Supply Chain Task Group

Task: SC-18-02

White Paper on CGD of Oil Lubricants

Prepared By:

John Hendricks, PE

EXECUTIVE SUMMARY

This white paper presents an acceptable method of performing commercial grade dedication (CGD) for Oil and Greases.

The method of dedication is by comparison of selected critical characteristics to determine if the item is equal to or better than the original item. National standard (e.g., ASTM) establishes certain process controls and end product acceptance requirements. The dedication parameters must verify the selected critical characteristics by independent testing.

Critical Characteristic	**Oil Method**
Product Name	Visual
Batch Identification	Visual, material control
	Operating temperature Appearance [clear-bright} Odor {compare original product} Feel {slippery}
Color	ASTM D1500
Viscosity, Kinematic 100F	ASTM D445/D88
Contaminants/Purity	Visual or ASTM D4006 &473 or D4007 for industrial oil
	Visual or ASTM D1233 for motor oil
Flash Point	ASTM D92
Additives/Neutralization-ACID	ASTM D664/D974 for industrial oil

ASTM D2896/D4739 for motor/engine oil

Zinc wt. % or PPM	Spectroscopic
API gravity	ASTM D-287 and Diesel Emergency Power Supplies per NRC Regulatory Guide 1.137

1. PURPOSE

To establish methods to satisfy the quality assurance (QA) requirements of

- U.S. Department of Energy (DOE) O414.1D with DOE G 414.2;
- American Society of Mechanical Engineers (ASME) Nuclear Quality Assurance (NQA) -1;
- the Office of Environmental Management, and
- Environmental Management-Quality Assurance Plan (EM-QAP)

This ensures that commercial grade items (CGI) of oil and grease lubricants are selected, purchased, and used in safety-related equipment will not degrade the safety or the qualification of the system/assembly in which they are installed.

To establish documentation to substantiate the engineering technical evaluation and verification of CG items being used in safety-related applications.

To obtain reasonable assurance via engineering evaluations that those items either already purchased or being purchased as Commercial Quality (CQ) are adequate for use in safety-related applications. Reasonable assurance consists of controlling or verifying the item's quality to an extent consistent with the item's importance to safety and/or ensuring that quality is adequately controlled by the supplier.

2. INTRODUCTION:

Oils must meet several requirements, as shown below:

Properties	Oils
Prevent metal/metal contact	x
Act as a hydraulic medium	x
Act as a coolant	x
Carry away contaminants	x
Protect against wear	x
Protect against corrosion	x
Protect against deposits	x
Resist foaming	x

Commercial lubricating oils consist of about 85–99% (or greater) base oil. The remainder consists of additives that are used to enhance the properties of the base oil or to create a necessary property. Base oils are classified as mineral oils and synthetic oils. The principal advantage of synthetic oils is their relatively

low viscosity at low temperatures. They also can have somewhat better high-temperature performance. However, the cost of synthetic-based lubricants is three to eight times the cost of mineral oil–based products. Although the synthetics represent less than 1% of the total lubricant inventory, they are available for and are used in many applications.

In normal operation, lubricants must withstand the stresses of temperature, shear, pressure (load), and exposure to oxygen in the air. An additional stress in nuclear facilities is exposure to nuclear radiation. The overall effects of thermal and radiation exposures are similar; in that, both show thresholds below which changes in properties are not significant.

Lubricants can be incompatible with one another on mixing and have the potential to cause degradation of properties and performance. Solid formation with oil mixtures can take place because of additive interaction or solubility difficulties. With greases, the usual result of incompatibility is breakdown of the grease gel structure to produce softness.

Most turbine and recirculating oils are compatible with each other. It is recommended to contact the lubrication supplier before mixing different oils. An example of a common incompatible situation is a mixture of a product that contains a chemically acidic additive (for example, a turbine oil) and a product that contains a basic additive (for example, an engine oil). One will neutralize the other in the presence of moisture and frequently cause a precipitate to form. Precipitates can plug filters and/or other oil passages and cause oil starvation and equipment failure. If you do not know the chemical makeup of particular products, your lubricant supplier can give guidance on this point so that you can avoid the acid/base concern.

Synthetic oils should not be mixed with other types of synthetic oils or mineral oils. They might form two separate phases.

The method of dedication is by comparison of selected critical characteristics for design to determine if the item is equal to or better than the original. This is done by determining selected critical characteristics for design of the items with the same critical characteristics for design of the original item. National standard (e.g., ASTM) only establishes certain process controls and end product acceptance requirements. The dedication parameters must verify the selected critical characteristics by independent testing.

3. TECHNICAL REQUIREMENTS:

DETERMINATE IF THE ITEM OR SERVICE IS ELIGIBLE FOR CGI DEDICATION

The following criteria validate the item as eligible for commercial grade item dedication:

- The item being dedicated is classified as safety related by the end user.
- The item is not subject to design or specification requirements that are unique to facilities or activities licensed or regulated by DOE or the USNRC (the item is used in applications other than facilities or activities licensed or regulated by the federal government).
- The item is ordered from the manufacturer/supplier based on specifications set forth in the manufacturer's published product description.
- The item's critical characteristics can be verified.

OIL FUNCTIONAL REQUIREMENTS

The function of engine or motor oil, gear oil, turbine oil, industrial oil and refrigeration/compressor oil is to remain in contact with and lubricate moving surfaces to reduce friction heat buildup and wear. Lubricants protect against rust, corrosion and deal with contaminants; and must function across the operating range including temperature and pressure conditions. The oil also provides a cooling function and in certain cases functions as an insulator

Oil additives improve the lubricant performance of base oil. Manufactures can choose different additives for specific application. Additives can comprise up to 5% by weight. Essentially all petroleum or synthetic oil contain additives which are vital for proper lubrication and prolonged use of motor oil. Without additives many oils would become contaminated, beak down, leak or not properly protect engine parts at all operating temperatures. Additives for oils inside gearboxes, and bearings are important additives used for viscosity and lubricity, contaminant control, for the control of chemical breakdown, and for seal conditioning. Some additives permit lubricants to perform better under severe conditions, such as extreme pressure and temperatures and high levels of contamination.

OIL SAFETY FUNCTION REQUIREMENTS:

The primary function of motor oils/engine oils, and industrial oils is to reduce friction. They protect against rust and corrosion and deal with contaminations in systems. They must function across operating ranges including temperature and pressure conditions.

Motor oils/engine oils also lubricate the engine and provide a cooling function.

The safety function is to perform the following functions to ensure safety related equipment performs its intended function:

Engine/motor oil:

1. Provide a barrier between moving parts to reduce friction, heat buildup and wear.
2. Disperse heat. Friction from moving parts and combustion of fuel produce heat that must be carried away.
3. Absorb and suspend dirt and other particles. Dirt and carbon particles need to be carried by oil to the oil filter where they can be trapped and removed.
4. Stay fluid in cold weather; yet remain thick enough to offer engine protection in hot weather.

Refrigeration/Compressor Oil

1. Solubility to assist in good oil return to the compressor.
2. Chemical stability to resist chemical reaction with the refrigerant or other materials present in the system.
3. Thermal stability to eliminate excess deposits at compressor hot spots.
4. Wax free and acid free content to prevent separation of flocculent wax from the oil mixture at the low temperature points in the system.
5. Low pour point to prevent separated lubricant from congealing and restricting flow.
6. High dielectric strength to ensure good insulating properties. In hermetic units, the lubricant-refrigerant mixture serves as an insulator between the motor and the compressor body.
7. Proper viscosity, even when diluted with refrigerant, to ensure high film strength at elevated operating temperatures and still provide good fluidity under coldest operating conditions.
8. Contamination free to prevent scarring of bearing surfaces, plugging of lines or oil ports and general deterioration.

Gear Lubricant/Oil

1. Lubrication fans, pumps and other heavy duty applications.
2. Viscosity levels are much higher to account for high or extreme pressure during service.
3. Mixed with additives to increase resistance to breakdowns under high temperature and pressure.

4. OIL CRITICAL CHARACTERISTICS FOR DESIGN (CCD):

Viscosity is the most important CCD and it reflects the lubricating properties of the oil.
Viscosity index is indicative of the oils viscosity variation with temperature. . Pour point and flash point are parameters that are critical to identify extreme temperature limits for the oil.

Additive package is important to the oils ability to protect against rust, corrosion, and deal with contaminants. Oil must be free from contaminates to ensure it doesn't cause any detrimental effects on the equipment.

CCD are defined by the manufacture. Typical Design parameters for Oil:

Gravity, API
Flash, F minimum
Viscosity, SUS at 100F and 210F
Viscosity Index
Pour Point, F maximum
Color
Floc Point, F maximum
Separation Temperature, F maximum
Dielectric Strength, KV minimum
Analine Point, F
Total Acid No. MgKOH/g
Water

5. OIL CRITICAL CHARACTERISTICS FOR ACCEPTANCE (CCA):

Viscosity

Viscosity is the most important characteristic of oil in determining its lubricating properties. Viscosity is described in:

- ASTM D445, "Test Method for Kinematic Viscosity of transparent and opaque liquids" or

- ASTM D88, "Stand Test Method for Saybolt Viscosity". This testing determine whether or not the lubricant meets design requirements and will perform as required.

Viscosity is a liquid's resistance to flowing. A fluid that has no resistance to shear stress is known as an ideal fluid or inviscid fluid. Otherwise all fluids have positive viscosity. A liquid whose viscosity substantially greater than water is called a

viscous liquid. Performance characteristics are associated with a lubricants actual viscosity.

Flash Point

Flash Point is significant in assuring the oil's useful temperature range. Flash Point testing is described in ASTM D92, "Standard Test Method for Flash and Fire Points by Cleveland Open Cup Tester". This test determine whether the lubricant meets design requirements and will perform as required. Pour point is not considered a CCA, as temperature range for most safety related oils do not approach the pour point.

Flash point can indicate the possible presence of highly volatile and flammable materials in a relatively nonvolatile or nonflammable material, a low flash point can indicate gasoline contamination.

The flash point of a volatile material is the lowest temperature at which it can vaporize to form an ignitable mixture in air.

Purity

Purity is extremely critical in the acceptance of lubricants/oil. Levels of purity are levels of contaminants or absence of contamination.

Initially a visual inspection is conducted to verify the oil is bright and clear and there is no water. Pending that inspection, a sediment test per ASTM D1233 "Standard Test Method for Water in Insulating Liquids by Coulometric Karl Fischer Titration" should be conducted to quantify the percentage of water or sediment. This test determines if the lubricant meets design requirements.

Additive Packages

Additive packages are the second most important characteristic and is selected as it is the main reason one type of oil is selected over another. Base oil is always blended with additives to help provide a more complete package of engine protection, including synthetic oils. Measuring neutralization number provides reasonable assurance that the additive are present or not present. The characteristic of being free from contaminants is also essential to the oil's performance.

Additives are tested to determine what additives are present:

<u>Industrial Oil</u>

- ASTM D974, "Standard Test Method for Acid and base number by Color-Indicator Titration" and/or

- ASTM D664, “Standard Test Method for Acid Number of Petroleum Products by Potentiometric Titration” which determine which additives are present and if it’s met design requirements.

Motor/engine Oil

- Testing to ASTM D2896, “Standard Test Method for Base number of Petroleum Products by Potentiometric Perchloric Acid Titration” and/or

- ASTM D4739, “Standard Test Method for Base No. Determination by Potentiometric Titration”

Zinc weight percentage is also required to be verified by spectroscopic exam. This test determines if it will meet design requirements.

ENVIRONMENTAL REQUIREMENTS

Generally, radiolysis of lubricants is not a problem in nuclear facilities. It takes radiation doses above those prevailing in normal nuclear plant operations to make appreciable changes in bulk properties of lubricants. See the following table for radiation effects on oils:

Common Oils

Radiation Dose	Effects
$<10^6$ rads	No unusual problems
10^6–10^7 rads	Things begin to happen; some turbine oils borderline
10^7–10^8 rads	Most oils usable; some marginal
10^8–10^9 rads	The best oils usable; most become unusable
10^9–10^{10} rads	Only special products will work
$>10^{10}$ rads	No oil usable

The approximate 10^7 rads level is an irradiation threshold. Below it, most lubricants can tolerate irradiation. Appreciably above it, the life of most lubricants is increasingly at risk. Similar temperature thresholds exist for many lubricants. Up to a certain level, thermal effects are relatively minor but, above that threshold, the thermal component of total stress can become increasingly large. This is tied in, of course, to the approximate doubling of chemical reaction rate by each increase of 10°C (18°F) in temperature. If the rate is very low, a doubling does not do much. When the reaction rate is appreciable, doubling has a discernible effect. The threshold is where this rate becomes apparent. This thermal effect provide the following approximation:

Operating temperature	Relubricated months
93C (200F) operation	36 months schedule
104C (220F)	18 months
121C (250F)	9 months

Thus, thermal has an effect of shortening the useful life of the lubricant up to a catastrophic event.

Oils are not subject to seismic considerations. This item is considered to be seismically rugged for nuclear facilities. Verification of the critical characteristics for acceptance listed in the evaluation are sufficient without requirement of seismic qualification needed. Essentially a Like-for-Like evaluation.

Although harsh applications affect the useful life of both grease and oils, the approach to dedication is identical; although the selection of products need to address elevated parameters. Thus additional testing for harsh environments, which is common for most items, will not be required.

6. VERIFICATION IS BY METHOD 1, SPECIAL TESTS and INSPECTION

The dedication parameters must verify the selected critical characteristics by independent testing.

Characteristic	**Method**
Product Name	Visual
Batch Identification	Visual, for material control
Viscosity	ASTM D445/D88
Contaminants/Purity *Contaminants* *Purity*	*Industrial oil* *Visual* or ASTM D4006 & 473 or D4007* *Motor oil* *Visual*, ASTM D1233*
Flash Point	ASTM D92
Additives/*Neutralization No.* *.*	*Industrial oil - ASTM D664/D974,* *Motor/ engine oil - ASTM D2896/D4739-*

API gravity	ASTM D-287 and Diesel Emergency Power Supplies per NRC Regulatory Guide 1.137

*: Industrial oil visual inspection that the oil is bright and clear and that there is no free water provide reasonable assurance. If not bright and clear or free from water a water and sediment test can be performed to quantify the % water and sediment. These tests may be performed instead of visual examination.

Motor oil/Engine water and sediment test per ASTM D1233

Product identification and color together provide reasonable assurance that the formulation is what was procured.

Product identification & Color; Sensory tests

Test performed at the plant by personnel with limited experience Oil identification & Color process

- Appearance. Is the oil clear and bright? Or is it hazy and cloudy, indicating the presence of water? Is it foamy? Does it show suspended matter? When examining grease, smear a small amount on a piece of white paper with a knife or spatula. Examine the sample for lumps and other particles, and do not forget the comparison with the fresh, unused sample.
- Color. Compare with that of the original product. This observation is sometimes useful with light-colored materials. Darkening can indicate oxidation and/or exposure to high temperatures or sunlight through a sight glass. Remember that color can change simply through the addition of the new lubricant to the system being lubricated.
- Odor. Again, compare with that of the original product. Oxidized oils and greases eventually acquire an acidic, pungent, or burned smell. This occurs also at a radiation dose of about 100 megarad. The strong odor of some additives might temporarily mask the developing pungent smell.
- Feel. Oils should feel slippery; greases should feel buttery, not stringy or lumpy. Neither should feel gritty, as from wear debris.

Sampling

Sampling shall be based upon standard statistical methods with supporting engineering justification and shall consider lot/batch traceability, homogeneity, and the complexity of the item. One generally accepted source for developing sampling plans is EPRI Final Report TR-017218-R1, “Guideline for Sampling in the Commercial-Grade Item Acceptance Process,” which provides an enhanced

methodology for the use of sampling in accepting and dedicating CGIs. Use of this EPRI guide provides useful information in establishing the basis for the sampling plan, but users of this report should consider the document in total and clearly document the rationale for the selected sampling method.

7. SOURCES OF DESIGN PARAMETERS

First and foremost, the selection of the proper lubricant should be based on the equipment manufacturer's recommendations.

The Safety Data Sheet for the product provides the "Typical Test Data" sheet which identify the design parameters; wherein, the related ASTM test and acceptance range can be determined.

Prior tests performed on the oil being replaced.

Manufactures over time may change absolute value, but remain within the ASTM ranges.

8. SUMMARY

The following characteristics are to be verified:

Characteristic	**Oil Method**
Product Name	Visual
Batch Identification	Visual, material control Operating temperature Appearance [clear-bright} Odor {compare original product} Feel {slippery}
Color	ASTM D1500
Viscosity, Kinematic 100F	ASTM D445/D88
Contaminants/Purity	Industrial Oil: Visual or ASTM D4006, 473 or D4007 (D96 deleted) Motor oil: Visual* or ASTM D1233
Flash Point	ASTM D92[1]

Additives/Neutralization -ACID	industrial oil ASTM D664/D974 motor/engine oil ASTM D2896/D4739
Zinc wt. % or PPM	Spectroscopic
API gravity	ASTM D-287 & Diesel Emergency Power Supplies per NRC Regulatory Guide 1.137[2]

NOTE [1] ASTM D-92 is the Cleveland Open Cup test and ASTM D-93 is the Pensky-Martens Closed Cup test. The closed cup is a few degrees lower, it possibly could be 20C lower.

NOTE [2] ASTM D975 is a specification for diesel fuel and is referenced in NRC Regulatory Guide 1.137 for additional testing over 30 days after receipt of fuel oil. ASTM D-287 is the test for API gravity. Since various organizations reference ASTM D975, the following information on ASTM D975 is provided:

- "Diesel fuel" is generic; it refers to any fuel for a compression ignition engine. Follow the manufacture recommendations when available.
- ASTM D975 is not specific to any one diesel engine type or fuel system.
- A diesel characteristic that is essential for some might be unnecessary or even undesirable for others

Industry reference ASTM that have changed

- ASTM D96 Standard Test Methods for Water and Sediment in Crude Oil by Centrifuge Method (Field Procedure) was withdrawn in 2000 with no replacement. This test was used to measure Purity
- ASTM D 4007**, "**Standard Test Methods for Water and Sediment in Crude Oil by Centrifuge Method", Laboratory Procedure

  This test method describes the laboratory determination of water and sediment in crude oils by means of the centrifuge procedure. This centrifuge method for determining water and sediment in crude oils is not

entirely satisfactory. The amount of water detected is almost always lower than the actual water content. When a highly accurate value is required, the revised procedures for water by distillation, Test Method D 4006 and sediment by extraction, Test Method D 473 shall be used. ASTM D4006, Standard Test Method for Water in Crude Oil by Distillation

9. . REFERENCES

1. EPRI Final report 1019518, December 2009, Nuclear Maintenance Applications Center: Lubrication Guide, Revision 4 (Formerly 1003085 which replaced EPRI NP-4916 Lubrication Guide R3, and EPRI NP-4735 Radiation Effects on Lubricants)

2. ASTM D445, “Test Method for Kinematic Viscosity of transparent and opaque liquids”

3. ASTM D88, “Stand Test Method for Saybolt Viscosity”.

4. ASTM D92, “Standard Test Method for Flash and Fire Points by Cleveland Open Cup Tester”.

5. ASTM D1233 “Standard Test Method for Water in Insulating Liquids by Coulometric Karl Fischer Titration”

6. ASTM D974, “Standard Test Method for Acid and base number by Color-Indicator Titration

7. ASTM D664, “Standard Test Method for Acid Number of Petroleum Products by Potentiometric Titration”

8. ASTM D2896, ““Standard Test Method for Base number of Petroleum Products by Potentiometric Perchloric Acid Titration

9. ASTM D4739, “Standard Test Method for Base No. Determination by Potentiometric Titration

10. ASTM D4006, Standard Test Method for Water in Crude Oil by Distillation

11. ASME D473, Standard Test Method for Sediment in Crude Oils and Fuel Oils by the Extraction Method

12. ASTM D-287 Standard Test Method for API Gravity of Crude Petroleum and Petroleum Products (Hydrometer Method)