per the label?				
• Is hard piping which contains MRF properly labeled?				
• Are employees using required personal protective equipment (e.g. safety glasses, gloves, respirators, etc.)?				
• Are metal removal fluid containers being stored according to specification?				
• Have Safe Use Instructions (SUI) for MRFs and applicable additives been reviewed with employees.				
Housekeeping				
• Are walking surfaces free of metal removal fluids or other machine fluids (e.g. hydraulic oil) that may be potential slip hazard?				
• Are machines washed down and cleaned regularly to prevent stagnation of MRFs?				
• Are drip pans, trenches and the surrounding floor free of cigarette butts, cups or other trash?				
• Are drip pans and other fluid reservoirs in good condition and cleaned regularly to avoid stagnation?				
• Are MRF and oil spills or leaks cleaned up promptly?				
• If "Floor Dry" or absorbent socks are used around machines to control continuous leaks or splashing, have work orders been submitted for repairs?				

• Are machine interiors, exteriors and the surrounding floor free of chip accumulations that can interfere with proper MRF circulation?				
• Are building structures (e.g., trusses, columns or pipes) free of dripping MRF?				
Ventilation and Exposure Control				
• Are exhaust ventilation hoods in good condition?				
• Does local exhaust ventilation adequately capture MRF aerosol?				
• Are man-cooling fans, if present, placed or directed so as not to interfere with the exhaust ventilation?				
• Are supply air diffusers and supply air ductwork in good condition and operating properly?				
• Do mist collector pressure gauge (e.g. Magnehelic) readings fall within the specified range?				
• Are mist collector(s) and ductwork free of any visible emissions				
• Is a record of mist collector maintenance (e.g., filter changes) attached to the collector(s)?				
• Is the flow of MRF at each operation interrupted or cycled off when machining or grinding is not occurring?				
• Is MRF delivered directly to the cutting zone and fluid pressure reduced to the minimum required?				
• Are coolant sumps covered with solid material or a moderate foam blanket to contain a mist?				
• Is ambient MRF aerosol routinely monitored to ensure employee exposures do not exceed 1.0 mg/m^3?				
• If employee exposures exceed 1.0 mg/m^3, have equipment repairs or other corrective actions been implemented?				
• Is new machinery designed and tested to ensure MRF aerosol Time Weighted Average (TWA) levels do not exceed 0.5 mg/m^3.				
Machine Guarding				
• Are machine guards in place and in good condition?				
• Does guarding contain splashing and prevent visible aerosol emissions?				
• Where necessary, are there provisions for mist containment at each machining station?				

MRF System Monitoring and Maintenance				
• Are MRF management responsibilities and testing protocols specified in a written plan?				
• Are coolant systems routinely monitored for MRF concentration, pH, microbial levels, tramp oil, suspended particulate etc?				
• Are fluid system additions controlled by the MRF Coordinator /Manager, recorded on a log sheet, and performed "off-shift" when the plant population is reduced?				
• Are system clean-outs routinely scheduled and follow standard operating procedures?				
• Is a method of obtaining operators observations regarding the system available?				
• Are systems thoroughly cleaned (e.g. power washing and rinsing) before recharging with fresh fluid?				

Attachment B
Definitions

Aerosol - a suspension of fine solid or liquid droplets in gas.

Aerosol Mapping – an engineering process that assesses general area metal removal fluid (MRF) aerosol levels in the machining work environment. The total particulate (TP) of airborne, MRF aerosol is measured to generate a concentration map of machining areas. This map identifies production processes that generate high MRF concentrations and highlights where MRF engineering controls are necessary.

Additive – a chemical substance added to a product to alter its chemical properties. Additives can be added to metal removal fluids to improve lubricity, reduce foaming, maintain pH, etc.

Air entrainment – fluid foam caused by high-pressure and high-volume fluid delivery systems. Air trapped in fluid forms bubbles and prevents fluid from acting as a lubricant and interferes with filtration of fluid. Large bubbles break more easily while smaller bubbles are more stable and problematic in machining systems. (*Manufacturing Engineering, June 2001, Vol. 126, No.6, Fluid Management Basics, by Robert B. Aronson, Senior Editor*)

Bacteria/Yeast/Fungus – unicellular microorganisms that are ubiquitous in the environment. Given the appropriate conditions, these microorganisms can propagate in MRFs and contaminate MRF systems.

Biocide – a chemical substance use to selectively, eliminate biological infestation and growth of organisms.

Biostability – the ability of a metal removal fluid (MRF) to deter growth of bacteria, fungus, Mycobacteria, and acid-fast bacilli (AFB) pellet stain. Periodically, metal removal fluids are collected from machining systems and submitted to labs to measure biostability.

Dermatitis – injury or illness involving the skin and subcutaneous tissue.

Dicyclohexylamine (DCHA) – is a strongly basic, clear, odorless liquid amine. GM allows only limited use of DCHA in MRFs.

Drain, Clean, Recharge (DCR) – a maintenance process referring to draining, cleaning, and recharging a metal removal fluid (MRF) system.

Hypersensitivity Pneumonitis (HP) – is a rare but serious disease characterized as an allergic response to an antigen and involves progressive lung damage as long as there exposure to a causative agent. (*www.cdc.gov/niosh*)

LS2 – General Motors Manufacturing Standard Lubricants for Industrial Equipment and Machine Tools are the recommended standards for manufacturing plant maintenance lubricants and metal removal fluids.

Lubricity – the ability of an oil or grease to lubricate; also, called film strength. Lubricity can be enhanced by additive treatment.

Metal Removal Fluid (MRF) – a fluid used for the purpose of removing material and cooling material during a machining (boring, drilling, grinding) process.

MRF Questionnaire – an element of the GM Medical Surveillance Program for Metal Removal Fluids to gather demographic, personal and historical data involving employees who are regularly exposed to metal removal fluids.

Metal Removal Fluid Control Committee (MRFCC) – Plant team responsible for management of the MRF systems.

Metal Removal Fluid Strategy Team (MRFST) - A corporate team, lead by Powertrain and represented by R&D, Worldwide Facilities Group, and other staffs, that makes recommendations on MRF's used in PT machining plants. The team is comprised of health and safety, industrial hygiene, fluid experts, microbial experts, 2000 account, etc.

Mycobacteria – are obligate, aerobic, acid-fast, gram positive rod-shaped, bacteria without an outer membrane. There are more than 70 species of Mycobacteria which are present in a diverse range of natural environments**.**

Productive Material Review Process (PMRv) – is a GM health and environmental review process where productive (direct) materials and high volume indirect materials (i.e., MRFs) are evaluated for toxicology, industrial hygiene, waste management, and permitting concerns. All material safety data sheets (MSDS) must meet GM Requirement TMC 003 and be submitted along with the PMRv request. PMRv approval must be obtained prior to release to GM facility. The facility's Hazardous Material Control Committee (HMCC) must also approve the product before use.

Secondary Amines – chemical compounds used as a corrosion inhibitor and antimicrobial agent (biocide) in metal removal fluids. Secondary amines are reactive amines, and together with nitrites can form nitrosamines, which are carcinogens.

Semi-synthetic – a metal removal fluid typically composed of a translucent micro-emulsion of water, chemicals and a small percentage of oil.

Sluice – a passage for fluid, also known as a velocity flume or trough.

Soluble oil – a metal removal fluid typically composed of a stable milky emulsion of water, oil, emulsifiers and

other functional additives. Commonly used where cooling is of primary importance.

Straight oils – a metal removal fluid typically composed of mineral or vegetable oil or esters and functional additives. Commonly used where lubricity is of primary importance.

Synthetic – a metal removal fluid composed of a transparent solution of chemical lubricants (typically glycols or esters) in water with functional additives. It contains no mineral oil.

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Tramp Oil – unwanted oil that has mixed with metal removal fluid in the machining process. Unwanted oil can originate from hydraulic oil or other lubricants and serve as MRF system contaminants that typically float on the surface. Tramp oil is non-homogeneous oil either introduced into the MRF system from machine tool oils (e.g., way oils), hydraulic fluids or the destabilization of soluble oil emulsion.

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APPENDIX A - TEST DESCRIPTION

Test Methods*	Test	Description	Significance
AFNOR NFT 60-187, IP 263	Emulsibility		Measures the emulsion stability of soluble cutting oil.
ANSI/AGMA 9005-E02	Industrial Gear Lubrication	Viscosity Classification for gear oils	Cross reference to ISO, SAE viscosity classifications.
ASTM D 91	Precipitation Number	The number of milliliters of precipitate formed when 10 ml of oil are mixed with 90 ml of naphtha and then centrifuged is determined.	Measures naphtha-insoluble material (asphalts) in oils.
ASTM D 92 ISO 2592 IP 36	Flash Point - Fire Point (Cleveland Open Cup)	A test cup is filled with a sample of the fluid and the temperature is raised at a regulated rate. At specified intervals, a small test flame is passed over the cup. The lowest temperature at which the flame causes the fluid vapors to ignite is the flash point. The lowest temperature at which the oil will ignite and burn for at least 5 seconds is the fire point.	Flash point measures the tendency of a fluid to form a flammable mixture with air. Can indicate the presence of volatile materials in a fluid. Fire point measures the tendency of the oil to support combustion. Often used in shipping and safety regulations.
ASTM D 94 ISO 6293 IP 136	Saponification Number	Measures the saponifiable material by means of a color indicator or potentiometric titration.	Measure of free acids, fats, esters, by conversion to metal soaps.
ASTM D 95 ISO 3733 IP 74 BS 4385	Water Content	Determination of water by distillation.	Contamination by water is generally harmful to fluid function. (Cf. ASTM D 1744)
ASTM D 97 ISO 3016 IP 15	Pour Point	A fluid sample is cooled at a specified rate and examined at 3°C intervals for flow characteristics. The lowest temperature at which motion is observed is the pour point of the fluid.	Measures low-temperature flow properties of the fluid; determines lowest use temperature for a fluid.
ASTM D 128 IP 284	Analysis of Lubricating Grease, (Oils)	Several wet chemistry methods are used for various chemical species and a procedure appended for separating soluble/insoluble components.	Used to identify and estimate the amount of some constituents of lubricating greases and oils, including fats and fatty acids.
ASTM D 129 IP 61	Determination of Total Sulfur	Sulfur is oxidized in a combustion bomb and precipitated as barium sulfate, which is then weighed.	Sulfur in metal removal fluids is generally present as an extreme pressure additive. (Cf. ASTM 2622, 4294)
ASTM D 130 ISO 2160 DIN 51759 IP 154	Copper Corrosion Test	A polished copper strip is immersed in a fluid sample at a specified temperature for a specified time. Then the strip is removed, cleaned, and compared with ASTM Copper Strip Corrosion Standards.	Detects corrosiveness of fluids to copper; some sulfur not removed in processing base oil can be corrosive, as can be some additives.

***Methods listed address the same properties and are similar, but may not be equivalent.**

Test Methods*	Test	Description	Significance
ASTM D 189 ISO 6615	Conradson Carbon Residue	A weighed sample of lubricant is placed in a crucible and destructively distilled. At the end of a fixed time period, the remaining residue is weighed and reported as the carbon residue.	Serves as a rough approximation of carbon-deposit forming tendency; not very useful when additives are present.
ASTM D 217 ISO 2137 IP 50	Cone Penetration of Lubricating Grease	The depth that a standard cone penetrates a grease sample under prescribed conditions of weight, time, and temperature is measured. It may be "worked" or sheared prior to testing.	Establishes the consistency of grease within the NLGI consistency numbers.
ASTM D 287	API Gravity	A hydrometer is inserted into the fluid at a specified temperature and the gravity is read from it.	Can be translated to mass for a given unit volume.
ASTM D 445 ISO 3104, 3105 DIN 51550, 51561, 51562, 51569 IP 71 BS 188	Kinematic Viscosity	Time required for a specified volume of oil to flow through a capillary tube at a specified temperature is determined.	Measures resistance to flow, or "thickness" of fluid.
ASTM D 471 ISO 1817, 868 DIN 53521,53505 IP 278 BS 4832 CETOP RP81H	Seal Com-patibility Test	Standard elastomer material is aged in the test lubricant at 100°C for 168 hours and the change in volume and hardness is determined.	Determines the effect of the lubricant on commonly used seal materials.
ASTM D 473 ISO 3735 IP 53	Sediment in Oils	A sample of the oil is extracted with hot toluene until the residue reaches a constant mass. The mass of the residue is reported as percent sediment.	Sediment content is important to the operation of refining and in buying and selling of the oil.
ASTM D 566 ISO 2176 DIN 51806 IP 132	Dropping Point of Lubricating Grease	A grease sample is placed in a cup with given dimensions and a hole in the bottom and is heated. The temperature at which the first drop of material falls from the cup is used to determine the dropping point.	The temperature at which the first drop of material falls from the test cup. (Cf. ASTM D 2265)
ASTM D 611 ISO 2977 DIN 51775, 51787 IP 2	Aniline Point	Equal volumes of the sample and aniline are placed in a tube and mixed and heated at a controlled rate. The mixture is then cooled under specified conditions and the temperature at which cloudiness occurs is the aniline point.	Provides a rough measure of the relative amounts of aromatic versus paraffinic components in a lubricant. This in turn may provide an indication of the lubricant's relative effect on seal materials.
ASTM D 664 DIN 51558 IP 177	Acid Number	The fluid is dissolved in toluene and isopropyl alcohol and titrated potentiometrically with potassium hydroxide.	Measures the acidic species in the oil and may be a useful measure of lubricant degradation. (Cf. ASTM D 974)

***Methods listed address the same properties and are similar, but may not be equivalent.**

Test Methods*	Test	Description	Significance
ASTM D 665 ISO 7120 DIN 51585 IP 135 CETOP RP48H	Rust Test	The test oil is mixed with a specified volume of either distilled water (D 665A) or synthetic sea water (D 665B) at 60°C with a steel specimen immersed for a period of time, typically 4 to 24 hours. The specimen is then examined for signs of rusting.	Evaluates the ability of inhibited mineral oils to aid in preventing the rusting of ferrous parts should water become mixed with the oil.
ASTM D 808	Determination of Chlorine	Sample is oxidized in a bomb. Chlorine liberated is absorbed in sodium carbonate solution and precipitated as silver chloride.	Chlorine may be present as an extreme pressure agent or as contamination by a chlorinated solvent.
ASTM D 892 ISO 6247 DIN 51566 IP 146	Foaming Characteristics	The oil sample is maintained at a specified temperature while air is blown through it at a specified flow rate for 5 minutes. The volume of foam generated is then measured, the oil is allowed to settle for ten minutes, and the volume of foam is again determined.	Oils' tendency to foam can be a serious problem in systems such as high-speed gearing, high-volume pumping, and splash lubrication. Inadequate lubrication, cavitation, and overflow loss of lubricant can lead to mechanical failure.
ASTM D 942 DIN 51808 IP 142	Oxidation Stability of Greases by Bomb Method	A grease sample is oxidized in a bomb heated to 99°C and filled with high-pressure oxygen. The degree of oxidation is determined over time by the decrease in oxygen pressure.	Can be used to estimate the relative static oxidative stability of greases of the same type, but should not be used to compare different grease types. (Cf. ASTM D 5482)
ASTM D 943 ISO 4263 DIN 51373 DIN 51587 IP 157	Oxidation Stability	An oil sample is reacted with oxygen in the presence of water and an iron-copper catalyst at 95°C. The test continues until the total acid number exceeds 2; the time at which this occurs is the "oxidation lifetime".	Estimates the oxidation stability of lubricants, especially those prone to contamination with water.
ASTM D 974 ISO 6618 IP 139	Acid and Base Number	The lubricant is dissolved in a mixture of toluene and isopropyl alcohol and then titrated with a standard alcoholic acid or base solution to an indicator color change.	A measure of the basic (usually detergent or anti corrosion additives) or acidic (often degradation products) species in a lubricant. (Cf. ASTM D 664)
ASTM E 1131 EPA 24	Volatile Organics by Oven Method or TGA		May be a crude measure of cutting oil's tendency to produce mist during machining.
ASTM D 1264 DIN 51807 IP 215	Water Washout Charactrstcs. of Greases	The grease is packed in a ball bearing and rotated at 600 rpm while water impinges on the bearing. The amount of grease washed out in 1 hour is measured.	This method estimates the resistance of greases to water washout from ball bearings.
ASTM D 1298 ISO 3675 DIN 51757 IP 160	Density, API Gravity	A hydrometer is used to determine the density of a sample at a given temperature.	May be important in commerce of lubricants. (Cf. ASTM D 287, D 4052)

***Methods listed address the same properties and are similar, but may not be equivalent.**

Test Methods*	Test	Description	Significance
ASTM D 1401 ISO 6614 DIN 51599 IP 19	Water Separability	Equal volumes of the test oil and water are stirred for 5 minutes at 54°C (82°C for products more viscous than 90 cSt at 40°C) in a graduated cylinder. The time required for the separation of the emulsion formed is recorded. The volumes of oil, water and emulsion remaining after a specified time period may be reported.	Determines the water separation characteristics of oils subject to water contamination and turbulence. (Cf. ASTM D2711)
ASTM 1500 ISO 2049 IP 196	ASTM Color of Petroleum Products	Liquid sample is placed in a glass container and compared to calibrated colored glass disks.	Often used as a first line quality control tool.
ASTM D 1662	Determination of Active Sulfur	Sample is treated with copper powder and then filtered. Sulfur is determined before and after Cu treatment – difference is active S.	A measure of an oil's sulfur content available to react with metallic surfaces; may also indicate incompatibility with copper.
ASTM D 1742 DIN 51817 IP 121	Oil Separation from Grease During Storage	A sample of grease is supported on a sieve and subjected to gentle air pressure. Any oil seepage that occurs is quantified.	Correlates directly with oil separation that occurs during storage.
ASTM D 1743	Corrosion Preventive Properties of Greases	Bearings coated with grease are exposed to water and then stored under static conditions at 100% relative humidity. After cleaning, the bearing cups are examined for corrosion.	Differentiates the relative corrosion prevention capabilities of greases. (Cf. DIN 51802, IP 220)
ASTM D 1744 (discontinued 2000)	Water Content	The lubricant is titrated with standard Karl Fischer reagent to an electrometric end point.	Water often has a direct impact on a lubricant's properties. (Cf. ASTM D 95)
ASTM D 1833 IP 185	Odor	A panel evaluates odor and assigns a numerical ranking in terms of intensity.	Often used as a first-line QA/QC technique.
ASTM D 2068	Filterability	A sample of fluid is passed through a glass fiber filter medium and the pressure drop is monitored.	Determines tendency of oil to plug filters.
ASTM D 2070 Cin. Milacron Procedure "A" or "B"	Thermal Stability	A beaker of the test fluid containing copper and iron rods is heated to 135°C ("A") or 101°C ("B") for 168 hours. At the end of the test, the rods are rated visually for discoloration. Additionally, the change in viscosity of the oil, the amount of sludge formed in the oil and the weight loss of the copper rod can be determined.	Evaluates the thermal stability (physical and chemical property changes which occur which may affect a lubricating oil's performance) in the presence of copper and steel.
ASTM D 2155-76 (discontinued 1980) ASTM E 659 ISO DIS 3988 DIN 51794 BS 4056	Autoignition Temperature	A fluid is injected into an apparatus that has been heated to a given temperature and the fluid is observed for ignition for ten minutes. If ignition doesn't occur, the procedure is repeated at successively higher temperatures until ignition occurs.	Measures a fluid's tendency to autoignite upon heating.

***Methods listed address the same properties and are similar, but may not be equivalent.**

Test Methods*	Test	Description	Significance
ASTM D 2265 ISO 2176 DIN 51806 IP 132	Dropping Point of Grease	A grease sample is heated in an Al block oven in a cup with given dimensions and a hole in the bottom. The temperature at which the first drop of material falls from the cup is used to determine the dropping point.	The temperature at which the first drop of material falls from the test cup. This procedure tests greases with a higher dropping point than does ASTM D 566.
ASTM D 2266	Four-Ball Wear Preventative Characteristic of Greases	Three steel balls are clamped together and covered with the test fluid. A fourth ball is pressed into the cavity formed by the three balls under specified test conditions (speed, temperature, load, time). The size of the scar diameters on the lower balls is then determined.	Determines the relative wear preventative quality of greases.
ASTM D 2270 ISO 2909 IP 226 BS 4459	Viscosity Index	Relates viscosities of a fluid at 40 and 100°C.	Describes variation in viscosity with temperature.
ASTM D 2422 ISO 3448 DIN 51519 BS 4231	Classification of Industrial Lubricants by Viscosity	Table relates kinematic viscosity to an ISO Viscosity Grade.	Viscosity is a critical performance parameter for lubricants.
ASTM D 2509 IP 239, 326	Load Carrying Capability of Grease (Timken Method)	A steel test cup is rotated against a steel block and grease is applied. The maximum load at which the cup will not rupture the lubricant film (OK Load) is determined.	Differentiates between greases having low, medium of high EP.
ASTM D 2595	Evaporation Loss of Greases	A grease sample is maintained at a desired (heated) temperature and air is passed over the grease. The percentage of weight lost due to evaporation is determined.	Determines loss of volatile materials from grease; may not correlate with service performance.
ASTM D 2596 DIN 51350	Measurement of Extreme Pressure (EP) Properties of Greases by Four-Ball Method	One steel ball is loaded against 3 steel balls at 27°C and rotated at 1770 rpm in the four-ball apparatus. Load is increased every ten seconds until welding occurs.	Differentiates between greases having low, medium and high EP characteristics.
ASTM D 2619 DIN 51348	Hydrolytic Stability (Beverage Bottle) Test	The fluid sample, water and a copper test specimen are sealed in a pressure-type beverage (coke) bottle. The bottle is rotated, end-for-end, for 48 hours at 93°C. After the layers separate, the weight change of the copper is measured, and the acid numbers of the fluid and water layers are determined.	Determines the relative stability of hydraulic fluids in the presence of water. Hydrolytically unstable fluids form acidic and insoluble contaminants, which can cause corrosion and valve sticking.
ASTM D 2622	Determination of Total Sulfur	Sulfur content is determined by x-ray spectometry.	Sulfur in metal removal fluids is generally present as an extreme pressure additive. (Cf. ASTM 129, 4294)

***Methods listed address the same properties and are similar, but may not be equivalent.**

Test Methods*	Test	Description	Significance
ASTM D 2711	Demulsibility	The fluid is mixed with a specified volume of water and stirred for 5 minutes at 82°C and allowed to settle for 5 hours in a special graduated separatory funnel. Water in oil, free water, and emulsion remaining are then determined.	Determines the demulsibility characteristics of fluids that are prone to water contamination. (Cf. ASTM D1401)
ASTM D 2782 IP 240	Timken OK Load Rating Test	The Timken Extreme Pressure Tester is operated with a steel cup rotating against a steel test block at 37.8°C and a speed of 123.7 m/min. The OK load is the maximum load at which the rotating cup will not rupture the lubricant film and cause scoring or seizure.	Determines extreme-pressure properties of fluids.
ASTM D 2783	Four-Ball EP Test	Three steel balls are clamped together and covered with the test fluid. A fourth ball is pressed into the cavity formed by the three balls, and rotated at 1760 rpm. A series of tests of ten seconds duration are made at increasingly higher loads until welding occurs.	Differentiates between fluids having low, medium, and high levels of extreme pressure properties.
ASTM D 2882 (withdrawn 2003) DIN 51389 CETOP RP67H IP 281	Vane Pump Wear Test	Vane and cam ring wear are determined in a Vickers M104C pump operated at 2000 psi and 1200 rpm for 100 hours.	Measures antiwear protection provided by hydraulic fluids. (Cf. Vickers M-2952-S)
ASTM D 2893	Oxidation Stability – Extreme Pressure Oils	The fluid sample is subjected to 95°C (GM uses 121°C) for 312 hours in the presence of dry air and the precipitation number and viscosity increase of the fluid are determined.	Measures the oxidation stability of gear oils and EP lubricating fluids.
ASTM D 2896 ISO 3771 IP 276	Total Base Number	Sample is dissolved in an acidic mixture and potentiometrically titrated with an acid solution.	Measures the reserve alkalinity of a lubricant and, hence, it's ability to prevent rust.
ASTM D 3228	Total Kjeldahl Nitrogen	Sample is digested and a titration follows.	Measure nitrogen containing additives, which may impact wastewater treatment plants.
ASTM D 3233	Falex Extreme Pressure Properties	Steel journal is rotated against V-blocks and load is increased.	Measures an oil's extreme pressure properties: low, medium or high.
ASTM D 3238	Paraffinic, Naphthenic, Aromatic Content	Refractive index and density are determined. Molecular weight is determined or estimated. Equations are used to calculate carbon distribution.	May provide insight into physical and chemical properties of an oil.

***Methods listed address the same properties and are similar, but may not be equivalent.**

Test Methods*	Test	Description	Significance
ASTM D 3336	Life of Lubricating Greases in Ball Bearings at High Temperatures	A ball bearing is rotated at 10000 rpm under light load and high temperature. Test is continued until failure or for a specified time.	Evaluates ability of grease to provide adequate lubrication of ball bearings at high speeds and temperatures.
ASTM D 3427 ISO 9120 DIN 51381 IP 313	Gas Bubble Separation Time of Oils	Compressed gas is blown through oil. After the gas flow is stopped, the time required to reduce the volume to 0.2% is determined.	Compares ability of oils to separate entrained air.
ASTM D 3519	Foam by Blender Test	A sample is agitated in a commercial blender for 30 seconds and the foam height is determined.	Measures an aqueous cutting oil's tendency to foam.
ASTM D 3527	Life Performance of Automotive Wheel Bearing Grease	Grease is distributed to bearings of an automotive hub-spindle bearing assembly and thrust loaded to 111 N at 1000 rpm and 160°C for 20 hours. The test hours are noted when the drive motor torque exceeds a specified value.	Distinguishes among greases having different high-temperature characteristics. Results are affected by the oxidative, thermal and shear properties of the grease.
ASTM D 3705	Misting Properties of Lubricating Fluids	The mist generator is charged with oil and operated in the mist system for 19 hours. The percent of oil in the reclassified oil collector, line condensate, and stray mist are determined by weighing.	Provides a method for evaluating the misting characteristics of oils to be used in industrial mist lubrication systems.
ASTM D 3707 DIN 51346	Storage Stability of Water-in-Oil Emulsions	A sample of the emulsion is placed in an oven at 85°C for 48 or 96 hours and examined for free oil and water.	Determines the stability of emulsions during storage and usage.
ASTM D 3946	Bacteria Resistance of Water-Dilutable Metalworking Fluids	An inoculum is introduced into different cutting oils and the progression of bacterial counts is monitored. The relative bioresistance of fluids is determined.	Useful in determining a new fluid's inherent resistance to bacterial contamination and or expected need for biocide additions.
ASTM D 4048 ISO 2160 DIN 51811 IP 112	Copper Corrosion from Grease	A copper strip is immersed in a grease sample and heated to 100°C for 24 hours. The strip is then removed, washed, and compared to the ASTM Copper Corrosion Standards.	Measures the tendency of grease to corrode copper under static conditions. Analogous to ASTM D 130, except for greases.
ASTM D 4170	Fretting Wear Protection with Grease	A Fafnir Fiction Oxidation Tester is operated with two ball thrust bearings lubricated with the test grease oscillated through a 12° arc at 30 Hz for 22 hours at room temperature under a 2450 N load. Fretting wear is the mass loss of the bearing races.	Evaluates the ability of lubricating greases to protect oscillating bearings from fretting wear. Differentiates among greases allowing low, medium and high amounts of fretting wear.

***Methods listed address the same properties and are similar, but may not be equivalent.**

Test Methods*	Test	Description	Significance
ASTM D 4172	Four-Ball Wear Test	Three steel balls are clamped together and covered with the test fluid. A fourth ball is pressed into the cavity formed by the three balls at a prescribed load at 75°C, and rotated at 1200 rpm for 1 hour. The size of the scar diameters on the lower balls is then determined.	Determines the relative wear preventative quality of fluids.
ASTM D 4290	Leakage Tendencies of Greases Under Accelerated Conditions	Grease is distributed to bearings of an automotive hub-spindle bearing assembly and thrust loaded to 111 N at 1000 rpm and 160°C for 20 hours. Leakage of grease and oil, and the condition of the bearing surface are then noted.	Distinguishes among greases having different high-temperature leakage characteristics. Uses same apparatus as ASTM D 3527, but different conditions.
ASTM D 4294	Determination of Total Sulfur	Sulfur is determined by Energy Dispersive X-Ray Fluorescence Spectroscopy.	Sulfur in metal removal fluids is generally present as an extreme pressure additive. (Cf. ASTM 129, 2622)
ASTM D 4425	Oil Separation from Grease by Centrifuging	Grease samples are centrifuged at a G value of 36,000 at 50°C. The resistance of grease to separate is the ratio of the percent of oil separated to the total number of test hours.	Useful in evaluating the resistance of a grease to separate into solid and fluid components when subjected to high centrifugal forces, such as in a flexible shaft coupling.
ASTM D 4627 DIN 51360	Corrosive Effect on Iron Chips	Chips are place on filter paper with diluted metalworking fluid and allowed to stand overnight. Rust stain on paper is determined.	Measures a cutting oil's ability to prevent rust; determine concentration required.
ASTM D 4628	Additive Metals in New Oil by Atomic Absorption	A sample is diluted and analyzed in an atomic absorption spectrophotometer using an acetylene/nitrous oxide flame.	Provides a measure of the additive content of new oils.
ASTM D 4927 ASTM D 4951	Phosphorus	Additive elements are determined by inductively coupled plasma emission spectroscopy (ICP).	Chemical determination of anitwear and/or extreme pressure additives in oil.
ASTM D 4951	Additive Metals in Oil by Inductively Coupled Plasma (ICP) Emission Spectrometry	A sample is diluted and analyzed in an ICP atomic emission spectrometer by comparing standard and sample intensities at wavelengths characteristic of elements of interest.	Provides a measure of the additive content of new oils.
ASTM D 5133 DIN 51569	Low Temperature Viscosity	A rotor immersed in oil is cooled at a programmed rate and the torque required is determined. The torque record is used to determine the viscosity over the temperature range.	Determines lowest pumping temperature of an oil.

***Methods listed address the same properties and are similar, but may not be equivalent.**

Test Methods*	Test	Description	Significance
ASTM D 5182 DIN 51354 IP 166, 334	FZG Test	An FZG gear test machine is operated at constant speed for a specified number of revolutions at successively increasing loads (stages) until scuffing and/or scoring occurs.	Evaluates scuffing load capacity of oils used to lubricate spur and helical gear units.
ASTM D 5183	Coefficient of Friction Using the Four Ball Test	Three steel balls are clamped together and covered with the test fluid. A fourth ball is pressed into the cavity formed by the three balls at a prescribed load at 75°C at 600 rpm. The coefficient of friction is determined as the load is increased at regular intervals.	Determines the coefficient of friction.
ASTM D 5185	Additive, Wear Metals and Contaminants in Oil by Inductively Coupled Plasma (ICP) Emission Spectrometry	A sample is diluted and analyzed in an ICP atomic emission spectrometer by comparing standard and sample intensities at wavelengths characteristic of elements of interest.	Provides a measure of the additive content of new oils. Also gives an indication of wear and fluid contamination during use.
ASTM D 6046	Classification of Fluids for Environmental Impact	Provides a classification for environmental persistence, ecotoxicity and bioaccumulation.	Can be used to define environmentally acceptable fluids.
ASTM D 5969	Rust Prevention of Greases	Exposes grease-lubricated taper roller bearings to various concentrations of synthetic seawater.	Determines to rust prevention capabilities of the grease.
ASTM D 6138 DIN 51802 IP 220	Emcor Rust	Evaluation of rust protection properties of lubricating greases under dynamic conditions. Distilled water is default, but more corrosive fluids can be specified.	Evaluates corrosion prevention properties of greases. Correlation with actual service is not known.
ASTM D 6304	Water Content	Determination of water by coulometric Karl Fischer titration.	Water contamination is harmful to fluid function.
ASTM E 70 DIN 51369	pH	Use of an electrode and pH meter to determine hydrogen ion concentration.	Determines whether an aqueous fluid is acidic or basic
ASTM E 1687	Determining Carcinogenic Potential of Base Oils (Modified Ames Test)	Microbiological test procedure based upon the Salmonella mutagenesis assay of AMES et al.	Can be used as a screening technique to detect the presence of potential dermal carcinogens in base oils.
ASTM F 1110	Corrosive Effect on Al		Measures a metal removal fluid's ability to prevent corrosion of aluminum.

***Methods listed address the same properties and are similar, but may not be equivalent.**

Test Methods*	Test	Description	Significance
Cincinnati Milacron Stick Slip Procedure ASTM D 2877-70 discontinued 1975 AFNOR NFT 60-183	Stick Slip Test	A steel base block is slowly traversed against a loaded top steel block, with lubricant between the blocks. The top block is held in place by two calibrated leaf springs. If the deflection of the springs is constant for a given load, than the blocks are sliding smoothly. If the movement is erratic, stick-slip is occurring.	Correlates with lubricant performance on slow-moving slideways.
Cincinnati Milacron Thermal Stability Test	Procedures A and B	Procedure A is essentially ASTM D2070. Procedure B is similar, but conducted for 24 or 72 hours at 101°C.	Determines thermal stability of lubricants.
Denison P-46	Hydraulic Piston Pump Test	A 100-hour hydraulic piston pump wear test run at 5000 psi and 2400 rpm. Piston shoes, swash plate, and port plate are all visually rated.	Evaluates ability of a hydraulic fluid to prevent wear in a piston pump.
Denison T5D Denison T6C	Hydraulic Vane Pump Test	T5D is a 100-hour hydraulic vane pump wear test run at 2500 psi (175 bar) and 2400 rpm. T6C is run 300 hour dry and 300 hour with 1% water at 1800 rpm and 3500 psi (250 bar). Cam ring and vane wear is evaluated.	Evaluates ability of an hydraulic fluid to prevent wear in a vane pump.
Denison T6H20C	Hydraulic Vane and Piston Pump Test	Two stages (one wet and one dry), 300-hour each. Hydraulic vane and piston pump wear test run at 250 bar. Cam ring, vane and piston wear is evaluated.	Evaluates ability of an hydraulic fluid to prevent wear in vane and piston pumps.
Denison TP 02100	Filterability	The test fluid, as received, and also a mixture with 2% by volume of water (mixed on a paint shaker) are filtered through a 1.2m absolute membrane filter disc at room temperature under a vacuum. The time required for 75 Ml of fluid to pass through the filter is recorded.	Evaluates the filterability characteristics of fluids, especially those subject to contamination by water.
DIN 38405, 38406, 38409	Determination of anions in water	Wet chemical methods for determining various anions in water.	Used to verify synthetic hard water used for testing metal removal fluids was blended correctly.
EPA SW-846 Technique 8270 Technique 8272	Polycyclic Aromatic Hydrocarbons (PAHs or PNAs)	Gas chromatographic determination of PNAs.	Many are known or suspected carcinogens; often generated by high-temperature processes, such as combustion in an engine.
EPA SW-846 Technique 8080 Technique 8082	Poly-chlorinated Biphenyls (PCBs.)	Gas chromatographic determination of PCBs.	Toxic substances sometimes contaminating mineral oils.

***Methods listed address the same properties and are similar, but may not be equivalent.**

Test Methods*	Test	Description	Significance
EPA SW-846 Technique 8120 Technique 9253	Total Halogens	Gas chromatographic/mass spectrographic, selective ion determination of Total Halogens.	Measure of contamination by organic solvents, such as trichloroethylene. May be legitimate additives to cutting oils.
Federal Test Method 6052.1	High-Pressure Spray Ignition	The liquid is pressurized to 1000 psi and forced through a 0.0145 in orifice. A torch is placed at various distances from the nozzle, and it is noted whether the fluid will flash with difficulty, flash readily, not ignite, etc.	Gives some indication of the flammability of hydraulic oil in the case of a line rupture in a high- pressure system.
Federal Test Method 6053.1	Manifold Ignition Test	The liquid is dripped onto the surface of a steel tube that has been heated to a given temperature and the ignition characteristics of the fluid in contact with the tube and after dripping off the tube are noted.	Gives some indication of the flammability of hydraulic oil in the case of contact with a high-temperature surface.
GM 9035P	Infrared (IR) Analysis	Comparative determination of concentration of organic species using IR reference spectra.	Used as an inspection and quality control tool.
ISO 4406 ISO 11171	Cleanliness	Particle count determination by pressure drop across a filter, by optical, or by other methods.	Determines relative concentrations of large and small particles, which relates to wear and possible valve plugging.
NFT 60-171	Worked Penetration – Grease	Cone penetration (ASTM D 217 apparatus) for determining grease consistency at low temperatures.	Estimates low-temperature performance; minimum value for dispensing applications.
Vickers 35VQ25 (2952-S)	Vane Pump Test	150-hour hydraulic vane pump wear test run at 3000 psi and 2500 rpm. Cam ring and vane weight loss is measured.	Evaluates ability of a hydraulic fluid to prevent wear in a vane pump. (Cf. ASTM D2882)

***Methods listed address the same properties and are similar, but may not be equivalent.**

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Many Publications Referenced, ASTM, BS, CEN, DIN, IP, ISO, and VDMA Standard hardcopies are available from the ILI Website (http://www.ili-info.com) or by contacting ILI at

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***Methods listed address the same properties and are similar, but may not be equivalent.**

APPENDIX A - TEST DESCRIPTION

Summary Table – Properties and Tests

Properties	Hydraulic Fluids	Fire-Resistant Hydraulics	Lubes	Greases	Metal Removal Fluids	ISO	DIN	ASTM	IP/BS	Other
Air release	X	X				9120	51381	D 3427	IP 313	
Aniline point				X		2977	51775 51787	D 128 X1 D 611 A2	IP 2	
API gravity			X					D 287		
Autoignition		X				3988	51794	E 659	BS 4056	
Base number					X	3771		D 2896	IP 276	
Chlorine					X			D 808		
Conradson Carbon			X			6615		D 189		
Copper corrosion	X	X	X		X	2160	51759/1	D 130	IP 154	
Density		X	X		X	3675	51757	D 1298 D 4052	IP 160	
Dirt content				X			51813		IP 134	FTM 3005.4
Emulsion stability		X					51346	D 3707 (water in oil)		
Environmental impact	X	X						D 6046		
Falex EP					X			D 3233		
Fatty Acids, & Esters					X			D 128	IP 284	
Fire point	X	X	X			2592	2592	D 92	IP 36	
Fire resistance - High pressure spray flammability		X								FTM 6052.1
Fire resistance - Hot manifold		X								FTM 6053.1 CETOP RP65H
Flash point	X	X	X	X	X	2592		D 92	IP 36	
Foam	X	X	X		X	6247	51566	D 892	IP 146	
Four ball wear (20 kg load) wear scar diameter			X					D 2783 D 4172		
FZG gear rig test	X	X	X				51534 part 2	D 5182	IP 166 IP 334	
Grease, centrifugal separation				X				D 4425		
Grease, copper corrosion				X			51811	D 4048	IP 112	
Grease, drop point				X		2176	51806	D 2265 D 566	IP 132	
Grease, EMCOR rust test				X			51802	D 6138	IP 220	
Grease, evaporation loss				X				D 2595		
Grease, four ball wear (20 kg load)				X			51350 part 4 51350 part 5	D 2266	IP 239	
Grease, four ball wear				X			51350/4&5	D 2596		
Grease, fretting wear				X				D 4170		
Grease, life in ball bearings				X				D 3336		
Grease, life performance				X				D 3527		
Grease, lower operating temp.				X			51805			

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Grease, low temperature worked penetration				X		2137		D 217	IP 50	
Grease, NLGI grade				X			51818			
Grease, oil separation				X				D 4290		
Grease, oxidation stability				X			51808	D 942	IP 142	
Grease, pressure separation				X			51817	D 1742	IP 121	
Grease, rust prevention				X			51802	D 1743	IP 220	
Grease, Timken load				X				D 2509	IP 326	
Grease, water washout				X			51807 part 2	D 1264	IP 215	
Hydrolytic stability	X	X					51348	D 2619		
Metals content	X	X	X	X	X			D 4628 D 4927 D 4951		
Misting			X					D 3705		
MRF, bacterial resistance					X			D 3946		
MRF, color					X	2049		D 1500	IP 196	
MRF, corrosive effect on aluminum					X			F 1110		
MRF, corrosive effect on iron chips					X		51 360/1&2	D 4627	IP 287 & 125	
MRF, emulsion Stability					X				IP 263	AFNOR NFT 60-187
MRF, filterability					X			D 2068		
MRF, foam by blender					X			D 3519		
MRF, four ball coefficient of friction					X			D 5183		
MRF, saponification number					X	6293		D 94	IP 136 (sec. 1)	
MRF, sticking/gumming tendency					X					TBD
Mutagenicity by Mod. Ames	X	X	X	X	X			E 1687		
Neutralization number, acid number	X	X	X		X	6618	51558 part 1	D 664 D 974	IP 139 IP 177	
Odor					X			D 1833	IP 185	
Organic halogens	X	X	X	X	X					EPA SW-846, TN 8121
Oxidation stability (1000 hrs)	X	X	X			4263	51373 51587	D 943	IP 157	
Oxidation stability (EP oils)			X					D 2893		
Paraffinic, Naphthenic, Aromatic content	X				X			D 3238 D 2140		
Particle contamination	X	X	X			4406 11171				
PCB's	X	X	X	X	X					EPA SW-846, TN 8082
Ph		X			X		51369	E 70		

APPENDIX A - TEST DESCRIPTION

Summary Table – Properties and Tests

Properties	Hydraulic Fluids	Fire-Resistant Hydraulics	Lubes	Greases	Metal Removal Fluids	ISO	DIN	ASTM	IP/BS	Other
Phosphorus	X				X			D 4927 D 4951		
Piston Pump test	X	X								Denison P-46
Total PNA's	X	X	X	X	X					EPA SW-846, TN 8270C
Pour point	X	X	X		X	3016		D 97	IP 15	
Precipitation Number			X					D 91		
Rust	X	X	X		X	7120	51585	D 665A or B	IP 135	CETOP R48H
Seal compatibility Relative change in % volume Change in shore hardness	X X	X X	X X		X X	1817 1817 868	53521 53521 53505	D 471 D 471	BS 903 IP 278 BS 4832	
Sediment					X			D 473		
Shear stability	X	X					51382	D 3945 D 5621	IP 294	CETOP RP112H
Stick slip			X					D 2877 (discontinued)		AFNOR NF T 60-183 Cinc. Stick Slip
Sulfur, active					X			D 1662	Sulfur, active	
Sulfur, total					X			D 129 D 2622 D 4294	IP 61	
Thermal stability	X		X					D 2070		Cinc. Proc. A/ B
Timken OK load			X					D 2782	IP 240	
Vane pump tests	X	X					51389 part 2	D 2882	IP 281	CETOP RP67 Vickers 35VQ-45 Denison T5D, T6C, T6H20C
Viscosity classification	X	X	X		X	3448	51519	D 2422	BS 4231	
Viscosity index	X	X	X		X	2909	2909	D 2270	IP 226 BS 4459	
Viscosity, kinematic	X	X	X		X	3104 3105	51561 51562 part 1 51569	D 445	IP 71(Sec. 1) BS 188	
Viscosity, low-temperature	X				X			D 5133		
Volatile Organics, TGA or oven					X			E 1131		EPA Method 24
Water content	X	X	X	X	X	3733		D 95 D 1744 D 6304	IP 74 BS 4385	
Water separability/ demulsibility	X		X			6614	51599	D 1401 D 2711	IP 19	

APPENDIX B -- Glossary of Terms

absolute viscosity - the ratio of shear stress to shear rate. It is a fluid's internal resistance to flow. The common unit of absolute viscosity is the poise (see viscosity). Absolute viscosity divided by the fluid's density equals kinematic viscosity.

acid number - The number of milligrams of potassium hydroxide required to neutralize one gram of an oil sample. ASTM D664 uses a potentiometric titration; D 974 uses a color-indicator titration.

additive - a chemical substance added to a petroleum product to impart or improve certain properties. Common petroleum product additives are: antifoam agent, anti-wear additive, corrosion inhibitor, demulsifier, detergent, dispersant, emulsifier, EP additive, oiliness agent, oxidation inhibitor, pour point depressant, rust inhibitor, tackiness agent, viscosity index (VI.) improver.

aeration - introduction of air into a lubricant

AGMA - American Gear Manufacturers Association, which, as one of its activities, establishes and promotes standards for gears and gear lubricants.

AGMA lubricant numbers - AGMA specification covering gear lubricants. The viscosity ranges of the AGMA numbers (or grades) conform to the International Standards Organization (ISO) viscosity classification system (see ISO viscosity classification system).

aniline point - lowest temperature at which equal volumes of aniline is soluble in a specified quantity of a petroleum product, as determined by test method ASTM D 611; hence, an empirical measure of the solvent power of a hydrocarbon. The lower the aniline point, the greater the solvency. Paraffinic hydrocarbons have higher aniline points than aromatic types.

ANSI (American National Standards Institute) - an organization of industrial firms, trade associations, technical societies, consumer organizations, and government agencies, intended to establish definitions, terminologies, and symbols; improve methods of rating, testing, and analysis; coordinate national safety, engineering and industrial standards; and represent U.S. interests in international standards work.

antifoam agent - one of two types of additives used to reduce foaming in petroleum products: silicone oil to break up large surface bubbles, and various kinds of polymers that decrease the amount of small bubbles entrained in the oils.

antiwear additive - additive in a lubricant that reduces friction and excessive wear.

API (American Petroleum Institute) - a trade association of petroleum producers, refiners, marketers, and transporters, organized for the advancement of the petroleum industry by conducting research, gathering and disseminating information, and maintaining cooperation between government and the industry on all matters of mutual interest.

aromatic - cyclic unsaturated hydrocarbons identified by one or more benzene rings or by chemical behavior similar to benzene. Aromatics are usually more reactive and have higher solvency than paraffins and naphthenes. Aromatics readily undergo electrophilic substitution; that is, they react to add other active molecular groups, such as nitrates, sulfonates, etc. Aromatics are used extensively as petrochemical building blocks.

ASTM (American Society for Testing and Materials) - an organization devoted to "the promotion of knowledge of the materials of engineering, and the standardization of specifications and methods of testing." A preponderance of the data used to describe, identify, or specify petroleum products is determined in accordance with ASTM test methods.

automatic transmission fluid (ATF) - a functional fluid for automatic transmissions in motor vehicles. Automatic transmission fluids must have a suitable coefficient of friction, good low-temperature viscosity, and antiwear properties. Other necessary properties are: high oxidation stability, anti-corrosion, anti-foaming, and compatibility with synthetic rubber seals.

bacteria count - is a measure of the bacteria in a metalworking fluid mix. A high Bacteria Count can lead to offensive odors and failure of your metalworking fluid mix. It is usually measured in colony forming units (cfu)/mL.

base number - The number of milligrams of acid required to neutralize one gram of an oil sample. ASTM D974 uses hydrochloric acid and a color-indicator titration; D 2896 uses perchloric acid in a potentiometric titration.

base stock - a primary refined petroleum fraction, usually lubricating oil, into which additives and other products are blended to produce finished products.

biodegradation - the chemical breakdown of materials by living organisms in the environment. The process depends on certain microorganisms, such as bacteria, yeast, and fungi, which break down molecules for sustenance. Certain chemical structures are more susceptible to microbial breakdown than others; vegetable oils, for example, will biodegrade more rapidly than petroleum oils. Most petroleum products typically will completely biodegrade in the environment within two months to two years.

boundary lubrication - a form of lubrication between two rubbing surfaces without development of a full-fluid lubricating film. Boundary lubrication can be made more effective by including additives in the lubricating oil that provide a stronger oil film, thus preventing excessive friction and possible scoring. There are varying degrees of boundary lubrication, depending on the severity of service. For mild conditions, oiliness agents may be used; these are polar compounds that have an exceptionally high affinity for metal surfaces. By plating out on these surfaces in a thin but durable film, oiliness agents prevent scoring under some conditions that are too severe for a straight mineral oil. Compounded oils, formulated with polar fatty oils, are sometimes used for this purpose. Antiwear additives are commonly used in more severe boundary lubrication applications. The more severe cases of boundary lubrication are defined as extreme pressure conditions; they are met with lubricants containing EP additives that prevent sliding surfaces from fusing together at high local temperatures and pressures.

Brookfield viscosity - the apparent viscosity of oil, usually determined by test method ASTM D 2983. The apparent viscosity of a non-Newtonian fluid is valid only for the shear rates and temperature at which it is determined. The Brookfield viscometer provides a known rate of shear by means of a spindle of specified configuration that rotates at a known constant speed in the fluid. The torque imposed by fluid friction can be converted to absolute viscosity units (centipoise) by a conversion factor or equation.

carcinogen - a cancer-causing substance. Certain petroleum products are classified as potential carcinogens under OSHA criteria. Suppliers are required to identify such products as potential carcinogens on package labels and Material Safety Data Sheets.

cavitation - the formation of an air or vapor pocket (or bubble) due to lowering of pressure in a liquid, often as a result of a solid body, such as a piston, moving through the liquid; also, the pitting or wearing away of a solid surface as a result of the collapse of a vapor bubble. Cavitation can occur in a hydraulic system as a result of low fluid levels that draw air into the system, producing tiny bubbles that expand explosively at the pump outlet, causing metal erosion and eventual pump destruction. Cavitation can also result when reduced pressure in lubricating grease-dispensing systems forms a void, or cavity, which impedes suction and prevents the flow of greases.

chlorinated wax - certain solid hydrocarbons treated with chlorine gas to form straight-chain hydrocarbons with a relatively high chlorine component. Chlorinated waxes are used primarily as polyvinyl chloride plasticizers, extreme-pressure additives for lubricants, and formulation components for many cutting fluids.

circulating lubrication system - a system in which oil is recirculated from a sump or tank to the lubricated parts, in most cases requiring a pump to maintain

circulation. Circulating lubrication makes possible extended lubricant use, and usually requires a high-quality rust and oxidation inhibited (R&O) oil.

clay filtration - a refining process using fuller's earth (activated clay), bauxite or other mineral to adsorb minute solids from lubricating oil, as well as remove traces of water, acids, and polar compounds.

compounded oil - a mixture of petroleum oil with animal or vegetable fat or oil. Compounded oils have a strong affinity for metal surfaces; they are particularly suitable for wet-steam conditions and for applications where lubricity and extra load-carrying ability are needed. They are not generally recommended where long-term oxidation stability is required.

concentration - is the percentage of metalworking fluid concentrate in a mix. The concentration can also be expressed as a ratio, the amount of metalworking fluid concentrate to the total volume of mix. Example: adding four gallons of concentrate to 96 gallons of water yields a 4% or 1:25 mix concentration. To maximize your fluid, maintain concentration within the recommended operating parameters. If the mix is too rich/strong, various problems can occur, such as foam and excess residue. If the mix is too lean/weak, other problems can occur. Such problems are poor tool or wheel life, rancidity, and corrosion.

conductivity - is a measure of the conductance of a metalworking fluid. It is expressed in MilliSiemens/cm. As the amount of dissolved materials, i.e., calcium, magnesium, sodium, chlorides, etc., increases, the conductivity increases. Conductivity is expected to increase slowly over time. The rate of the increase depends on the quality and amount of water used, and the amounts and types of other contaminants. High levels of conductivity can promote various metalworking fluid problems, such as insoluble residues, mix instability, and loss of overall performance. Emulsion instability can be expected with a conductivity that reaches the 4 to 5 mS range.

consistency (grease) - a basic property describing the softness or hardness of a grease, i.e., the degree to which a grease resists deformation under the application of force. Consistency is usually measured by means of a cone penetration test. The consistency of grease depends on the viscosity of the base oil and the type and proportion of the thickener. It can also be affected by recent agitation; to take this phenomenon into consideration, grease is usually subjected to working (a standard churning process) prior to measuring its penetration value.

corrosion - a chemical attack on a metal or other solid by contaminants in a lubricant. Common corrosive contaminants are: (1) water, which causes rust of ferrous materials, and (2) acids, which may form as oxidation products in a deteriorating oil, or may be introduced into the oil as combustion by-products in piston engines.

corrosion inhibitor - an additive for protecting lubricated metal surfaces against chemical attack by water or other contaminants. There are several types of corrosion inhibitors. Polar compounds wet the metal surface preferentially, protecting it with a film of oil. Other compounds may absorb water by incorporating it in a water-in-oil emulsion so that only the oil touches the metal surface. Another type of corrosion inhibitor combines chemically with the metal to present a non-reactive surface.

cream - is light colored oil, typically opaque yellow. It is part water and part oil, is creamy in texture, and included in the amount of free oil.

cylinder oil - a lubricant for independently lubricated cylinders, such as those of steam engines and air compressors; also for lubrication of valves and other elements in the cylinder area. Steam cylinder oils are available in a range of grades with high viscosity's to compensate for the thinning effect of high temperatures; of these, the heavier grades are formulated for super-heated and high-pressure steam, and the lighter grades for wet, saturated, or low-pressure steam. Some grades are compounded for service in excessive moisture; see compounded oil. Cylinder oils lubricate on a once-through basis.

demulsifier - an additive that promotes oil water separation in lubricants that are exposed to water or steam.

detergent - an important component of engine oils and some industrial lubricants, such as paper machine oils and hydraulic fluids; helps control deposits by preventing contaminants of combustion from directly contacting metal surfaces and, in some cases, by neutralizing acids. A detergent is usually a metallic (commonly barium, calcium or magnesium) compound, such as a sulfonate, phosphonate, thiophosphonate, phenate, or salicylate. Because of its metallic composition, a detergent leaves a slight ash when the oil is burned. A detergent is normally used in conjunction with a dispersant.

DIN (Deutsches Institut fur Normung) - German standardization organization.

dirt volume - is the percentage of solids in your metalworking fluid mix that separates from the mix after settling or centrifuging. High dirt volumes usually indicate either inadequate filtration or filter problems. A high dirt volume can affect the performance of your metalworking fluid and lead to such problems as residue, poor finish, poor grinding wheel or tool life and microbial growth.

Elasto-hydrodynamic (EHD) lubrication - a lubrication phenomenon occurring during elastic deformation of two non-conforming surfaces under high load. A high load carried by a small area (as between the ball and race of a rolling contact bearing) causes a temporary increase in lubricant viscosity as the lubricant is momentarily trapped between slightly deformed opposing surfaces.

elastomer - a rubber or rubber-like material, both natural and synthetic, used in making a wide variety of products, such as seals and hoses. In oil seals, an elastomer's chemical composition is a factor in determining its compatibility with a lubricant.

elastomer (seal) compatibility – the quality of a lubricant to remain in contact with an elastomer without significantly affecting the chemical and physical properties of either. Immersion tests at elevated temperatures are commonly used to evaluate compatibility. Changes in volume (see seal swell) and hardness (Durometer) are most often determined in lubricant laboratories; rubber laboratories usually run additional tests, such as tensile strength and elongation.

electrical insulating oil - a high-quality oxidation-resistant oil refined to give long service as a dielectric and coolant for electrical equipment, most commonly transformers. Insulating oil must resist the effects of elevated temperatures, electrical stress, and contact with air, which can lead to sludge formation and loss of insulation properties. It must be kept dry, as water is detrimental to dielectric strength - the minimum voltage required to produce an electric arc through an oil sample, as measured by test method ASTM D 877.

emulsifier - an additive that promotes the formation of a stable mixture, or emulsion, of oil and water. Common emulsifiers are: metallic soaps, certain animal and vegetable oils, and various polar compounds (having molecules that are water-soluble at one extremity of their structures and oil-soluble at the other).

emulsion - a two-phase liquid system in which small droplets of one liquid are immiscible in, but uniformly dispersed throughout, a second, continuous phase. Generally of a milky or cloudy appearance, emulsions may be of two types; oil-in-water (where water is the continuous phase) and water-in-oil (where water is the discontinuous phase). Oil-in-water emulsions are used as cutting fluids because of the need for the cooling effect of the water. Water-in-oil, or invert, emulsions are used where the oil, not the water, must contact a surface - as in rust preventives, non-flammable hydraulic fluids, and compounded steam cylinder oils (see compounded oil); such emulsions are sometimes referred to as invert emulsions. Emulsions are produced by adding emulsifiers. Emulsibility is not a desirable characteristic in certain lubricating oils, such as hydraulic or turbine oils, that must separate from water readily. Unwanted emulsification can occur as a result of oxidation products - which are usually polar compounds - or other contaminants in the oil.

EP additive - a lubricant additive that prevents sliding metal surfaces from seizing under conditions of extreme pressure (EP). At the high local temperatures associated with metal-to-metal contact, an EP additive combines chemically with the metal to form a surface film that prevents the welding of opposing asperities, and the consequent scoring that is destructive to sliding surfaces under high loads. Reactive compounds of sulfur, chlorine, or phosphorus are used to form these inorganic films.

EP oil - lubricating oil formulated to withstand extreme pressure (EP) operating conditions.

ferrography - a method of particle analysis using precision magnets to strip iron-laden and other susceptible particles from a used lubricating oil for study; results indicate extent of equipment wear and likelihood of imminent failure. Direct-reading ferrography uses optical sensors to measure the density of particles collected and the ratio of large particles to small (fatigue-related catastrophic failure generally is characterized by generation of particles larger than 10-15 microns). Analytical ferrography employs microscopic and photographic evaluation of wear particles. The test provides in-depth analysis of particle composition (e.g., steel, copper, bronze) and type of wear (e.g., corrosion, metal-to-metal contact).

fire-resistant fluid - a lubricant used especially in high-temperature or hazardous hydraulic applications, such as steel mills and underground mining. Three common types of fire-resistant fluids are: (1) water-petroleum oil emulsions, in which the water prevents burning of the petroleum constituent; (2) water-glycol fluids; and (3) non-aqueous fluids of low volatility, such as phosphate esters, silicones, and halogenated hydrocarbon-type fluids.

foaming - a frothy mixture of air and a petroleum product (e.g., lubricant, fuel oil) that can reduce the effectiveness of the product, and cause sluggish hydraulic operation, air binding of oil pumps, and overflow of tanks or sumps. Foaming can result from excessive agitation, improper fluid levels, air leaks, cavitation, or contamination with water or other foreign materials. Foaming can be inhibited with an antifoam agent. The foaming characteristics of a lubricating oil can be determined by blowing air through a sample at a specified temperature and measuring the volume of foam, as described in test method ASTM D 892.

free oil - is the percentage of oil or oil-like material which is not emulsified and floats on the surface of your metalworking fluid mix. Free oil is usually the machine lubricating oils which leak into a mix. A high free oil percentage in your mix can lead to such problems as microbial growth, residue and grinding wheel loading. A significantly higher free oil than tramp oil value often indicates mix instability.

fretting - a form of attritive wear resulting from small-amplitude oscillations or vibrations that cause the removal of very finely divided particles from rubbing surfaces (e.g., the vibrations imposed on the wheel bearing of an automobile when transported by rail car). With ferrous metals the wear particles oxidize to a reddish, abrasive iron oxide, which has the appearance of rust or corrosion, and is therefore sometimes called fretting corrosion; other terms applied to this phenomenon are false brinelling (localized fretting involving the rolling elements of a bearing) and friction oxidation. Generally, lubricants will not prevent fretting, but they can alleviate the problem to varying degrees. ASTM D 4170 is used to determine the fretting wear protection quality of greases, but it cannot distinguish between fretting wear and false brinelling.

friction - the resistance to the motion of one surface over another. The amount of friction is dependent on the smoothness of the contacting surfaces, as well as the force with which they are pressed together. Friction between unlubricated solid bodies is independent of speed and area. The coefficient of friction is obtained by dividing the force required to move one body over a horizontal surface at constant speed by the weight of the body. Coefficients of rolling friction (e.g., the motion of a tire or ball bearing) are much less than coefficients of sliding friction. Sliding friction is thus more wasteful of energy and can cause more wear. Fluid friction occurs between the molecules of

a gas or liquid in motion, and is expressed as shear stress. Unlike solid friction, fluid friction varies with speed and area. In general, lubrication is the substitution of low fluid friction in place of high solid-to-solid friction.

full-fluid-film lubrication - the presence of a continuous lubricating film sufficient to completely separate two surfaces, as distinct from boundary lubrication. Full-fluid-film lubrication is normally hydrodynamic lubrication, whereby the oil adheres to the moving part and is drawn into the area between the sliding surfaces, where it forms a pressure, or hydrodynamic, wedge. A less common form of full-fluid lubrication is hydrostatic lubrication, wherein the oil is supplied to the bearing area under sufficient external pressure to separate the sliding surfaces.

fungal count - is a measure of the mold or other fungus in a metalworking fluid mix. A high fungal count can lead to offensive odors, plugged fluid lines and failure of a fluid mix. Unlike bacteria counts which mirror the growth of bacteria in the system, fungal counts often do not detect fungus present in or around the system. Fungus is more likely to cling to surfaces and, therefore, may be well established in a system without being detectable in a small fluid sample.

gear - a machine part that transmits motion and force by means of successively engaging projections, called teeth. The smaller gear of a pair is called the pinion; the larger, the gear. When the pinion is on the driving shaft, the gear set acts as a speed reducer; when the gear drives, the set acts as a speed multiplier. The basic gear type is the spur gear, or straight-tooth gear, with teeth cut parallel to the gear axis. Spur gears transmit power in applications utilizing parallel shafts. In this type of gear, the teeth mesh along their full length, creating a sudden shift in load from one tooth to the next, with consequent noise and vibration. This problem is overcome by the helical gear, which has teeth cut at an angle to the center of rotation, so that the load is transferred progressively along the length of the tooth from one edge of the gear to the other. When the shafts are not parallel, the most common gear type used is the bevel gear, with teeth cut on a sloping gear face, rather than parallel to the shaft. The spiral bevel gear has teeth cut at an angle to the plane of rotation, which, like the helical gear, reduces vibration and noise. A hypoid gear resembles a spiral bevel gear, except that the pinion is offset so that its axis does not intersect the gear axis; it is widely used in automobiles between the engine driveshaft and the rear axle. Offset of the axes of hypoid gears introduces additional sliding between the teeth, which, when combined with high loads, requires a high-quality EP oil. A worm gear consists of a spirally grooved screw moving against a tooth wheel; in this type of gear, where the load is transmitted across sliding, rather than rolling, surfaces, compounded oils or EP oils are usually necessary to maintain effective lubrication.

gearbox (gear housing) - a casing for gear sets that transmit power from one rotating shaft to another. A gearbox has a number of functions: it is precisely bored to control gear and shaft alignment, it contains the gear oil, and it protects the gears and lubricant from water, dust, and other environmental contaminants. Gearboxes are used in a wide range of industrial, automotive, and home machinery. Not all gears are enclosed in gearboxes; some are open to the environ-ment and are commonly lubricated by highly adhesive greases.

gear oil - a high-quality oil with good oxidation stability, load-carrying capacity, rust protection, and resistance to foaming, for service in gear housings and enclosed chain drives. Specially formulated industrial EP gear oils are used where highly loaded gear sets or excessive sliding action (as in worm gears) is encountered.

grease (lubricating) - a mixture of a fluid lubricant (usually petroleum oil) and a thickener (usually soap) dispersed in the oil. Because greases do not flow readily, they are used where extended lubrication is required and where oil would not be retained. The thickener plays as important a role as the oil in the lubrication mechanism. Soap thickeners are formed by reacting (saponifying) a metallic hydroxide, or alkali, with a fat, fatty acid, or ester. The type of soap used depends on the grease properties desired. Calcium (lime) soap greases are highly resistant to water, but unstable at high

temperatures, so are seldom used any more. Sodium soap greases are stable at high temperatures, but wash out in moist conditions. Lithium soap greases resist both heat and moisture. A mixed-base soap is a combination of soaps, offering some of the advantages of each type. A complex soap is formed by the reaction of an alkali with a high-molecular-weight fat or fatty acid to form a soap, and the simultaneous reaction of the alkali with a short-chain organic or inorganic acid to form a metallic salt (the complexing agent). Complexing agents usually increase the dropping point of grease. Lithium, calcium, and aluminum greases are common alkalis in complex-soap greases. Non-soap thickeners, such as clays, silica gels, carbon black, and various synthetic organic materials (especially polyureas) are also used in grease manufacture. Multi-purpose greases are designed for different applications. They provide resistance to heat, as well as water, and may contain additives to increase load-carrying ability and inhibit rust.

hydraulic fluid - a fluid serving as the power transmission medium in a hydraulic system. The most commonly used fluids are petroleum oils, synthetic lubricants, oil-water emulsions, and water-glycol mixtures. The principal requirements of a premium hydraulic fluid are proper viscosity, high viscosity index, anti-wear protection (if needed), good oxidation stability, adequate pour point, good demulsibility, rust inhibition, resistance to foaming, and compatibility with seal materials. Antiwear oils are frequently used in compact, high-pressure, and high-capacity pumps that require superior lubrication protection. Certain synthetic lubricants and water-containing fluids are used where fire resistance is needed. Synthetic lubricants also are used in extreme-temperature conditions.

hydraulic system - a system designed to transmit power through a liquid medium, permitting multiplication of force in accordance with Pascal's law, which states that "a pressure exerted on a confined liquid is transmitted undiminished in all directions and acts with equal force on all equal areas." Hydraulic systems have six basic components: (1) a reservoir to hold the fluid supply; (2) a fluid to transmit the power; (3) a pump to move the fluid; (4) a valve to regulate pressure; (5) a directional valve to control the flow, and (6) a working component -- such as a cylinder and piston or a shaft rotated by pressurized fluid -- to turn hydraulic power into mechanical motion. Hydraulic systems offer several advantages over mechanical systems: they eliminate complicated mechanisms such as cams, gears, and levers; are less subject to wear; are usually more easily adjusted for control of speed and force; are easily adaptable to both rotary and linear transmission of power; and can transmit power over long distances and in any direction with small losses.

hydrogenation - in refining, the chemical addition of hydrogen to a hydrocarbon in the presence of a catalyst; a severe form of hydrogen treating. Hydrogenation may be either destructive or non-destructive. In the former case, hydrocarbon chains are ruptured (cracked) and hydrogen is added where the breaks have occurred. In the latter, hydrogen is added to a molecule that is unsaturated with respect to hydrogen. In either case, the resulting products are highly stable. Temperatures and pressures in the hydrogenation process are usually greater than in hydrofining.

immiscible - incapable of being mixed without separation of phases. Water and petroleum oil are immiscible under most conditions, although they can be made miscible with the addition of an emulsifier.

industrial lubricant - any petroleum or synthetic-base fluid or grease commonly used in lubricating industrial equipment, such as gears, turbines, and compressors.

infrared (IR) analysis - a form of absorption spectroscopy that identifies organic functional groups present in a used oil sample by measuring their light absorption at specific infrared wavelengths; absorbance is proportional to concentration. The test can indicate additive depletion, the presence of water, hydrocarbon contamination of a synthetic lubricant, oxidation, nitration, and glycol contamination from coolant. Fourier Transform Infrared (FTIR) permits the generation of complex curves from digitally represented data.

inhibitor - an additive that improves the performance of a petroleum product through the control of undesirable chemical reactions.

insolubles - a test for contaminants in used lubricating oils, such as test method ASTM D 893. In this method, the oil is first diluted with pentane, causing the oil to lose its solvency for certain oxidation resins, and also causing the precipitation of such extraneous materials as dirt, soot, and wear metals. These contaminants are called pentane insolubles. The pentane insolubles may then be treated with toluene, which dissolves the oxidation resins (benzene was formerly used). The remaining solids are called toluene insolubles. The difference in weight between the pentane insolubles and the toluene insolubles is called insoluble resins. Testing for grease insolubles is described in ASTM D 128.

ISO (International Organization for Standardization) - an international society for standardization.

ISO viscosity classification system - an international system, approved by ISO, for classifying industrial lubricants according to viscosity. Each ISO viscosity grade number designation corresponds to the mid-point of a viscosity range expressed in centistokes (cSt) at 40°C. For example, a lubricant with an ISO grade of 32 has a viscosity within the range of 28.8 -- 35.2 cSt, the mid-point of which is 32.

load-wear index (LWI) - measure of the relative ability of a lubricant to prevent wear under applied loads; it is calculated from data obtained from the Four Ball EP Method. Formerly called mean Hertz load.

lubricant - any usually oily liquid or solid that reduces friction, heat, or wear when applied to the surfaces of moving parts.

lubrication - the control of friction and wear by the introduction of a friction-reducing film between moving surfaces in contact. The lubricant used can be a fluid, solid, or plastic substance.

lubricity - the ability of an oil or grease to lubricate; also, called film strength. Lubricity can be enhanced by additive treatment.

Material Safety Data Sheet (MSDS) - a publication containing health and safety information on a product (including petroleum). The OSHA Hazard Communication Standard requires that manufacturers provide an MSDS to distributors or purchasers prior to or at the time of product shipment. An MSDS must include the chemical and common names of all ingredients that have been determined to be health hazards if they constitute 1% or greater of the product's composition (0.1% for carcinogens). An MSDS also includes precautionary guidelines and emergency procedures.

Metal forming fluid (MFF) – any fluid in the subclass of metalworking fluids used for the purpose of drawing, rolling, stamping or other metal shaping process.

Metal removal fluid (MRF) – any fluid in the subclass of metalworking fluids used to either cut or otherwise remove material from a part or piece of metal stock. Metal removal processes include broaching, cutting, grinding, gunning, honing, machining, sawing, and tapping.

Metalworking fluid (MWF) – any liquid product used for the purpose of metal removal, forming, or both. MWF are typically classified by the general chemical composition as soluble oils, semi-synthetic oils, straight oils or synthetic fluid MWF are used primarily to cool and lubricate.

mineral oil - any petroleum oil, as contrasted to animal or vegetable oils or synthetic fluids.

mineral seal oil - a distillation fraction between kerosene and gas oil, widely used as a solvent oil in gas adsorption processes, as a lubricant for the rolling of metal foil, and as a base oil in many specialty formulations. Mineral seal oil takes its name - not from any sealing function - but from the fact that it originally replaced oil derived from seal blubber for use as an illuminant for signal lamps and lighthouses.

miscible - capable of being mixed in any concentration without separation of phases; e.g., water and ethyl alcohol are miscible.

mold (release) lubricant - a compound, often of petroleum origin, for coating the interiors of molds for glass and ceramic products. The mold lubricant facilitates removal of the molded object from the mold, protects the surface of the mold, and reduces or eliminates the need for cleaning it.

molybdenum disulfide - a black, lustrous powder (MoS_2) that serves as a dry-film lubricant in certain high-temperature and high-vacuum applications. It is also used in the form of pastes to prevent scoring when assembling press-fit parts, and as an additive to impart residual lubrication properties to oils and greases. Molybdenum disulfide is often called moly or molysulfide.

mutagenicity – the tendency of a substance to cause genetic mutations under long-term exposure. Defined by modified Ames test or long-term dermal bioassay.

neutralization number – a number used as a measure of the acidic or basic constituents. This term is ambiguous and now obsolete. (See acid/base number, TAN/TBN.)

Newtonian fluid - any fluid, such as a straight mineral oil, whose viscosity does not change with rate of flow.

NLGI (National Lubricating Grease Institute) - trade association whose main interest is grease and grease technology. NLGI is best known for its system of rating greases by penetration.

NLGI Automotive Grease Classifications - automotive lubricating grease quality levels established jointly by SAE, ASTM, and NLGI. There are several categories in two classifications: Chassis Lubricants and Wheel Bearing Lubricants. Quality or per-formance levels within each category are defined by ASTM tests.

NLGI consistency grades - simplified system established by the National Lubricating Grease Institute (NLGI) for rating the consistency of grease.

non-Newtonian fluid - fluid, such as a grease or a polymer-containing oil (e.g., multi-grade oil), in which shear stress is not proportional to shear rate.

normal paraffin - a hydrocarbon consisting of molecules in which any carbon atom is attached to no more than two other carbon atoms; also called straight chain paraffin and linear paraffin.

oiler - a device for once-through lubrication. Three common types of oilers are: drop-feed, wick-feed, and bottle-feed; all depend on gravity to induce a metered flow of oil to the bearing. The drop-feed oiler delivers oil from the bottom of a reservoir to a bearing one drop at a time; flow rate is controlled by a needle valve at the top of the reservoir. In a wick-feed oiler, the oil flows through a wick and drips from the end of the wick into the bearing; feed is regulated by chaining the number of strands, by raising or lowering the oil level, or by applying pressure to the wick. In a bottle-feed oiler, a vacuum at the top of the jar keeps the fluid from running out; as tiny bubbles of air enter, the vacuum is reduced and a small amount of oil enters the bearing or is added to a reservoir from which the bearing is lubricated.

open gear - a gear that is exposed to the environment, rather than being housed in a protective gearbox. Open gears are generally large, heavily loaded, and slow moving. They are found in such applications as mining and construction machinery, punch presses, plastic and rubber mills, tube mills, and rotary kilns. Open gears require viscous, adhesive lubricants that bond to the metal surfaces and resist run-off. Such lubricants are often called gear shields. Top-quality lubricants for such applications are specially formulated to protect the gears against the effects of water and other contaminants.

OSHA – United States Occupational Safety and Health Administration.

oxidation - the chemical combination of a substance with oxygen. All petroleum products are subject to oxidation, with resultant degradation of their composition

and performance. The process is accelerated by heat, light metal catalysts (e.g., copper) and the presence of water, acids, or solid contaminants. The first reaction products of oxidation are organic peroxides. Continued oxidation catalyzed by peroxides, forms alcohols, aldehydes, ketones, and organic acids, which can be further oxidized to form high-molecular-weight, oil-insoluble polymers; these settle out as sludges, varnishes, and gums that can impair equipment operation. The organic acids formed from oxidation are corrosive to (i.e., cause oxidation of) metals. Oxidation resistance of a product can be improved by careful selection of base stocks (paraffins have greater oxidation resistance than naphthenes), special refining methods, and addition of oxidation inhibitors. Also, oxidation can be minimized by good maintenance of oil and equipment to prevent contamination and excessive heat.

oxidation inhibitor - a substance added in small quantities to a petroleum or other product to increase its oxidation resistance, thereby lengthening its service or storage life; also called antioxidant. An oxidation inhibitor may work in one of three ways: (1) by combining with an modifying peroxides (initial oxidation products) to render them harmless, (2) by decomposing the peroxides, or (3) by rendering an oxidation catalyst (metal or metal ions) inert.

oxidation stability - the resistance of a petroleum product to oxidation; hence, a measure of its potential service or storage life. There are a number of ASTM tests to determine the oxidation stability of a lubricant or fuel, all of which are intended to simulate service conditions on an accelerated basis. In general, the test sample is exposed to oxygen or air at an elevated temperature, and sometimes to water or catalysts (usually iron or copper). Depending on the test, results are expressed in terms of the time required to produce a specified effect (such as a pressure drop), the amount of sludge or gum produced, or the amount of oxygen consumed during a specified period.

paraffin - any hydrocarbon identified by saturated straight (normal) or branched (iso) carbon chains; also called an alkane. The generalized paraffinic molecule can be symbolized by the formula CnH2n+2. Paraffins are relatively non-reactive and have excellent oxidation stability. In contrast to naphthenic oils, paraffinic lubricating oils have relatively high wax content and pour point, and generally have a high viscosity index (VI.). Paraffinic solvents are generally lower in solvency than naphthenic or aromatic solvents.

particulates - particles made up of a wide range of natural materials (e.g., pollen, dust, resins), combined with man-made pollutant (e.g., smoke particles, metallic ash); in sufficient concentrations, particulates can be a respiratory irritant.

PCB - polychlorinated biphenyl, a class of synthetic chemicals consisting of an homologous series of compounds beginning with monochlorobiphenyl and ending with decachlorobiphenyl. PCBs do not occur naturally in petroleum, but have been found as contaminants in used oil. PCBs have been legally designated as a health hazard, and any oil so contaminated must be handled in strict accordance with state and federal regulations.

pH - a measure of the acidity or alkalinity of an aqueous solution. The pH scale ranges from 0 (very acidic) to 14 (very alkaline), with a pH of 7 indicating a neutral solution equivalent to the pH of distilled water. It is a good indicator of the condition of a metal removal fluid mix. Each MRF product has a pH range within which it is designed to operate. Most metalworking fluids operate in a pH range of 8.8 - 9.2. If the mix pH is too low, various aspects of your metalworking fluid mix are affected, such as rancidity control, ferrous corrosion control, and mix stability. If the mix's pH is too high, various other aspects of your metalworking fluid mix are affected, such as mildness and nonferrous corrosion control.

phenol - a white, crystalline compound (C_6H_5OH) derived from benzene, used in the manufacture of phenolic resins, weed killers, plastics, disinfectants; also used in solvent extraction, a petroleum refining process. Phenol is a toxic material; skin contact must be avoided.

phosphate ester - any of a group of synthetic lubricants having superior fire resistance. A phosphate ester generally has poor hydrolytic stability, poor compatibility with mineral oil, and a relatively low viscosity index (VI). It is used as a fire-resistant hydraulic fluid in high-temperature applications.

PNA (polynuclear aromatic) - any of numerous complex hydrocarbon compounds consisting of three or more benzene rings in a compact molecular arrangement. Some types of PNA's are formed in fossil fuel combustion and other heat processes, such as catalytic cracking.

polar compound - a chemical compound whose molecules exhibit electrically positive characteristics at one end and negative characteristics at the other end. Polar compounds are used as additives in many petroleum products. Polarity gives certain molecules a strong affinity for solid surfaces; as lubricant additives, such molecules plate out to form a tenacious friction-reducing film. Some polar molecules are oil-soluble at one end and water soluble at the other end; in lubricants, they act as emulsifiers, helping to form stable-oil water emulsions. Such lubricants are said to have good metal-wetting properties. Polar compounds with a strong attraction for solid contaminants act as detergents.

polyglycols - polymers of ethylene or propylene oxides used as a synthetic lubricant base. Properties include very good hydrolytic stability, high viscosity index (VI), and low volatility. Used particularly in water emulsion fluids.

polymer - a substance formed by the linkage (polymerization) of two or more simple, molecules, called monomers, to form a single larger molecule having the same elements in the same proportions as the original monomers; i.e. each monomer retains its structural identify. A polymer may be liquid or solid; solid polymers may consist of millions of repeated linked units. A polymer made from two or more dissimilar monomers is called a copolymer; a copolymer composed of three different types of monomers is a terpolymer. Natural rubber and synthetic rubbers are examples of polymers. Polymers are commonly used as viscosity index improvers in multi-grade oils and tackifiers in lubricating greases.

polyolefin - a polymer derived by polymerization of relatively simple olefins. Polyethylene and polyisoprene are important polyolefins.

polyol ester - a synthetic lubricant base, formed by reacting fatty acids with a polyol (such as a glycol) derived from petroleum. Properties include good oxidation stability at high temperatures and low volatility. Used in formulating lubricants for turbines, compressors, jet engines, and automotive engines.

ppb - parts per billion.

ppm - parts per million.

process oil - an oil that serves as a temporary or permanent component of a manufactured product. Aromatic process oils have good solvency characteristics; their applications include proprietary chemical formulations, ink oils, and extenders in synthetic rubbers. Naphthenic process oils are characterized by low pour points and good solvency properties. Paraffinic process oils are characterized by low aromatic content and light color.

pump - a mechanism through which force is applied to a liquid. There are two basic categories of pumps: positive displacement and centrifugal. Positive displacement pumps force liquid to flow in volumetric proportion to decreasing pump volume. Hydraulic systems are a primary application, wherein the hydraulic fluid functions as the lubricant. Positive displacement pumps can be divided into reciprocating and rotary. Reciprocating pumps use pistons, plungers, or diaphragms to increase and decrease volume. Rotary pumps use a rotating device (gear, screw, or vane) to force liquid from the pump. Centrifugal pumps, also called kinetic pumps, differ from positive displacement pumps in that they provide uniform (non-pulsing) flow and adjustable flow velocity. Movement is imparted to the liquid through centrifugal force created by a rotating impeller. There are two basic types of centrifugal pumps: radial flow and axial flow.

In the former type, liquid enters the pump at the impeller's axis of rotation and is forced outward by vanes. In the latter type, a propeller or screw on a rotating shaft moves liquid in the axial direction of the shaft.

quenching oil - (also called heat treating oil) a high quality, oxidation-resistant petroleum oil used to cool metal parts during their manufacture, and is often preferred to water because the oil's slower heat transfer lessens the possibility of cracking or warping of the metal. Quenching oil must have excellent oxidation and thermal stability, and should yield clean parts, essentially free of residue. In refining terms, quenching oil is oil introduced into high temperature vapors of cracked (see cracking) petroleum fractions to cool them.

R&O - rust-and-oxidation inhibited. A term applied to highly refined industrial lubricating oils formulated for long service in circulating lubrication systems, compressors, hydraulic systems, bearing housing, gear boxes, etc. The finest R&O oils are often referred to as turbine oils.

refining - a series of processes for converting crude oil and its fractions to finished petroleum products. Following distillation, a petroleum fraction may undergo one or more additional steps to purify or modify it. These refining steps include: thermal cracking, catalytic cracking, polymerization, alkylation, reforming, hydrocracking, hydroforming, hydrogenation, hydrogen treating, hydrofining, solvent extraction, dewaxing, deoiling, acid treating, clay filtration, and deasphalting. Refined lubricating oils may be blended with other lube stocks, and additives may be incorporated, to impart special properties.

re-refining – a series of processes used to convert used oil into high quality base-stock. (See L7 for a more complete discussion of the various oil recycling processes.)

rheology - the study of the deformation and flow of matter in terms of stress, strain, temperature, and time. The rheological properties of grease are commonly measured by penetration and apparent viscosity.

rolling oil - an oil used in hot- or cold-rolling of ferrous and non-ferrous metals to facilitate feed of the metal between the work rolls, improve the plastic deformation of the metal, conduct heat from the metal, and extend the life of the work rolls. Because of the pressures involved, a rolling oil may be compounded or contain EP additives. In hot rolling, the oil may also be emulsifiable.

rust inhibitor - a type of corrosion inhibitor used in lubricants to protect surfaces against rusting.

rust preventive - a compound for coating metal surfaces with a film that protects against rust; commonly used for the preservation of equipment in storage. The base material of a rust preventive may be a petroleum oil, solvent, wax, or asphalt, to which a rust inhibitor is added. A formulation consisting largely of a solvent and additives is commonly called a thin-film rust preventive because of the thin coating that remains after evaporation of the solvent. Rust preventives are formulated for a variety of conditions of exposure, e.g., short time "in-process" protection, indoor storage, exposed outdoor storage, etc.

SAE (Society of Automotive Engineers) - technical society concerned with engineering related to transportation.

saponification number - the number of milligrams of potassium hydroxide (KOH) that combine with one gram of oil under conditions specified by test method ASTM D 94. Saponification number is an indication of the amount of fatty saponifiable material in a compounded oil. Caution must be used in interpreting test results if certain substances -- such as sulfur compounds or halogens -- are present in the oil, since these also react with KOH, thereby increasing the apparent saponification number.

Saybolt Universal viscosity - the efflux time in Saybolt Universal Seconds (SUS) required for 60 milliliters of a petroleum product to flow through the calibrated orifice of a Saybolt Universal viscometer, under carefully controlled temperature, as prescribed by test method ASTM D 88. In the petroleum industry, this method has

largely been replaced by the kinematic viscosity method ASTM D 455.

saponification – the alkaline hydrolysis of fats to form a soap; more generally, the hydrolysis of an ester by an alkali with the formation of an alcohol and a salt of the acid portion. *In situ* saponification is the traditional method of making soap-type grease thickeners.

scoring - distress marks on sliding metallic surfaces in the form of long, distinct scratches in the direction of motion. Scoring is an advanced stage of scuffing.

scuffing - localized distress marks on sliding metallic surfaces, appearing as a matte-finished area rather than as individual score marks.

seal swell (rubber swell) - the swelling of rubber (or other elastomer) gaskets, or seals, when exposed to petroleum, synthetic lubricants, or hydraulic fluids. Seal materials vary widely in their resistance to the effect of such fluids. Some seals are designed so that a moderate amount of swelling improves sealing action.

semi-synthetic – a metal removal fluid typically composed of a translucent micro-emulsion of water, chemicals and a small percentage of oil.

shear rate - the rate at which adjacent layers of a fluid move with respect to each other, usually expressed as reciprocal seconds (also see shear stress). When the fluid is placed between two parallel surfaces moving relative to each other:

shear rate $(\text{seconds})^{-1} = \frac{\text{relative velocity of surface (meters/second)}}{\text{distance between surfaces (meters)}}$

shear stress - the frictional force overcome in sliding one "layer" of fluid along another, as in any fluid flow. The shear stress of a petroleum oil or other Newtonian fluid at a given temperature varies directly with shear rate (velocity). The ratio between shear stress and shear rate is constant; this ratio is termed viscosity. The higher the viscosity of a Newtonian fluid, the greater the shear stress as a function of rate of shear. In a non-Newtonian fluid -- such as grease or a polymer-containing oil (e.g., multi-grade oil) -- shear stress is not proportional to the rate of shear. A non-Newtonian fluid may be said to have an apparent viscosity, a viscosity that holds only for the shear rate (and temperature) at which the viscosity is determined.

SI – from the French name, *Système International d'Unités*, the international system of units developed and maintained by the General Conference on Weights and Measures. This is the modern metric system based on the fundamental units of meters, kilograms, and seconds (MKS). The fundamental units of the older (cgs) metric system are centimeters, grams and seconds. (See ASTM E 380.)

soluble oil – a metal removal fluid typically composed of a stable milky emulsion of water, oil, emulsifiers and other functional additives. Commonly used where cooling is of primary importance.

solvent - a material with a strong capability to dissolve a given substance. The most common petroleum solvents are mineral spirits, xylene, toluene, hexane, heptane, and naphthas. Aromatic-type solvents have the highest solvency for organic chemical materials, followed by naphthenes and paraffins. In most applications, the solvent disappears, usually by evaporation, after it has served its purpose. The evaporation rate of a solvent is very important in manufacture.

solvent extraction - a refining process used to separate components (unsaturated hydrocarbons) from lube distillates in order to improve the oil's oxidation stability, viscosity index, and response to additives. The oil and the solvent extraction media are mixed in an extraction tower, resulting in the formation of two phases: a heavy phase consisting of the undesirable unsaturates dissolved in the solvent. and a lighter phase consisting of a high quality oil with some solvent dissolved in it. The phases are separated and the solvent recovered from each by distillation.

spectrographic analysis (elemental analysis) - a technique for detecting and quantifying metallic elements resulting from

wear, contamination, or additives. The oil sample is energized to make each element emit or absorb a quantifiable amount of energy, which indicates the element's concentration in the oil.

spindle oil - a low-viscosity oil of high quality for the lubrication of high-speed textile and metalworking (grinding) machine spindles. In addition to the rust and oxidation inhibitors needed for prolonged service in humid environments, spindle oils are often fortified with antiwear additives to reduce torque load and wear, especially at start-up.

statistical process control (SPC) - the use of control charts to track and eliminate variables in repetitive manufacturing processes, in order to ensure that the product is of consistent and predictable quality. If a chart reveals only chance variations that are inherent in the system, the process is said to be in a state of "statistical control". If the chart reveals variations traceable to changes in equipment, procedures or workers, the process is said to be "out of control". Statistical process control differs from statistical quality control in that the former monitors manufacturing process parameters and the latter monitors product quality parameters.

stick-slip motion - erratic, noisy motion characteristic of some machine ways, due to the starting friction encountered by a machine part at each end of its back-and-forth (reciprocating) movement. This undesirable effect can be overcome with a way lubricant, which reduces starting friction.

STLE (Society of Tribologists and Lubrication Engineers) - a technical organization intended to advance the knowledge and application of lubrication and related sciences. Formerly known as the American Society of Lubrication Engineers (ASLE).

straight mineral oil - petroleum oil containing no additives. Straight mineral oils include such diverse products as low-cost once-through lubricants and thoroughly refined white oils. Most high-quality lubricants, however, contain additives.

straight oil – a metal removal fluid typically composed of mineral or vegetable oil or esters and functional additives. Commonly used where lubricity is of primary importance.

sulfonate - a hydrocarbon in which a hydrogen atom has been replaced with the highly polar (SO_2OX) group, where X is a metallic ion or alkyl radical. Petroleum sulfonates are refinery by-products of the sulfuric acid treatment of white oils. Sulfonates have important applications as emulsifiers and chemical intermediates in petrochemical manufacture, and substituted sulfonates are widely used as corrosion inhibitors. Synthetic sulfonates can be manufactured from special feedstocks rather than from white oil base stocks.

sulfur - a common natural constituent of petroleum and petroleum products. While certain sulfur compounds are commonly used to improve the EP, or load-carrying, properties of an oil, high sulfur content in a petroleum product may be undesirable as it can be corrosive and create an environmental hazard when burned. For these reasons, sulfur limitations are specified in the quality control of fuels, solvents, etc.

synthetic fluid – a metal removal fluid composed of a transparent solution of chemical lubricants (typically glycols or esters) in water with functional additives.

synthetic lubricant - a lubricating fluid made by chemically reacting materials of a specific chemical composition to produce a compound with planned and predictable properties; the resulting base stock may be supplemented with additives to improve specific properties. Many synthetic lubricants -- also called synlubes -- are derived wholly or primarily from petrochemicals; other synlube raw materials are derived from coal and oil shale, or are lipochemicals (from animal and vegetable oils). Synthetic lubricants may be superior to petroleum oils in specific performance areas. Many exhibit higher viscosity index (VI), better thermal stability and oxidation stability, and low volatility (which reduces oil consumption). Most synlubes offer longer service life and, in some cases, better biodegradability than conventional lubricants. Consequently, they are increasingly being used in industrial and

automotive applications. Individual synthetic lubricants offer specific outstanding properties: phosphate esters, for example, are fire resistant, diesters have good oxidation stability and lubricity, and silicones offer exceptionally high VI. Polyalphaolefins are versatile lubricants with low pour points, and excellent thermal and oxidation stability; they have good compatibility with petroleum lubricants and most seals used with petroleum lubricants. Most synthetic lubricants can be converted to grease by adding thickeners. Because synthetic lubricants are higher in cost than petroleum oils, they are used selectively where performance or safety requirements may exceed the capabilities of a conventional oil.

tackifier (tackiness additive or **agent) –** a high molecular weight, fluid polymer added to greases to improve adhesiveness.

TAN - (total) acid number.

TBN - (total) base number.

thermal stability - the ability to resist chemical degradation at high temperatures.

thixotropy - the tendency of grease or other material to soften or flow when subjected to shearing action. Grease will usually return to its normal consistency when the action stops. Thixotropy is also an important characteristic of drilling fluids, which must thicken when not in motion so that the cuttings in the fluid will remain in suspension.

total alkalinity - is a measure of the alkaline materials, both inorganic and organic, in the metalworking fluid mix. Significantly higher than normal total alkalinity can promote a more irritating mix, promote corrosion of nonferrous metals, and other problems. Alkalinity tends to increase with the age of the system.

total oil - is the percentage of oil or oil-like material present in your metalworking fluid mix. This value includes both product oil and tramp oil.

tramp oil - is the percentage of oil or oil-like material which is not product oil. Product oil is that oil which comes from metalworking fluid concentrate. The calculation of the Tramp Oil level is presented in the following equation.

Total Oil % in the Mix -
[(Mix Concentration %) x (Product Oil)]
= Tramp Oil %

EXAMPLE: For each 1% of a mix, 0.46% oil and oil-like material are present according to the Acid Split Determination Method. A field sample had 3.5% Total Oil and a mix concentration determined by the MI Titration of 4.1%.

3.5% TOTAL OIL - ((4.1%/1.0%) * 0.46%)
=
3.5% - 1.9% = 1.6% TRAMP OIL

A high Tramp Oil percentage can promote problems, such as residue, poor grinding and machining performance, and microbial growth. Significant negative tramp oil values, such as less than -0.5%, can indicate either mix instability or contamination by a material that is picked up on the concentration determination method. Significant performance problems can be expected when tramp oil levels reach half the metalworking fluid concentration.

tribology - the science of the interactions between surfaces moving relative to each other. Such interactions usually involve the interplay of two primary factors: the load, or force, perpendicular to the surfaces, and the frictional force that impedes movement. Tribological research on friction reduction has important energy conservation applications, since friction increases energy consumption.

turbine oil - a top-quality rust- and oxidation-inhibited (R&O) oil that meets the rigid requirements traditionally imposed on steam-turbine lubrication. Quality turbine oils are also distinguished by good demulsibility, a requisite of effective oil-water separation. Turbine oils are widely used in other exacting applications for which long service life and dependable lubrication are mandatory. Such applications include circulating systems, compressors, hydraulic systems, gear drives, and other equipment. Turbine oils can also be used as heat transfer fluids in open systems, where oxidation stability is of primary importance.

varnish - a hard coating formed from oil oxidation products, that bakes on to surfaces during high-temperature operation of automotive engines and industrial machinery. Varnish can accelerate cylinder wear. Varnish formation can be reduced with the use of a detergent-dispersant and an oxidation inhibitor in the oil.

viscosity - a fluid's resistance to flow. The common metric unit of absolute viscosity is the poise, which is defined as the force in dynes required to move a surface one square centimeter in area past a parallel surface at a speed of one centimeter per second with the surfaces separated by a fluid film one centimeter thick. For convenience, the centipoise (cP) - one one-hundredth of a poise -- is the unit customarily used in the petroleum industry. Laboratory measurements of viscosity normally use the force of gravity to produce flow through a capillary tube (viscometer) at a controlled temperature. This measurement is called kinematic viscosity. The unit of kinematic viscosity is the stoke, expressed in square centimeters per second. The more customary unit is the centistoke (cSt) - one one-hundredth of a stoke. Kinematic viscosity can be related to absolute viscosity by the equation:

cSt = cP ÷ fluid density

In addition to kinematic viscosity, there are other methods for determining viscosity, including Saybolt Universal viscosity, Saybolt Furol viscosity, Engler viscosity, and Redwood viscosity. See Appendix C for a comparison of different viscosity classification systems. Since viscosity varies inversely with temperature, its value is meaningless unless the temperature at which it is determined is reported.

viscosity index (VI) - an empirical, unitless number indicating the effect of temperature on the kinematic viscosity of an oil. Liquids change viscosity with temperature, becoming less viscous when heated; the higher the VI of an oil, the lower its change in viscosity with temperature. The VI of an oil -- with known viscosity at 40°C -- is determined by comparing the oil with two standard oils having an arbitrary VI of 0 and 100, respectively, and both having the same viscosity at 100°C as the test oil. The following formula is used, in accordance with test method ASTM D 2270:

$$VI = \frac{L - U}{L - H} x100$$

where L is the viscosity at 40°C of the 0-VI oil, H is the viscosity at 40°C of the 100-VI oil, and U is the viscosity at 40°C of the test oil. There is an alternative calculation, also in ASTM D 2270, for oils with VI's above 100. The VI. of paraffinic oils is inherently high, but is low in naphthenic oils, and even lower in aromatic oils (often below 0). The VI of any petroleum oil can be increased by adding a viscosity index improver. High-VI lubricants are needed wherever relatively constant viscosity is required at widely varying temperatures.

viscosity-temperature relationship - the manner in which the viscosity of a given fluid varies inversely with temperature. Because of the mathematical relationship that exists between these two variables, it is possible to predict graphically the viscosity of a petroleum fluid at any temperature within a limited range if the viscosities at two other temperatures are known. The charts used for this purpose are the ASTM Standard Viscosity-Temperature Charts for Liquid Petroleum Products, available in 6 ranges. If two known viscosity-temperature points of a fluid are located on the chart and a straight line drawn through them, other viscosity-temperature values of the fluid will fall on this line; however, values near or below the cloud point of the oil may deviate from the straight-line relationship.

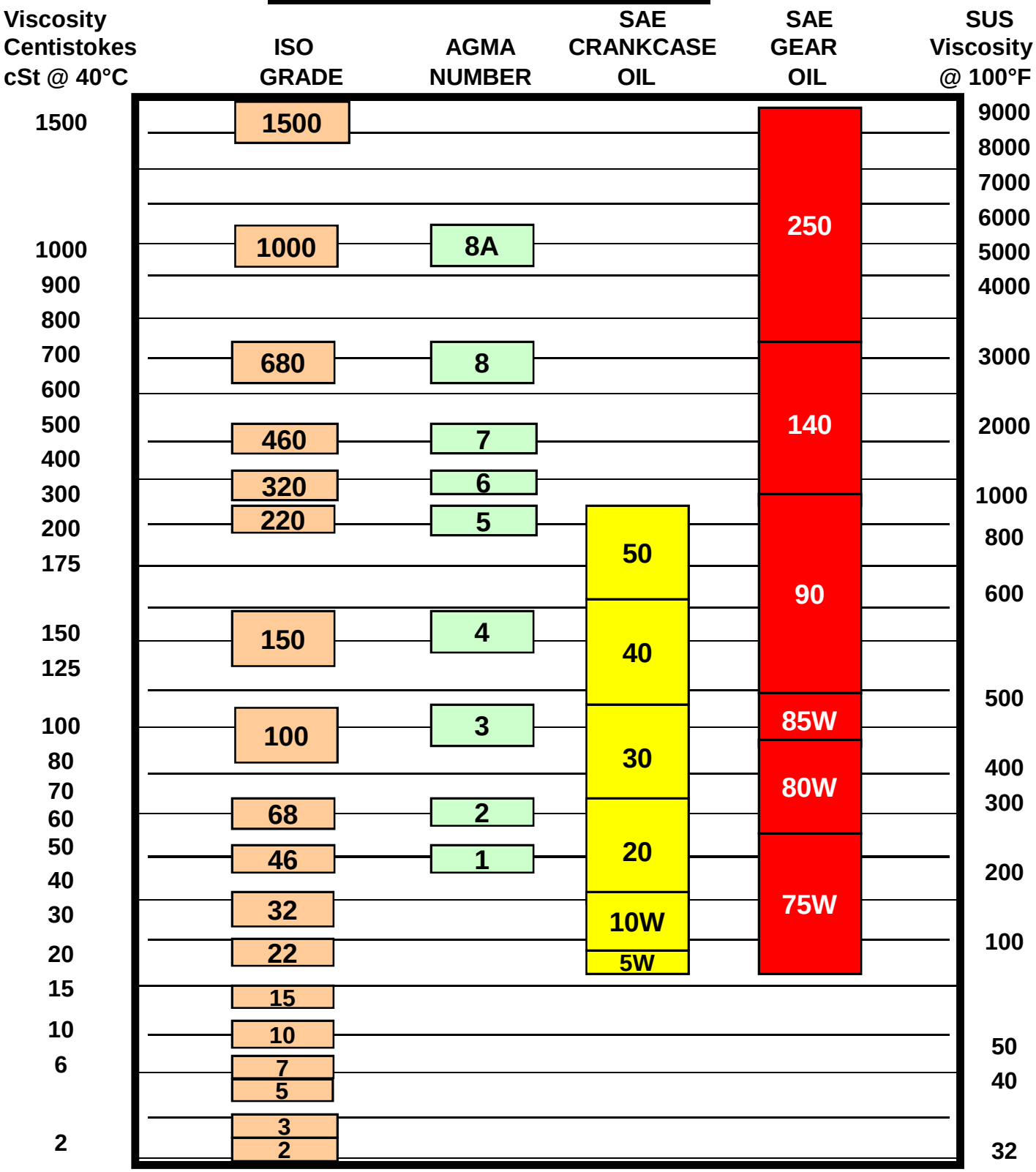
way - longitudinal surface that guides the reciprocal movement of a machine part.

way lubricant - lubricant for the sliding ways of machine tools such as planers, grinders, horizontal boring machines, shapers, jig borers, and milling machines. A good way lubricant is formulated with special frictional characteristics designed to overcome the stick-slip motion associated with slow moving machine parts.

weld point - the lowest applied load in kilograms at which the rotating ball in the Four Ball EP test either seizes and welds to the three stationary balls, or at which extreme scoring of the three balls results.

ZDTP or ZDP (zinc dialkyl or diaryl dithiophosphate) - widely used as an anti-wear-additive in engine oils to protect heavily loaded parts, particularly the valve train mechanisms (such as the camshaft and cam followers) from excessive wear. It is also used as an anti-wear agent in hydraulic fluids and certain other products. ZDTP is also an effective oxidation inhibitor. Oils containing ZDTP should not be used in machines that employ silver alloy bearings.

Viscosity Equivalent Chart



Viscosities can be related horizontally only. SAE 75W, 80W, 85W and 5W and10W are specified at low temperatures. SAE 90 to 250 and 20 to 50 are specified at 100°C.

APPENDIX D -- COMPARISON OF ISO, DIN SAE AND GM LUBRICANT SPECIFICATIONS

GM Standard	ISO L-	DIN	SAE, MS	Description	Symbol
LA-	P	D	1009 (PAB, PBC)	Air-Cylinder/Valve/Tool Oils	☐
LB-	AB, AW	AN	1001 (AN)	General Purpose, Press Oil	☐
LC-	FC?	-----	-----	Submrgd. Clutch & Brake Oil	
LD-	-----	-----	-----	Chain/Conveyor Lubricants	
LE-	-----	-----	-----	Environmentally Acceptable	
LF-04-1	HFDR	HFDR	1005 (HFDR)	FR Phosphate Ester Hydraulic	⊟
LF-04-2	HFC	HFC	1005 (HFC)	FR Water/Polymer (Glycol)	⊟
LF-10-3	HFB	HFB	1005 (HFB)	FR Water-In-Oil Hydraulic	⊟
LF-XX-4	HFDU	HFDU	1005 (HFDU)	FR Polyol Ester Hydraulic	⊟
LF-00-5	HFAS	HFAS	1005 (HFAS)	FR High-Water Based Hydraulic Oil	⊟
LG-	X	K, G, OG, M	1011 (X)	Greases	Δ or ◊
LH-	HM	H	1004 (HR)	Antiwear Hydraulic Oil	☐
LJ-XX-1	T D	V	1010 (TSA) 1003 (DAA, DAB)	Compressor/Turbine Oils	☐
LJ-XX-2 LJ-XX-3	T D	V	1010 (TSC) 1003 (DAA, DAB)	Synthetic Compressor/Turbine Oils	☐
LM	-----	-----	-----	Misting Oil	
LR-XX-1	CKC/D	CLP	1002 (CKC)	Gear Oil with EP	☐
LR-XX-2	CKE	CLP, Z?	1002 (CKE)	Worm Gear Oil	☐
LR-XX-3	CKC/D	CLP HC	1002 (CKS)	Synthetic Gear Oil with EP	☐
LS-	FD	B?	1006 (FD)	Spindle Oil	☐
LW-	G	CG	1007 (G)	Slideway Lubricants	☐
LX-	MHA -F	-----	1008 (MH-)	Straight Metal Removal Fluids	
LY-	MAA -F	-----	1008 (MA-)	Aqueous Metal Removal Flds.	

ISO = International Standards Organization FR = Fire Resistant
DIN = Deutsches Institut fur Normung
SAE = Society of Automotive Engineers

GM LS2 LUBRICANT

SUBMISSION WORKSHEETS

GM LUBRICANT SUBMISSION WORKSHEET LA-FORM 1

The following information will be required for an on-line submission of a lubricant for LS2 approval. On-line submissions can be made at: https://gmr2.ttsvcs.com/gmr2portal/Default.aspx

Product Name/No. _____

Product Type: Air Cylinder and Valve Oil/ Air Tool Oil

GM Lubricant Standard No. LA-0 -1-04 ISO Viscosity Grade _____

The product above must meet the requirements of the standard shown, the tests must be run in qualified laboratories and the results shown must be on a product identical (within normal blending tolerances) in base fluid, additives and performance to the product offered for approval, unless any exceptions are specifically described in writing on the on-line submission . **NOTE: NO CHANGES CAN BE MADE TO A PRODUCT APPROVED WITHOUT REQUESTING REAPPROVAL.**

The lubricant contains the following base fluids (for non mineral oil fluids, skip source, method, %S)

Percent (vol)	Supplier	Method of Refining	% S	Viscosity at 40 ^{o}C cSt
		Base Fluid Blend		

(e.g. Supplier = Exxon, Source = Mid-east, Method = Hydrotreating)

The lubricant contains the following additives.

Percent	Name of Additive	Source	Generic Description

(e.g. Percent - indicate mass or volume, Name = PD-007, Source = Acme Additive Company Generic Description = antiwear/antioxidant)

You will also need to include the following information:

1. Test Reports for those tests as indicated on the on-line submission (marked by an asterisk on Forms 2 and 3).
2. Completed and signed Material Safety Data Sheets (see LS2 - Appendix F for directions).
3. ISO or QS 9000 certificate.

_____ _____

(E-mail Address) (Name)

GM LUBRICANT SUBMISSION WORKSHEET LA-FORM 2

SUMMARY OF TEST RESULTS

Product Name/ No. _____

Product Type: Air Cylinder and Valve Oil/ Air Tool Oil

GM Lubricant Standard No. LA-0 -1-04 ISO Viscosity Grade _____

(NOTE: For Tests in red marked with *, must attach test report to on-line submission)

Test Procedure:	Specification	Result	Lab
1. Viscosity at 40 /100° C (ASTM D 445)	_____ to _____ cSt		
2. Viscosity Index (ASTM D 2270)	90 minimum		
3. Pour Point (ASTM D 97)	_____ °C maximum		
4. Cu Corrosion (ASTM D 130)	1b maximum		
5*. Thermal Stability - 72 hrs. at 101° C (ASTM D 2070)			
Neutralization Number Change	0.15 maximum		
Viscosity Change at 40/100° C	5% maximum		
Sludge	25 mg/100 ml max		
Copper Rod Color (Cin. Mil.)	5 maximum		
Copper Weight Loss	10 mg maximum		
Steel Rod Color (Cin. Mil.)	No Discoloration		
6* Oxidation Stability TAN = 2 (ASTM D 943)	1000 hr. minimum		
7. Rust Test (ASTM D 665B)	Pass (No rust)		
8*. Demulsibility - 55° C (ASTM D 1401)	40/37/3 (30 min.) max		
9. Foam Tendency - 190 ml fluid (ASTM D 892)	10 min settling		
Sequence I	50/0 maximum		
Sequence II	50/0 maximum		
Sequence III	50/0 maximum		
10. Cleanliness as Rcvd (ISO 4406, ISO 11171)	20/16/13 max		
11. Four Ball Wear - 20 kg load (ASTM D 4172)			
Wear Scar Diameter	Report		
12. API Gravity at 60 ° F (ASTM D 287)	Report		
13. Flash Point (ASTM D 92)	_____ ° C min.		
14. Precipitation No. (ASTM D 91)	0.05 maximum		
15. Conradson Carbon Residue (ASTM D 189)	0.05 % maximum		
16.* Compatibility with Seals (ISO 1817)			
SRE-NBR Volume Change, %	-10 to 10%		
Shore A Hardness Change	-7 to 10		
Other Volume Change, %	Report		
seals Shore A Hardness Change	Report		
17. Water, ppm (ASTM D 6304)	200 maximum		
18. Metals, mass % by (list method) _____	Zn		
	P		
	Ca		
	Mg		
	Ba		
	S		
	Others		

GM LUBRICANT SUBMISSION WORKSHEET LA-FORM 3

SUMMARY OF TEST RESULTS, CONT.

Product Name/ No. _____

Product Type Air Cylinder and Valve Oil/ Air Tool Oil

GM Lubricant Standard N. LA-0 -1-04 ISO Viscosity Grade _____

Base Stock Requirements	Specification	Result	Lab
19.* Tot. PNA's ppm (EPA SW-846, TN 8270)	100 maximum		
20. Residual Elements (ASTM D 5185)			
(As, B, Ca, Mn, Na, Cu, Fe, Ni, Si, Sn			
Cd, Cr, Pb, Ba, Zn), ppm	25 maximum total		
	2 maximum each		
Phosphorous	5 maximum		
21. Total PCB's (EPA SW-846, TN 8092)	not detectable		
22. Total Organic Halogens, ppm			
(EPA SW-846, TN 8120)			
	5 maximum		
23.* Modified Ames Test (ASTM E1687)			
Fold Increase	Report		
Mutagenicity Index	1 maximum		
Mutagenicity Potency Index	Report		

Be prepared to describe differences (if any) between formulation(s) tested and the formulation for which approval is sought _____

Any other comments or data pertinent to the review of the product:

GM LUBRICANT SUBMISSION WORKSHEET LB-FORM 1

The following information will be required for an on-line submission of a lubricant for LS2 approval. On-line submissions can be made at: https://gmr2.ttsvcs.com/gmr2portal/Default.aspx

Product Name/No. _____

Product Type: General Purpose Oil / Heavy Press and Machine Oil

GM Lubricant Standard No. LB- _____ ISO Viscosity Grade _____

The product above must meet the requirements of the standard shown, the tests must be run in qualified laboratories and the results shown must be on a product identical (within normal blending tolerances) in base fluid, additives and performance to the product offered for approval, unless any exceptions are specifically described in writing on the on-line submission . **NOTE: NO CHANGES CAN BE MADE TO A PRODUCT APPROVED WITHOUT REQUESTING REAPPROVAL.**

The lubricant contains the following base fluids (for non mineral oil fluids, skip source, method, %S)

Percent (vol)	Supplier	Method of Refining	% S	Viscosity at 40 °C, cSt
		Base Fluid Blend		

(e.g. Supplier = Exxon, Source = Mid-east, Method = Hydrotreating)

The lubricant contains the following additives.

Percent	Name of Additive	Source	Generic Description

(e.g. Percent - indicate mass or volume, Name = PD-007, Source = Acme Additive Company
Generic Description = antiwear/antioxidant)

You will also need to include the following information:

1. Test Reports for those tests as indicated on the on-line submission (marked by an asterisk on Forms 2 and 3).
2. Completed and signed Material Safety Data Sheets (see LS2 - Appendix F for directions).
3. ISO or QS 9000 certificate.

_____ (E-mail Address)

_____ (Name)

GM LUBRICANT SUBMISSION WORKSHEET LB-FORM 2

SUMMARY OF TEST RESULTS

Product Name/ No. _____

Product Type General Purpose Oil / Heavy Press and Machine Oil

GM Lubricant Standard No. LB- _____ ISO Viscosity Grade _____

(NOTE: For Tests in red marked with *, must attach test report to on-line submission)

Test Procedure:	Specification	Result	Lab
1. Viscosity at 40° C/ 100° C (ASTM D 445)	_____ to _____ cSt	_____	
2. Viscosity Index (ASTM D 2270)	90 minimum	_____	
3. Pour Point (ASTM D 97)	-10° C max.	_____	
4. Cu Corrosion (ASTM D 130)	1b maximum	_____	_____
5*. Thermal Stability - 72h at 101° C (ASTM D 2070)			_____
Neutralization Number Change	0.15 maximum	_____	
Viscosity Change at 40/100 ° C	5% maximum	_____	
Sludge	25 mg/100 ml max.	_____	
Copper Rod Color (Cin. Mil)	5 maximum	_____	
Copper Weight Loss	10 mg max.	_____	
Steel Rod Color (Cin. Mil.)	No Discoloration	_____	
6*. Oxidation Stability			
for LB-04-1, TAN = 2, (ASTM D 943)	1000 hr minimum	_____	_____
for LB-22-1 (ASTM D 2893) Vis Incr.	6.0% maximum	_____	_____
Photos of Glassware After Test	Report	_____	
7. Rust Test (ASTM D 665B)	Pass (No Rust)	_____	_____
8*. Demulsibility			
for LB-04-1 (ASTM D1401)	40/40/0 30 minutes max		_____
for LB-22-1 (ASTM D 2711)			_____
Water in Oil, after 5 hours	1 ml maximum	_____	
Cuff after centrifuge	2.0 ml maximum	_____	
Total free H2O	60.0 ml minimum	_____	
9. Foam Tendency - 190 ml fluid (ASTM D 892) - 10 min settling			_____
Sequence I	50/0 maximum	_____	
Sequence II	50/0 maximum	_____	
Sequence III	50/0 maximum	_____	
10. Four Ball Wear - 20 kg load (ASTM D 4172), LB-22-1 only			_____
Wear Scar Diameter	Report	_____	
11 .API Gravity at 60° F (ASTM D 287)	Report	_____	
12. Flash Point (ASTM D 92)	190/210 ° C min.	_____	
13. Acid No. of Base Oil (ASTM D 974)	0.25 maximum	_____	
14. Precipitation Number (ASTM D 91)	0.05 max	_____	
15. Cleanliness as Rcvd. (ISO 4406, ISO 11171)	20/18/14 max	_____	
16. Phosphorus content (LB-22-1 only)	5 ppm maximum	_____	_____
17*. Compatibility with Seals (ISO 1817)			_____
SRE-NBR1 Volume Change	-10 to 10%	_____	
Shore A Hardness Change	-7 to 10	_____	
Other Volume Change	Report	_____	
Seals Shore A Hardness Change	Report	_____	
18. Water, as received (ASTM D 6304)	_____ ppm max	_____	

GM LUBRICANT SUBMISSION WORKSHEET LB-FORM 3

SUMMARY OF TEST RESULTS, CONT.

Product Name/ No. _____

Product Type General Purpose Oil / Heavy Press and Machine Oil

GM Lubricant Standard No. LB- _____ ISO Viscosity Grade _____

19. Metals, typical range, mass % by (method) _____

Sulfur (LB-22-1 only)	
Zn	
P	
Ca	
Mg	
Ba	
S	
Others	

Base Stock Requirements	Specification	Result	Lab
20.* Tot. PNA's ppm (EPA SW-846, TN 8720)	100 maximum		
21. Residual Elements (ASTM D 5185)			
(As, B, Ca, Mn, Na, Cu, Fe, Ni, Si, Sn			
Cd, Cr, Pb, Ba, Zn), ppm	25 maximum total		
	2 maximum each		
Phosphorous	5 maximum		
22. Total PCB's (EPA SW-846, TN 8092)	not detectable		
23. Total Organic Halogens, ppm			
(EPA SW-846, TN 8120)			
	5 maximum		
24.* Modified Ames Test (ASTM E1687)			
Fold Increase	Report		
Mutagenicity Index	1 maximum		
Mutagenicity Potency Index	Report		

Be prepared to describe differences (if any) between formulation(s) tested and the formulation for which approval is sought _____

Any other comments or data pertinent to the review of the product:

GM LUBRICANT SUBMISSION WORKSHEET LC-FORM 1

The following information will be required for an on-line submission of a lubricant for LS2 approval. On-line submissions can be made at: https://gmr2.ttsvcs.com/gmr2portal/Default.aspx

Product Name/No. _____

Product Type: Submerged Clutch and Brake Oil

GM Lubricant Standard No. LC-06-1-00 ISO Viscosity Grade 68

The product above must meet the requirements of the standard shown, the tests must be run in qualified laboratories and the results shown must be on a product identical (within normal blending tolerances) in base fluid, additives and performance to the product offered for approval, unless any exceptions are specifically described in writing on the on-line submission . **NOTE: NO CHANGES CAN BE MADE TO A PRODUCT APPROVED WITHOUT REQUESTING REAPPROVAL.**

The lubricant contains the following base fluids (for non mineral oil fluids, skip source, method, %S)

Percent (vol)	Supplier	Method of Refining	% S	Viscosity at 40 °C cSt
		Base Fluid Blend		

(e.g. Supplier = Exxon, Source = Mid-east, Method = Hydrotreating)

The lubricant contains the following additives.

Percent	Name of Additive	Source	Generic Description

(e.g. Percent - indicate mass or volume, Name = PD-007, Source = Acme Additive Company Generic Description = antiwear/antioxidant)

You will also need to include the following information:

1. Test Reports for those tests as indicated on the on-line submission (marked by an asterisk on Forms 2 and 3).
2. Completed and signed Material Safety Data Sheets (see LS2 - Appendix F for directions).
3. ISO or QS 9000 certificate.

_____ _____

(E-mail Address) (Name)

GM LUBRICANT SUBMISSION WORKSHEET LC-FORM 2

SUMMARY OF TEST RESULTS

Product Name/ No. _____

Product Type: Submerged Clutch and Brake Oil

GM Lubricant Standard No. LC-06-1-00 ISO Viscosity Grade 68

(NOTE: For Tests in red marked with *, must attach test report to on-line submission)

Test Procedure:	Specification		Result	Lab
1. Dexron or Ford Type F	License No.			
2. Metals, mass % by (method)				
		Zn	10 ppm max	
		P		
		Ca		
		Mg		
		Ba		
		S		
		Others		

Base Stock Requirements	Specification	Result	Lab
3.* Tot. PNA's ppm (EPA SW-846, TN 8270)	100 maximum		
4. Residual Elements (ASTM D 5185)			
(As, B, Ca, Mn, Na, Cu, Fe, Ni, Si, Sn			
Cd, Cr, Pb, Ba, Zn), ppm	25 maximum total		
	2 maximum each		
Phosphorous	5 maximum		
5. Total PCB's (EPA SW-846, TN 8092)	not detectable		
6. Total Organic Halogens, ppm			
(EPA SW-846, TN 8120)	5 maximum		
7.* Modified Ames Test (ASTM E1687)			
Fold Increase	Report		
Mutagenicity Index	1 maximum		
Mutagenicity Potency Index	Report		

Be prepared to describe differences (if any) between formulation(s) tested and the formulation for which approval is sought _____

Any other comments or data pertinent to the review of the product:

GM LUBRICANT SUBMISSION WORKSHEET LD-FORM 1

The following information will be required for an on-line submission of a lubricant for LS2 approval. On-line submissions can be made at: https://gmr2.ttsvcs.com/gmr2portal/Default.aspx

Product Name/No. _____

Product Type: Dry Film Lubricant/ Chain and Conveyer Lubricant - Oil Based

GM Lubricant Standard No. LD- _____ ISO Viscosity Grade (LD-XX-2 only) _____

The product above must meet the requirements of the standard shown, the tests must be run in qualified laboratories and the results shown must be on a product identical (within normal blending tolerances) in base fluid, additives and performance to the product offered for approval, unless any exceptions are specifically described in writing on the on-line submission . **NOTE: NO CHANGES CAN BE MADE TO A PRODUCT APPROVED WITHOUT REQUESTING REAPPROVAL.**

The lubricant contains the following base fluids (for non mineral oil fluids, skip source, method, %S)

Percent (vol)	Supplier	Method of Refining	% S	Viscosity at 40 °C cSt
		Base Fluid Blend		

(e.g. Supplier = Exxon, Source = Mid-east, Method = Hydrotreating)

The lubricant contains the following additives.

Percent	Name of Additive	Source	Generic Description

(e.g. Percent - indicate mass or volume, Name = PD-007, Source = Acme Additive Company Generic Description = antiwear/antioxidant)

You will also need to include the following information:

1. Test Reports for those tests as indicated on the on-line submission (marked by an asterisk on Forms 2 and 3).
2. Completed and signed Material Safety Data Sheets (see LS2 - Appendix F for directions).
3. ISO or QS 9000 certificate.

_____ _____

(E-mail Address) (Name)

GM LUBRICANT SUBMISSION WORKSHEET LD-FORM 2
SUMMARY OF TEST RESULTS

Product Name/ No. _____
Product Type: Dry Film Lubricant/ Chain and Conveyer Lubricant - Oil Based
GM Lubricant Standard No. LD- _____ ISO Viscosity Grade (LD-XX-2 only) _____

(NOTE: For Tests in red marked with *, must attach test report to on-line submission)

Test Procedure: (LD-00-1 and LD-XX-2)	Specification	Result	Lab
1. Rust Preventing Char. (ASTM D 665A)	Pass		
2. Cu Corrosion (ASTM D 130)	1b maximum		
3. Four Ball Wear, 20 kg load (ASTM D 4172)*			
Wear Scar diameter	Report		
4. Four Ball Coeff. of Friction (ASTM D 5183)*	Report		
5. Adherence	Must how good adherence		
6. Metals, mass % by (method) _____			
Zn			
P			
Ca			
Mg			
Ba			
S			
Others			
For LD-00-1 (Dry Film) only			
7. Stability - shall not separate on standing			
8. Drying time at room temperature	2-3 minutes		
9. Four Ball EP (ASTM D 2783)*			
Load Wear Index	Report		
Weld Load	Report		
* tests to be run after solvent has been allowed to evaporate			
For LD-XX-2 Chain/ Conveyer Lube-Oil Based only			
10. Viscosity at 40/ 100^{o} C (ASTM D 445)	Report		
11. Viscosity Index (ASTM D 2270)	Report		
12. Pour Point (ASTM D 97)	-10^{o} C maximum		
13. Flash Point (ASTM D 92)	_____^{o} C minimum		

Base Stock Requirements	Specification	Result	Lab
14.* Tot. PNA's ppm (EPA SW-846, TN 8270)	100 maximum		
15. Residual Elements (ASTM D 5185)			
(As, B, Ca, Mn, Na, Cu, Fe, Ni, Si, Sn			
Cd, Cr, Pb, Ba, Zn), ppm	25 maximum total		
	2 maximum each		
Phosphorous	5 maximum		
16. Total PCB's (EPA SW-846, TN 8092)	not detectable		
17. Total Organic Halogens, ppm			
(EPA SW-846, TN 8120)			
	5 maximum		
18.* Modified Ames Test (ASTM E 1687)			
Fold Increase	Report		
Mutagenicity Index	1 maximum		
Mutagenicity Potency Index	Report		

GM LUBRICANT SUBMISSION WORKSHEET LD-FORM 3

SUMMARY OF TEST RESULTS, CONT.

SUMMARY OF TEST RESULTS

Product Name/ No. _____

Product Type: Dry Film Lubricant/ Chain and Conveyer Lubricant - Oil Based

GM Lubricant Standard No. LD- _____ ISO Viscosity Grade (LD-XX-2 only) _____

Be prepared to describe differences (if any) between formulation(s) tested and the formulation for which approval is sought _____

Any other comments or data pertinent to the review of the product:

GM LUBRICANT SUBMISSION WORKSHEET LF-FORM 1

The following information will be required for an on-line submission of a lubricant for LS2 approval. On-line submissions can be made at: https://gmr2.ttsvcs.com/gmr2portal/Default.aspx

Product Name/No. _____

Product Type: _____

GM Lubricant Standard No. LF- _____ ISO Viscosity Grade _____

The product above must meet the requirements of the standard shown, the tests must be run in qualified laboratories and the results shown must be on a product identical (within normal blending tolerances) in base fluid, additives and performance to the product offered for approval, unless any exceptions are specifically described in writing on the on-line submission . **NOTE: NO CHANGES CAN BE MADE TO A PRODUCT APPROVED WITHOUT REQUESTING REAPPROVAL.**

The lubricant contains the following base fluids (for non mineral oil fluids, skip source, method, %S)

Percent (vol)	Supplier	Method of Refining	% S	Viscosity at 40 ^{o} C cSt
		Base Fluid Blend		

(e.g. Supplier = Exxon, Source = Mid-east, Method = Hydrotreating)

The lubricant contains the following additives.

Percent	Name of Additive	Source	Generic Description

(e.g. Percent - indicate mass or volume, Name = PD-007, Source = Acme Additive Company Generic Description = antiwear/antioxidant)

You will also need to include the following information:

1. Test Reports for those tests as indicated on the on-line submission (marked by an asterisk on Forms 2 and 3).
2. Completed and signed Material Safety Data Sheets (see LS2 - Appendix F for directions).
3. ISO or QS 9000 certificate.

_____ _____

(E-mail Address) (Name)

GM LUBRICANT SUBMISSION WORKSHEET LF-FORM 2

SUMMARY OF TEST RESULTS

Product Name/ No. _____

Product Type _____

GM Lubricant Standard No. LF- _____ ISO Viscosity Grade: _____

(NOTE: For Tests in red marked with *, must attach test report to on-line submission)

Test Procedure:	Specification	Result	Lab
1. Viscosity at 40 /100 °C (ASTM D 445)	_____ to _____ cSt	_____	_____
2. Viscosity Index (ASTM D 2270)#%	_____	_____	
3. Pour Point (ASTM D 97)	_____ °C maximum	_____	
4. Cu Corrosion (ASTM D 130)	1b maximum	_____	_____
5. Rust Test (ASTM D 665B)	Pass (No rust)	_____	_____
6. Foam Tendency - 190 ml fluid (ASTM D 892)	10 min settling		_____
Sequence I	50/0 maximum	_____	
Sequence II	50/0 maximum	_____	
Sequence III	50/0 maximum	_____	
7. Cleanliness as Rcvd (ISO 4406)	18/16/13 maximum	_____	
8.* Vickers 35VQ25 Pump Test (M-2952-S)#			
Vane Wear	10 mg maximum	_____	_____
Ring Wear	50 mg maximum	_____	
or Vickers M104-C Pump Test (ASTM D 2882)@&%			_____
Vane and Ring Wear	50 mg maximum	_____	
9.* Denison P-46 Piston Pump Test#			_____
no smearing, scoring, scratching, bronze transfer		_____	
10. Hydrolytic Stability (ASTM D 2619)#%			_____
Copper Weight Loss	0.20 mg/cm2 max	_____	
Acidity of Water Layer	_____ mg KOH max	_____	
11.* Oxidation Stability TAN = 2 (ASTM D943)#	1000 hr. minimum	_____	_____
(ASTM D943 run without water)%	1000 hr. minimum	_____	_____
12. Flammability-Hot Manifold (704 oC) (FTM 6053.1)	does not flash/burn	_____	_____
13. Flammability-High Pressure Spray (FTM 6052.1)	spray does not ignite	_____	_____
Flammability may be defined by FM or 7th Luxembourg Appr.	FM Group _____	_____	
14. Spray Ignition Test Ignitability, min (ISO 15029-2)	Report	_____	
15. Manifold Ignition Test, °C (ISO 20823)	Report	_____	
16. Wick Flame Persistence, sec (ISO 14935)	Report	_____	
17. Emulsion Stability (ASTM D 3707)&	no sep. in 48 h/25 days	_____	_____
18. API Gravity at 60 ° F (ASTM D 287)	Report	_____	
19. Flash Point (ASTM D 92)#&%	_____ ° C min.	_____	
20. Fire Point (ASTM D 92)#	Report	_____	
21. Autoignition (ASTM E 659)#%@	_____ ° C min.	_____	_____
22. Water Content (ASTM D 1744 or D 6304)	_____	_____	
23. Air Release at 50 °C (ASTM D 3427)#@%	_____ minutes max.	_____	_____
24.* Compatibility with Seals (ISO 1817)@&, #,%(agreed upon seal material)			_____
SRE-NBR1 Volume Change, %	_____ to _____	_____	
Shore A Hardness Change	_____ to _____	_____	
Other Volume Change, %	Report	_____	
Seals Shore A Hardness Change	Report	_____	

to be run for phosphate ester (LF-04-1) fluids
@ to be run for water/glycol (LF 04-2) fluids
& to be run for invert emulsions (LF-10-3) fluids
% to be run for polyol ester (LF-XX-4) fluids

GM LUBRICANT SUBMISSION WORKSHEET LF-FORM 3

SUMMARY OF TEST RESULTS

Product Name/ No. _____

Product Type _____

GM Lubricant Standard No. LF- _____ ISO Viscosity Grade _____

Test Procedure:	Specification	Result	Lab
25. pH@20 deg C @	6.7 to 11.0		
26. Acid No., (ASTM D 665)#%	0.15(#), 3(%) maximum		
27. FZG Test (ASTM D 5182)%	Report		
28. Shear Stability (ASTM D 2603 or D 5621)%	Report		
29. Metals, mass % by (method)			
Zn			
P			
Ca			
Mg			
Ba			
S			
Others			
Base Stock Requirements			
30.* Tot. PNA's ppm (EPA SW-846, TN 8270)&	100 maximum		
31. Residual Elements (ASTM D 5185)#&%			
(As, B, Ca, Mn, Na, Cu, Fe, Ni, Si, Sn			
Cd, Cr, Pb, Ba, Zn), ppm	25 maximum total		
	2 maximum each		
Phosphorous	5 maximum		
32. Total PCB's (EPA SW-846, TN 8092)#&	not detectable		
33. Total Organic Halogens, ppm #&			
EPA SW-846, TN 8120)	5 maximum		
34.* Modified Ames Test (ASTM E 1687)&			
Fold Increase	Report		
Mutagenicity Index	1 maximum		
Mutagenicity Potency Index	Report		

to be run for phosphate ester (LF-04-1) fluids
@ to be run for water/glycol (LF 04-2) fluids
& to be run for invert emulsions (LF-10-3) fluids
% to be run for polyol ester (LF-XX-4) fluids

Be prepared to describe differences (if any) between formulation(s) tested and the formulation for which approval is sought _____

Any other comments or data pertinent to the review of the product:

GM LUBRICANT SUBMISSION WORKSHEET LG-FORM 1

The following information will be required for an on-line submission of a lubricant for LS2 approval. On-line submissions can be made at: https://gmr2.ttsvcs.com/gmr2portal/Default.aspx

Product Name/No. _____

Product Type: Grease _____

GM Lubricant Standard No. LG- _____ NLGI Grade _____

The product above must meet the requirements of the standard shown, the tests must be run in qualified laboratories and the results shown must be on a product identical (within normal blending tolerances) in base fluid, additives and performance to the product offered for approval, unless any exceptions are specifically described in writing on the on-line submission . **NOTE: NO CHANGES CAN BE MADE TO A PRODUCT APPROVED WITHOUT REQUESTING REAPPROVAL.**

The lubricant contains the following base fluids (for non mineral oil fluids, skip source, method, %S)

Percent (vol)	Supplier	Method of Refining	% S	Viscosity at 40 °C, cSt
		Base Fluid Blend		

(e.g. Supplier = Exxon, Source = Mid-east, Method = Hydrotreating)

The lubricant contains the following additives.

Percent	Name of Thickener or Additive	Source	Generic Description

for additional components use LG-Form 1B (LG Form 1, page 2)

(e.g. Percent - indicate mass or volume, Name = PD-007, Source = Acme Additive Company Generic Description = antiwear/antioxidant)

You will also need to include the following information:

1. Test Reports for those tests as indicated on the on-line submission (marked by an asterisk on Forms 2 and 3).
2. Completed and signed Material Safety Data Sheets (see LS2 - Appendix F for directions).
3. ISO or QS 9000 certificate.

_____ (E-mail Address)

_____ (Name)

GM LUBRICANT SUBMISSION WORKSHEET LG-FORM 1B

Product Name/No. _____

Product Type: Grease _____

GM Lubricant Standard No. LG- _____ NLGI Grade _____

The lubricant contains the following thickener and additives.

Percent	Name of Thickener or Additive	Source	Generic Description

GM LUBRICANT SUBMISSION WORKSHEET LG-FORM 2
SUMMARY OF TEST RESULTS

Product Name/ No. _____
Product Type Grease _____
GM Lubricant Standard No. LG- _____ NLGI Grade _____

(NOTE: For Tests in red marked with *, must attach test report to on-line submission)

Test Procedure:	Specification	Result	Lab
1. Base Oil Viscosity at 40 °C (ASTM D 445)	_____ cSt	_____	
1b. Base Oil Viscosity at 100 °C (ASTM D 445)	Report	_____	
2. Base Oil Viscosity Index (ASTM D 2270)	75 minimum	_____	
3. Worked Penetration at 25 °C (ASTM D 217)	_____ to _____	_____	_____
4. Prolonged (10,000 strokes) Worked Penetration at 25 °C (ASTM D 217)@	_____ to _____	_____	_____
5. Dropping Point (ASTM D 2265 or D 566)	_____ °C min.	_____	_____
6. Water Washout at 79 °C (ASTM D 1264)	_____	_____	_____
7. Rust Preventing Characteristics (ASTM D 1743)**	Pass	_____	_____
8. Emcor Rust Test (IP 220 or DIN 51802)@	#1 rating max	_____	
9. Evaporation Loss (ASTM D 2595)@	_____ maximum	_____	_____
10. Oil Separation (ASTM D 4290)@	_____ maximum	_____	_____
11. Pressure Oil Separation (ASTM D 1742)@	0.5 to _____%	_____	_____
12. Centrifugal Separation, K36 value at 50 °C (ASTM D 4425)@&	Report	_____	_____
13. Four Ball EP (ASTM D 2596)@			
Load Wear Index	40 kg min	_____	
Weld Load	250 kg min	_____	
14. Four Ball Wear, Scar Diamtr. (ASTM D 2266)	_____ mm max	_____	_____
15. Fretting Wear Test (ASTM D 4170)	_____ mg max	_____	_____
16*. Life Performance (ASTM D 3527)@	_____ hours minimum	_____	_____
17*. Oxidation Stability, pres. drop (ASTM D 942)	35 kPa max	_____	_____
18. Copper Corrosion (ASTM D 4048)	1b/3b max	_____	_____
19. Extracted Fluid Aniline Point (ASTM D 128 X1)	94 °C min	_____	_____
20*. Performance in Ball Bearing (ASTM D 3336)#@%			
L50 life at 177 °C	250 h min	_____	_____
21. Base Oil Flash Point (ASTM D 92)	190 °C min	_____	
22.Timken OK Load (ASTM D 2509)@&	18.3 kg min	_____	_____
23. Thickener Type	Report	_____	
24. Metals, typical range, mass % by (method)	_____		

Zn	_____
P	_____
Ca	_____
Mg	_____
Ba	_____
S	_____
Others	_____

not required for Multi- Purpose Greases
@ not required for Fretting and Corrosion Inhibiting Greases
& not required for High Speed Bearing Grease
% not required for High-Temperature Grease
** For LG 01-2, use synthetic seawater

GM LUBRICANT SUBMISSION WORKSHEET LG-FORM 3

SUMMARY OF TEST RESULTS, CONT.

Product Name/ No. _____

Product Type Grease _____

GM Lubricant Standard No. LG- _____ NLGI Grade _____

Base Stock Requirements	Specification	Result	Lab
25.* Tot. PNA's ppm (EPA SW-846, TN 8270)	100 maximum		
26. Residual Elements (ASTM D 5185)			
(As, B, Ca, Mn, Na, Cu, Fe, Ni, Si, Sn			
Cd, Cr, Pb, Ba, Zn), ppm	25 maximum total		
	2 maximum each		
Phosphorous	5 maximum		
27. Total PCB's (EPA SW-846, TN 8092)	not detectable		
28. Total Organic Halogens, ppm			
(EPA SW-846, TN 8120)	5 maximum		
29.* Modified Ames Test (ASTM E 1687)			
Fold Increase	Report		
Mutagenicity Index	1 maximum		
Mutagenicity Potency Index	Report		

Be prepared to describe differences (if any) between formulation(s) tested and the formulation for which approval is sought _____

Any other comments or data pertinent to the review of the product:

GM LUBRICANT SUBMISSION WORKSHEET LH-FORM 1

The following information will be required for an on-line submission of a lubricant for LS2 approval. On-line submissions can be made at: https://gmr2.ttsvcs.com/gmr2portal/Default.aspx

Product Name/No. _____

Product Type: Antiwear Hydraulic fluid

GM Lubricant Standard No. LH- _____ ISO Viscosity Grade _____

The product above must meet the requirements of the standard shown, the tests must be run in qualified laboratories and the results shown must be on a product identical (within normal blending tolerances) in base fluid, additives and performance to the product offered for approval, unless any exceptions are specifically described in writing on the on-line submission . **NOTE: NO CHANGES CAN BE MADE TO A PRODUCT APPROVED WITHOUT REQUESTING REAPPROVAL.**

The lubricant contains the following base fluids (for non mineral oil fluids, skip source, method, %S)

Percent (vol)	Supplier	Method of Refining	% S	Viscosity at 40 °C cSt
		Base Fluid Blend		

(e.g. Supplier = Exxon, Source = Mid-east, Method = Hydrotreating)

The lubricant contains the following additives.

Percent	Name of Additive	Source	Generic Description

(e.g. Percent - indicate mass or volume, Name = PD-007, Source = Acme Additive Company Generic Description = antiwear/antioxidant)

You will also need to include the following information:

1. Test Reports for those tests as indicated on the on-line submission (marked by an asterisk on Forms 2 and 3).
2. Completed and signed Material Safety Data Sheets (see LS2 - Appendix F for directions).
3. ISO or QS 9000 certificate.

_____ _____

(E-mail Address) (Name)

GM LUBRICANT SUBMISSION WORKSHEET LH-FORM 2

SUMMARY OF TEST RESULTS

Product Type Antiwear Hydraulic

GM Lubricant Standard No. LH- _____ ISO Viscosity Grade: _____

(NOTE: For Tests in red marked with *, must attach test report to on-line submission)

For multiple test results, place the mean value in blank below and show raw data or data range in comments section

Test Procedure:	Specification	Result	Lab
1. Viscosity at 40 /100 ^{o} C (ASTM D445)	_____ to _____ cSt	/	
1b. Viscosity at 0^{o} C (ASTM D 5133)	_____ maximum		
2. Viscosity Index (ASTM D2270)	95 minimum		
3. Pour Point (ASTM D97)	_____ ^{o}C max.		
4. Cu Corrosion (ASTM D130)	1b maximum		
5*. Thermal Stability - 168 hr at 135^{o} C (ASTM D2070)			
Neutralization Number Change	+/- 50% maximum		
Viscosity Change at 40/100 ^{o}C	5 % Maximum		
Sludge	25 mg/100 ml Max.		
Copper Rod Color (Cin. Mil.)	5 Maximum		
Copper Weight Loss	10 mg maximum		
Steel Rod Color (Cin. Mil.)	No Discoloration		
6.* Oxidation Stability TAN = 2 (ASTM D943)	1500 hr. minimum		
7. Rust Test (ASTM D665B)	Pass (No rust)		
8*. Water Separability - 55 ^{o} C (ASTM D1401)	40/40/0 (30 minutes max..)		
9. Foam Tendency - 190 ml fluid (ASTM D892)	10 min settling		
Sequence I	50/0 maximum		
Sequence II	50/0 maximum		
Sequence III	50/0 maximum		
10. Cleanliness as Rcvd (ISO 4406)	19/16/13		
11.* Vickers 35VQ25 Pump Test (M-2952-S)			
Vane Wear	10 mg maximum		
Ring Wear	50 mg maximum		
12.* Denison T5D or T6C Vane Pump Test (see also 13)			
Vane Wear	0.01 in Maximum		
Ring Wear	no distress		
13.* Denison T6H20C Vane & Piston Pump Test -can be run instead of **T5D or T6C and P-46**			
Piston weight loss, mg	350 mg. Max		
Vane pump & pin weight loss, mg	15 mg. max		
Cam surface (u inch)	Report (no limits yet)		
14.* Denison P-46 Piston Pump Test (see also 13)			
no smearing, scoring, scratching, bronze transfer			
15. Filterability (TP-02100)			
Without water	600 sec max.		
With 2% water	<2x w/out water		
16. Hydrolytic Stability (ASTM D2619)			
Copper Weight Loss	0.20 mg/cm2 max		
Acidity of Water Layer	4.0 mg KOH max		
17. API Gravity at 60 ^{o} F (ASTM D287)	Report		
18. Flash Point (ASTM D92)	190 ^{o}C min.		
19. Neutralization No. (ASTM D664)	1.0 Maximum		
20. Air Release at 50 ^{o} C (ASTM D3427)	_____ minutes max.		
21. FZG Test (ASTM D5182)	10 stage fail min.		

GM LUBRICANT SUBMISSION WORKSHEET LH-FORM 3

SUMMARY OF TEST RESULTS, CONT.

Product Name/ No. _____

Product Type Antiwear Hydraulic

GM Lubricant Standard No. LH- _____ ISO Viscosity Grade _____

21.* Compatibility with Seals (ISO 1817)

SRE-NBR1	Volume Change, %	_____	to	_____ %	_____
	Shore A Hardness Change		to	_____	_____
Other	Volume Change, %	Report			_____
Seals	Shore A Hardness Change	Report			_____

26. Metals, ppm by (method) _____

Zn	_____
P	_____
Ca	_____
Mg	_____
Ba	_____
S	_____
Others	_____

Base Stock Requirements	Specification	Result	Lab
27.* Tot. PNA's ppm (EPA SW-846)	100 maximum	_____	_____
28. Residual Elements (ASTM D5185			
(As, B, Ca, Mn, Na, Cu, Fe, Ni, Si, Sn			
Cd, Cr, Pb, Ba, Zn), ppm	25 maximum total	_____	
	2 maximum each	_____	
Phosphorous	5 maximum	_____	
29. Total PCB's (EPA SW-846)	not detectable	_____	_____
30. Total Organic Halogens, ppm			_____
Technique No. 8120		_____	
	5 maximum	_____	
31.* Modified Ames Test (ASTM E1687)			_____
Fold Increase	Report	_____	
Mutagenicity Index	1 maximum	_____	
Mutagenicity Potency Index	Report	_____	

Be prepared to describe differences (if any) between formulation(s) tested and the formulation for which approval is sought _____

Any other comments or data pertinent to the review of the product:

GM LUBRICANT SUBMISSION WORKSHEET LJ-FORM 1

The following information will be required for an on-line submission of a lubricant for LS2 approval. On-line submissions can be made at: https://gmr2.ttsvcs.com/gmr2portal/Default.aspx

Product Name/No. _____

Product Type: Compressor/ Turbine Oil

GM Lubricant Standard No. LJ- _____ ISO Viscosity Grade _____

The product above must meet the requirements of the standard shown, the tests must be run in qualified laboratories and the results shown must be on a product identical (within normal blending tolerances) in base fluid, additives and performance to the product offered for approval, unless any exceptions are specifically described in writing on the on-line submission . **NOTE: NO CHANGES CAN BE MADE TO A PRODUCT APPROVED WITHOUT REQUESTING REAPPROVAL.**

The lubricant contains the following base fluids (for non mineral oil fluids, skip source, method, %S)

Percent (vol)	Supplier	Method of Refining	% S	Viscosity at 40 ^{o}C cSt
		Base Fluid Blend		

(e.g. Supplier = Exxon, Source = Mid-east, Method = Hydrotreating)

The lubricant contains the following additives.

Percent	Name of Additive	Source	Generic Description

(e.g. Percent - indicate mass or volume, Name = PD-007, Source = Acme Additive Company Generic Description = antiwear/antioxidant)

We are also including the following information:

You will also need to include the following information:

1. Test Reports for those tests as indicated on the on-line submission (marked by an asterisk on Forms 2 and 3).
2. Completed and signed Material Safety Data Sheets (see LS2 - Appendix F for directions).
3. ISO or QS 9000 certificate.

_____ _____

(E-mail Address) (Name)

GM LUBRICANT SUBMISSION WORKSHEET LJ-FORM 2

SUMMARY OF TEST RESULTS

Product Name/ No. _____

Product Type: Compressor/ Turbine Oil

GM Lubricant Standard No. LJ- _____ ISO Viscosity Grade _____

(NOTE: For Tests in red marked with *, must attach test report to on-line submission)

Test Procedure:	Specification	Result	Lab
1. Viscosity at 40 /100 ^{o} C (ASTM D445)	_____ to _____ cSt	_____	
2. Viscosity Index	_____ minimum	_____	
3. Pour Point (ASTM D97)	_____ ^{o}C maximum	_____	
4. Cu Corrosion (ASTM D130)	1b maximum	_____	_____
5*. Thermal Stability - 168 hrs. at 135^{o} C (ASTM D2070)			_____
lization Number Change	0.15 maximum	_____	
ity Change at 40/100^{o} C	5% maximum	_____	
Sludge	25 mg/100 ml max	_____	
per Rod Color (Cin. Mil.)	5 maximum	_____	
Copper Weight Loss	10 mg maximum	_____	
eel Rod Color (Cin. Mil.)	No Discoloration	_____	
6* Oxidation Stability TAN = 2 (ASTM D943)	_____ hr. minimum	_____	_____
TM D943 run w/o water)	Report	_____	_____
7. Rust Test (ASTM D665B)	Pass (No rust)	_____	_____
8*. Water Separability (ASTM D1401)	_____ (30 min.) max.	_____	_____
9. Foam Tendency - 190 ml fluid (ASTM D892)	10 min settling		_____
Sequence I	50/0 maximum	_____	
Sequence II	50/0 maximum	_____	
Sequence III	50/0 maximum	_____	
10. Cleanliness as Rcvd (ISO 4406)	20/17/14	_____	_____
11. Four Ball Wear - 20 kg load (ASTM D4172)			_____
Wear Scar Diameter	0.4 mm maximum	_____	
12. Aniline Point (ASTM D611)	Report	_____	
13. API Gravity at 60 ^{o} F (ASTM D287)	Report	_____	
14. Flash Point (ASTM D92)	_____ ^{o}C min.	_____	
15. Autoignition Temperature (ASTM D2155)#	_____ ^{o}C min.	_____	
16. Conradson Carbon Residue (ASTM D189)	0.05 % maximum		
16.* Compatibility with Seals (ISO 1817)			_____
SRE-NBR1 Change, %	-10 to 10%	_____	
ore A Hardness Change	-7 to 10	_____	
Other Change, %	Report	_____	
Seals ss Change	Report	_____	
		_____	
17. Metals, mass % by (method) _____			
Zn		_____	
P		_____	
Ca		_____	
Mg		_____	
Ba		_____	
S		_____	
Others		_____	

for synthetic fluids (LJ-XX-2, LJ-XX-3) only

GM LUBRICANT SUBMISSION WORKSHEET LJ-FORM 3

SUMMARY OF TEST RESULTS, CONT.

Product Name/ No. _____

Product Type: Compressor/ Turbine Oil

GM Lubricant Standard No. LJ- _____ ISO Viscosity Grade _____

Base Stock Requirements	Specification	Result	Lab
18.* Tot. PNA's ppm (EPA SW-846)	100 maximum		
19. Residual Elements (ASTM D5185)			
(As, B, Ca, Mn, Na, Cu, Fe, Ni, Si, Sn			
Cd, Cr, Pb, Ba, Zn), ppm	25 maximum total		
	2 maximum each		
Phosphorous	5 maximum		
20 Total PCB's (EPA SW-846)	not detectable		
21. Total Organic Halogens, ppm			
Technique No. 8120			
	5 maximum		
22.* Modified Ames Test (ASTM E1687)			
Fold Increase	Report		
Mutagenicity Index	1 maximum		
Mutagenicity Potency Index	Report		

Be prepared to describe differences (if any) between formulation(s) tested and the formulation for which approval is sought _____

Any other comments or data pertinent to the review of the product:

GM LUBRICANT SUBMISSION WORKSHEET LM-FORM 1

The following information will be required for an on-line submission of a lubricant for LS2 approval. On-line submissions can be made at: https://gmr2.ttsvcs.com/gmr2portal/Default.aspx

Product Name/No. _____

Product Type: Misting Oil

GM Lubricant Standard No. LM- _____ ISO Viscosity Grade _____

The product above must meet the requirements of the standard shown, the tests must be run in qualified laboratories and the results shown must be on a product identical (within normal blending tolerances) in base fluid, additives and performance to the product offered for approval, unless any exceptions are specifically described in writing on the on-line submission . **NOTE: NO CHANGES CAN BE MADE TO A PRODUCT APPROVED WITHOUT REQUESTING REAPPROVAL.**

The lubricant contains the following base fluids (for non mineral oil fluids, skip source, method, %S)

Percent (vol)	Supplier	Method of Refining	% S	Viscosity at 40 °C, cSt
		Base Fluid Blend		

(e.g. Supplier = Exxon, Source = Mid-east, Method = Hydrotreating)

The lubricant contains the following additives.

Percent	Name of Thickener or Additive	Source	Generic Description

(e.g. Percent - indicate mass or volume, Name = PD-007, Source = Acme Additive Company
Generic Description = antiwear/antioxidant)

You will also need to include the following information:

1. Test Reports for those tests as indicated on the on-line submission (marked by an asterisk on Forms 2 and 3).
2. Completed and signed Material Safety Data Sheets (see LS2 - Appendix F for directions).
3. ISO or QS 9000 certificate.

_____ _____

(E-mail Address) (Name)

GM LUBRICANT SUBMISSION WORKSHEET LM-FORM 2

SUMMARY OF TEST RESULTS

Product Name/ No. _____

Product Type Misting Oil

GM Lubricant Standard No. LM- _____ ISO Viscosity Grade _____

(NOTE: For Tests in red marked with *, must attach test report to on-line submission)

Test Procedure:		Specification	Result	Lab
1. Viscosity at 40 ^{o} C/ 100 ^{o} C (ASTM D445)		90 to 110 cSt		
2. Viscosity Index (ASTM D2270)		90 minimum		
3. Pour Point (ASTM D97)		-15^{o} C max		
4. Cu Corrosion (ASTM D130)		1b maximum		
5*. Thermal Stability - 72h at 101 ^{o} C (ASTM D2070)				
	Neutralization Number Change	0.15 maximum		
	Viscosity Change at 40/100 ^{o} C	5% maximum		
	Sludge	25 mg/100 ml max.		
	Copper Rod Color (Cin. Mil)	5 maximum		
	Copper Weight Loss	10 mg max.		
	Steel Rod Color (Cin. Mil.)	No Discoloration		
6*. Oxidation Stability (ASTM D2893)				
	Viscosity Increase 100^{o} C	5% maximum		
	Precipitation No.	0.1 maximum		
7. Rust Test (ASTM D665B)		Pass (No Rust)		
8*. Demulsibility 90 ml H2O (ASTM D2711 App.X2)				
	Water in Oil, after 5 hours	1% maximum		
	Cuff after centrifuge	2.0 ml maximum		
	Total free H2O	60.0 ml minimum		
9. Timken OK Load Rating (D2782)		27 kg minimum		
10. Foam Tendency - 190 ml fluid (ASTM D892) - 10 min settling				
	Sequence I	50/0 maximum		
	Sequence II	50/0 maximum		
	Sequence III	50/0 maximum		
11.* FZG (ASTM D5182)		11 fail stages minimum		
12. Four Ball Wear EP (ASTM D2783),				
	Weld Point	250 kg minimum		
	Load Wear Index	45 kg minimum		
13. Four Ball Wear 20 kg load (ASTM D4172)				
	Wear Scar diameter	0.35 maximum		
14. Misting Properties (ASTM 3705)				
	Reclassified	50 % minimum		
	Oil lost in manifold	Report		
	Oil lost in stray fog	5 % maximum		
15. API Gravity (ASTM D287 or D1298)		Report		
16. Flash Point (ASTM D92)		200^{o} C min		
17. Precipitation Number (ASTM D91)		0.25 maximum		
18*. Compatibility with Seals (ISO 1817)				
SRE-NBR1	Volume Change	-10 to 10%		
	Shore A Hardness Change	-7 to 10		
Other	Volume Change	Report		
Seals	Shore A Hardness Change	Report		

GM LUBRICANT SUBMISSION WORKSHEET LM-FORM 3

SUMMARY OF TEST RESULTS, CONT.

Product Name/ No. _____

Product Type Misting Oil

GM Lubricant Standard No. LM- _____ ISO Viscosity Grade _____

19. Metals, typical range, mass % by (method) _____

Zn	
P	
Ca	
Mg	
Ba	
S	
Others	

Base Stock Requirements	Specification	Result	Lab
20.* Tot. PNA's ppm (EPA SW-846)	100 maximum		
21. Residual Elements (ASTM D5185)			
(As, B, Ca, Mn, Na, Cu, Fe, Ni, Si, Sn Cd, Cr, Pb, Ba, Zn), ppm	25 maximum total		
	2 maximum each		
Phosphorous	5 maximum		
22. Total PCB's (EPA SW-846)	not detectable		
23. Total Organic Halogens, ppm Technique No. 8120	5 maximum		
24.* Modified Ames Test (ASTM E1687)			
Fold Increase	Report		
Mutagenicity Index	1 maximum		
Mutagenicity Potency Index	Report		

Be prepared to describe differences (if any) between formulation(s) tested and the formulation for which approval is sought _____

Any other comments or data pertinent to the review of the product:

GM LUBRICANT SUBMISSION WORKSHEET LR-FORM 1

The following information will be required for an on-line submission of a lubricant for LS2 approval. On-line submissions can be made at: https://gmr2.ttsvcs.com/gmr2portal/Default.aspx

Product Name/No. _____

Product Type: EP, WORM or SYNTHETIC EP GEAR OIL

GM Lubricant Standard No. LR- _____ ISO Viscosity Grade _____

The product above must meet the requirements of the standard shown, the tests must be run in qualified laboratories and the results shown must be on a product identical (within normal blending tolerances) in base fluid, additives and performance to the product offered for approval, unless any exceptions are specifically described in writing on the on-line submission . **NOTE: NO CHANGES CAN BE MADE TO A PRODUCT APPROVED WITHOUT REQUESTING REAPPROVAL.**

The lubricant contains the following base fluids (for non mineral oil fluids, skip source, method, %S)

Percent (vol)	Supplier	Method of Refining	% S	Viscosity at 40 °C, cSt
		Base Fluid Blend		

(e.g. Supplier = Exxon, Source = Mid-east, Method = Hydrotreating)

The lubricant contains the following additives.

Percent	Name of Thickener or Additive	Source	Generic Description

(e.g. Percent - indicate mass or volume, Name = PD-007, Source = Acme Additive Company
Generic Description = antiwear/antioxidant)

You will also need to include the following information:

1. Test Reports for those tests as indicated on the on-line submission (marked by an asterisk on Forms 2 and 3).
2. Completed and signed Material Safety Data Sheets (see LS2 - Appendix F for directions).
3. ISO or QS 9000 certificate.

_____ _____

(E-mail Address) (Name)

GM LUBRICANT SUBMISSION WORKSHEET LR-FORM 2

SUMMARY OF TEST RESULTS

Product Name/ No. _____

Product Type EP, WORM or SYNTHETIC EP GEAR OIL

GM Lubricant Standard No. LR- _____ ISO Viscosity Grade _____

(NOTE: For Tests in red marked with *, must attach test report to on-line submission)

Test Procedure:	Specification	Result	Lab
1. Viscosity at 40 °C/ 100 °C (ASTM D 445)	_____ to _____ cSt	/	
2. Viscosity Index (ASTM D 2270)	_____ minimum		
3. Pour Point (ASTM D 97)	_____ °C max.		
4. Cu Corrosion (ASTM D 130)	1b maximum		
5*. Thermal Stability - 72h at 101 °C (ASTM D 2070)@			
Neutralization Number Change	0.15 maximum or report		
Viscosity Change at 40/100 °C	5% maximum or report		
Sludge	25 mg/100 ml Max. or report		
Copper Rod Color (Cin. Mil)	5 maximum or report		
Copper Weight Loss	10 mg maximum or report		
Steel Rod Color (Cin. Mil.)	No Discoloration or report		
6*. Oxidation Stability (ASTM D 2893) at 121 °C rather than 95 °C@			
Viscosity Increase at 100 °C	% maximum		
Photos of Glassware After Test	Report		
7. Rust Test (ASTM D 665B)	Pass (No Rust)		
8*. Demulsibility 90 ml H2O (ASTM D 2711 App X2)&			
Water in Oil, after 5 hours	1% maximum		
Cuff after centrifuge	2.0 ml maximum		
Total free H2O	60.0 ml minimum		
9. Timken OK Load Rating (ASTM D 2782)&	_____ kg minimum		
10. Foam Tendency - 190 ml fluid (ASTM D 892) - 10 min settling			
Sequence I	50/0 maximum		
Sequence II	50/0 maximum		
Sequence III	50/0 maximum		
11*. FZG (ASTM D 5182)	_____ fail stages minimum		
12. Four Ball EP (ASTM D 2783)&			
Weld Point	250 kg minimum		
Load Wear Index	45 kg minimum		
13. Four Ball Wear - 20 kg load (ASTM D 4172)			
Wear Scar Diameter	0.35 mm maximum		
14. Cleanliness as Rcvd. (ISO 4406)	20/18/14 maximum		
15. API Gravity (ASTM D 287 or D 1298)	Report		
16. Flash Point (ASTM D 92)	_____ °C min.		
17. Precipitation Number (ASTM D 91)	0.05 max or Report		
18*. Compatibility with Seals (ISO 1817)			
SRE-NBR1 Volume Change	-10 to 10%		
Shore A Hardness Change	-7 to 10		
Other Volume Change	Report		
Seals Shore A Hardness Change	Report		

'@ for Worm Gear Oil (LR-XX-2) parameters are "Report"

& not required for Worm Gear Oil (LR-XX-2)

GM LUBRICANT SUBMISSION WORKSHEET LR-FORM 3

SUMMARY OF TEST RESULTS, CONT.

Product Name/ No. _____

Product Type EP, WORM or SYNTHETIC EP GEAR OIL

GM Lubricant Standard No. LR- _____ ISO Viscosity Grade _____

19. Water (ASTM D 6304)	200 ppm maximum			
20. Metals, typical range, mass % by (list method)				
		Zn		
		P		
		Ca		
		Mg		
		Ba		
		S		
		Others		

Base Stock Requirements	Specification	Result	Lab
21.* Tot. PNA's ppm (EPA SW-846, TN 8270)	100 maximum		
22. Residual Elements (ASTM D 5185)			
(As, B, Ca, Mn, Na, Cu, Fe, Ni, Si, Sn			
Cd, Cr, Pb, Ba, Zn), ppm	25 maximum total		
	2 maximum each		
Phosphorous	5 maximum		
23. Total PCB's (EPA SW-846, TN 8082)	not detectable		
24. Total Organic Halogens, ppm			
(EPA SW-846, TN 9253)	5 maximum		
25.* Modified Ames Test (ASTM E 1687)			
Fold Increase	Report		
Mutagenicity Index	1 maximum		
Mutagenicity Potency Index	Report		

Be prepared to describe differences (if any) between formulation(s) tested and the formulation for which approval is sought _____

Any other comments or data pertinent to the review of the product:

GM LUBRICANT SUBMISSION WORKSHEET LS-FORM 1

The following information will be required for an on-line submission of a lubricant for LS2 approval. On-line submissions can be made at: https://gmr2.ttsvcs.com/gmr2portal/Default.aspx

Product Name/No. _____

Product Type: Spindle Oil

GM Lubricant Standard No. LS- _____ ISO Viscosity Grade _____

The product above must meet the requirements of the standard shown, the tests must be run in qualified laboratories and the results shown must be on a product identical (within normal blending tolerances) in base fluid, additives and performance to the product offered for approval, unless any exceptions are specifically described in writing on the on-line submission . **NOTE: NO CHANGES CAN BE MADE TO A PRODUCT APPROVED WITHOUT REQUESTING REAPPROVAL.**

The lubricant contains the following base fluids (for non mineral oil fluids, skip source, method, %S)

Percent (vol)	Supplier	Method of Refining	% S	Viscosity at 40 °C, cSt
		Base Fluid Blend		

(e.g. Supplier = Exxon, Source = Mid-east, Method = Hydrotreating)

The lubricant contains the following additives.

Percent	Name of Thickener or Additive	Source	Generic Description

(e.g. Percent - indicate mass or volume, Name = PD-007, Source = Acme Additive Company
Generic Description = antiwear/antioxidant)

You will also need to include the following information:

1. Test Reports for those tests as indicated on the on-line submission (marked by an asterisk on Forms 2 and 3).
2. Completed and signed Material Safety Data Sheets (see LS2 - Appendix F for directions).
3. ISO or QS 9000 certificate.

_____ _____

(E-mail Address) (Name)

GM LUBRICANT SUBMISSION WORKSHEET LS-FORM 2

SUMMARY OF TEST RESULTS

Product Name/ No. _____

Product Type Spindle Oil

GM Lubricant Standard No. LS- _____ ISO Viscosity Grade _____

(NOTE: For Tests in red marked with *, must attach test report to on-line submission)

Test Procedure:	Specification	Result	Lab
1. Viscosity at 40 °C/ 100 °C (ASTM D 445)	_____ to _____	/	
2. Viscosity Index (ASTM D 2270)	95 minimum or report		
3. Pour Point (ASTM D 97)	_____ °C maximum.		
4. Cu Corrosion (ASTM D 130)	1b maximum		
5*. Thermal Stability - 168 h at 135 °C (ASTM D 2070)			
Neutralization Number Change	(+/-) 0.15 maximum		
Viscosity Change at 40/100 °C	5% maximum		
Sludge	25 mg/100 ml maximum		
Copper Rod Color (Cin. Mil)	5 maximum		
Copper Weight Loss	10 mg maximum		
Steel Rod Color (Cin. Mil.)	No Discoloration		
6*. Oxidation Stability TAN =2 (ASTM D 943)	_____ hr. minimum		
7. Rust Test (ASTM D 665B)	Pass (No Rust)		
8*. Water Separability - 55°C (ASTM D 1401)	40/40/0 (30 min) max.		
9. Foam Tendency - 190 ml fluid (ASTM D 892) - 10 min	settling		
Sequence I	50/0 maximum		
Sequence II	50/0 maximum		
Sequence III	50/0 maximum		
10. Four Ball Wear 20 kg load (ASTM D 4172)			
Wear Scar diameter	0.35 maximum or report		
11. API Gravity (ASTM D 287 or D 1298)	Report		
12. Flash Point (ASTM D 92)	_____ °C minimum		
13. Acid No. (ASTM D 974)	0.25 maximum or report		
14. Precipitation Number (ASTM D 91)	0.05 maximum		
15. Aniline Point (ASTM D 611)	85°C minimum		
16*. Compatibility with Seals (ISO 1817)			
SRE-NBR-1 Volume Change	-10 to 10% or report		
Shore A Hardness Change	-7 to 10 or report		
Other Volume Change	Report		
Seals Shore A Hardness Change	Report		
17. Cleanliness (ISO 4406)	/ / maximum		
18. Metals, typical range, mass % by (list method)	_____		
Zn	_____		
P	_____		
Ca	_____		
Mg	_____		
Ba	_____		
S	_____		
Others	_____		
19. Water (ASTM D 6304)	200 ppm maximum		

GM LUBRICANT SUBMISSION WORKSHEET LS-FORM 3

SUMMARY OF TEST RESULTS, CONT.

Product Name/ No. _____

Product Type Spindle Oil

GM Lubricant Standard No. LS- _____ ISO Viscosity Grade _____

Base Stock Requirements	Specification	Result	Lab
20.* Tot. PNA's ppm (EPA SW-846, TN 8270)	100 maximum		
21. Residual Elements (ASTM D 5185)			
(As, B, Ca, Mn, Na, Cu, Fe, Ni, Si, Sn			
Cd, Cr, Pb, Ba, Zn), ppm	25 maximum total		
	2 maximum each		
Phosphorous	5 maximum		
22. Total PCB's (EPA SW-846, TN 8092)	not detectable		
23. Total Organic Halogens, ppm			
(EPA SW-846, TN 9253)	5 maximum		
24.* Modified Ames Test (ASTM E 1687)			
Fold Increase	Report		
Mutagenicity Index	1 maximum		
Mutagenicity Potency Index	Report		

Be prepared to describe differences (if any) between formulation(s) tested and the formulation for which approval is sought _____

Any other comments or data pertinent to the review of the product:

GM LUBRICANT SUBMISSION WORKSHEET LW-FORM 1

The following information will be required for an on-line submission of a lubricant for LS2 approval. On-line submissions can be made at: https://gmr2.ttsvcs.com/gmr2portal/Default.aspx

Product Name/No. _____

Product Type: Way Oil

GM Lubricant Standard No. LW- _____ ISO Viscosity Grade _____

The product above must meet the requirements of the standard shown, the tests must be run in qualified laboratories and the results shown must be on a product identical (within normal blending tolerances) in base fluid, additives and performance to the product offered for approval, unless any exceptions are specifically described in writing on the on-line submission . **NOTE: NO CHANGES CAN BE MADE TO A PRODUCT APPROVED WITHOUT REQUESTING REAPPROVAL.**

The lubricant contains the following base fluids (for non mineral oil fluids, skip source, method, %S)

Percent (vol)	Supplier	Method of Refining	% S	Viscosity at 40 ^{o} C, cSt
		Base Fluid Blend		

(e.g. Supplier = Exxon, Source = Mid-east, Method = Hydrotreating)

The lubricant contains the following additives.

Percent	Name of Additive	Source	Generic Description

(e.g. Percent - indicate mass or volume, Name = PD-007, Source = Acme Additive Company Generic Description = antiwear/antioxidant)

You will also need to include the following information:

1. Test Reports for those tests as indicated on the on-line submission (marked by an asterisk on Forms 2 and 3).
2. Completed and signed Material Safety Data Sheets (see LS2 - Appendix F for directions).
3. ISO or QS 9000 certificate.

_____ _____

(E-mail Address) (Name)

GM LUBRICANT SUBMISSION WORKSHEET LW-FORM 2
SUMMARY OF TEST RESULTS

Product Name/ No. _____
Product Type Way Oil
GM Lubricant Standard No. LW- _____ ISO Viscosity Grade: _____

(NOTE: For Tests in red marked with *, must attach test report to on-line submission)

Test Procedure:	Specification	Result	Lab
1. Viscosity at 40 /100 °C (ASTM D 445)	_____ to _____ cSt	/	
2. Viscosity Index (ASTM D 2270)	Report		
3. Pour Point (ASTM D 97)	-15/-10/-5 °C maximum		
4. Cu Corrosion (ASTM D 130)	1b maximum		
5. Rust Test (ASTM D 665B)	Pass (No rust)		
6. Timken OK Load (ASTM D 2782)	_____ kg minimum		
7*. Water Separability (ASTM D 1401)	40/37/3 (30 min.) maximum		
8*. Demulsibility (ASTM D 2711)			
Water in Oil	1.0% maximum		
Emulsion	2.0% maximum		
Total Free Water	60 ml minimum		
9.* Stick Slip (ASTM D 2877-70)			
Ratio of static/kinetic coefficients of friction	0.80 maximum		
10. API Gravity (ASTM D 287)	Report		
11. Flash Point (ASTM D 92)	190 °C min (200°C - ISO 220)		
12. Sediment (ASTM D 473)	Nil		
13. Water (ASTM D 6304)	500 ppm maximum		
14. Precipitation Number (ASTM D 91)	0.05 maximum		
15. Cleanliness (ISO 4406)	20/18/14 maximum		
16. Tackifier added?	Report		
17. Metals, mass % by (list method) _____			
	Zn		
	P		
	Ca		
	Mg		
	Ba		
	S		
	Others		

GM LUBRICANT SUBMISSION WORKSHEET LW-FORM 3

SUMMARY OF TEST RESULTS, CONT.

Product Name/ No. _____

Product Type Way Oil

GM Lubricant Standard N. LW- _____ ISO Viscosity Grade: _____

Base Stock Requirements	Specification	Result	Lab
18.* Tot. PNA's ppm (EPA SW-846, TN 8270)	100 maximum		
19. Residual Elements (ASTM D 5185)			
(As, B, Ca, Mn, Na, Cu, Fe, Ni, Si, Sn			
Cd, Cr, Pb, Ba, Zn), ppm	25 maximum total		
	2 maximum each		
Phosphorous	5 maximum		
20. Total PCB's (EPA SW-846, TN 8082)	not detectable		
21. Total Organic Halogens, ppm			
(EPA SW-846, TN 9253)	5 maximum		
22.* Modified Ames Test (ASTM E 1687)			
Fold Increase	Report		
Mutagenicity Index	1 maximum		
Mutagenicity Potency Index	Report		

Be prepared to describe differences (if any) between formulation(s) tested and the formulation for which approval is sought _____

Any other comments or data pertinent to the review of the product:

GM LUBRICANT SUBMISSION WORKSHEET LX-FORM 1

The following information will be required for an on-line submission of a lubricant for LS2 approval. On-line submissions can be made at: https://gmr2.ttsvcs.com/gmr2portal/Default.aspx

Product Name/No. _____

Product Type: Straight Cutting or Grinding Oil

GM Lubricant Standard No. LX-00

The product above must meet the requirements of the standard shown, the tests must be run in qualified laboratories and the results shown must be on a product identical (within normal blending tolerances) in base fluid, additives and performance to the product offered for approval, unless any exceptions are specifically described in writing on the on-line submission . **NOTE: NO CHANGES CAN BE MADE TO A PRODUCT APPROVED WITHOUT REQUESTING REAPPROVAL.**

The fluid contains the following base fluids (for non mineral oil fluids, skip source, method, %S)

Percent (vol)	Supplier	Method of Refining	% S	Viscosity at 40 °C cSt
		Base Stock Blend		

(e.g. Supplier = Exxon, Source = Mid-east, Method = Hydrotreating)

The fluid contains the following additives.

Percent	Name of Additive	Source	Generic Description

(e.g. Percent - indicate mass or volume, Name = PD-007, Source = Acme Additive Company Generic Description = antiwear/antioxidant)

You will also need to include the following information:

1. Test Reports for those tests as indicated on the on-line submission (marked by an asterisk on Forms 2 and 3).
2. Completed and signed Material Safety Data Sheets (see LS2 - Appendix F for directions).
3. ISO or QS 9000 certificate.

_____ (E-mail Address)

_____ (Name)

GM LUBRICANT SUBMISSION WORKSHEET LX-FORM 2

SUMMARY OF TEST RESULTS

Product Type: Straight Cutting or Grinding Oil

GM Lubricant Standard No. LX-00 _____

(NOTE: For Tests in red marked with *, must attach test report to on-line submission)

For multiple test results, place the mean value in blank below and show raw data or data range in comments section

Test Procedure:		Specification	Result	Lab
1. Viscosity at 40 /100 °C (ASTM D 445)		Report	/	
2. Viscosity Index (ASTM D 2270)		Report		
3. Pour Point (ASTM D 97)		5°C maximum		
4. Flash Point (ASTM D 92)		____ °C min.		
5. Cu Corrosion (ASTM D 130)		1b maximum or report		
6. Rust Test (ASTM D 665B)		Pass (No rust)		
7. Four Ball EP (ASTM D 2783)				
	Load Wear Index, kg	45 kg minimum or report		
	Weld Load, kg	200 kg minimum or report		
8.* Compatibility with Seals (ISO 1817)				
SRE-NBR-1	Volume Change	Report		
	Shore A Hardness Change	-7 to 10		
Other	Volume Change	Report		
Seals	Shore A Hardness Change	Report		
9.* Oxidation Stability (ASTM D 2893)				
	Viscosity Increase	Report		
10. Foam Tendency - 190 ml fluid (ASTM D892) - 10 min settling				
	Sequence I	Report		
	Sequence II	Report		
	Sequence III	Report		
12. Misting Properties		As agreed upon		
13. Machining Properties		As agreed upon		
14. Coefficient of Friction by 4-ball (ASTM D5183)		Report		
15*. Thermal Stability - 168 hr at 135°C (ASTM D 2070)				
	Neutralization Number Change	Report		
	Viscosity Change at 40/100 °C	Report		
	Sludge	Report		
	Copper Rod Color (Cin. Mil.)	Report		
	Copper Weight Loss	Report		
16. Waste Treatability		As agreed upon		
17. Filterability 20um filter (ASTM D 2068)		Report		
18. Four Ball Wear, 20kg load (ASTM D 4172)		Report		
19. Base Number (ASTM D 2896)		Report		
20. Density (ASTM D 4052, D 1208)		Report		
21. Color (ASTM D 1500)		Report (indicate if dyed)		
22. Aluminum Corrosion (ASTM F 1110)				
	Al 319, Al 356, Al 380	1 maximum	/ /	
	Al 383, Al 390	1 maximum	/	
23. Metals, ppm by (list method) _____				
		Zn		
		Si		
		Na		
		others		

GM LUBRICANT SUBMISSION WORKSHEET LX-FORM 3

SUMMARY OF TEST RESULTS, CONT.

Product Name/ No. _____

Product Type Straight Cutting or Grinding Oil

GM Lubricant Standard N. LX-00 _____

	Specification	Result	Lab
24. Saponification Number (ASTM D 94)	Report		
25. Chlorine (ASTM D 808)	Report		
26. Total Sulfur (ASTM D129, D 4294, D 4951)	Report		
27. Active Sulfur (ASTM D 1662)	Report		
28. Esters (ASTM D 128 or as agreed upon)	Report		
29. Fatty Acids (ASTM D 128 or as agreed upon)	Report		
30. Acid Number, mg KOH (ASTM D 664)	Report		
31. Volatile Organics (TGA or oven, ASTM E 1131)	Report		
32. Odor (ASTM D 1311)	Report		
Base Stock Requirements#:			
33.* Tot. PNA's ppm (EPA SW-846, TN 8270)	100 maximum		
34. Residual Elements (ASTM D 5185)			
(As, B, Ca, Mn, Na, Cu, Fe, Ni, Si, Sn			
Cd, Cr, Pb, Ba, Zn), ppm	25 maximum total		
	2 maximum each		
Phosphorous	5 maximum		
35. Total PCB's (EPA SW-846, TN 8082)	not detectable		
36. Total Organic Halogens, ppm			
(EPA SW-846, TN 9253)	5 maximum		
37.* Modified Ames Test & (ASTM E1687)			
Fold Increase	Report		
Mutagenicity Index	1 maximum		
Mutagenicity Potency Index	Report		

only required for mineral oil components

Be prepared to describe differences (if any) between formulation(s) tested and the formulation for which approval is sought _____

Any other comments or data pertinent to the review of the product:

GM LUBRICANT SUBMISSION WORKSHEET LY-FORM 1

The following information will be required for an on-line submission of a lubricant for LS2 approval. On-line submissions can be made at: https://gmr2.ttsvcs.com/gmr2portal/Default.aspx

Product Name/No. _____

Product Type: (Circle one) Soluble Semi-Synthetic Synthetic

GM Lubricant Standard No. LY-00 _____

The product above must meet the requirements of the standard shown, the tests must be run in qualified laboratories and the results shown must be on a product identical (within normal blending tolerances) in base fluid, additives and performance to the product offered for approval, unless any exceptions are specifically described in writing on the on-line submission . **NOTE: NO CHANGES CAN BE MADE TO A PRODUCT APPROVED WITHOUT REQUESTING REAPPROVAL.**

For complete MRF Approval, be prepared to complete ALL sections.
For MRF base oil approvals only, use MRFBO Submission Worksheet

BASE FLUID COMPOSITION

Mineral oil formulations: indicate percent, supplier (e.g., Exxon), source (e.g., Middle East), method (e.g., hydrotreating), %S: and viscosity @40 of both the components and the blend.
Non-mineral oil formulation: indicate major components of the fluid and viscosities (skip source, method, %S)

Percent (vol)	Supplier	Method of Refining	% S	vis@ 40 °C cSt
		Base Stock Blend		

ADDITIVES (e.g. Percent - indicate mass or volume, Name = PD-007, Source = Acme Additive Company, Generic Description = antiwear/antioxidant)

Percent	Name of Additive	Source	Generic Description

You will also need to include the following information:
1. Test Reports for those tests as indicated on the on-line submission (marked by an asterisk on Forms 2 and 3).
2. Completed and signed Material Safety Data Sheets (see LS2 - Appendix F for directions).
3. ISO or QS 9000 certificate.

_____ (E-mail Address)

_____ (Name)

GM LUBRICANT SUBMISSION WORKSHEET LY-FORM 2

SUMMARY OF TEST RESULTS

Product Name/ No. _____

Product Type: (Circle one) Soluble Semi-Synthetic Synthetic

GM Lubricant Standard No. LY-00 _____

(NOTE: For Tests in red marked with *, must attach test report to on-line submission)

For multiple test results, place the mean value in blank below and show raw data or data range in comments section

Test Procedure:	Specification	Result	Lab
1. Viscosity at 40 /100 °C (ASTM D 445)	Report		
2. Pour Point, °C (ASTM D 97)	Report		
3. Flash Point, °C (ASTM D 92)	Report		
These tests to be run on the undiluted concentrate:			
4. Four Ball EP (ASTM D 2783)			
Load Wear Index, kg	45 kg minimum or report		
Weld Load, kg	200 kg minimum or report		
5. Emulsion Stability (AFNOR NFT 60-187)# @	Report		
6. Cu Corrosion (ASTM D 130)	1b max or report		
7*. Cast Iron Chip Rust Test (ASTM D 4627)	Report breakpoint conc.		
8. Corrosive Effect on Aluminum (ASTM F 1110)			
Al 319, Al 356, Al 380	1 maximum	/ /	
Al 383, Al 390	1 maximum	/	
9.* Compatibility with Seals (ISO 1817)			
SRE-NBR-1 Volume Change	Report		
Shore A Hardness Change	-7 to 10		
Other Volume Change	Report		
Seals Shore A Hardness Change	Report		
These tests to be run at the manufacturer's recommended concentration using the standard water specified in LS2 LY-, Appendix A, p. 5-102, or local plant water as agreed upon between the user and supplier.			
10. Foam by blender test, run in both deionized and standard water (ASTM D 3519)			
Maximum Foam Height	Report	/	
Time to Defoam to 10 mm	Report	/	
After Filterability test: Max. Foam Height	Report	/	
Time to Defoam to 10 mm	Report	/	
11. Filterability, 20 um filter paper (ASTM D 2068)	Report FBT		
12. Phosphorus, % (ASTM 4927)	Report		
13. Misting Properties	As agreed upon		
14. Machining Properties	As agreed upon		
15. Coefficient of Friction by 4-ball (ASTM D 5183)	Report or NA		
16. Sticking, Gumming Tendency (LS2, p. 5-103)			
Fluid or non-fluid?	Report		
Appearance of residue	Report		
Resolubility of residue at 15 sec, 24 h	Report	/	
17. Bioresistance, 5% solution (ASTM D 3946)			
Bacteria, fungal count, 0 days	Report	/	
5 days	Report	/	
8 days	Report	/	
13 days	Report	/	
18. Tramp Oil Rejection, 5% solution, 24 h (ASTM D 1401 w/ water replaced w/hydr. Oil)			
Oil Layer/Emulsion/Product Layer, ml	Report	/ /	

Soluble oils

@ Semi-synthetics

GM LUBRICANT SUBMISSION WORKSHEET LY-FORM 3

SUMMARY OF TEST RESULTS, CONT.

Product Name/ No. _____

Product Type: (Circle one) Soluble Semi-Synthetic Synthetic

GM Lubricant Standard No. LY-00 _____

	Specifications		Result	Lab
19. Waste Treatability				
Biochemical Oxygen Demand (EPA 405.1)	Report			
Chemical Oxygen Demand (EPA 410.1)	Report			
Total Kjeldahl Nitrogen (EPA 351.3)	Report			
20. Base Number, mg KOH (ASTM D 2896)	Report			
21. pH at 5% dilution (ASTM E 70)	Report			
These tests to be run on the undiluted concentrate:				
22. Color (ASTM D 1500)	Report (indicate if dyed)			
23. Metals, ppm by (list method) _____		B		
		Ca		
		Na		
		Si		
		Others		
24. Density (ASTM D 4052, D 1298)	Report			
25. Mineral base oil content, mass %	Report			
26. Chlorine (ASTM D 808)	Report			
27. Total Sulfur (ASTM D 129, D 4294, D 4951)	Report			
28. Active Sulfur (ASTM D 1662)	Report			
29. Esters (ASTM D 128 or as agreed upon)	Report			
30. Fatty Acids (ASTM D 128 or as agreed upon)	Report			
31. Recommended hardness range of water	Report			
Base Stock Requirements#				
32.* Tot. PNA's ppm (EPA SW-846, TN 8270)	100 maximum			
33. Residual Elements (ASTM D 5185)				
(As, B, Ca, Mn, Na, Cu, Fe, Ni, Si, Sn				
Cd, Cr, Pb, Ba, Zn), ppm	25 maximum total			
	2 maximum each			
Phosphorous	5 maximum			
34. Total PCB's (EPA SW-846, TN 8092)	not detectable			
35. Total Organic Halogens, ppm				
(EPA SW-846, TN 8092)	5 maximum			
36.* Modified Ames Test (ASTM E 1687)				
Fold Increase	Report			
Mutagenicity Index	1 maximum			
Mutagenicity Potency Index	Report			

only required for mineral oil components

Be prepared to describe differences (if any) between formulation(s) tested and the formulation for which approval is sought _____

Any other comments or data pertinent to the review of the product: _____

GM LUBRICANT SUBMISSION WORKSHEET LMRFBO-FORM 1

The following information will be required for an on-line submission of a lubricant for LS2 approval. On-line submissions can be made at: https://gmr2.ttsvcs.com/gmr2portal/Default.aspx

MRF Supplier and Product Name/No. _____

Base Fluid Type: Naphthenic / Paraffinic / Other (specify) _____

Crude Source and Refinery or Synthetic Fluid Supplier _____

The product above must meet the requirements of the standard shown, the tests must be run in qualified laboratories and the results shown must be on a product identical (within normal blending tolerances) in base fluid, additives and performance to the product offered for approval, unless any exceptions are specifically described in writing on the on-line submission . **NOTE: NO CHANGES CAN BE MADE TO A PRODUCT APPROVED WITHOUT REQUESTING REAPPROVAL.**

Supplier/Source	Method of Refining	% S	Viscosity at 40 ^{o}C cSt

(e.g. Supplier = Exxon, Source = Mid-east, Method = Hydrotreating, or (for synthetics) Glycol, etc.)

You will also need to include the following information:

1. Test Reports for those tests as indicated on the on-line submission (marked by an asterisk on Forms 2 and 3).
2. Completed and signed Material Safety Data Sheets (see LS2 - Appendix F for directions).
3. ISO or QS 9000 certificate.

_____ (E-mail Address)

_____ (Name)

GM LUBRICANT SUBMISSION WORKSHEET LMRFBO-FORM 2

SUMMARY OF TEST RESULTS

Base Fluid Type: Naphthenic / Paraffinic / Other (specify)

Crude Source and Refinery or Synthetic Fluid Supplier

(NOTE: For Tests in red marked with *, must attach test report to on-line submission)

For multiple test results, place the mean value in blank below and show raw data or data range in comments section

Test Procedure:	Specification	Result	Lab
1. Viscosity at 40 °C (ASTM D 445)	Report		
2. Viscosity at 100 °C (ASTM D 445)	Report		
3. Viscosity Index (ASTM D 2270)	Report		
4. Pour Point (ASTM D 97)	5°C maximum or Report		
5. Flash Point (ASTM D 92)	Report		
6. Phosphorus, % (ASTM 4927)	Report		
7. Base Number (ASTM D 2896)	Report		
8. Density (ASTM D 4052, D 1208)	Report		
9. Color (ASTM D 1500)	Report (indicate if dyed)		
10. Saponification Number (ASTM D 94) straight oils	Report		
11. Chlorine (ASTM D 808)	Report		
12. Total Sulfur (ASTM D129, D 4294, D 4951)	Report		
13. Active Sulfur (ASTM D 1662)	Report		
14. Esters (ASTM D 128 or as agreed upon)	Report		
15. Fatty Acids (ASTM D 128 or as agreed upon)	Report		
16. Acid Number, mg KOH (ASTM D 664)	Report		
17. Volatile Organics (TGA or oven, ASTM E 1131)	Report		
18. Odor (ASTM D 1311)	Report		
19. pH at 5% dilution (ASTM E 70) aqueous fluids only	Report		
20. Mineral base oil content, mass %	Report		
21. Recommended hardness range of water aqueous fluids			
22. Metals, ppm by (list method) _____	Zn		
	Si		
	Na		
	others		
23.* Tot. PNA's ppm (EPA SW-846, TN 8270)	100 maximum		
24. Residual Elements (ASTM D 5185)			
(As, B, Ca, Mn, Na, Cu, Fe, Ni, Si, Sn			
Cd, Cr, Pb, Ba, Zn), ppm	25 maximum total		
	2 maximum each		
Phosphorous	5 maximum		
25. Total PCB's (EPA SW-846, TN 8082)	not detectable		
26. Total Organic Halogens, ppm			
(EPA SW-846, TN 9253)	5 maximum		
27.* Modified Ames Test & (ASTM E1687)			
Fold Increase	Report		
Mutagenicity Index	1 maximum		
Mutagenicity Potency Index	Report		

*only required for mineral oil components

Be prepared to describe differences (if any) between formulation(s) tested and the formulation for which approval is sought

Any other comments or data pertinent to the review of the product:

GENERAL MOTORS CORPORATION
MATERIAL SAFETY DATA SHEET INFORMATION REQUIREMENTS

Introduction

The following policies and instructions are intended as guidelines for the completion of material safety data sheets (MSDS's) to General Motors' (GM) standards. The information provided will be used in programs to protect the health, safety and environment of individuals and communities associated with GM sites. The chemical manufacturer, importer, distributor or employer preparing the MSDS shall ensure that the information recorded accurately reflects the scientific evidence used in making the hazard determination and complies with all applicable international, national, state, province, and local laws. An MSDS for a product used in the United States **must** have a statement indicating that all ingredients in the product are listed on the TSCA inventory or, if exempt, the reason for the exemption.

Materials that require MSDS's

- All liquids, gases, pastes, powders, flakes, gels, aerosols, and many solids.
- Any product that generates dust, fumes, fog, vapor, etc., during shipping, storage, handling, use, or disposal.
- Any product with specific ventilation requirements.
- Any product with personal protective equipment (PPE) requirements or recommendations.
- Any product stored in a pressurized cylinder or container.
- Any product that emits radiation higher than background.
- Any product intended to be altered, processed, etc., (e.g., cut, mold, grind).
- Lubricants or coatings on steel or other articles.
- "Articles" that will be processed by GM.
- "Consumer products" that are not used in a manner typical to a consumer.

Examples of these products include but are not limited to:

Abrasives
Acids & caustics
Adhesives & sealers
Castings, forging
Cleaners
Compressed gases
Coolants & metalworking fluids
Flux (e.g., soldering)
Fuels (e.g., coal & gasoline)
Insulating materials
Lubricating oils & greases
Nylons & other plastics
Office supplies containing hazardous chemicals
Oxidizers
Paint & related chemicals
Pesticides & biocides
Printer's inks
Resins
Soaps
Solder
Solvents
Steel
Welding rods & wires
Wood

✪: Indicates an essential information standard that must be met for all products.

General instructions (Applicable to all MSDS's submitted to GM)

Language
The MSDS must be provided in the language of the country of origin and in the language of the country of destination. A copy of the MSDS must also be available in English.

Readability
The MSDS must be legible. Font, point type, margin width and format for an MSDS must allow for quality reproduction, copying, and faxing.

Blanks/Negative Responses
Blank data fields are not acceptable as a negative response. Terms like "not applicable (NA)", "not established (NE)", "not available", "none", "none known", "unknown", "not determined", etc., may be accepted in place of data on the MSDS or addendum. If abbreviations are used for these terms, a legend should be provided explaining them. For Canadian use, only "not applicable" (not app) or "not available" (not ava) can be used as a negative response for a Workplace Hazardous Materials Information System (WHMIS) controlled product.

Full Disclosure
Ingredients listed in **Section 2** or on the addendum must add up to at least 100%. (See **Section 2** of this document for details.)

Confidentiality Policy
Any MSDS, attachment or addendum marked "confidential" "proprietary" "trade secret" or words to that effect will be returned to the supplier or destroyed. Material marked "for GM use only" will be accepted but will not constitute a secrecy agreement on the part of GM. **GM does not sign secrecy agreements**. (See **Section 2** of this document for guidelines on protecting trade secret information.)

Addendum/Addenda
GM does not have a standard MSDS format. (Form TMC002 has been obsolete for several years.) Instead, your company's MSDS should be submitted along with a separate page listing any remaining data required by GM. It may be called an addendum, attachment, additional information or words to that effect. This addendum, however, must be clearly labeled with the trade name and should be dated.

Regulatory Compliance
All suppliers are expected to comply with local, regional, national and international regulations. For example, the US and Canada maintain listings (Toxic Substance Control Act (TSCA) and Domestic Substance List (DSL), respectively) of chemicals approved for commercial commerce within their borders that may require usage reports and/or are restricted in some fashion. **Suppliers must include this information on the MSDS**. Furthermore, the MSDS or addendum must include:

- A listing of all ingredients constituting 1% or more of the product
- A listing of all ingredients constituting 0.1% or more of the product that are recognized as carcinogens
- Written statements of compliance to all local, regional, national and international regulations for all non-listed ingredients constituting less than 1% of the product

(See **Section 2** of this document for details.)

✪: Indicates an essential information standard that must be met for all products.

Dates (Policy & Definitions)

- The MSDS date of preparation or effective/revision date must be less than 3 years old when initially received by General Motors. (See **Section 1** for exceptions to this rule.) Although it is GM's goal to maintain an up-to-date MSDS for each product used by GM for US sites, GM only requires an updated MSDS when a change to the MSDS occurs. However, GM facilities in Canada must have MSDS's that are less than 3 years old.
- Date of Preparation - The date the MSDS was prepared or originated. This could also be the effective/revision date.
- Effective/Revision Date - The date the MSDS is considered to be as complete and accurate as possible in describing the product as provided and relevant information such as manufacturer/supplier name, address and phone number. The effective and/or revision date will change as the product formulation changes or when new data on health, safety, environmental impact, regulations, toxicology or handling information becomes available.
- Print Date - The print date will not be considered the effective date.

Essential versus Optional Information

The following 16-section format, based on the ISO 11014 and ANSI Z400.1 standards, is the preferred format for an MSDS, but other formats are acceptable.

Those items identified with a circled star (✪) represent minimum requirements that must be met for all materials. Those items not identified with ✪ are not required, but are desirable.

Data sheets and addenda that do not meet these requirements will be labeled non-compliant and remain so as long as these key areas of information are not provided. In these cases, GM sites will be encouraged to find alternate materials from compliant suppliers. Suppliers are strongly encouraged to supply all the other remaining information but will not be labeled as non-compliant if that information is incomplete.

The following are section-by-section instructions for Sections 1 - 16 of the MSDS's.

SECTION 1 - Product and Company Identification

✪ 1. Indicate the product name or number **as it appears on the label**.
✪ 2. Provide appropriate synonyms that apply to the product.
✪ 3. Indicate the name of the manufacturer **as it appears on the label**. If the supplier is different from the manufacturer, then clearly identify the responsible party (ies) preparing or distributing the MSDS who could provide additional information on chemical components and/or emergency procedures. Include complete addresses and phone numbers for each party. Indicate the specific nature of the phone numbers such as information, fax, emergency, national emergency response lines (e.g., CHEMTREC - Chemical Transportation Emergency Center USA, NRC - National Response Center USA, CCOHS - Canadian Center for Occupational Health and Safety).
4. Indicate the preparer's name and title and include a phone number if it is different from the emergency or information phone number.
✪ 5. Clearly indicate the date of preparation or the revision/effective date of the MSDS. If the date is more than three years old and no changes have been made to the data sheet (e.g. area code, address, verbiage) or the product, then a written statement with a current date may be submitted and it will be considered the effective date in lieu of revising the document.

✪: Indicates an essential information standard that must be met for all products.

SECTION 2 - Composition/Information on Ingredients

✪ 1. General Motors requires 100% disclosure of all ingredients found in a product. This means an ingredient present at 1% or greater (0.1% for carcinogens) must be listed, even if it is generally considered non-hazardous (e.g., water). In addition, ingredients present at less than 1% in the product must be listed if those ingredients would be present at 1% or greater in the "dry" product. (For example, if zinc oxide is present at 0.7% in the product as shipped, but is present at 1.2% after applying the product to a substrate, this ingredient must be listed.) If a CAS (Chemical Abstract Services) registry number exists for an ingredient, it must be listed along with the proper chemical name or common chemical name or synonym on the MSDS or addendum. Exceptions to CAS number disclosure for trade secret ingredients may be granted if a good chemical description is provided (see below for an explanation of a "good chemical description").

If a CAS registry number of an ingredient is not available because the item is not a discrete chemical that can be represented by a chemical formula or is a mixture where the identity of individual components may be unknown or may vary, then a good chemical description must be provided. **Examples** of good chemical descriptions include, but are not limited to, those shown in the following table:

Unacceptable Name	Acceptable Name
Resin	[Alkyd or benzophenol or other] resin (see other examples below)
Urethane resin/polymer	Diphenylmethane diisocyanate (MDI) based urethane resin
Polyurethane resin/polymer	Diphenylmethane diisocyanate (MDI) based urethane resin
Hydrocarbon resin	Alkyd resin
Plasticizer	Phthalate plasticizer
Surfactant	Linear alkyd sulfonate (LAS), non-ionic, cationic, anionic
UV Absorber	Benzotriazole
Additive	A specific chemical family is required
Epoxy resin	Bisphenol A diglycidyl ether epoxy resin
Phenol resin/polymer	benzophenol based resin
Thickener	Starch (gelatin, semi-synthetic cellulose)
Pigment or Colorant	Yellow iron oxide pigment
Inhibitor	Acetanilide
Antioxidant	β-Naphthylamine
Curing agent	TDI based urethane prepolymer
Emulsifier	Fatty acid emulsifier
Detergent	Alkyl benzene sulfonate (ABS)

If hazards are attributed to a component or impurity in this ingredient, then this information should be cited. In these situations where CAS numbers are not available, PMN (Premanufacturing Notification) numbers or EPA (Environmental Protection Agency) Accession Numbers or equivalent should be submitted. New Jersey Trade Secret Numbers (NJT #) are not acceptable.

It **is not** the intention of General Motors to obtain exact formulations of trade secret ingredients. It **is** the intention of General Motors to protect the environment and the

✪: Indicates an essential information standard that must be met for all products.

health and safety of its employees and to comply with regulatory reporting requirements. Therefore, "trade secret" ingredients should be used infrequently, and then, only with a good chemical description in its stead. With that in mind, GM will not label MSDS's as GM compliant unless ingredient information meets the requirements listed above

Ingredients may be segregated by subheadings such as hazardous and non-hazardous ingredients or words to that effect. As mentioned above, **all ingredients constituting 1% or more of the product must be listed. Components recognized as carcinogens by IARC (International Agency for Research on Cancer), or in the United States by NTP (National Toxicology Program) or OSHA (Occupational Safety and Health Administration), must be listed if they are present in the product at concentrations of 0.1% or greater.** In addition, biocides used in metalworking fluids, flame retardants, and pigments having concentrations of 0.1% or greater must be listed. Disclosure must comply with country of origin and country of destination classification of hazardous and carcinogenic substances.

Items subject to national reporting requirements by CAS registry number, such as SARA (Superfund Amendments and Reauthorization Act) in the USA and NPRI (National Pollutant Release Inventory) in Canada, must always be submitted with CAS registry numbers. Known or suspected carcinogens must also be reported with CAS registry numbers. <u>These items cannot be claimed as trade secret</u>.

✪ 2. Indicate the percentage of each ingredient in the product and identify if the value represents percent by weight or percent by volume. Ranges should be within ± 5% of the true value for all components (both hazardous and non-hazardous). Exceptions will be made in those situations where a ± 5% range will not accurately describe the product (e.g., when the base oils vary from batch to batch depending on crude oil availability). For a WHMIS controlled product for Canadian use, ranges must comply, at a minimum, with WHMIS regulations. Summation of exact percentages must equal 100%. Summation of maximum ranges must equal or exceed 100%. Summation of minimum ranges must equal or be less than 100%. **Carcinogens and chemicals subject to national reporting requirements by CAS registry number (e.g., SARA 313, NPRI) should be given in exact percentages**. For non-carcinogenic ingredients present in the product at <1%, but still provided on the MSDS, T for trace will be accepted in place of a numeric value (for carcinogenic, biocide, flame retardant, and pigment ingredients, T may be used for items < 0.1%). One item on the list may be listed as "balance" or "remainder".
   - If the ingredient is present in the product at less than 1% and is not a hazardous substance, carcinogen, or known to cause toxicological problems in and of itself, or during processing, but is still provided on the MSDS, then a functional description such as "additive" will be acceptable.
   - In addition, similar items may be grouped (e.g., "colorants"), even if their total is greater than 1% (0.1% for appropriate chemicals), <u>provided</u> that no one chemical is present in the product at > 1%.

✪ 3. List appropriate exposure guidelines or limits for all of the product's components identifying the source, e.g., OSHA PEL (Occupational Safety and Health Administration Permissible Exposure Limits), ACGIH TLV (American Conference of Governmental Industrial Hygienists Threshold Limit Values), NIOSH REL (National Institute of Occupational Safety and Health Recommended Exposure Limits),

✪: Indicates an essential information standard that must be met for all products.

manufacturer standard, etc., and clearly indicating the units of measure for the given guidelines.

✪ 4. For any ingredient that is not identified by the CAS number, the following toxicological information requirements apply.
- If the component is greater than 10% of the chemical material, industrial hygiene sampling, monitoring and/or toxicological data must be provided on the component.
- If the component is less than 10% of the chemical material, industrial hygiene sampling, monitoring and/or toxicological data may be required.
- If industrial hygiene or toxicity information is not available, then a statement or words to that effect must appear on the MSDS or addendum.

See **Sections 3, 8, 9, 10** and **11** for examples of industrial hygiene and toxicology information.

SECTION 3 - Hazards Identification

1. Provide a clear, brief emergency overview describing the material's appearance and most significant immediate concerns for emergency response personnel. This section may contain adverse human health effects, environmental effects, physical or chemical hazards.

✪ 2. Indicate the primary routes of entry such as skin, eye, inhalation, and ingestion or any combination thereof. If no applicable information is available; then a statement or words to that effect must appear on the MSDS or addendum.

✪ 3. Describe medical conditions (e.g., asthma), which are generally recognized as being aggravated by exposure to the product or its constituents. If no applicable information is available, then a statement or words to that effect must appear on the MSDS or addendum.

SECTION 4 - First-Aid Measures

✪ 1. Provide emergency and first aid instructions to be followed in the event of overexposure to the product. If no applicable information is available, then a statement or words to that effect must appear on the MSDS or addendum.

2. Describe any procedures to be used by trained medical personnel above and beyond first-aid procedures in event of overexposure.
3. List any known antidotes, if applicable.
4. Include notes to physicians, if applicable.
5. Provide advice for the protection of first-aiders, if appropriate.

SECTION 5 - Fire-Fighting Measures

✪ 1. Indicate the flash point of the product and specify the method used. Use exact values whenever possible. For those instances where the flash point is difficult to determine (e.g., it boils out of the cup), or extremely dangerous to test, the following convention will be accepted: if the flash point is greater than 212°F (100°C), then >212°F (100°C) may be used if the actual value is unknown. If the flash point is less than 0°F (-17°C), then <0°F (-17°C) may be used. If no applicable information is available, then a statement or words to that effect must appear on the MSDS or addendum.

✪ 2. LEL/UEL (Lower Explosive Limits/Upper Explosive Limits) must be provided for

✪: Indicates an essential information standard that must be met for all products.

liquids and gases. If no applicable information is available, then a statement or words to that effect must appear on the MSDS or addendum.

3. List autoignition temperature for the product, if applicable.
✪ 4. Specify the appropriate fire extinguishing media. If no applicable information is available, then a statement or words to that effect must appear on the MSDS or addendum.
✪ 5. Indicate fire or explosion hazards. If no applicable information is available, then a statement or words to that effect must appear on the MSDS or addendum.
6. Describe special fire fighting procedures, if applicable.
✪ 7. Give health, flammability and reactivity ratings for the product using NFPA criteria, if available.

SECTION 6 - Accidental Release Measures

✪ 1. Indicate steps to be taken in case material is released or spilled including recovery, neutralization or disposal if they are different than Section 13.
2. Describe expected environmental impact resulting from the release of the product.
3. Provide information on secondary hazards and their prevention (e.g., contaminated surfaces may be slippery, post appropriate warnings, etc.).

SECTION 7 - Handling and Storage

✪ 1. Indicate storage precautions (e.g., incompatible products, conditions to avoid, temperature requirements, etc.,). If no applicable information is available, then a statement or words to that effect must appear on the MSDS or addendum.
2. Indicate handling precautions recommended for other activities associated with the product such as grinding, power sanding, welding, etc.

SECTION 8 - Exposure Controls/Personal Protection

✪ 1. If appropriate, indicate engineering measures or controls recommended to reduce exposure including ventilation type and rate.
✪ 2. Provide any generally applicable personal protective equipment (PPE) recommendations in accordance with the intended use of the product **including specific suitable materials** (e.g., neoprene gloves - not impervious gloves; safety glasses - not eye protection; organic vapor respirator - not respirator) for respiratory, hand, eye, skin and/or body protection. If applicable, include qualifiers such as processing conditions, quantities, concentrations, temperature and/or pressure conditions that warrant special and/or additional PPE precautions. If no applicable information is available, then a statement or words to that effect must appear on the MSDS or addendum.
✪ 3. If appropriate, indicate any specific hygiene measures or practices that should be followed.

SECTION 9 - Physical and Chemical Properties

✪ 1. Identify the physical and chemical properties that characterize the product including specific information on physical state. Report data in appropriate units of measurement with pertinent reference conditions and/or test methods. If a change of physical state is foreseeable within the context of normally expected conditions or uses, details of those changes, including the new physical and chemical properties, must be provided.

✪: Indicates an essential information standard that must be met for all products.

✪ 2. List the specific gravity or a range for all liquid and semi solid materials (water = 1). If a range must be used, then it should be no greater than ± 0.05. In the case of compressed gases, list the pressure expected within containers under normal circumstances.

✪ 3. Indicate the density of the product.

✪ 4. Provide the theoretical or analytical Volatile Organic Content (VOC) in lbs/gal, gms/liter, or percent by weight, or if a solid, in gms/gm or lbs/lb.

- **For SURFACE COATINGS (such as paints, inks, and adhesives) and SOLVENT-BASED MATERIALS**, **analytical VOC content** is preferred for all products and **is required for productive materials**. The analytical method used must be U.S. EPA Method 24 or 24a.
- **For METALWORKING FLUIDS (water-based coolants, drawing compounds, and cutting oils) and PRODUCTION PARTS WASHER FLUIDS, the analytical VOC content must be determined using U.S. EPA Method 24.** For these materials, US EPA Method 24, ASTM D2369 (Section 1.7 and footnote 3), should be used**. ASTM D2369 allows for the actual time and temperature used to cure the material in practice to be substituted for the specified time and temperature in the test procedure (i.e., 1 hour at 110° C). GM recommends that this alternative be used when applicable.** In addition, U.S. EPA Method 24 allows the use of ASTM D3792 (water content by Gas Chromatograph) or ASTM 4017 (water content by Karl Fischer Method) to be used to determine the percent water content.
- For **FOUNDRY CORE RESINS, CORE COATINGS, CORE AND MOLD RELEASE AGENTS, CORE OR PATTERN ADHESIVES AND OTHER RELATED FOUNDRY MATERIALS, the analytical VOC content** is preferred for all foundry related products, and **is required for productive and non- productive materials**. The analytical method used must be U.S. EPA Method 24 or 24a.
- If the VOC is 0 lb/gal, then a statement such as 0, zero, none, no VOC present, or words
- To that effect must appear on the MSDS or addendum.
- If the product obviously has no VOC content because of its ingredients, physical state (e.g., wood, oxygen, welding rod, inorganic) or generally accepted processing practices, then the VOC statement does not have to appear on the MSDS or addendum. If the product releases VOCs during processing (e.g., plastics, elevated temperatures), then a VOC value as described above must be reported.

✪ 5. If appropriate, provide a pH value or description. Use exact values whenever possible. Terms such as acidic, neutral, caustic, or alkaline may be accepted in some rare situations, but more specific information such as <4 or >10 is to be used when actual values are not available. For materials that will be diluted and where pH measurements are appropriate, provide the pH of both the packaged material (i.e., concentrate) and diluted material. When a dilution pH is given, list the dilution percentage. If no applicable information is available, then a statement or words to that effect must appear on the MSDS or addendum.

6. Indicate the specific temperature or temperature ranges at which changes in physical state occur (e.g., boiling point, freezing/melt point).
7. Indicate the vapor density and specify the temperature at which it was determined.
8. Indicate the vapor pressure in mm Hg and specify the temperature at which it was determined.
9. Indicate the percent solid by weight, and for paints, by volume.
10. Indicate the evaporation rate. Specify the reference solvent (e.g., n-butyl acetate or ether as equal to 1).
11. Indicate the product's solubility in water.
12. Indicate the molecular weight of products that are pure chemicals (e.g., gases).
13. Indicate the viscosity of the product as supplied, specify the temperature at which it was determined and the method used for that determination.

✪ 14. Include additional chemical and physical data as deemed necessary to promote safe use and handling of the product (e.g., color, odor, radioactivity, particle size, softening point, octanol/water partition coefficient).

✪: Indicates an essential information standard that must be met for all products.

SECTION 10 - Stability and Reactivity

✪ 1. State if the material is stable or unstable under normal, anticipated storage and handling conditions of ambient temperature and pressure.

✪ 2. Indicate any hazardous material releases that will or may occur including both potential and actual releases through normal processes such as baking, welding, spraying, etc., that are not specifically listed as ingredients in **Section 2** or listed below as hazardous decomposition products.

3. List any conditions such as heat, pressure, shock, or other physical stresses that might result in a hazardous situation.
4. Indicate incompatible materials that the product could react with to produce a hazardous situation.

✪ 5. Indicate hazardous decomposition products produced by burning, oxidation, heating or chemical reaction (e.g., phenol, formaldehyde and isocyanates.)

6. State if the material is subject to hazardous polymerization and specify the conditions that might induce polymerization.

SECTION 11 - Toxicological Information

✪ 1. Summarize the information on the various possible health effects which might arise if the user comes in contact with the product. If no data is available on the product, then information on the hazardous constituents may be used. Information may cover clinical test data on acute toxicity (e.g., LD50-oral/dermal [species specific], LC50-inhalation [species specific]), irritation scores, target organs, effect and no-effect levels, species differences, local effects, subchronic and/or long-term toxicity, and sensitization. If applicable, list the information according to different exposure routes (e.g., inhalation, skin contact, eye contact and ingestion).
   - If applicable, list effects due to single exposure, repeated exposure and continuous exposure.
   - If applicable, list immediate and delayed effects.
   - If applicable, include specific results from studies or reports in areas such as teratogenicity, neurotoxicity, mutagenicity, reproductive effects and epidemiology.

✪ 2. State the carcinogenic status of any ingredient per NTP, IARC, OSHA, ACGIH and/or any other source appropriate to the country of origin and the country of destination.

SECTION 12 - Ecological Information

1. Summarize information on the possible environmental effects of the material including potential environmental impact, soil mobility, product persistence or degradability, bioaccumulation and ecotoxicology data. If no applicable information is available, then a statement or words to that effect should appear on the MSDS or addendum.
2. Provide a Material Environmental Data Sheet (MEDS), if available.

SECTION 13 - Disposal Considerations

✪ 1. Recommend methods for safe and environmentally preferred disposal of uncontaminated bulk product, residue, or emptied packaging.

✪: Indicates an essential information standard that must be met for all products.

SECTION 14 - Transport Information

✪ 1. List appropriate national and international information on codes, classifications, hazardous material descriptions, proper shipping names and packing groups for regulatory purposes differentiated by mode of transport.

- US Suppliers: indicate Department of Transportation (DOT) hazardous materials description/proper shipping name, hazard class, UN (United Nations)/NA (North American) identification numbers and packing group according to 49 CFR 172.101 and other international restrictions as applicable. Include classification changes based on quantity, packaging or shipment. If the material is not regulated by DOT, include a statement to that effect.
- Canadian Suppliers: indicate Transportation of Dangerous Goods (TDG) classification and/or other international restrictions as applicable.

2. Indicate additional transportation restrictions.
3. Specify any precautionary transport measures and/or conditions.

SECTION 15 - Regulatory Information

✪ 1. Indicate information on regulations specifically applicable to the chemical product and/or its constituents and include appropriate international and national requirements.

- US:
  - ⇒ List the chemical identity of any EPCRA (SARA Title III) 302 Extremely Hazardous Substance. Provide its threshold planning quantity (TPQ) and its reportable quantity (RQ).
  - ⇒ Indicate the appropriate categories for the product under EPCRA (SARA Title III) 311 and 312 (i.e., immediate health hazard, delayed health hazard, fire hazard, sudden pressure release hazard, and reactivity hazard).

  Specify product components subject to EPCRA (SARA Title III) 313 reporting. (**See *Section 2* for chemical name, CAS number and percentage requirements**).
  - ⇒ **Indicate whether the product or its constituents are listed in the EPA Toxic Substance Control Act (TSCA) inventory**. Where appropriate, include information on other elements of TSCA such as Significant New Use Rule (SNUR), Final Consent Orders, Research and Development Limitations, Export Notification Requirements, and Exemptions from TSCA (e.g., pesticides, foods, and drugs).
  - ⇒ List the RCRA hazardous waste codes that apply to the product as packaged.
  - ⇒ List the CERCLA Reportable Quantity (RQ) for the product and its constituents.
- Canada:
  - ⇒ Workplace Hazardous Materials Information System (WHMIS) Hazardous Product Act - Part II, Controlled Products Regulations; Hazardous Materials Information Review Act and Regulations;
  - ⇒ Canadian Environmental Protection Act (CEPA) - Domestic Substance List (DSL) or Non-Domestic Substance List (NDSL), Export Notification.
  - ⇒ National Pollutant Release Inventory (NPRI)

✪ 2. In the United States and/or Canada, list any state or province health & safety and

✪: Indicates an essential information standard that must be met for all products.

environmental regulations for ingredients contained in the product for the states or provinces where the material is manufactured or marketed. Include state right-to-know listed substances or specialized data requirements.

SECTION 16 - Other Information

1. Use this section for information that does not fit into a previous category. Examples of data to include here are: label text, hazard ratings, revision indicators, key/legend, references, recommended use, special training needs and possible restrictions.
2. Indicate the sections that have been revised or changed since the previous issue of the MSDS.

For additional information or compliance questions regarding this document contact:

GM Canada
Industrial Hygiene:
905-644-3361

GM USA
Chemical Risk Management (CRM)
248-255-7617 (Warren, MI Office)

MSDS Processing Center
gm-msds@tetratech.com
734-213-5045

REVISION DATE	CHANGE AUTHOR	DESCRIPTION OF CHANGE
April 2005	Mariann V. Anticoli Chemical Risk Management	Added new VOC test requirements for metalworking fluids, production parts washer fluids, and foundry core resins and materials.
September 2011	Donald J. Hart Chemical Risk Management	Changed phone number and e-mail address for MSDS Processing Center
July 2011	Donald J. Hart Chemical Risk Management	Additional information on Transport requirements and clarification of other requirements
December 1999	Donald J. Hart Chemical Risk Management	Significant additions to clarify requirements including the use of examples

✪: Indicates an essential information standard that must be met for all products.

APPENDIX G – SYMBOL AND COLOR CODING

APENDIX G -– Suggested Symbol and Color Coding for Containers and Fill Points

The tags shall be a **minimum** of 1" in height and 2" in width, in accordance with the designated shape and color specification shown in Table G-1. Lettering to be 3/16" minimum.

Mandatory: One line of print on each tag shall be the GM LS-2 code designation for the lubricant and one a generic description, such as found in the "Lubricant Type" column. An additional line will contain the appropriate **ISO Viscosity Grade** and/or **AGMA Number or NLGI Grease grade, including Base Oil Viscosity.** Some examples are shown in Table G-2.

Optional: Individual plants may specify to add their stock and symbol number on the tag for the lubricant. Some examples are shown in Table G-2. This optional requirement may increase the size of the tag.

For Reference of all GM Lubricants, see elsewhere in GM LS-2.

Table G-1 Symbol and Color Codes for Each Lubricant Type

GM Code	Lubricant Type	Symbol	Color	Color Codes
LA-0X-1	Air Cylinder/Valve, Air Tool Oils		Lt Purple	JAS 045-9966C, RGB 178:140:216 CMYK 31:37:0:0, Thermal 2567U
LB-04-1	General Purpose Oil - 46 cSt		Yellow	JAS 191-FF6600, RGB 255:255:0 CMYK 1:0:100:0, Thermal Yellow C
LB-22-1	Heavy Press and Machine Oil 220 cSt		Blue	JAS 073-0000FF, RGB 0:0:255 CMYK 100:100:0:0, Thermal 293U
LC-06-1	Submerged Clutch and Brake Oil 68 cSt		Brown	JAS 187-663300, RGB 102:51:0 CMYK 49:67:100:22, Thermal 496U
LD-00-1	Dry Film Lubricant		Black	JAS BLACK, RGB 0:0:0 CMYK 0:0:0:100
LD-XX-2	Chain/Conveyor Lubricant Oil Based		Orange	JAS 191-FF6600, RGB 255:102:0 CMYK 0:60:100:0, Thermal 152U
LE-XX-1	Environmentally Acceptable Industrial Lubricants		Green	JAS 129-009933, RGB 0:153:51 CMYK 100:0:100:0
LF-04-1	Phosphate Ester Hydraulic Fluid 46 cSt		Black White	
LF-04-2	Water-Glycol Hydraulic Fluid 46 cSt		Red White	

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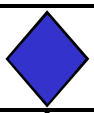
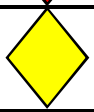
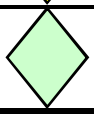
Table G-1, Continued Symbol and Color Codes for Each Lubricant Type

GM Code	Lubricant Type	Symbol	Color	Color Codes
LF-10-3	Invert Emulsion Hydraulic Fluid 100 cSt		Yellow White	
LF-XX-4	Polyol Ester Hydraulic Fluid		Green White	
LF-03-5	High Water-Based Hydraulic Fluid		Blue White	
LG-0X-1	Multi-Purpose Greases NLGI No. 0,1,2		Red	JAS 207-FF0000, RGB 255:0:0 CMKK 0:100:100:0, Thermal 032U
LG-01-2	Fretting, Corrosion Inhib. Grease NLGI No. 1		White	JAS 211-FFFFF, RGB 255:255:255 CMYK 0:0:0:0
LG-02-3	High-Speed Bearing Grease NLGI No. 2		Blue	JAS 073-0000FF, RGB 0:0:255 CMYK 100:100:0:0, Thermal 293U
LG-0X-4	High-Temperature EP Greases Synthetic NLGI No. 1,2		Orange	JAS 191-FF6600, RGB 255:102:0 CMYK 0:60:100:0, Thermal 152U
LH-0X-1	Antiwear Hydraulic Oils 22, 32, 46, 68 cSt		Purple	JAS 040-660099, RGB 102:0:153 CMYK 65:99:0:0, Thermal 2617U
LH-0X-2	Zinc Free Antiwear Hydraulic Oils		Purple	JAS 040-660099, RGB 102:0:153 CMYK 65:99:0:0, Thermal 2617U
LJ-XX-1	Compressor/Turbine Oils 32, 46, 68,100 cSt		White	JAS 211-FFFFF, RGB 255:255:255, CMYK 0:0:0:0
LJ-XX-2	Synthetic Compressor/Turbine Oils - Ester Based		Gray White	JAS 213-999999, RGB 153:153:153 CMYK 40:27:25:2 Thermal Cool Grey 5U
LJ-XX-3	Synthetic Compressor/Turbine Oils - Non-Ester		Dk Gray White	JAS214-666661, RGB 91:91:91 CMYK 60:45:46:13
LM-10-1	Misting Oil 100 cSt		Pink	JAS 012-FF99CC, RGB 255:153:204 CMYK 40:27:25:2

APPENDIX G – SYMBOL AND COLOR CODING

Table G-1, Continued Symbol and Color Codes for Each Lubricant Type

GM Code	Lubricant Type	Symbol	Color	Color Codes
LR-XX-1	EP Gear Oils 68,100,150,220,320,460,680 cSt		Light Blue	JAS 079-99CCFF, RGB 153:204:255 CMYK 40:6:0:0, Thermal 277U
LR-XX-2	Worm Gear Oil 460, 680, 1000 cSt		Light Green	JAS 132-CCFFCC, RGB 204:255:204 CMYK 20:0:20:0, Thermal 344U
LR-XX-3	Synthetic EP Gear Oils		Lt Blue White	
LS-0X-1	Spindle Oils 10, 22, 32 cSt		Light Brown	JAS 187-663301, RGB 178:153:127 CMYK 29:29:38:3, Thermal 446U
LS-0X-2	High-Speed Spindle Oils 2, 5, 10 cSt		Light Brown	JAS 187-663301, RGB 178:153:127 CMYK 29:29:38:3, Thermal 446U
LW-XX-1	Way Oils 32, 68, 220 cSt		Red	JAS 207-FF0000, RGB 255:0:0 CMYK 0:100:100:0, Thermal 032U
LX-XX-_	Straight Cutting and Grinding Oils 1,2,3,4,5,6		Blue	JAS 073-0000FF, RGB 0:0:255 CMYK 100:100:0:0, Thermal 293U
LY-00-_	Aqueous Metal Removal Fluids Soluble Oils – 1,2,3,4		Red	JAS 207-FF0000, RGB 255:0:0 CMYK 0:100:100:0, Thermal 032U
LY-00-_	Aqueous Metal Removal Fluids Semi-synthetic Fluids – 5,6		Yellow	JAS 191-FF6600, RGB 255:255:0 CMYK 1:0:100:0, Thermal Yellow C
LY-00-_	Aqueous Metal Removal Fluids Synthetic Fluids – 7,8		Light Green	JAS 132-CCFFCC, RGB 204:255:204 CMYK 20:0:20:0, Thermal 344U

Note: The Color Code is intended for a reference to be used with different forms of media to publish these symbols.

•The JAS number represents a color mix used on Internet Documents.

•The RGB,(Red, Green Blue) designation will be found in Desktop Publishing Programs such as PowerPoint and Word.

•The CMYK, (Cyan, Magenta, Yellow, Black) numbers represents the Custom Ink Mix that a printing company can use.

•The Thermal Color Represents The Process used for Printing Mylar or Nylon Tags.

APPENDIX G – SYMBOL AND COLOR CODING

Table G-2 Example Symbol and Color Codes for Each Lubricant Type

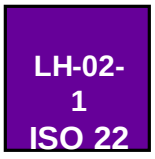
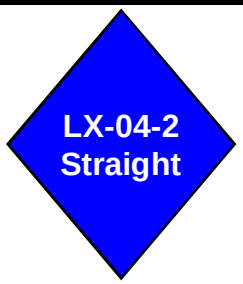
GM Code	Lubricant Type	Symbol	Color Code
LD-15-2	Viscosity 15 Use this symbol & designation position for all of the following LD fluids & types		Orange JAS 191-FF6600 RGB 255:102:0 CMYK 0:60:100:0 Thermal 152U
LD-XX-2	Viscosity XX Chain/Conveyor Lubricant - Oil Based		
LG-00-1A	Viscosity 150 Use this symbol & designation position for all of the following LG fluids & types Multi Purpose Grease		Red JAS 207-FF0000 RGB 255:0:0 CMYK 0:100:100:0 Thermal 032U
LG-00-1B	Viscosity 220 Multi Purpose Grease		
LG-01-1A	Viscosity 150 Multi Purpose Grease		
LG-01-1B	Viscosity 220 Multi Purpose Grease		
LG-02-1A	Viscosity 150 Multi Purpose Grease		
LG-02-1B	Viscosity 220 Multi Purpose Grease		
LH-02-1	*22 Use this symbol & designation position for all of the following LH fluids & types (*) Antiwear Hydraulic Fluid		Purple JAS 040-660099 RGB 102:0:153 CMYK 65:99:0:0 Thermal 2617U
LH-03-1	*32 Antiwear Hydraulic Fluid		
LH-04-1	*46 Antiwear Hydraulic Fluid		
LH-06-1	*68 Antiwear Hydraulic Fluid		

Table G-2 Example Symbol and Color Codes for Each Lubricant Type

GM Code	Lubricant Type		Symbol	Color Code
LJ-03-1	Compressor / Turbine Viscosity *32 Use this symbol & designation position for all of the following LJ fluids & types (*).		LJ-03-1 ISO 32	White JAS 211-FFFFF RGB 255:255:255 CMYK 0:0:0:0
LJ-04-1	Compressor / Turbine Viscosity *46			
LJ-06-1	Compressor / Turbine Viscosity *68			
LJ-10-1	Compressor / Turbine Viscosity *100			
LJ-03-2	Synthetic Compressor / Turbine Ester Viscosity *32		LJ-03-2 ISO 32	Grey JAS 213-999999 RGB 153:153:153 CMYK 40:27:25:2 Thermal Cool Grey 5U
LJ-04-2	Synthetic Compressor / Turbine Ester Viscosity *46			
LJ-06-2	Synthetic Compressor / Turbine Ester Viscosity *68			
LJ-10-2	Synthetic Compressor / Turbine Ester Viscosity *100			
LJ-03-3	Synthetic Compressor / Turbine Other Viscosity *32		LJ-03-3 ISO 32	Dark Grey JAS214-666661 RGB 91:91:91 CMYK 60:45:46:13
LJ-04-3	Synthetic Compressor / Turbine Other Viscosity *46			
LJ-06-3	Synthetic Compressor / Turbine Other Viscosity *68			
LJ-10-3	Synthetic Compressor / Turbine Other Viscosity *100			
LM-10-1	Misting Oil	Refer to LS-2 for Viscosity's	LM-10-1 *	Pink JAS 012-FF99CC RGB 255:153:204 CMYK 40:27:25:2

Table G-2 Example Symbol and Color Codes for Each Lubricant Type

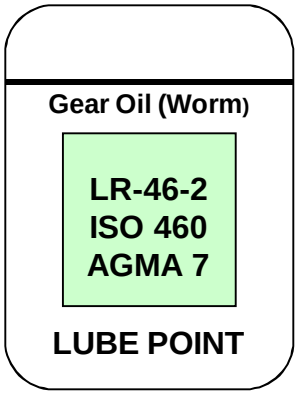
GM Code	Lubricant Type		Symbol	Color Code
LR-46-2	Worm Gear	Viscosity 460	LR-46-2 ISO 460 AGMA 7	Light Green JAS 132-CCFFCC RGB 204:255:204 CMYK 20:0:20:0 Thermal 344U
LR-68-2	Worm Gear	Viscosity 680		
LR-99-2	Worm Gear	Viscosity 1000		
LR-06-1	EP Gear Oil	Viscosity 68	LR-06-1 ISO 68 AGMA 2	Light Blue JAS 079-99CCFF RGB 153:204:255 CMYK 40:6:0:0 Thermal 277U
LR-10-1	EP Gear Oil	Viscosity 100		
LR-15-1	EP Gear Oil	Viscosity 150		
LR-22-1	EP Gear Oil	Viscosity 220		
LR-32-1	EP Gear Oil	Viscosity 320		
LR-46-1	EP Gear Oil	Viscosity 460		
LR-68-1	EP Gear Oil	Viscosity 680		
LS-01A-1	Spindle Oil Viscosity 10(A) or 15(B)		LS-01A-1 ISO 10	Light Brown JAS 187-663301 RGB 178:153:127 CMYK 29:29:38:3 Thermal 446U
LS-01B-1	Use this symbol & designation position for all of the following LS fluids & types (*).			
LS-02-1	Spindle Oil	Viscosity 22		
LS-03-1	Spindle Oil	Viscosity 32		
LS-00A-2	High Speed Spindle Oil Viscosity 2(A) or 5(B)		LS-00A-2 ISO 2	Light Brown
LS-00B-2				
LS-01-2	High Speed Spindle Oil Viscosity 10			
LW-03-1	Way Oil	Viscosity 32	LW-03-1 ISO 32	Red JAS 207-FF0000 RGB 255:0:0 CMYK 0:100:100:0 Thermal 032U
LW-06-1	Way Oil	Viscosity 68		
LW-22-1	Way Oil	Viscosity 220		

GM Code	Lubricant Type	Symbol	Color Code
LX-xx-1 LX-xx-2 LX-xx-3 LX-xx-4 LX-xx-5 LX-xx-6	Straight Metal Removal Fluids See LS-2 For Application and Properties		Blue JAS 079-99CCFF RGB 153:204:255 CMYK 40:6:0:0 Thermal 277U
LY-00-1 LY-00-2 LY-00-3 LY-00-4	Aqueous Metal Removal Fluids – Soluble Oils See LS-2 For Application and Properties		Red JAS 207-FF0000 RGB 255:0:0 CMYK 0:100:100:0 Thermal 032U
LY-00-5 LY-00-6	Aqueous Metal Removal Fluids Semi-synthetic Fluids See LS-2 For Application and Properties		Yellow JAS 191-FF6600 RGB 255:255:0 CMYK 1:0:100:0 Thermal Yellow C
LY-00-7 LY-00-8	Aqueous Metal Removal Fluids Synthetic Fluids See LS-2 For Application and Properties		Lt. Green JAS 132-CCFFCC RGB 204:255:204 CMYK 20:0:20:0 Thermal 344U

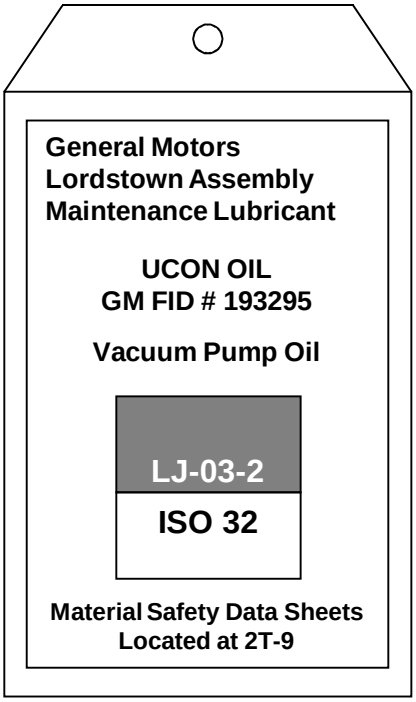
The tags shall be a **minimum** of 1½ " in height and 2 " in width, in accordance with the designated shape and color specification. Lettering 3/16" minimum.

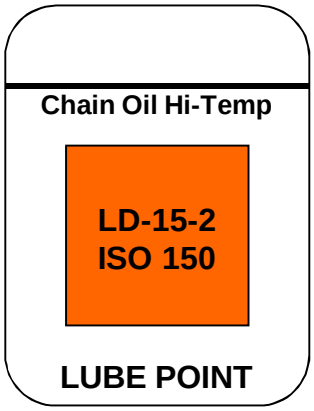
Mandatory: Each tag shall contain the GM LS-2 code designation for the fluid and either "Straight", "Soluble", "Semi-Synthetic" or "Synthetic".
Optional: Product codes or descriptions (e.g., Bubba's Super Special soluble) may also be included. Alternatively, such additional information may be provided on stick-on labels.

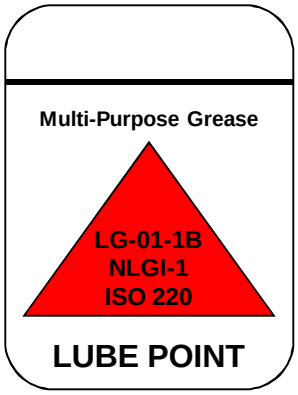
Table G-3 Example Tags for Selected Lubricant Types



Transfer Container Tag







APPENDIX H – Metal Removal Fluid Monitoring Procedures

SCOPE – This document is intended to provide an applications-oriented guide to Metal Removal Fluid (MRF) monitoring procedures. This effort will help to:

- Enhance worker health and safety.
- Improve equipment life.
- Incorporate these methods into divisional and plant practices.
- Support Section L15 on Metal Removal Fluid Management.
- Drive common – use of best practices.

Top priority has been given to enhancement of safety in operation and maintenance of metal removal fluids in conjunction with compliance with Federal, State, Provincial and municipal regulations, including national consensus standards and qualified testing laboratories' standards.

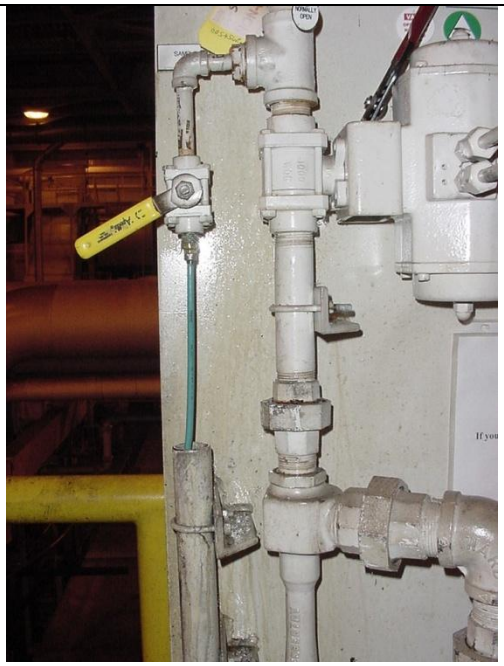
The methods described in this section are intended for use in General Motors plants. They are not intended for use at non-GM operations, and General Motors accepts no responsibility for their use outside GM.

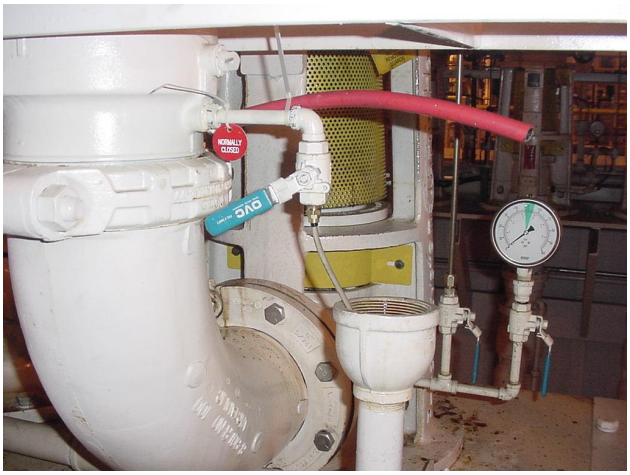
Some of the MRF methods herein are to be run in plant routinely (daily or weekly), some are to be run on-site or at an off-site lab as problems or issues dictate, while others are meant more as research tools for very unusual or special situations. Individual procedure scopes will help define which applies.

MRF PROCEDURE 1 – SAMPLING

Sample Collection and Submittal

Samples should be collected aseptically in new (preferably sterile) containers from free flowing streams of MRF. Microbial samples must not be obtained from larger samples collected for routine chemical and physical characterization. Dedicated continuously-running sample collection ports such as shown in the photos below are preferred sampling points.

Sampling Systems	
	
This continuous-flow sampling point drains a stream of MRF from a supply line through a ¼" polyethylene tube and into a 1" pipe that drains back to the MRF filter system. By removing the tube from the drain pipe and directing it toward the sample collection bottle, a proper sample can be obtained without waiting minutes for the system to purge.	Do not change flow once it has been established as it can dislodge material from the surface of the valve or other locations in the system. Consider removing the control value handle once the desired flow rate is obtained. (This flow rate is probably slower than desired)

	
This seemingly good sample point is actually on > 10 ft of “dead leg” pipe and the funnel for flushing the line goes to a containment trench and eventually to waste, not back to the filter. This type of sample point must not be used for collecting microbiological samples.	Another version of a constant-running sample location—note the proximity to the MRF delivery header. Again, removing the adjustment handle should be considered once the desired flow rate is established.

If samples are not collected from continuously flowing streams, the sample line should be purged for a minimum of two minutes. Microbial samples must never be collected from hoses or “dead leg” piping.

If intended for microbial analyses, collected samples should be immediately cooled on ice (do not freeze). Samples should be labeled with the individual machine or central MRF system label, e.g., GM BT43218. The fluid name should generally not be used as part of the sample label. Samples and the submission forms should be delivered to the laboratory or shipped overnight for morning delivery in an insulated shipping container with “blue ice” or other means of keeping them cool, but not frozen.

Acknowledgement: Thanks to Jim D’Arcy (GM Research Labs), who provided this information.

MRF PROCEDURE 2 – METAL REMOVAL FLUID SENSORY EVALUATION

1.0 Purpose

This procedure will be utilized to make qualitative sensory evaluations of metal removal fluids. Observations are more likely to be made simply by observing the MRF system. In some cases a fluid sample may be drawn.

2.0 Scope

This procedure will be used daily to observe changes to or an unusual appearance or odor of MRF baths. NOTE: this procedure does not address corrective actions.

3.0 Requirements

3.1 *Abnormal fluid color or clarity*. Determine if the fluid color looks "normal". When in good condition, many synthetic fluids are clear, semi-synthetics are often transparent to milky, and soluble oils usually look milky white with no free oil layer. If the fluid turns gray or black, bacteria are often present. If the fluid picks up a yellow or brown tint, tramp oil or another contaminant may be present. Dye fading may indicate that a fluid is aging.

3.2 *Foul smell (rancidity).* When fluids smell bad, it usually means that there is uncontrolled microbial growth. Although it may be possible to mask the odor, it's best to address the underlying cause, because microorganisms present in the fluid can be aerosolized into the air as part of the mist. If the fluid has a strong "locker room" odor, it likely has biological growth.

3.3 *Floating solids on the fluid.* If the fluid has excessive floating chips or swarf, this is not desirable. The level of dirt (total suspended solids) in the fluid is a measure of the efficiency of the filtering system.

3.4 The presence of fungus (either suspended in the fluid or as a biofilm on surfaces) should also be noted.

3.5 *Tramp oil floating on the surface.* With water-diluted fluids, there is too much tramp oil present if the sump is completely covered with oil and the machinist cannot "swish" the oil out of the way for more than 5 to 8 seconds before the sump is covered again in an area of low agitation. Tramp oil is one of the main causes of dermatitis, as some components of machine lubricants are irritating to the skin. Unemulsified (tramp) oils can be a significant carrier of metallic fines, which can be deposited on the skin and cause mechanical irritation and dermatitis.

3.6 *Recording.* Record any unusual observations on the daily log sheet. Be as specific as possible. For instance, rather than "smells bad", "fluid has a rotten egg odor" or fluid has an ammonia odor" is more useful for determining next steps.

MRF PROCEDURE 3 – EVALUATION OF METAL REMOVAL FLUID CONCENTRATION BY REFRACTOMETER

1.0 Purpose

This procedure is utilized to estimate the concentration of aqueous metal removal fluids (MRF's).

2.0 Scope

This procedure is routinely used for quick determination of the concentration of aqueous MRF's. It is generally more useful for trending than absolute measurements. **NOTE: The method is subject to interferences by solid contamination, tramp oil, and other MRF's. It will also tend to vary with the age of the fluid**. Visual interpretation may affect results. (See also Concentration by Titration.) NOTE: this procedure does not address sampling or corrective actions.

3.0 Requirements

3.1 **Select a model of refractometer** that can measure the concentration of the fluid(s) of interest over the range of 0 to 30%. Contact the LS2 committee for recommendations on refractometer models.

3.1.1 Refractometer Calibration

3.1.2 This should be done at least weekly (preferably at least daily).

3.1.3 Place enough DI water on the clean, dry prism to completely flood it. Make sure that there are no bubbles under the prism.

3.1.4 Note the scale reading where the boundary line separates the light and dark areas on the scale.

3.1.5 The level should be at zero. If it is above or below the zero level, zero the refractometer as specified in its operating instructions

3.1.6 Record results on a calibration log sheet.

3.1.7 Lift plastic cover and dry the prism with a clean, dry cloth, such as a Kimwipe.

3.2 Refractometer reading

3.2.1 Place a sufficient amount of a representative sample of coolant on the prism to sufficiently coat it.

3.2.2 Note the scale reading where the boundary line separates the light and dark areas on the scale.

3.2.3 If clear demarcation doesn't exist, add three drops of a surfactant, such as Pluronic L61 or equivalent and shake/stir well. This may sharpen the line without affecting the reading obtained. If this typically occurs, you may want to determine concentration by titration.

3.2.4 Determine the concentration by multiplying the refractometer scale reading by the specific factor for each MRF provided by the supplier of the MRF concentrate, preferably generated using plant water. If a specific factor is not provided by the fluid supplier for the given fluid with the plant water, the plant chemical manager should generate the factor. To do this, make up mixtures of new concentrate at several different percentages (spanning the MRF concentrations generally used) in plant water and determine the refractive index for each. Plot the refractive indexes vs. concentration. The slope of the line is the factor to be used.

3.2.5 Record the results on a Daily Testing Recording Sheet; format to be determined jointly by the plant and chemical manager.

3.2.6 Lift the plastic cover and dry the prism with a clean dry cloth.

MRF PROCEDURE 4 – EVALUATION OF METAL REMOVAL FLUID CONCENTRATION BY ALKALINITY TITRATION

1.0 Purpose

This procedure is utilized to determine the concentration of aqueous metal removal fluids (MRF's).

2.0 Scope

This procedure is routinely used for determination of the concentration of aqueous MRF's by way of correlating the alkalinity measured by titration and a multiplier specific for the coolant sampled. The method is subject to interferences by contamination by tramp oil, other MRF's or other contaminants. For instance, alkalinity may increase over time due to the intrusion of cleaners or other alkaline substances. (See also Concentration by Refractometer.)

This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety concerns associated with its use. The user of this standard must establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. Specific hazard statements may appear within the procedure.

3.0 Requirements

3.1 Making the Titrant Solution

3.1.1 Obtain recommendations for titration mixing amounts from the supplier of the MRF.
3.1.2 Measure the recommended amount of 1N HCL (Hydrochloric Acid) and de-ionized water.
3.1.3 Place a stir bar in the beaker and place on a stir plate.
3.1.4 Turn on the stir plate and allow the mixture to blend several minutes.

3.2 Titrant Sample Preparation

3.2.1 By means of a pipette, transfer a sample of MRF from the MRF sample bottle (be sure that it is thoroughly mixed prior to acquiring the sample). The amount to pipette will be specified by the supplier of the MRF.
3.2.2 Top off sample to 100 mls with de-ionized water.

3.3 Titration of Sample

3.3.1 Bring the fluid level in the titration buret containing the titration solution to zero.
3.3.2 Place sample to be titrated on the stir plate and place a stir bar in the beaker of the sample to be tested.
3.3.3 Meter in the titrant solution until the pH reaches the value provided by the supplier of the MRF.
3.3.4 Record the amount of titrant used on the daily testing sheet. Repeat steps 3.3.1 through 3.3.3 for all MRF samples. If the titration requires only a few mls. or more than 50 mls., a change in the normality of the titrant may be required.

3.4 Calculating Sample Concentration

3.4.1 Multiply the amount of titrant used by the factor provided by the supplier for each MRF.
3.4.2 If a specific factor is not provided by the fluid supplier for the given fluid with the plant water, the plant should generate the factor. To do this, the plant should make up mixtures of new concentrate at several percentages (spanning the MRF concentrations generally used) in plant water and determine the titrant volume required for each. Plot the titrant volume vs. concentration. The slope of the line is the factor to be used.
3.4.3 Record the value on the daily testing sheet for each respective sample.

MRF PROCEDURE 5 – METAL REMOVAL FLUID pH DETERMINATION

1.0 Purpose

This procedure is the preferred method for determining the pH of aqueous metal removal fluids (MRF's).

2.0 Scope

This procedure is routinely used daily for on-site determination of the pH of new and used aqueous metal removal fluids (MRF's). See also ASTM Standard E 70. Indicator paper or other indicators may be used, according to the individual manufacturer's instructions, for pH determination, but do not generally provide the accuracy or sensitivity of this method.

This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety concerns associated with its use. The user of this standard must establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. Specific hazard statements may appear within the procedure.

3.0 Requirements

3.1 pH Meter Preparation

3.1.1 Calibrate the pH meter over the necessary range (usually 7.0 to 10.0) daily according to the manufacturer's directions.
3.1.2 Store the electrode in a buffer of pH 7 or electrode storage solution when not in use.
3.1.3 Maintaining the cleanliness of the electrode is of critical importance.

3.2 Sample Preparation

3.2.1 By means of a pipette, transfer a sample of MRF from the MRF sample bottle to a beaker (be sure to shake the sample well prior to acquiring the sample). The amount of sample transferred must be sufficient to adequately immerse the electrode.
3.2.2 Agitate the sample by a stirring bar during the analysis.

3.3 Determining the pH of the Sample

3.3.1 Conduct these tests at ambient temperature. Immerse the electrode in the sample and allow it to equilibrate before taking the reading.
3.3.2 Once the reading has stabilized, record it.
3.3.3 Clean the electrode by rinsing in the appropriate solvent as recommended by the manufacturer after analyzing each sample. High oil MRF's and MRF's with high levels of tramp oil may coat the pH electrode, causing the readings to "wander" and possibly equilibrate to an erroneous pH. In the case of such fluids, we recommend rechecking the electrode calibration after every 5 samples or so by placing it in the pH 10 buffer. If the reading is off by more than 0.2 pH units, check the pH 7 buffer. If this is also off by more than 0.2 pH units, recalibrate the pH meter and rerun the analyses.
3.3.4 Never wipe the electrode with a dry Kimwipe; moisten it with deionized water first.
3.3.5 There is no precision statement for this method.

MRF PROCEDURE 6 – METAL REMOVAL FLUID TRAMP OIL, FREE OIL AND TOTAL OIL DETERMINATION

1.0 Purpose

These procedures are utilized to determine the tramp oil (non-product oil), free oil, and total oil concentration of aqueous metal removal fluids (MRF's).

2.0 Scope

These procedures are routinely used for determination of the concentration of tramp oil (non-MRF product oil, such as hydraulic fluid or way lube, which has leaked into the MRF), free oil (non-emulsified oil), and total oil of aqueous MRF's.

3.0 Caution

This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety concerns associated with its use. The user of this standard must establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. Specific hazard statements may appear within the procedure.

4.0 Requirements for Free Oil Determination

4.1 Sample Preparation

4.1.1 Obtain a well-agitated representative MRF sample.
4.1.2 Fill a Babcock bottle with MRF sample. Choose a bottle that is appropriate for the model of centrifuge used and whatever size results in all of the oil in the neck after the separation. Note the sample volume.
4.1.3 Place the Babcock bottle in the centrifuge and spin it at 2500 rpm for 10 minutes to obtain a complete separation. (Depending on the centrifuge model and the nature of the fluid, adjustments may have to be made to the rpm or time.)
4.1.4 Remove the bottle from the centrifuge and note the volume of the oil separated. The volume of oil should be within the readings of the neck of the bottle. If it is not, rerun either using a larger bottle or diluting the sample, as appropriate.

4.2 Sample Calculation

4.2.1 Divide the volume of separated oil by the total sample volume and multiply by 100 to obtain the percentage of free oil.

5.0 Requirements for Total Oil Determination

5.1 Sample Preparation

5.1.1 Obtain a well-agitated, representative MRF sample.
5.1.2 Pipette 25 ml of the sample into a Babcock bottle.
5.1.3 Add 10 mls of concentrated (>98%) reagent grade sulfuric acid – **CAUTION**: Strong oxidizer (other acids may be substituted, but may require other procedural changes).
5.1.4 Swirl to mix the ingredients.
5.1.5 If a clean break (e.g., a clear demarcation of phases) is obtained, note the volume of oil separated.
5.1.6 If a clean break is not obtained, consult with the fluid supplier regarding two alternatives. Options include:
5.1.6.1 Heat the sample in a 200°F water bath for 15 minutes and note the volume of oil separated. Or,
5.1.7 Add water to fill the Babcock bottle to approximately 75 ml. Place the Babcock bottle in the centrifuge and spin it at 2500 rpm for 10 minutes. Remove the bottle from the centrifuge and note the volume of oil separated. (Depending on the centrifuge model and the nature of the fluid, adjustments may have to be made to the rpm or time.)
5.1.7.1 High oil content soluble, semi-synthetic and fully-synthetic coolants may behave slightly differently in these procedures; consult the MRF supplier.

5.2 Sample Calculation

5.2.1 Divide the volume of separated oil by 25 and multiply by 100 to obtain the percent total oil.

6.0 Calculation for Tramp Oil

6.1 Product Oil Content Estimation

6.1.1 It is possible to estimate the tramp oil in an MRF sample by calculating the product oil and subtracting that from the total oil.
6.1.2 Determine the MRF concentration using the LS2 Procedure for Metal Removal Fluid (MRF) Concentration by Alkalinity Titration or other methods excluding refractometer, and multiply this value by the nominal oil content of the concentrate (provided by the MRF supplier) to obtain the expected product oil concentration.
6.1.3 Subtract this value from the total oil as determined in section 4 above, to obtain the tramp oil concentration.

7.0 Interpretation of Results

	Product Oil	Foreign (contaminant) oil
Non-Emulsified	A	B
Emulsified	C	D
	Total product oil	Total contaminant oil

7.1 Free Oil = A + B (is directly measured)
7.2 Total Oil = A + B + C + D (is directly measured)
7.3 Product Oil = A + C (is indirectly measured by alkalinity or cationic titration, and known oil content of the concentrate)
7.4 Tramp Oil = B + D (is calculated by subtracting product oil from total oil).

8.0 Precision

8.1 The precision of this procedure is currently being developed.

MRF PROCEDURE 7 – METAL REMOVAL FLUID CONCENTRATION BY CATIONIC TITRATION

1.0 Purpose

This procedure is utilized to determine the concentration of aqueous metal removal fluids (MRF's) based on anionic emulsifier concentration.

2.0 Scope

This procedure is routinely used for determination of the concentration of aqueous MRF's by way of correlating the anionic emulsifier measured by titration and a multiplier for the specific MRF sampled. The method is subject to interferences by contamination by tramp oil, other MRF's or other contaminants. For instance, emulsifier content may increase over time due to tankside additives, the intrusion of cleaners or other substances. Note that this method is an alternative to concentration by alkalinity titration; anionic emulsifiers are sometimes less affected by contaminants than alkalinity is. (See also Concentration by Titration, Concentration by Refractometer.)

This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety concerns associated with its use. The user of this standard must establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. Specific hazard statements may appear within the procedure.

3.0 Requirements

3.1 Making the Titrant Solution

3.1.1 Mix thoroughly the following ingredients until the powder is dissolved:
3.1.1.1 750 ml reagent grade isopropyl alcohol
3.1.1.2 3000 ml deionized water
3.1.1.3 2.40 grams hexadecyltrimethylammonium chloride
This is commonly known as "Hyamine" solution and is commercially available.

3.2 **Making the Red Dye Solution** (This solution may be commercially available pre-mixed.)
3.2.1 Mix thoroughly the following ingredients until the powder is dissolved:
3.2.1.1 3750 ml deionized water
3.2.1.2 0.3 grams dimidium bromide

3.3 **Making the Blue Dye Solution** (This solution may be commercially available pre-mixed.)
3.3.1 Mix thoroughly the following ingredients until the powder is dissolved:
3.3.1.1 2500.5 ml deionized water
3.3.1.2 985.0 grams isopropyl alcohol
3.3.1.3 0.15 grams erioglaucine
3.3.1.4 7.50 grams potassium chloride

3.4 Titration of Sample

3.4.1 Thoroughly mix the MRF sample to be tested. Place 1 ml of the sample into a 100 ml graduated cylinder.
3.4.2 Add 10 ml red dye solution.
3.4.3 Add 10 ml blue dye solution.
3.4.4 Add 20 ml chloroform (Note: chloroform is a hazardous substance).
3.4.5 Place a stopper on the graduated cylinder and shake vigorously Allow the contents to separate; the bottom layer will be pink and the top layer will be blue.
3.4.6 Add titrant solution in small increments, shake well and allow to separate.
3.4.7 When the bottom layer begins to turn from pink to purple, the endpoint is near.
3.4.8 When the bottom layer turns blue with no sign of pink, the endpoint has been reached. If there is difficulty in determining a clear endpoint, consult the fluid supplier for advice.
3.4.9 To more repeat ably determine the endpoint to this titration, a few options are available:
3.4.9.1 Using an instrument to electronically determine the endpoint is strongly recommended. An Orion 960 autotitrator connected to a pH meter/ion selective electrode, for instance.
3.4.9.2 Have the same analyst always run the same fluid. This would minimize variations in the determination of the endpoint due to different interpretations of the color change. Recognize that dyes used in the concentrate, different types of tramp oils, etc., can make an optical determination of endpoint difficult.

3.5 Calculating Sample Concentration

3.5.1 Multiply the amount of titrant used by the factor provided by the supplier for each MRF to obtain the product concentration.
3.5.2 If a specific factor is not provided by the fluid supplier for the given fluid with the water used in the plant system, the plant should generate the factor. To do this, the plant should make up mixtures of new concentrate at several percentages (spanning the MRF concentrations generally used) in water used in the plant system

and determine the titrant volume required for each. Plot the titrant volume vs. concentration. The slope of the line is the factor to be used.
3.5.3 Record the value on the daily testing sheet for each respective sample.

4.0 Precision

4.1 The precision of this procedure has not been determined.

MRF PROCEDURE 8 – METAL REMOVAL FLUID M ICROBIOLOGICAL CONCENTRATION ESTIMATION

1.0 Purpose

These procedures are utilized to estimate the extent of microbial growth (bacteria or fungi) in an aqueous metal removal fluid.

2.0 Scope

There are at least three procedures routinely used to estimate the extent of microbial growth (bacteria or fungi) in an aqueous metal removal fluid: dipslides, plate counts or dissolved oxygen readings. The use of commercially-available dipslides or dipsticks is the most common of the three methods. Plate counts are generally run off-site at a laboratory that specializes in microbial analyses. For these two methods, the choice of agar substrate is selected to favor the specific microbes of interest while inhibiting competing organisms. This overcomes the problem of faster growing species overgrowing slower growing species. Dissolved oxygen measurement is less common, but can be run in the plant. **Note:** Proper sampling and sample handling are extremely critical to obtaining valid results. Please consult LS2 Appendix H, Procedure 1.

This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety concerns associated with its use. The user of this standard must establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. Specific hazard statements may appear within the procedure.

3.0 Requirements

3.1 Dipslides

3.1.1 Obtain commercially-available dipslides, specific for fungus or bacteria, either gram negative or mycobacteria. Follow the directions included with the dipslides, including storage conditions and expiration date.

3.1.2 Generally the slide coated with the specific agar is removed from its glass tube and dipped in the MRF and returned to its tube.

3.1.3 The tube is incubated for a specified time at a specified temperature. Note: It is very important to follow the manufacturer's recommendations for time and temperature to ensure consistent results.

3.1.4 A dye is used to help visual the microbiological colonies. The appearance of the tube is compared to standard reference pictures supplied by the dipslide manufacturer to allow estimation of microbial counts.

3.1.5 It may be useful to periodically reference these dipslides against results from dilution plate counts run at an outside lab.

3.1.6 Dispose of the used dipslides in accordance with proper plant practices (consult with dipslide manufacturer).

3.2 Dilution Plate Counts

3.2.1 Generally this procedure would be run at an off-site lab. Increasing dilutions of an MRF sample are made and a measured amount is spread on agar in a Petri dish

3.2.2 The slide is incubated for a specified period (usually 2 - 3 days).

3.2.3 The number of colonies is counted at the end of the incubation.

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3.3 Dissolved Oxygen

3.3.1 A dissolved oxygen probe is cleaned and calibrated as recommended by the manufacturer.

3.3.2 A fluid sample is taken and the dissolved oxygen measured immediately.

3.3.3 A second reading is taken after the sample has been allowed to sit for a specified time, such as 2 hours.

3.3.4 The change in concentration of dissolved oxygen is related to the total microbial concentration. This is used for trending rather than estimating an absolute microbial count. Also, it does not distinguish between fungus and bacteria.

4.0 Report

4.1 The results for bacteria or fungi are typically reported in Colony Forming Units per ml of fluid (CFU/ml) for dipslides or plate counts.

5.0 Precision

5.1 The precision of these procedures has not been reported. With microbial growth, an order of magnitude result is often sufficient; and the change of this value over time is more useful than the absolute value at a given time. Note: dip slide measurements and plate count measure-ments may not be comparable, depending on the media used. It is recommended to use a consistent measurement method for daily measurements and the control plan. Control and management methods set up based on dip slides may not be appropriate for responding to plate count measurements that may reveal very different CFU/mL numbers and vice-versa.

MRF PROCEDURE 9 – METAL REMOVAL FLUID SEDIMENT CONCENTRATION DETERMINATION

1.0 Purpose

These procedures are utilized to determine the concentration of dirt or sediment in an aqueous metal removal fluid.

2.0 Scope

There are at least three procedures that can be used to determine the concentration of sediment in an aqueous metal removal fluid: gravimetric testing, centrifuging or particle counting. Gravimetric testing and centrifuging are most commonly used, but particle counting can be used for more sensitive machining applications, with generally low levels of sediment.

This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety concerns associated with its use. The user of this standard must establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. Specific hazard statements may appear within the procedure.

3.0 Requirements

3.1 Gravimetric Testing

3.1.1 Select the filter media to be used, both in terms of the type of media and nominal pore size (e.g., 5 um). It is possible to run successive filtrations with finer filters and report the concentration at several different particle sizes.
3.1.2 Weigh the filter media to the nearest 0.1 mg.
3.1.3 Obtain a well-mixed representative 100 ml sample of the MRF and pass it through the filter.
3.1.4 Rinse the filter with distilled water and acetone and dry it in a 100°C oven for 1 hour. (Caution: acetone is flammable.)
3.1.5 Reweigh the filter paper.
3.1.6 Subtract the original weight from the final weight and divide by 100 to obtain the weight of sediment per ml of fluid.
3.1.7 If the filter plugs before 100 ml of fluid passes, re-run using a smaller sample size, or repeat by utilizing a filter with a larger pore size and running successive filtrations with finer filters, as suggested in 3.1.1 above.

3.2 Sediment by Centrifuge

3.2.1 Mix MRF sample thoroughly until homogeneous.
3.2.2 Fill centrifuge tube (40ml or 50 ml, with graduations at least to the 20 ml level) to the 20 ml mark with sample.
3.2.3 Fill centrifuge tube to 40 ml mark with lab grade solvent naphtha (Open cup flash point of the solvent naphtha must be > 140°F) and mix thoroughly.
3.2.4 Centrifuge for a minimum of 10 minutes at 2500 rpm.
3.2.5 Contents of centrifuge tube may be stratified into 4 phases; the bottom phase will be solids. Calculate volume ratio for this phase.

3.3 Particle Counts

3.3.1 Obtain a well-mixed representative sample of the MRF. If the MRF is a synthetic fluid (true solution) with no visible tramp oil or if a pore blockage type particle counter is to be used, skip to 3.3.3.
3.3.2 If the MRF is a soluble oil or semi-synthetic fluid, mix it with an equal volume of ultra clean solvent to completely dissolve the oil and water emulsion. Selection of an appropriate solvent may require some trial and error. Isopropyl alcohol has been used successfully for some MRF's.
3.3.3 Use a commercially available particle counter to obtain counts of particles greater than 4 um, 6 um and 14 um per ml of fluid. If dilution with a solvent was required, double these numbers.

4.0 Report

4.1 For gravimetric measurements, report the weight % of sediment per volume of fluid and reference the filter pore size.
4.2 For centrifuge, report the volume % of sediment.
4.3 For particle counts, use ISO 4406 to convert the numbers to an ISO particle count. (see LS2 L1.4.4)

5.0 Precision

5.1 The precision of these procedures has not been reported.

MRF PROCEDURE 10 – METAL REMOVAL FLUID CONDUCTIVITY DETERMINATION

1.0 Purpose
This procedure is the preferred method for determining the conductivity of aqueous metal removal fluids (MRF's).

2.0 Scope
This procedure is routinely used for determination of the conductivity of new and used aqueous metal removal fluids (MRF's). Conductivity is a function of the MRF, the mineral content of the water and other contaminants, and tends to increase as the fluid ages.

This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety concerns associated with its use. The user of this standard must establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. Specific hazard statements may appear within the procedure.

3.0 Requirements
3.1 Conductivity Meter Preparation
3.1.1 Calibrate the conductivity meter over the necessary range daily according to the manufacturer's directions. The type of conductivity meter is not generally important; it is prudent to use the same type and method for trending.
3.1.2 Maintain the cleanliness of the electrode, as recommended by the manufacturer.

3.2 Sample Preparation
3.2.1 By means of a pipette, transfer a sample of MRF from the MRF sample bottle to a beaker (be sure to shake the sample well prior to acquiring the sample). The amount of sample transferred must be sufficient to adequately immerse the electrode.
3.2.2 Agitate the sample by a stirring bar during the analysis.

3.3 Determining the Conductivity of the Sample
3.3.1 Conduct these tests at ambient temperature. Immerse the electrode in the sample and allow it to equilibrate before taking the reading.
3.3.2 Once the reading has stabilized, record it.
3.3.3 Clean the electrode by rinsing in the appropriate solvent as recommended by the manufacturer after analyzing each sample. High oil MRF's and MRF's with high levels of tramp oil may coat the electrode, causing the readings to "wander" and possibly equilibrate to an erroneous value. In the case of such fluids, we recommend rechecking the electrode calibration as needed.
3.3.4 Never wipe the electrode with a dry Kimwipe; moisten it with deionized water first.

4.0 Report
4.1 Report the result observed in microSiemens/cm.

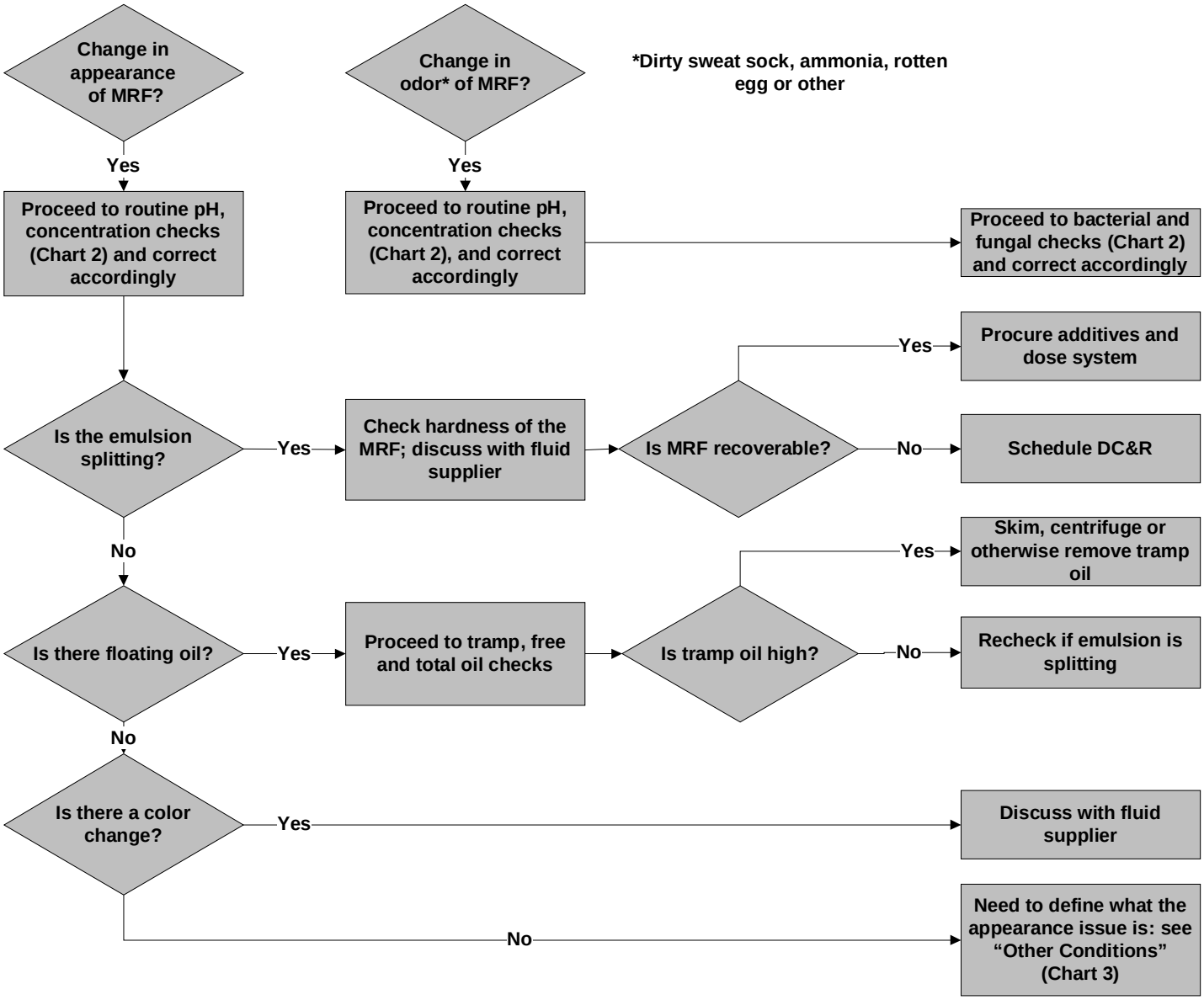
5.0 Precision
5.1 The precision of these procedures has not been reported.

ANNEX - MRF MONITORING AND MANAGEMENT FLOWCHARTS

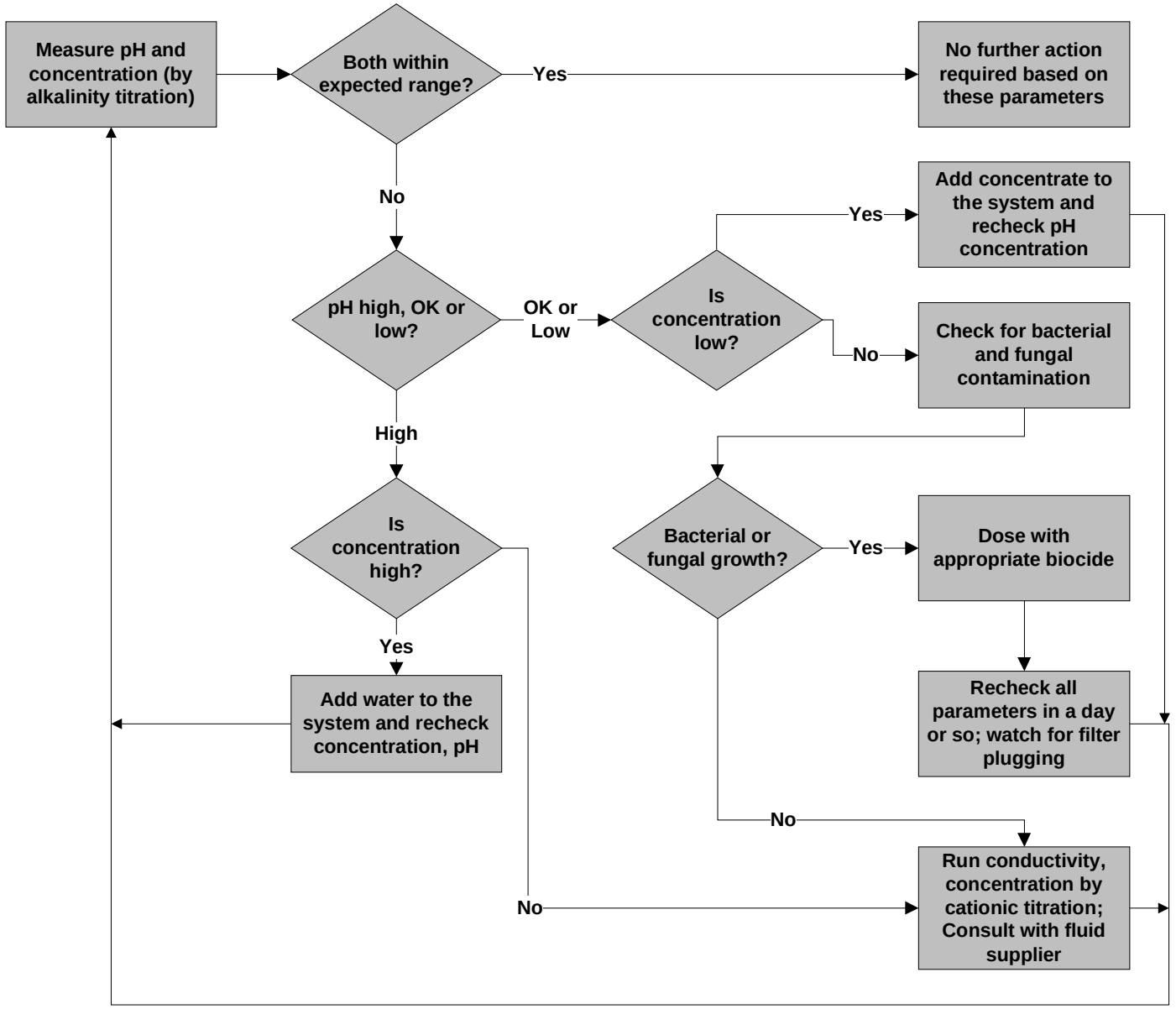
1. LS2 is providing guidance on how to interpret results from the MRF monitoring procedures in this section of LS2. The next three figures are flowcharts that provide advice on reacting to most common results. Suggestions include additional tests to run, corrective action to the sump, etc.
2. The intent of these flowcharts is to cover 80-90% of situations normally encountered with a minimal number of charts. It would be impossible to cover all or unusual occurrences. Some will require more extensive follow up outside the scope of this document.
3. Three flowcharts follow.

- Flowchart 1 involves sensory evaluation
- Flowchart 2 involves routine analyses, such as pH and concentration.
- Flowchart 3 covers other conditions.

Sensory Evaluation (Chart 1)



Routine Analyses (Chart 2)



Other Conditions (Chart 3)